Deutsche Physikalische Gesellschaft DPG

2. DPG-Herbsttagung 2025

2nd DPG Fall Meeting

of the Sections on
Atomic, Molecular, Quantum Optics and Photonics (SAMOP)
Condensed Matter (SKM)
Matter and Cosmos (SMuK)

100 Years of Quantum Physics

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8 – 12 September 2025

Georg-August-Universität Göttingen

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Verantwortlich für den Inhalt: Dr. Bernhard Nunner, DPG e. V., Hauptstraße 5, 53604 Bad Honnef
Telefon: +49 (0)2224 9232-0; E-Mail: dpg@dpg-physik.de

Content

Dear guests,

Welcome to the second DPG-Herbsttagung (Fall Meeting) at the University of Göttingen dedicated to the topic of “Quantum Physics“, comprising both quantum science and technology.

This Fall Meeting is jointly organised by the DPG Sections on “Atomic, Molecular, Quantum Optics and Photonics“ (SAMOP), “Condensed Matter“ (SKM) and “Matter and Cosmos“ (SMuK). The exciting programme covers the status and perspectives of all fields of modern physics reigned by quantum mechanics.

With this Fall Meeting we are also celebrating 100 years of quantum mechanics. On 7 June 2024, the United Nations, with the participation and support of the DPG, proclaimed 2025 the “International Year of Quantum Science and Technology” to celebrate the formulation of quantum mechanics.

Quantum mechanics has laid a lasting foundation for our physical understanding of nature. Quantum mechanics also has an impact on all areas of our culture, science, technology and art and permeates, unconsciously for most people, our entire living and working environment — and future applications of innovations based on quantum physics are diverse and far from fully foreseeable! In order to make this outstanding role of quantum mechanics visible in society and politics in Germany and Europe, we have organised an impressive variety of activities this year, also together with the European Physical Society (EPS) and our sister societies in Europe. This has brought a great deal of attention and visibility to physics and quantum physics in particular.

The origins of quantum mechanics are inextricably linked to Göttingen and the University of Göttingen, where 100 years ago numerous researchers in mathematics and physics (including Max Born, Werner Heisenberg, Pascual Jordan and Wolfgang Pauli) developed the foundations of quantum mechanics in order to systematically describe processes at the atomic level.

I am therefore delighted that the Fall Meeting is taking place at this very special location! As President of the DPG, I would like to express my sincere thanks for the great commitment of everyone involved in the successful organisation of this outstanding event.

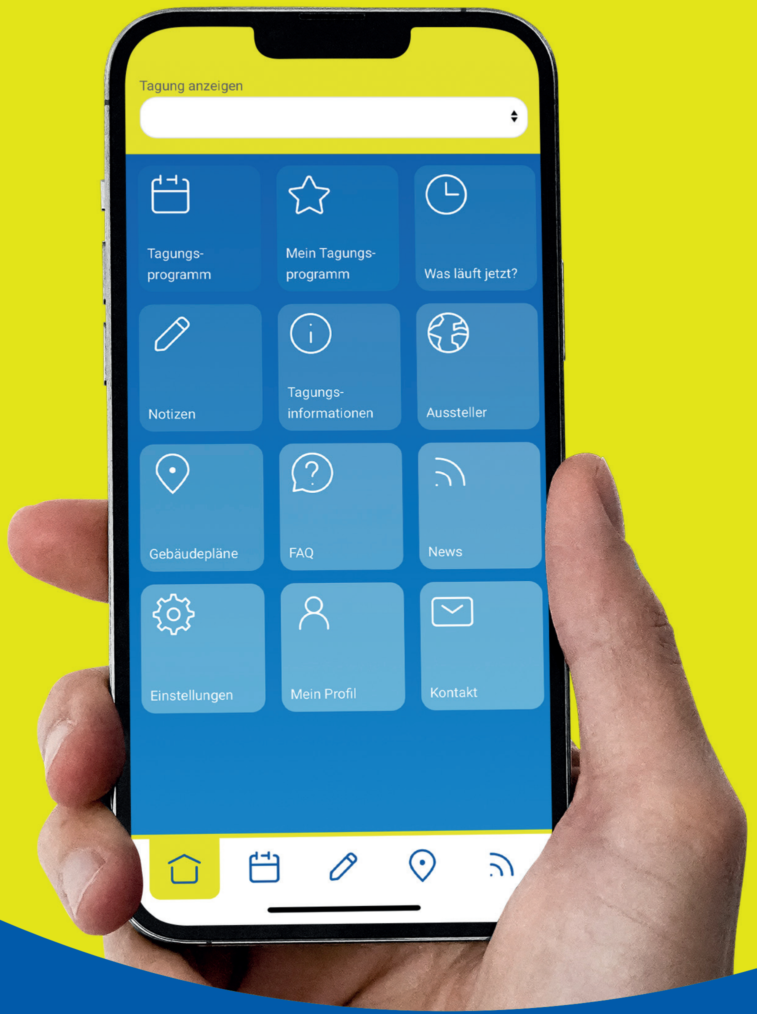
My special thanks also go to

- the University of Göttingen for their hospitality and support,
- the Wilhelm and Else Heraeus Foundation for its financial support,
- the organisers of the Fall Meeting, here the team around Prof. Stefan Kehrein (Institute for Theoretical Physics) and Prof. Thomas Weitz (I. Institute of Physics) at University of Göttingen,
- the DPG Head Office for their support of this Fall Meeting and all other DPG conferences during the “Quantum Year”.

I wish you all an exciting conference with many new insights!

Prof. Dr. Klaus Richter

President
Deutsche Physikalische Gesellschaft e. V.



DPG

Download on the App Store

GET IT ON Google Play

Navigate the Fall Meeting with the DPG App!

The DPG app informs you about the conference programme, the venues and the exhibitors. Features such as your personal conference calendar and detailed floor plans simplify finding your way around the conference!

for iOS

for Android

Explore conference contributions on the new DPG Map.

CURRENTLY IN BETA

Dive into our network visualization and find related contributions.

Visit our platform at map.dpg-verhandlungen.de

Organisation

Organiser

Deutsche Physikalische Gesellschaft e. V.
Hauptstraße 5, 53604 Bad Honnef
Phone +49 (0) 2224 9232-0
Email dpg@dpg-physik.de
Website www.dpg-physik.de

Local Organisers

Prof. Dr. Stefan Kehrein
Institut für Theoretische Physik
Georg-August-Universität Göttingen
Friedrich-Hund-Platz 1, 37077 Göttingen
Email quantum25@dpg-tagungen.de

Prof. Dr. Thomas Weitz
I. Physikalisches Institut - Experimentalphysik
Georg-August-Universität Göttingen
Friedrich-Hund-Platz 1, 37077 Göttingen
Email quantum25@dpg-tagungen.de

Scientific Organisation

Programme Committee

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Michael Fleischhauer, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau
Otfried Gühne, Universität Siegen
Wilhelm Kaenders, TOPTICA Photonics AG, Graefelfing (München)
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Ralph Schützhold, Helmholtz-Zentrum Dresden-Rossendorf
Johanna Stachel, Universität Heidelberg
Thomas Weitz, Georg-August-Universität Göttingen (Chair)

Symposia

SYCC – Quantum Computing and Communication: Early Days and New Developments
SYCQ – Correlated Quantum Matter – From Cold Atoms to the Solid State
SYDK – Joint Symposium of the Danish and German Physical Societies
SYEC – Entanglement and Complexity – How “Complex” is Nature?
SYFA – Foundational Aspects of Quantum Theory
SYFQ – Frustrated Quantum Systems
SYHB – Quantum Physics at the High-Energy Frontier: The Higgs Boson in the Standard Model and Beyond
SYLB – Loosely-Bound States – From the Coldest to the Hottest Environments
SYQD – Precise Quantum Detectors in Space, Time and Energy — Semi- and Superconductors in Particle and Condensed Matter Physics
SYQI – Quantum Information and the Quest for Fault-Tolerant Quantum Computing
SYQM – Precise Quantum Molecules
SYQS – Quantum Sensing and Decoherence in Solid-State and Photonics Systems
SYQT – Quantum Thermalization
SYSF – Quantum Physics in Strong Fields
SYUH – The Charm of Unconventional Hadrons
SYWS – Quantum 2D-Moiré and Rhombohedral van-der-Waals Systems

Organisation of the Exhibition of Scientific Instruments and Literature
DPG-Ausstellungs-, Kongreß- und Verwaltungsgesellschaft mbH
Hauptstraße 5, 53604 Bad Honnef
Phone +49 (0)2224 9232-0
Email info@dpg-gmbh.de
Website www.dpg-gmbh.de

Programme
The scientific programme consists of **672** contributions:

12	Plenary talks
2	Evening talks
86	Invited talks
4	Lunch talks
404	Talks
156	Posters
4	Panel Discussions
4	Tutorials

The programme stated in this document corresponds to the status from 25 July 2025. You will find the updated programme using the DPG App and at

www.dpg-verhandlungen.de/year/2025/conference/quantum

Information for Participants

The conference will be held 8-12 September 2025.

Conference Information

Conference Venue
Universität Göttingen
Zentrales Hörsaalgebäude
Platz der Göttinger Sieben 5
37073 Göttingen

The conference will take place in the Central Lecture Hall Building (ZHG) of the University of Göttingen.

Conference Office / Information Desk
The conference office and the information desk are located in seminar room 0.168 (ground floor) of the Oeconomicum building (opposite the main entrance to the main lecture hall building). The opening hours are the following:

		Registration	Information Desk
Sunday	7 September	15:00 – 18:00	15:00 – 18:00
Monday	8 September	08:00 – 18:30	08:00 – 18:30
Tuesday	9 September	08:00 – 17:00	08:00 – 17:00
Wednesday	10 September	08:00 – 17:00	08:00 – 17:00
Thursday	11 September	08:00 – 16:30	08:00 – 16:30
Friday	12 September	08:00 – 12:00	08:00 – 12:00

You will receive your name tag and a receipt for your conference fee at the registration. The name tag must be worn visibly during the entire conference.

The organisers, the staff of the conference desk, and the student assistants will be identifiable by name tags and Φ-T-shirts in a uniform colour. Please contact them if you have any questions.

Do not hesitate to enquire about all necessary information concerning the conference, orientation in Göttingen, accommodation, restaurants, going out, and cultural events at the information desk.

Presentations

Scientific presentations will be held either orally or by poster and will be given in English (conference language) or German.

All lecture halls will be equipped with a projector (16:9) connected to a local computer that supports PDF and Powerpoint presentations. The presentation should be recorded onto an USB stick in PDF or PowerPoint format. Personal laptops can also be connected to the projector via HDMI. Please bring your own adapters (e.g., HDMI—USB-C) if necessary, as they will not be provided in the lecture halls. Presenters and/or laser pointers will be available in all lecture rooms.

All lecture halls will be opened, at the latest, 30 minutes prior to the talks. Speakers are kindly requested to arrive at the lecture hall at least 20 minutes before the session begins to check in with the session chair and technical staff. This provides time to ensure the proper functioning of your presentation and to receive a concise overview of the lecture hall's equipment. If you need other presentation facilities, please ask for availability at the information desk as soon as you arrive at the conference.

Usually, presentations will have the following durations:

- For contributed talks a total of 15 minutes including discussion time and speaker change (12 min talk + 3 min discussion/speaker change).
- For invited talks please refer to the programme for the exact presentation time.
- For plenary talks a total of 45 minutes plus 15 min discussion time and speaker change. Questions will be collected via the app "Particify" www.particify.de/en/. More details will be announced before the talk.

Poster Presentations

The site for poster sessions is located at the foyer (1st floor) of the lecture hall building. Posters must fit within a rectangle 85 cm wide and 120 cm high (DIN A0, portrait format!).
The poster boards will be marked with the number according to the scientific programme. Authors are asked to mount their poster once the poster board with the corresponding poster number is prepared. Each poster should display the number according to the scientific programme.

For the mounting of the poster please use the prepared pins/strips at the poster frame or contact the available student staff. The presenting authors should be at hand for discussion at their poster during at least half of the poster session and should note this time at the poster. The posters have to be removed after the session. **Any posters remaining on display will be removed and disposed without requesting your permission.** The conference management accepts no liability for the posters.

Broadcast of Plenary Talks

All plenary talks will be presented in lecture hall ZHG011 and broadcast in lecture hall ZHG010.

Wilhelm and Else Heraeus Communication Programme

Important notes for participants who apply for a grant in the WEH Communication Programme:

At the beginning of the conference you will receive an identification form at the conference office. Your participation in the conference must be certified at the conference office. At the end of the conference, you may leave this certificate with DPG staff members at the conference office (preferably) or submit it to the DPG head office (DPG-Geschäftsstelle, Hauptstr. 5, 53604 Bad Honnef, Germany) by **26 September, 2025 at the latest.** For more detailed information refer to *weh.dpg-physik.de*.

The Deutsche Physikalische Gesellschaft thanks the Wilhelm and Else Heraeus Foundation for the generous financial support of young academic talents. We hope that young physicists will continue to benefit from the offered opportunity for active scientific communication at DPG meetings. A total of about 41,900 young academics were supported by this programme so far.

Communication / Internet Access

The University of Göttingen is a member of the eduroam union. If your university is also part of the eduroam union, you can use the university WiFi in all buildings via your own eduroam account. Alternatively, you can use the "guest on campus" network and receive corresponding credentials at the conference office.

Catering

Coffee breaks: Coffee and tea are offered for free in the foyer of the lecture hall building during the breaks.

Lunch: The "Zentralmensa" right next to the central lecture hall building and the "Mensa am Turm" in 100 m walking distance offer plenty of opportunities for lunch at moderate prices (self-payment). Only payment by cards (Debit, Credit, Google Pay, Apple Pay) is possible in the mensa. Please wear your badge to get staff or student prices. In the city centre there is a large selection of opportunities to get a meal or a snack.

Storage

Participants are asked to look carefully after their wardrobe, valuables, laptops, and other belongings. The organisers decline any liability. In the foyer of the ZHG building you will find a storage area managed by student assistants. The opening hours are as follows:

Sunday	7 September	15:00 – 20:30
Monday	8 September	08:00 – 20:30
Tuesday	9 September	08:00 – 19:30
Wednesday	10 September	08:00 – 18:00
Thursday	11 September	08:00 – 19:00
Friday	12 September	08:00 – 14:00

Notice Board

All changes to the conference programme (i.e. cancellation of presentations, change of rooms, etc.) are also transferred directly to the online version of the programme which will be updated continuously and is available in different formats (sorted by publication date, filterable by conference parts and as an rss-feed). Please use the form *www.quantum25.dpg-tagungen.de/programm/notice-board* to notify changes or cancellations.

Lost Property

You can hand in lost property at the information desk. You can also collect your lost property there.

Liability Exclusion

Participants are asked to look carefully after their wardrobe, valuables, laptops and other belongings. There can be no liability assumed.

SAY CHEESE!

The DPG Fall Meeting is basically public to the press. Please note: On behalf of DPG, photos and videos will be recorded during the Fall Meeting. In the context of public relations, these recordings (as the case may be) will be published on our website, in social media or within prints of the DPG for example.

Tactfulness

All participants are requested to contribute to a successful and enjoyable conference through respect and tactful behaviour. Please contact the conference office or the local conference organisers in the event of disturbances. §§ 9 and 12 of the DPG's Statutes are applicable.

CO_2 Compensation for the DPG conferences

By decision of its council, the DPG will compensate for fossil CO_2 emissions resulting from mobility for DPG conferences and committee meetings.

Acknowledgement

The Deutsche Physikalische Gesellschaft (DPG) and the local organisers want to thank the following institutions for supporting the conference:

- the University of Göttingen
- the Wilhelm and Else Heraeus Foundation, Hanau
- and all staff, who make the success of the conference possible.

Social Events

Welcome Evening
Sunday, 7 September, 18:00 – 20:30
On Sunday, the Welcome Evening will be held in the foyer of the lecture hall centre to which all registered participants are kindly invited. Snacks and drinks will be served. Register in time (15:00 – 18:00) and do not miss the opportunity to meet people in informal atmosphere. Please wear your name tag which you have received during registration.

Welcome Address
The opening address will be given by the local conference organisation on Monday, 8 September, 8:20 – 8:30, in the lecture hall ZHG011.

Exhibition of Scientific Instruments and Literature
From Tuesday, 9 September, to Thursday, 11 September, there will be an exhibition of scientific instruments and literature in the foyer of the lecture hall centre. Companies (see list of exhibitors at the end of this booklet) will present their products. Opening hours are Tue-Wed 10:30 – 17:30, Thur 10:30 – 18:30. All conference participants are welcome to attend the exhibition. The entrance is free.

Plenary Podium Discussions
Two plenary podium discussions will take place during the conference.
The first will be held on Tuesday, 9 September, during the lunch break (13:15 – 14:00), focusing on science communication under the title „Wissenschaftskommunikation: Verlässliche Stimmen in unruhigen Zeiten". Participants include Harald Lesch and Nicolas Wöhrl, with Axel Lorke as moderator. This discussion will be held in german language.

The second discussion with the title „A century after 1925: Do we now understand quantum mechanics?" will follow at Tuesday afternoon (17:45 – 18:45), featuring distinguished scientists Gianfranco Bertone, Anton Zeilinger, Wojciech Zurek, and Reinhard Werner. This discussion will be held in english language.

Industry Day on Quantum Technology
Wednesday, 10 September, 14:00 – 17:30
The Industry Day on Quantum Technology, held in a new format, will highlight the achievements made in recent years within the emerging field of quantum technologies, often referred to as Quantum 2.0. Leading national and international companies in this field will present their product concepts to the physics community gathered in Göttingen through conference contributions. The programme will be fully tailored to the needs of industry. By specifically inviting funding organisations (VDI, DLR, BMBF, BMWK and so on) and venture capitalists, the event will provide a holistic perspective. The afternoon aims to provide a comprehensive overview of diverse approaches.

Public Evening Event
Wednesday, 10 September, 18:30 – 20:30, Stadthalle Göttingen (City Hall)
Programme:

- **Welcome Address**
- **Special Evening Talk**
  by Heike Riel, Designated DPG President
  "Quanten-Computer: Die neue Art des Rechnens"
- **Concert by Universitätsmusik Göttingen presenting the Orchestral World Premiere:**
  "Ordnung der Wirklichkeit"

The Public Evening Event is open for the interested public and all conference participants. It will be held in German with simultaneous translation. The entrance is free of charge. However, due to the limited number of seats, we kindly request that you register in advance.

Public Evening Lecture *(entry free of charge)*
Thursday, 11 September, 19:00 – 20:00, ZHG011
Matthias Maurer, ESA-Astronaut, will speak about "*Neue Quantentechnologien für den Weltraum*"

All conference participants and the interested public are welcome.

Theatre
On Thursday, 11 September, 20:00 – 21:30, the piece "*Und der Alte würfelt doch!*" is performed as a stage reading (in German) at the Deutsche Theater in Göttingen. The performance celebrates a pivotal moment in scientific history: In 1925, groundbreaking ideas reshaped the understanding of the natural world and marked the beginning of a revolution in physics. This event is organised by Deutsches Theater in collaboration with the Faculty of Physics, University of Göttingen.

Special Exhibition at Forum Wissen
The special exhibition "*What the Quantum?!*" at the Knowledge Museum of the University of Göttingen explores the formulation of quantum mechanics in 1925 and takes a look at the present day. The exhibition features examples where quantum technologies are currently in use. Games and theatre sequences developed by youths as well as artworks invite visitors to explore the world of quantum mechanics in the Forum Wissen.
The museum is open Tuesday through Sunday (10:00 – 18:00) with free admission.

SciencePub Göttingen – Qubits, Quiz & a Cold Pint
Quantum computing is no longer just science fiction! Instead, it's an exciting and rapidly evolving field that's shaping the future of technology. At our SciencePub event in Göttingen, we bring this complex topic to the pub in a relaxed and accessible way. Organised by the 1st DPG graduate school on Next Generation Computing, the evening features an introduction to the topic, including a fun interactive quiz, and plenty of time for discussion!
The event will take place in the fantastic bar DOTS in the inner city of Göttingen (Barfüßerstraße 12-13, 37073 Göttingen) on Saturday, 6 September starting at 20:00.

Whether you're a student, science enthusiast, or just curious: everyone is welcome! No prior knowledge is needed, just bring your curiosity and enjoy science with a drink in hand.

Sponsors of the 2nd DPG Fall Meeting Göttingen 2025

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Synopsis of the Daily Programme

Sunday, September 7, 2025

TUT

			Tutorials
15:00	ZHG104	TUT 1.1	Basics of quantum information and computation •Ralf Schuetzhold
15:00	ZHG105	TUT 2.1	What can quantum computers do – and what can't they? •Jens Eisert
17:00	ZHG104	TUT 3.1	Quantum foundations from a QI perspective •Markus Frembs
17:00	ZHG105	TUT 4.1	Quantum Optimal Control in a Nutshell •Daniel Reich
			Sessions
15:00	ZHG104	TUT 1	Tutorial Basics of Quantum Information and Computation
15:00	ZHG105	TUT 2	Tutorial What can quantum computers do – and what can't they?
17:00	ZHG104	TUT 3	Tutorial Quantum Foundations from a QI Perspective
17:00	ZHG105	TUT 4	Tutorial Quantum Optimal Control

18:00	ZHG Foyer		**Welcome Evening** (for registered participants)

Monday, September 8, 2025

08:20	ZHG011		**Welcome Address**
			Plenary Talks
08:30	ZHG011	PLV I	The Long Quantum Revolution •Jürgen Renn
09:30	ZHG011	PLV II	The Laser and fundamental quantum science •Serge Haroche
			Lunch Talk
13:15	ZHG008	PSV I	KnabenPhysik: Social Crises, Postdoctoral Culture, and International Contexts of the Quantum Revolution. •Alexei Kojevnikov

SYDK

			Invited Talks
10:45	ZHG008	SYDK 1.1	Quantum physics and the spirit of Copenhagen •Klaus Molmer
11:25	ZHG008	SYDK 1.2	General Relativity from Quantum Theory •Niels Emil J. Bjerrum-Bohr
12:05	ZHG008	SYDK 1.3	Frontiers in quantum gravity •Astrid Eichhorn
			Session
10:45	ZHG008	SYDK 1	Joint Symposium of the Danish and German Physical Societies

SYFA

			Invited Talks
10:45	ZHG010	SYFA 1.1	Towards a Completion of Quantum Mechanics •Jürg Fröhlich
11:25	ZHG010	SYFA 1.2	Locality and its generalizations in quantum field theory •Kasia Rejzner
12:05	ZHG010	SYFA 1.3	Heisenberg's Operational Program •Reinhard Werner
			Session
10:45	ZHG010	SYFA 1	Foundational Aspects of Quantum Theory

SYLB

			Invited Talks
10:45	ZHG104	SYLB 1.1	Fermion Pairing and Correlation at Ultralow Temperatures •Philipp Preiss
11:25	ZHG104	SYLB 1.2	The structure of loosely-bound nuclear states: when the tail wags the dog •Hans-Werner Hammer
12:05	ZHG104	SYLB 1.3	Fragile Matter in Extreme Conditions: insights from the LHC •Francesca Bellini
			Session
10:45	ZHG104	SYLB 1	Loosely-Bound States – From the Coldest to the Hottest Environments

SYQS

			Invited Talks
10:45	ZHG105	SYQS 1.1	Quantum Technologies for Sensing and Imaging in the Life Sciences •Martin B Plenio

Monday, September 8, 2025

SYQS

11:15	ZHG105	SYQS 1.2	Quantum technologies with semiconductor color centers in integrated photonics •Jelena Vuckovic
11:45	ZHG105	SYQS 1.3	Towards spin-based quantum sensing in hybrid nanomechanical systems based on silicon carbide •Eva Weig
12:15	ZHG105	SYQS 1.4	Quantum Sensing of Quantum Matter •Amir Yacoby
			Session
10:45	ZHG105	SYQS 1	Quantum Sensing and Decoherence in Solid-State and Photonics Systems

MON

			Sessions
14:15	ZHG001	MON 1	QIP Implementations: Photons I
14:15	ZHG002	MON 2	Quantum Control
14:15	ZHG003	MON 3	Many-Body Quantum Dynamics I
14:15	ZHG004	MON 4	DPG Promotionskolleg Next Generation Computing
14:15	ZHG006	MON 5	Optical Quantum Devices
14:15	ZHG007	MON 6	QIP Implementations: Trapped Ions
14:15	ZHG008	MON 7	Foundational / Mathematical Aspects – Quantum Measurement
14:15	ZHG009	MON 8	Quantum Sensing and Decoherence: Contributed Session to Symposium I
14:15	ZHG101	MON 9	Quantum Entanglement
14:15	ZHG103	MON 10	Standard Model and Beyond
14:15	ZHG104	MON 11	Quantum Transport I
14:15	ZHG105	MON 12	Quantum Magnets
16:30	ZHG001	MON 13	QIP Implementations: Photons II
16:30	ZHG002	MON 14	QIP Implementations: Solid-State Devices I
16:30	ZHG003	MON 15	Many-Body Quantum Dynamics II
16:30	ZHG004	MON 16	Quantum Spectroscopy
16:30	ZHG006	MON 17	Quantum Communication and Networks: Theory
16:30	ZHG007	MON 18	Quantum Algorithms
16:30	ZHG008	MON 19	Foundational / Mathematical Aspects – Quantum Optics and Quantum Information
16:30	ZHG009	MON 20	Quantum Sensing and Decoherence: Contributed Session to Symposium II
16:30	ZHG103	MON 21	Quantum Materials
16:30	ZHG104	MON 22	Quantum Transport II
18:30	ZHG Foyer 1. OG	MON 23	Poster Session: Fundamental Aspects and Model Systems

JOB

			Invited Talks
12:45	ZHG005	JOB 1.1	Basycon Unternehmensberatung GmbH: Aus der Wissenschaft in die Beratung •Tobias Weisrock, •Maximilian Kurjahn
13:30	ZHG005	JOB 1.2	PlanQC GmbH: Building quantum computers atom by atom •Davide Dreon
			Session
12:45	ZHG005	JOB 1	Job Market I

Tuesday, September 9, 2025

Plenary Talks

08:30	ZHG011	PLV III	The Quantum Roots of the Cosmos •Gianfranco Bertone
09:30	ZHG011	PLV IV	Decoherence and Quantum Darwinism •Wojciech Zurek
16:30	ZHG011	PLV V	From Heisenberg in Göttingen to Quantum Information •Anton Zeilinger

Lunch Talk, Discussions

13:15	ZHG008	PSV II	The Gendered History of Quantum Physics •Daniela Monaldi
13:15	ZHG009	PSV III	Wissenschaftskommunikation: Verlässliche Stimmen in unruhigen Zeiten •Axel Lorke
17:45	ZHG011	PSV IV	Panel Discussion: "A century after 1925: Do we now understand quantum mechanics?" •Gianfranco Bertone

SYCQ

Invited Talks

10:45	ZHG008	SYCQ 1.1	New synthetic quantum systems with ultracold fermions in optical lattices •Leonardo Fallani
11:15	ZHG008	SYCQ 1.2	Realization of Andreev-molecules •Szabolcs Csonka
11:45	ZHG008	SYCQ 1.3	Giant transverse magnetic fluctuations at high fields in UTe_2 •Kimberly Modic
12:15	ZHG008	SYCQ 1.4	Emerging platforms to answer basic theoretical questions about correlated quantum matter •Joel Moore

Session

10:45	ZHG008	SYCQ 1	Correlated Quantum Matter – From Cold Atoms to the Solid State

SYCC

Invited Talks

10:45	ZHG010	SYCC 1.1	Founding Concepts for Solid State Quantum Computers •David DiVincenzo
11:25	ZHG010	SYCC 1.2	Semiconductor spin qubits – vision, opportunities and challenges •Lieven Vandersypen
12:05	ZHG010	SYCC 1.3	Perspectives on Control and Characterization of Temporally Correlated Non-classical Noise •Lorenza Viola

Session

10:45	ZHG010	SYCC 1	Quantum Computing and Communication: Early Days and New Developments

SYSF

Invited Talks

10:45	ZHG104	SYSF 1.1	Nuclear physics with strong electromagnetic fields •Adriana Pálffy
11:25	ZHG104	SYSF 1.2	Strong fields and fundamental physics •Anton Ilderton
12:05	ZHG104	SYSF 1.3	Weakly coupled new physics in strong fields •Babette Döbrich

Tuesday, September 9, 2025

SYSF

			Session
10:45	ZHG104	SYSF 1	Quantum Physics in Strong Fields

SYUH

			Invited Talks, Discussion
10:45	ZHG105	SYUH 1.1	The social life of quarks •Marek Karliner
11:00	ZHG105	SYUH 1.2	The enigmatic strong interaction •Christoph Hanhart
11:15	ZHG105	SYUH 1.3	Paving the future: new experimental approaches to subatomic forces •Chiara Pinto
11:30	ZHG105	SYUH 1.4	Tracks and Tetraquarks •Mikhail Mikhasenko
11:45	ZHG105	SYUH 1.5	Charmed by hadrons – a flavorful debate •Sebastian Neubert
			Session
10:45	ZHG105	SYUH 1	The Charm of Unconventional Hadrons

TUE

			Sessions
14:15	ZHG001	TUE 1	QIP Implementations: Photons III
14:15	ZHG002	TUE 2	Quantum Networks: Technologies
14:15	ZHG003	TUE 3	Quantum Field Theory
14:15	ZHG004	TUE 4	Education and Outreach
14:15	ZHG006	TUE 5	QIP Certification and Benchmarking
14:15	ZHG007	TUE 6	Quantum Computing and Communication: Contributed Session I (Algorithms & Theory)
14:15	ZHG008	TUE 7	Entanglement and Complexity: Contributed Session to Symposium I
14:15	ZHG009	TUE 8	Correlated Quantum Matter: Contributed Session to Symposium I
14:15	ZHG101	TUE 9	Quantum Physics in Strong Fields: Contributed Session to Symposium
14:15	ZHG103	TUE 10	Foundational / Mathematical Aspects – Rigorous Results
14:15	ZHG104	TUE 11	Quantum Optics and Quantum Computation
14:15	ZHG105	TUE 12	Quantum Sensing and Decoherence: Contributed Session to Symposium III

10:30 ZHG Foyer **Exhibition of Scientific Instruments and Literature** (free entrance)

Wednesday, September 10, 2025

			Plenary Talks
08:30	ZHG011	PLV VI	The Higgs Boson and the Quantum Vacuum: Understanding Mass and Symmetry Breaking •Beate Heinemann
09:30	ZHG011	PLV VII	The Quantum Revolution in Metrology •Klaus von Klitzing
			Lunch Talk
13:15	ZHG008	PSV V	Bohr was not obscure! •Guido Bacciagaluppi

SYFQ

			Invited Talks
10:45	ZHG008	SYFQ 1.1	Detection of anyon braiding through pump-probe spectroscopy •Nandini Trivedi
11:25	ZHG008	SYFQ 1.2	Fate of quantum spin liquid in 2D •Alexander A. Tsirlin
12:05	ZHG008	SYFQ 1.3	Quantum disorder and quantum critical states in organic systems with triangular lattices •Kazushi Kanoda
			Session
10:45	ZHG008	SYFQ 1	Frustrated Quantum Systems

SYQI

			Invited Talks
10:45	ZHG010	SYQI 1.1	Quantum Computing and Simulation in the presence of errors •Ignacio Cirac
11:25	ZHG010	SYQI 1.2	Scalable quantum computing with trapped ions •Ferdinand Schmidt-Kaler
12:05	ZHG010	SYQI 1.3	New opportunities in hybrid atom arrays combining single atoms and ensembles •Wenchao Xu
			Session
10:45	ZHG010	SYQI 1	Quantum Information and the Quest for Fault-Tolerant Quantum Computing

SYQT

			Invited Talks
10:45	ZHG104	SYQT 1.1	Probing quantum many-body dynamics using subsystem Loschmidt echos •Monika Aidelsburger
11:15	ZHG104	SYQT 1.2	Approach to thermalisation in the Schwinger model •Adrien Florio
11:45	ZHG104	SYQT 1.3	Timescales for thermalization and many-body quantum chaos •Lea Santos
12:15	ZHG104	SYQT 1.4	Observation of Hilbert-space fragmentation and fractonic excitations in tilted Hubbard models •Johannes Zeiher
			Session
10:45	ZHG104	SYQT 1	Quantum Thermalization

Wednesday, September 10, 2025

SYHB

			Invited Talks
10:45	ZHG105	SYHB 1.1	The Higgs Boson -- Key to our Understanding of the Universe •Milada M. Mühlleitner
11:15	ZHG105	SYHB 1.2	The path to the discovery of the Higgs boson •Karl Jakobs
11:45	ZHG105	SYHB 1.3	The Higgs boson revealed: What current experiments teach us about this unique quantum state •Karsten Köneke
12:15	ZHG105	SYHB 1.4	A Quantum Leap Forward: Unlocking the Higgs Boson at Future Colliders •Markus Klute
			Session
10:45	ZHG105	SYHB 1	Symposium Quantum Physics at the High-Energy Frontier: The Higgs Boson in the Standard Model and Beyond

WED-ID

			Plenary Talk, Invited Talks, Discussion
14:05	ZHG011	WED-ID 1.1	Quantum technologies roadmaps perspective and challenges •Olivier Ezratty
14:45	ZHG001	WED-ID 2.1	Trapped-Ion Quantum Computing at Infineon •Clemens Rössler
15:10	ZHG001	WED-ID 2.2	Planck's Reluctant Constant and the Second Semiconductor Revolution •Mark Mattingley-Scott
15:35	ZHG001	WED-ID 2.3	Quantencomputing: Von der universitären Forschung zum Startup neQxt •Ferdinand Schmidt-Kaler
16:00	ZHG001	WED-ID 2.4	Building quantum computers, atom by atom •Alexander Glätzle
16:25	ZHG001	WED-ID 2.5	Progress on superconducting quantum processors at IQM •Frank Deppe
14:45	ZHG101	WED-ID 3.1	Quantum Internet: Technologies & Applications •Imran Khan
15:10	ZHG101	WED-ID 3.2	From Promise to Practice: The Challenges in Finding Quantum Computing Applications •Nicole Holzmann
15:35	ZHG101	WED-ID 3.3	Deterministic Photon-Emitter Interfaces for Quantum Technology •Peter Lodahl
16:00	ZHG101	WED-ID 3.4	Entanglement-based Quantum Key Distribution •Sebastian Neumann
14:45	ZHG007	WED-ID 4.1	Quantum magnetometers and the aspect of industrialisation •Thomas Strohm
15:10	ZHG007	WED-ID 4.2	From Lab to Industry: Fiber Microcavities for Quantum Tech •Michael Förg
15:35	ZHG007	WED-ID 4.3	Advance semiconductor chip analysis with quantum diamond magnetoemters •Nimba Oshnik
16:00	ZHG007	WED-ID 4.4	A commercial optical frequency standard based on a single $^{171}Yb^{+}$ ion •Stephan Ritter
16:25	ZHG007	WED-ID 4.5	Accelerating semiconductor developments with Quantum Metrology •Mathieu Munsch
14:45	ZHG105	WED-ID 5.1	Pathways to Maturity for the Quantum Industry •Claudius Riek
15:10	ZHG105	WED-ID 5.2	From Bottlenecks to Breakthroughs: Simplified & Scalable Cryogenics for the Quantum Age •Tomek Schulz

Wednesday, September 10, 2025

WED-ID

15:35	ZHG105	WED-ID 5.3	Quantum technologies enabled by Photonic Integrated Circuits •Michael Geiselmann
16:00	ZHG105	WED-ID 5.4	Light Modulators Driving Quantum Innovation •Enrico Vogt
16:25	ZHG105	WED-ID 5.5	PicoQuant Insights: Precision and Innovation for Quantum Research and Industry •Uwe Ortmann
16:00	ZHG006	WED-ID 6.3	Driven by Quantum, empowered by Quandela •Thomas Volz
17:00	ZHG011	WED-ID 8.1	Quantum technology at the inflection point? •Wilhelm Kaenders
			Sessions
14:00	ZHG011	WED-ID 1	Plenary Talk
14:45	ZHG001	WED-ID 2	Quantum Computers & Simulators
14:45	ZHG101	WED-ID 3	Quantum Communication & Internet
14:45	ZHG007	WED-ID 4	Quantum Sensing & Metrology
14:45	ZHG105	WED-ID 5	Quantum Enabling I
15:10	ZHG006	WED-ID 6	Quantum Hardware, Software & Solutions
15:10	ZHG104	WED-ID 7	Quantum Enabling II
17:00	ZHG011	WED-ID 8	Panel Discussion

10:30	ZHG Foyer		**Exhibition of Scientific Instruments and Literature** (free entrance)

			Public Evening Event (free entrance)
			Evening Talk
18:30	Stadthalle Göttingen	PSV VI	Quanten Computer – Die neue Art des Rechnens •Heike Riel
			Concert Orchestral World Premiere: “Ordnung der Wirklichkeit”

Deutsche Physikalische Gesellschaft DPG

2ND DPG FALL MEETING

100 YEARS OF QUANTUM PHYSICS

PUBLIC EVENING EVENT

Smithsonian Institution Archives, Image No. SIA2008-3637, edited.

DATE

Wednesday, 10 September 2025
18:30 – 20:30

LOCATION

Stadthalle Göttingen,
Jina-Mahsa-Amini-Platz 1
37073 Göttingen

Admission is free.
Tickets under:

Programme under:
https://quantum25.dpg-tagungen.de/programm/evening-event

Concert "Die Ordnung der Wirklichkeit"

Cantata for the 2nd DPG Fall Meeting
by Manuel Durão (*1987)

Evening Talk:
"Quanten Computer –
Die neue Art des Rechnens"

Heike Riel (IBM, Head of Science of Quantum and Information Technology and Lead of IBM Research Quantum Europe)

The talk will be held in German!
Simultaneous translation into English will be provided.

INTERNATIONAL YEAR OF Quantum Science and Technology

2025 Quantum2025

Thursday, September 11, 2025

			Plenary Talks
08:30	ZHG011	PLV VIII	Entanglement in quantum materials •Silke Bühler-Paschen
09:30	ZHG011	PLV IX	Enabling optical quantum technologies with semiconductor quantum dots •Pascale Senellart
			Lunch Talk
13:15	ZHG008	PSV VII	Innovation made in Göttingen and in concert. What can we draw from history? •Arne Schirrmacher

SYWS

			Invited Talks
10:45	ZHG008	SYWS 1.1	Twisted transition metal dichalcogenides for new topological states •Jie Shan
11:15	ZHG008	SYWS 1.2	Exciton dynamics in 2D-moiré materials in space and time •Stefan Mathias
11:45	ZHG008	SYWS 1.3	Fractional Quantum Anomalous Hall Effect and Chiral Superconductivity in Graphene •Long Ju
12:15	ZHG008	SYWS 1.4	Electron Correlations in Moiré vs. Moiréless Quantum Matter •Tim Wehling
			Session
10:45	ZHG008	SYWS 1	Quantum 2D-Moiré and Rhombohedral van-der-Waals Systems

SYEC

			Invited Talks
10:45	ZHG010	SYEC 1.1	Quantum Information and Spacetime: New Ideas and Results •Michal P. Heller
11:15	ZHG010	SYEC 1.2	Entanglement in holography •Nele Callebaut
11:45	ZHG010	SYEC 1.3	The theory of learnability of local Hamiltonians from Gibbs states •Anurag Anshu
12:15	ZHG010	SYEC 1.4	There's a hole in my quantum bucket – complexified quantum theory and its classical limit •Eva-Maria Graefe
			Session
10:45	ZHG010	SYEC 1	Entanglement and Complexity – How "Complex" is Nature?

SYQD

			Invited Talks
10:45	ZHG104	SYQD 1.1	Symposium introduction: semiconductor quantum sensors/detectors in particle physics – a success story •Norbert Wermes
11:00	ZHG104	SYQD 1.2	Precision Timing with Silicon Detectors •Nicolo Cartiglia
11:25	ZHG104	SYQD 1.3	Quantum sensor systems for enhanced precision particle detection •Michael Doser
11:50	ZHG104	SYQD 1.4	High-performance superconducting nanowire single photon detectors •Val Zwiller
12:15	ZHG104	SYQD 1.5	ALICE ITS3 – the ultimate paper wrap pixel detector •Magnus Mager

Thursday, September 11, 2025

SYQD

			Session
10:45	ZHG104	SYQD 1	Precise Quantum Detectors in Space, Time and Energy – Semi- and Superconductors in Particle and Condensed Matter Physics

SYQM

			Invited Talks
10:45	ZHG105	SYQM 1.1	The quantum world of molecules revealed with rotational coherence spectroscopy •Melanie Schnell
11:15	ZHG105	SYQM 1.2	Accurate calculation of non-covalent interactions using explicitly correlated local correlation methods •Hans-Joachim Werner
11:45	ZHG105	SYQM 1.3	High-resolution spectroscopy of molecular ions •Stephan Schlemmer
12:15	ZHG105	SYQM 1.4	Quantum Simulations in the Chemical Industry •Ansgar Schäfer
			Session
10:45	ZHG105	SYQM 1	Precise Quantum Molecules

THU

			Invited Talks
14:15	ZHG003	THU 3.1	Reshaping the History of Quantum Physics: Paths to Gender Equality •Andrea Reichenberger
14:45	ZHG003	THU 3.2	Women in the History of Quantum Physics •Margriet van der Heijden
15:15	ZHG003	THU 3.3	Visibility, invisibility and hypervisibility of women in quantum technologies •Andrea Bossmann
15:45	ZHG003	THU 3.4	Leadership, Cooperation and Conflicts in Physics: Research Leaders' Perspectives • Maike Reimer
			Sessions
14:15	ZHG001	THU 1	Fault-Tolerant Quantum Computing: Contributed Session (Quantum Error Correction)
14:15	ZHG002	THU 2	Quantum Information: Concepts and Methods I
14:15	ZHG003	THU 3	Arbeitskreis Chancengleichheit (AKC)
14:15	ZHG004	THU 4	Precise Quantum Molecules: Contributed Session to Symposium
14:15	ZHG006	THU 5	QIP Implementations: Interfaces
14:15	ZHG007	THU 6	Quantum Computing and Communication: Contributed Session II (Concepts)
14:15	ZHG008	THU 7	Entanglement and Complexity: Contributed Session to Symposium II
14:15	ZHG009	THU 8	Frustrated Quantum Systems: Contributed Session to Symposium
14:15	ZHG101	THU 9	Correlated Quantum Matter: Contributed Session to Symposium II
14:15	ZHG103	THU 10	Foundational / Mathematical Aspects – Methods and Approximations
14:15	ZHG104	THU 11	Quantum Technology and Industry
14:15	ZHG105	THU 12	Quantum Thermalization: Contributed Session to Symposium
16:30	ZHG Foyer 1. OG		
		THU 13	Poster Session: Applications

JOB

			Invited Talks
12:45	ZHG005	JOB 2.1	Carl Zeiss AG: Challenge the Limits of Imagination •Nils Haverkamp, •Sebastian Vauth

Thursday, September 11, 2025

JOB

13:30	ZHG005	JOB 2.2	Data-Analytics in der HUK-COBURG – Wie Physiker den Weg in ein datengetriebenes Versicherungsunternehmen mitgestalten •Jannik Hofestädt, •Andreas Gleixner, •Thomas Körzdörfer
			Session
12:45	ZHG005	JOB 2	Job Market II

10:30	ZHG Foyer	**Exhibition of Scientific Instruments and Literature** (free entrance)

19:00	ZHG011	**Public Evening Lecture** (free entrance) Neue Quantentechnologien für den Weltraum •Matthias Maurer

20:00	Deutsches Theater Göttingen	**Theatre: "Und der Alte würfelt doch!"**

Friday, September 12, 2025

			Plenary Talks
08:30	ZHG011	PLV X	Quantum Simulation and Quantum Computing with Ultracold Atoms •Immanuel Bloch
09:30	ZHG011	PLV XI	The hottest fluid on earth: characterizing deconfined quark-gluon matter at the Large Hadron Collider •Anton Andronic

FRI

			Sessions
10:45	ZHG001	FRI 1	Quantum Information: Concepts and Methods II
10:45	ZHG002	FRI 2	Many-Body Quantum Dynamics III
10:45	ZHG003	FRI 3	Quantum Chaos
10:45	ZHG004	FRI 4	Foundational / Mathematical Aspects – Alternative Views
10:45	ZHG006	FRI 5	QIP Implementations: Solid-State Devices II
10:45	ZHG007	FRI 6	Quantum Error Mitigation
10:45	ZHG008	FRI 7	Entanglement and Complexity: Contributed Session to Symposium III
10:45	ZHG009	FRI 8	Quantum Detectors in Optics and Particle Physics
10:45	ZHG101	FRI 9	Fundamental Quantum Tests
10:45	ZHG103	FRI 10	Foundational / Mathematical Aspects – Unconventional Approaches
10:45	ZHG104	FRI 11	Quantum 2D-Moiré and Rhombohedral van-der-Waals Systems: Contributed Session to Symposium
10:45	ZHG105	FRI 12	Quantum Phenomena in Solid-State Devices

Plenary Talks

Plenary Talk PLV I Mon 8:30 ZHG011

The Long Quantum Revolution — •Jürgen Renn — Max Planck Institute for Geoanthropologiy, Jena, Germany

The talk will review different phases of the quantum revolution with an emphasis on critical developments in the 1920s and the 1950s. On the basis of joint work in the context of the quantum project of the Max Planck Institute for the History of Science it will be shown how the exploration of the limits of classical physics yielded results that served as the scaffolding for the first quantum revolution of the 1920s. The talk will further argue that the second quantum revolution associated with the work of Clauser, Aspect, and Zeilinger goes back to the challenges to the Copenhagen interpretation by quantum dissidents like David Bohm.

Plenary Talk PLV II Mon 9:30 ZHG011

The Laser and fundamental quantum science — •Serge Haroche — Laboratoire Kastler Brossel, Collège de France, Paris, France

Among all the inventions born of quantum physics, the laser occupies an essential place, both for the rich history of discoveries that led to its birth, and for the role it plays today in fundamental and applied research. This history began at the time of the old quantum theory with Einstein's discovery of stimulated emission in 1916 and Stern's discovery of the spatial quantization of the atomic angular momentum in 1922. Nuclear magnetic resonance (1945), optical pumping (1952), atomic clocks and the maser (1954) followed, leading in 1960 to the invention of the laser.

This extraordinary light source plays an essential role in many modern technologies. It has also opened up fields of research in blue sky science that could not have been imagined at the time of its birth. We owe to it the cooling and trapping of atoms, the study of quantum gases of bosons and fermions, the discovery of gravitational waves and the manipulation of individual quantum particles, which has led to current research into quantum simulation and quantum computing. The laser may also provide answers to fundamental questions about the link between quantum physics and gravitation, or about the nature of the hypothetical dark matter. The history of the laser is a vivid illustration of the close link between fundamental research and technology

Plenary Talk PLV III Tue 8:30 ZHG011

The Quantum Roots of the Cosmos — •Gianfranco Bertone — University of Amsterdam, Amsterdam, 1098 XH, Netherlands

Quantum physics has far-reaching consequences beyond the microscopic: physicists tackling the greatest puzzles in cosmology - dark matter, dark energy and the Big Bang - routinely draw on their quantum field theory toolkit for answers. Gravitational-wave astronomy offers a new frontier to unlock these mysteries and forge a connection between the micro- and macrocosmos. As an example, I show how future interferometers will allow us to probe the matter surrounding black holes, opening up the possibility to discover new quantum fields, and to characterise the fundamental nature of dark matter.

Plenary Talk PLV IV Tue 9:30 ZHG011

Decoherence and Quantum Darwinism — •Wojciech Zurek — Los Alamos National Laboratory, USA

The measurement problem has been a central puzzle of quantum theory since its inception, and understanding how the classical world emerges from our fundamentally quantum Universe is key to its resolution. While the "Copenhagen" and "Many Worlds" interpretations have dominated discussion of this philosophically charged question, I will show how the physics of decoherence and the theory of Quantum Darwinism accounts for the emergence of classical reality.

Plenary Talk PLV V Tue 16:30 ZHG011

From Heisenberg in Göttingen to Quantum Information — •Anton Zeilinger — Austrian Academy of Sciences / University of Vienna, Austria

In the talk I will build a bridge from the early days of quantum mechanics to modern experiments. Heisenberg's role is particularly interesting as he also had very modern views of the interpretation which put knowledge of the observer in a central position. This can be seen in a modern way as putting information in the most central position.

Plenary Talk PLV VI Wed 8:30 ZHG011

The Higgs Boson and the Quantum Vacuum: Understanding Mass and Symmetry Breaking — •Beate Heinemann — DESY, Notkestr. 85, 22607 Hamburg, Germany

In 2012, the ATLAS and CMS collaborations at CERN announced the discovery of the Higgs boson * the quantum excitation of the scalar field responsible for electroweak symmetry breaking within the Standard Model of particle physics. This long-sought particle provides direct evidence for the Higgs mechanism, which explains how elementary particles acquire mass through their interaction with the Higgs field. The Higgs field constitutes an essential component of the quantum vacuum: its nonzero vacuum expectation value spontaneously breaks the electroweak symmetry, thereby endowing gauge bosons and fermions with mass.

In this talk, we will examine the theoretical framework of the Higgs mechanism and the role of the Higgs field in quantum field theory. We will discuss how spontaneous symmetry breaking shapes the structure of the Standard Model and consider the broader implications for our understanding of fundamental interactions and the vacuum structure of the universe. The presentation will also highlight the experimental challenges and milestones in the search for the Higgs boson, culminating in its discovery at the Large Hadron Collider. Particular emphasis will be placed on the key measurements, detector technologies, and the collaborative global effort that led to one of the most significant achievements in contemporary physics.

Plenary Talk PLV VII Wed 9:30 ZHG011

The Quantum Revolution in Metrology — •Klaus von Klitzing — Max Planck Institute for Solid State Research, Stuttgart, Germany

In celebration of the 2025 International Year of Quantum Science and Technology, this presentation will delve into the revolutionary impact of the quantum Hall effect on metrology. What began as fundamental research on silicon field-effect transistors culminated in the surprising discovery of the quantum Hall effect. This breakthrough ignited a paradigm shift in measurement science, paving the way for the worldwide implementation of an International System of Units (SI) based on constants of nature with e.g. a fixed value for the Planck constant to redefine the kilogram.

Plenary Talk PLV VIII Thu 8:30 ZHG011

Entanglement in quantum materials — •Silke Bühler-Paschen — Institute of Solid State Physics, TU Wien, Vienna, Austria

Entanglement is one of the most striking – and potentially most useful – phenomena in quantum physics. Over the past century, we've witnessed remarkable progress: from the discovery of the quantum nature of matter to the precise control and utilization of quantum states across a variety of platforms, with entanglement playing a pivotal role. Curiously, however, these advances have largely stalled at the doorstep of quantum materials – systems governed by the intricate interplay of multiple quantum degrees of freedom, and likely shaped in essential ways by their entanglement structure. In this talk, I will discuss recent developments in this field, focusing on the enigmatic "strange metal" state, which is uniquely suited to make progress.

Plenary Talk PLV IX Thu 9:30 ZHG011

Enabling optical quantum technologies with semiconductor quantum dots. — •Pascale Senellart — Université Paris-Saclay, Centre de Nanosciences et de Nanotechnologies, CNRS, 10 Boulevard Thomas Gobert, 91120, Palaiseau, France

Semiconductor quantum dots have emerged as excellent sources of single and entangled photons, opening new paths for light-based quantum technologies. We develop quantum light sources and spin-photon interfaces using InGaAs quantum dots embedded in microcavities. These devices generate highly indistinguishable single photons at high rates, and are now fiber pigtailed for plug-and-play operation. These sources are incorporated into early quantum computing prototypes together with integrated photonic chips and detectors. A software stack allows full control of the system and enables users to run small-scale quantum protocols.

To scale up the number of qubits and implement error correction, we are adopting measurement-based quantum computing protocols based on photonic graph states. By exploiting the spin degree of freedom of a charge trapped in a quantum dot, we can now generate various spin multi-photon entangled states. These results paves the way for hybrid quantum computing that leverage both spin and photonic qubits. As a first example, we analysed the resource requirements for implementing a logical qubit and showed that our hybrid approach can reduce the number of components needed by six orders of magnitude compared to a fully photonic implementation.

Plenary Talk PLV X Fri 8:30 ZHG011

Quantum Simulation and Quantum Computing with Ultracold Atoms — •Immanuel Bloch — Ludwig Maximilians Universität, München, Germany — Max Planck Institute of Quantum Optics (MPQ), Garching, Germany

Quantum simulation has become a powerful interdisciplinary tool for probing quantum matter with microscopic resolution, both in and out of equilibrium. Platforms based on ultracold atoms in optical lattices and tweezers have played a crucial role in the development of the field, with applications ranging from strongly correlated electronic or spin systems to novel quantum optical light matter interfaces. These systems offer complementary insights to those obtained from advanced numerical methods. In particular, fermionic quantum simulators have begun to reveal new aspects of strongly interacting regimes that challenge conventional computational approaches. Alongside analog approaches, gate-based quantum computing offers broader universality, though it remains limited by scalability and error correction demands. Hybrid strategies combining both paradigms may offer a promising route to address complex quantum many-body problems in the near term.

This talk will survey recent progress, highlight key challenges, and discuss future directions at the interface of quantum simulation, computation, and many-body physics.

Plenary Talk PLV XI Fri 9:30 ZHG011

The hottest fluid on earth: characterizing deconfined quark-gluon matter at the Large Hadron Collider — •Anton Andronic — University of Münster, Germany

Deconfined quark-gluon matter, a state of matter which must have prevailed in our Universe in its first 10 microseconds of existence, is produced in collisions of nuclei at the Large Hadron Collider. I will discuss our knowledge and questions on the early thermalization of the hot and dense deconfined matter and focus on what we learned about its still-mysterious transition to hadrons with confined quarks and gluons.

Lunch, Evening Talks and Discussions

Lunch Talk PSV I Mon 13:15 ZHG008

KnabenPhysik: Social Crises, Postdoctoral Culture, and International Contexts of the Quantum Revolution. — •Alexei Kojevnikov — University of British Columbia, Vancouver, Canada

The majority of initial contributions to quantum mechanics between 1925 and 1927, as is well known, came from younger students of physics under the age of 30. It is thus worth analyzing historically how the quantum revolution and the emerging new discipline looked from the perspective of not a professor, but a recent or actual Ph.D. student just embarking on an uncertain academic career in economically and politically troubled times. International cooperation in science had been badly damaged by World War I. Many countries in Europe experienced serious crises, economic hardships and political turmoil, including violent coups and revolutions. Temporary assistantships, postdoctoral positions and their equivalents were the chief mode of existence for young academics during the period. Using documents from the Rockefeller Archives and other collections, the paper describes the resulting varying patterns of postdoctoral traffic to the main centers of quantum physics: München, Göttingen, Copenhagen and Berlin. By following the work of several students, such as Pauli, Heisenberg, and Jordan, who moved between various centers of research, it is possible to see how the transitory postdoctoral way of life influenced their choices between rival approaches in the field and important problems to handle. Insecure career trajectories and unpredictable moves through non-stable temporary positions thus contributed to the general outlook and interpretation of the emerging theory of quantum mechanics.

Lunch Talk PSV II Tue 13:15 ZHG008

The Gendered History of Quantum Physics — •Daniela Monaldi — York University, Toronto, Canada

The book _Women in the History of Quantum Physics: Beyond Knabenphysik_ is the result of an international, interdisciplinary project initiated as part of the broader effort to celebrate the centennial of quantum mechanics. It presents original analyses of the lives and work of sixteen women who, throughout the twentieth century, from various locations and in diverse ways, participated in the development of quantum physics. By focusing on lesser-known figures and introducing a gender perspective to historical studies of physics, we aim to challenge the conventional all-male narratives that often reinforce the masculine image of the field. From these richly detailed microhistories, several themes emerge, offering insights into the historically persistent gendered dynamics of physics research.

Discussion PSV III Tue 13:15 ZHG009

Wissenschaftskommunikation: Verlässliche Stimmen in unruhigen Zeiten — •Nicolas Wöhrl[1], •Harald Lesch[2] und Axel Lorke[3] — [1]Universität Duisburg-Essen und CENIDE, Duisburg, Deutschland — [2]Ludwig-Maximilians-Universität München, München, Deutschland — [3]Universität Duisburg-Essen, Duisburg, Deutschland

Die Fähigkeit, kritisch zu hinterfragen, zwischen Fakten und Fiktion zu unterscheiden und evidenzbasierte Argumente zu entwickeln, macht Forschende zu wichtigen Stimmen in einer Zeit, in der gesellschaftliche Debatten zunehmend politisiert sind und von Falschinformationen überlagert werden. Dabei geht es nicht nur darum, belastbare Daten zu erheben. Ebenso wichtig ist es, Vertrauen in die wissenschaftliche Methode aufzubauen und zu erhalten. Dieses Vertrauen ist entscheidend: Nur mit einer informierten Öffentlichkeit lassen sich wissenschaftsbasierte Entscheidungen treffen und umsetzen.

Vertrauen entsteht jedoch nicht allein durch exzellente Forschungsergebnisse. Es wächst auch dadurch, dass Prozesse und Methoden wissenschaftlicher Arbeit nachvollziehbar werden und die Menschen sichtbar werden, die hinter den Erkenntnissen stehen. Diese Aufgabe können und sollten prinzipiell alle Forschenden mitübernehmen.

In der Podiumsdiskussion wollen wir folgenden Fragen nachgehen: Welchen Stellenwert hat Wissenschaftskommunikation in der Gesellschaft? Warum braucht es neben Pressestellen und Journalismus auch kommunizierende Wissenschaftler:innen? Wie kann Öffentlichkeitsarbeit trotz der vielen anderen Aufgaben in Forschung und Lehre gelingen? Welchen Platz sollte sie in der wissenschaftlichen Ausbildung haben? Und welche Möglichkeiten gibt es für den wissenschaftlichen Nachwuchs, sich in der Wissenschaftskommunikation zu engagieren?

Discussion PSV IV Tue 17:45 ZHG011

Panel Discussion: "A century after 1925: Do we now understand quantum mechanics?" — •Gianfranco Bertone[1], •Anton Zeilinger[2], •Wojciech Zurek[3], •Reinhard Werner[4], and others TBA[5] — [1]University of Amsterdam, Netherlands — [2]University of Vienna, Austria — [3]Los Alamos National Lab, USA — [4]Leibniz University Hannover, Germany — [5]TBA

Exactly 100 years ago Werner Heisenberg's "Umdeutung" paper set a radical change of our understanding of nature in motion. The classical worldview was replaced by quantum theory, leading to many conceptual and fundamental challenges which are still with us today.

This panel discussion at the birthplace of this paradigm shift aims to answer the question of how much progress has been made regarding these issues since 1925. Is there still a problem, and if yes what exactly is it?

Lunch Talk PSV V Wed 13:15 ZHG008

Bohr was not obscure! — •Guido Bacciagaluppi — Freudenthal Institute and Descartes Centre, Utrecht University, The Netherlands

Niels Bohr was both one of the founding fathers of quantum mechanics and someone who held strong convictions about the wider implications of quantum mechanics. His writings on the foundations of quantum mechanics, for instance the Como lecture or his reply to Einstein, Podolsky and Rosen, have however often been seen as obscure. Like other recent researchers, I believe that such criticisms are due to misunderstandings, and in this talk I shall try to present some of the main aspects of Bohr's views on quantum mechanics in a way that may hopefully help clarify some of the misunderstandings surrounding them.

Evening Talk PSV VI Wed 18:30 Stadthalle Göttingen

Quanten Computer – Die neue Art des Rechnens — •Heike Riel — IBM Research, Rüschlikon, Switzerland

Quantentechnologie und insbesondere Quantencomputer, die sich die Phänomene der Quantenphysik zunutze machen, werden in einem beispiellosen Tempo entwickelt. Quantencomputer eröffnen einen neuen Weg zur Weiterentwicklung des Rechnens und ermöglichen die Lösung schwieriger und komplexer Probleme, die jenseits der Möglichkeiten klassischer Computer liegen.

In den letzten Jahren wurden erhebliche Fortschritte über den gesamten Quantencomputer stack erzielt, von der Hardware, über die Software, der Systemintegration, dem Zusammenspiel mit klassichen Rechnern bis hin zu praktischen Anwendungen in Forschung und Industrie. In dieser Präsentation werden die Kernkonzepte des Quantencomputings kurz erklärt, der aktuelle Stand des Feldes erörtert und die Voraussetzungen für die Entwicklung zu einem robusten Tool für die Lösung realer Probleme erläutert. Um die Leistungsfähigkeit - Anzahl Qubits, Qualität und Geschwindigkeit des Systems - so schnell wie möglich zu steigern, sind Verbesserungen in allen Bereich erforderlich. Eine modulare Architektur kombiniert mit einem effizienten Fehlerkorrekturalgorithmus ermöglicht es bis 2029 einen hochskalierenden, fehlertoleranten Quantencomputer mit 200 logischen Qubits zu bauen, die 100 Millionen Quantenoperationen ausführen koennen. Ein Überblick über die Herausforderungen, die jüngsten Fortschritte bei der Entwicklung und die Technologie Roadmap werden diskutiert.

Lunch Talk PSV VII Thu 13:15 ZHG008

Innovation made in Göttingen and in concert. What can we draw from history? — •Arne Schirrmacher — Humboldt-Universität zu Berlin, Berlin, Germany

As the final historical lunch talk of this meeting and of the whole series of talks organised by the DPG on the history of quantum physics in general and the formulation of quantum mechanics in particular, this talk tries to reap up the discussion with Göttingen in the focus.

Talk of revolution and Heureka moments has mostly given room for more complex and multi-faceted accounts, combining longer-term developments with intense periods of collaboration at Göttingen and in concert with other centres of quantum science worldwide in 1925. Given the exceptional success of interdisciplinary and international collaboration, it is asked what insights one might draw from this example for orchestrating successful research today.

Evening Talk PSV VIII Thu 19:00 ZHG011

Neue Quantentechnologien für den Weltraum — •Matthias Maurer — European Astronaut Center, Linder Höhe, 51147 Köln

Die Weltraumbedingungen sind für einige Quantentechnologien wie Atomuhren, Quantensensoren und Quantenkommunikation von großem Vorteil. In dem Vortrag geht es speziell um das Cold Atom Lab CAL der NASA, in dem Bose-Einstein-Kondensate in der Schwerelosigkeit erzeugt und untersucht werden und für welches derzeit die deutsche Nachfolgeapparatur BECCAL entwickelt wird, sowie um das kürzlich auf die ISS gebrachte Projekt Atomic Clock Ensemble in Space ACES mit zwei hochgenauen Atomuhren. Es wird auf die technischen Herausforderungen für Quantenexperimente im Weltraum sowie auf deren praktischen Nutzen eingegangen.

Tutorials

TUT 1: Tutorial Basics of Quantum Information and Computation

Time: Sunday 15:00–16:30 Location: ZHG104

Tutorial TUT 1.1 Sun 15:00 ZHG104

Basics of quantum information and computation — •Ralf Schuetzhold — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — TU Dresden, Germany

The goal of this tutorial is to provide a brief introduction into the basics ideas and concepts of quantum information and computation at the beginners level (assuming no knowledge besides the basic laws of quantum theory). The basic question is: how can we exploit the laws of quantum physics in order to perform task better than with classical physics? Apart from computation, this may also include communication, sensing, simulation and other applications.

TUT 2: Tutorial What can Quantum Computers do – and what can't they?

Time: Sunday 15:00–16:30 Location: ZHG105

Tutorial TUT 2.1 Sun 15:00 ZHG105

What can quantum computers do - and what can't they? — •Jens Eisert — Dahlem Center for Complex Quantum Systems, Freie Universität Berlin

Quantum computers - so computers whose fundamental units of information are quantum systems - promise solutions to computational problems that are beyond the reach of classical supercomputers. However, this does not mean they can solve all problems faster. In fact, this advantage seems to apply only to a small number of highly structured problems - those for which a provable separation exists between quantum and classical capabilities.

This tutorial introduces some elementary quantum algorithms, explores more sophisticated ones, and examines both the potential and the limitations of fully fault-tolerant quantum computers. It also serves as an invitation to contribute to this field, as each new class of quantum algorithms has historically begun with a genuinely novel idea.

TUT 3: Tutorial Quantum Foundations from a QI Perspective

Time: Sunday 17:00–18:30 Location: ZHG104

Tutorial TUT 3.1 Sun 17:00 ZHG104

Quantum foundations from a QI perspective — •Markus Frembs — Leibniz University, Hannover, Germany

Even 100 years after its inception, the foundations of quantum theory remain an active area of research. A plethora of competing interpretations offer different views on long-standing issues such as the infamous measurement problem, Einstein's 'spooky action at a distance' and Bohr's complementarity. At the core of these lies the discrepancy between the unparalleled predictive success of the mathematical apparatus of quantum mechanics and our every-day experience, which by and large obeys the laws of classical physics.

The first part of the tutorial will discuss two famous no-go-theorems in quantum foundations - by Bell, Kochen and Specker - which throw into sharp relief how this discrepancy between classical and quantum physics has drastic consequences for our physical understanding of the world: first, certain quantum correlations defy a causal classical explanation and, second, contextuality expresses the incompatibility with classical realism altogether. The experimental verification of entanglement which has recently been awarded the Nobel Prize in Physics leaves little room for adhering to a classical interpretation.

Rather than challenging such counterintuitive predictions, the field of quantum information theory embraces them as features, asking if and how they can be put to use in computational or information-processing tasks. The second part of the tutorial will list a number of examples to the resourcefulness of quantum theory e.g. in cryptography and computation.

TUT 4: Tutorial Quantum Optimal Control

Time: Sunday 17:00–18:30 Location: ZHG105

Tutorial TUT 4.1 Sun 17:00 ZHG105

Quantum Optimal Control in a Nutshell — •Daniel Reich — Freie Universität Berlin, Dahlem Center for Complex Quantum Systems and Fachbereich Physik, Berlin, Germany

Since the start of the 21st century, research and development of technologies actively exploiting quantum properties of light and matter has experienced a surge in popularity. To this end, quantum optimal control is one of the main tools for devising concrete protocols to manipulate quantum systems in order to achieve specific tasks in the best way possible. In the first part of this tutorial I tell you about the main principles of quantum optimal control and provide a brief summary of the key techniques used in the field. In the second part I demonstrate the power of the quantum optimal control toolbox via practical use cases. Finally, I introduce some of the available software packages such that you can start controlling quantum systems, too.

Joint Symposium of the Danish and German Physical Societies (SYDK)

Sebastian Hofferberth
University of Bonn
Wegelerstraße 8
53115 Bonn, Germany
hofferberth@iap.uni-bonn.de

Klaus Molmer
University of Copenhagen
Blegdamsvej 17
2100 Copenhagen, Denmark
klaus.molmer@nbi.ku.dk

One of the epicenters of the early development of quantum physics was Copenhagen. This happened because Niels Bohr in 1921 defined the new Institute of Theoretical Physics as an international hub and invited the brightest minds of the time to visit and enjoyed long- and short-term positions in Copenhagen. In this symposium, we will have lectures recalling the special history and the special flavor of quantum physics as it was developed and discussed in Copenhagen in the 1920'es, and we will have research talks reporting on modern scientific research from some of the many strong collaborations that have always united scientists in Denmark and Germany.

Overview of Invited Talks and Sessions

(Lecture hall ZHG008)

Invited Talks

SYDK 1.1	Mon	10:45–11:25	ZHG008	**Quantum physics and the spirit of Copenhagen** — •Klaus Molmer
SYDK 1.2	Mon	11:25–12:05	ZHG008	**General Relativity from Quantum Theory** — •Niels Emil J. Bjerrum-Bohr
SYDK 1.3	Mon	12:05–12:45	ZHG008	**Frontiers in quantum gravity** — •Astrid Eichhorn

Sessions

SYDK 1.1–1.3	Mon	10:45–12:45	ZHG008	**Joint Symposium of the Danish and German Physical Societies**

Sessions

– Invited Talks –

SYDK 1: Joint Symposium of the Danish and German Physical Societies

Time: Monday 10:45–12:45 Location: ZHG008

Invited Talk SYDK 1.1 Mon 10:45 ZHG008

Quantum physics and the spirit of Copenhagen — •Klaus Molmer — Niels Bohr Institute, University of Copenhagen, Denmark

With his 1913 theory model of atoms and molecules, Niels Bohr joined Planck and Einstein as co-founder of the early quantum theory. In 1920, he was given the opportunity to lead the new institute in Copenhagen, that now carries his name, and he designed it as a modern and progressive hub for a whole generation of young scientists from all over the world. Bohr's own model of atoms turned out to be insufficient, while a new theory, quantum mechanics, was spearheaded by Heisenberg and Schrödinger in 1925-26.

The seminar will recall the appearance at the Niels Bohr institute of central international figures in the development of quantum theory, and how many elements of the new theory and its interpretation were centerpiece of discussions in Copenhagen. A bust of Albert Einstein in Bohr's office in Copenhagen, reminds the visitor that today's pursuit of quantum computers and other quantum technologies borrows elements and inspiration from the famous discussions between Bohr and Einstein.

Invited Talk SYDK 1.2 Mon 11:25 ZHG008

General Relativity from Quantum Theory — •Niels Emil J. Bjerrum-Bohr — Niels Bohr Institute, Copenhagen

Gravity is an elemental theory of physics, but its exact quantum mechanical nature remains a mystery. A significant breakthrough is that we can now directly measure the effects of massive black holes colliding in the Universe through gravitational waves. This exciting development has opened up possibilities for intriguing comparisons between measurements of gravitational interactions and theoretical expectations. In this talk, I will describe how to derive results for observables in classical gravity using quantum field theory by applying the Bohr correspondence principle. This approach provides new insights into the fundamental nature of gravitational interactions and could potentially reveal deviations from Einstein's theory of general relativity.

Invited Talk SYDK 1.3 Mon 12:05 ZHG008

Frontiers in quantum gravity — •Astrid Eichhorn — Institute for Theoretical Physics, Heidelberg University, Heidelberg

After decades of research, understanding the quantum structure of spacetime remains an open challenge. I will provide an overview of that challenge and some recent progress, highlighting two aspects: First, I will contrast different candidate theories of quantum gravity and discuss whether or not they are related to each other. Second, I will discuss the challenge of connecting theories of quantum gravity to observational data and review ideas how to address this challenge.

Symposium Foundational Aspects of Quantum Theory (SYFA)

Martin Zirnbauer
University of Cologne
Zülpicher Str. 77a
50937 Köln, Germany
zirnbauer@uni-koeln.de

Featuring three highly renowned speakers from mathematical physics, this symposium addresses a number of foundational issues in quantum mechanics and quantum field theory, ranging from the basic notion of entanglement to the perennial question: "Do we understand quantum theory?"

Overview of Invited Talks and Sessions

(Lecture hall ZHG010)

Invited Talks

SYFA 1.1	Mon	10:45–11:25	ZHG010	**Towards a Completion of Quantum Mechanics** — •Jürg Fröhlich
SYFA 1.2	Mon	11:25–12:05	ZHG010	**Locality and its generalizations in quantum field theory** — •Kasia Rejzner
SYFA 1.3	Mon	12:05–12:45	ZHG010	**Heisenberg's Operational Program** — •Reinhard Werner

Sessions

SYFA 1.1–1.3	Mon	10:45–12:45	ZHG010	**Foundational Aspects of Quantum Theory**

Sessions

– Invited Talks –

SYFA 1: Foundational Aspects of Quantum Theory

Time: Monday 10:45–12:45 Location: ZHG010

Invited Talk SYFA 1.1 Mon 10:45 ZHG010

Towards a Completion of Quantum Mechanics — •Jürg Fröhlich — ETH Zurich, 8093 Zurich, Switzerland

A basic physical mechanism, dubbed Principle of Declining Potentialities (PDP), underlying the dissipative nature of Heisenberg-picture time-evolution in systems of matter coupled to the quantized radiation field is exhibited. When combined with a natural State-Reduction Postulate PDP gives rise to a natural theory of quantum jumps, more precisely to a general law governing the stochastic time-evolution of states of individual systems in non-relativistic quantum electrodynamics. Our approach appears to lead to solutions of the so-called measurement problem and unitarity paradox. Some generalizations of our ideas to relativistic quantum theory will be sketched.

Invited Talk SYFA 1.2 Mon 11:25 ZHG010

Locality and its generalizations in quantum field theory — •Kasia Rejzner — University of York, York, UK

The principle of locality has been one of the guiding principles underlying quantum field theory (QFT). It is crucial in the Haag-Kastler framework of algebraic quantum field theory (AQFT) and it has been generalized to curved spacetimes through the principle of general local covariance. However, the simple idea of localization in relatively compact regions fails already in gauge theories (e.g. Dirac string or Wilson loops) and in quantum gravity one expects observables that are relational in nature, hence non-local. In this talk I will argue that non-locality enters QFT in a natural way when we consider measurements and introduce quantum reference frames.

Invited Talk SYFA 1.3 Mon 12:05 ZHG010

Heisenberg's Operational Program — •Reinhard Werner — Leibniz Universität Hannover

To build the new quantum theory just on observable quantities was an important guideline for Heisenberg's early work. In the Uncertainty Paper (1927) he tried to make this the principle of theory construction, in close analogy to Einstein's critical evaluation of simultaneity, which turned out to be the core of relativity theory. Heisenberg declares success of this program, although in hindsight one has to admit that he failed miserably, with the famous microscope thought experiment the only surviving bit of that chapter. I will retrace his arguments, and put them in the context of operational thinking in physics before and after Heisenberg. Indeed, operational ideas were current in Born's group quite independently of Heisenberg. On the other hand, modern quantum mechanics, especially quantum information theory, is much more radical than Heisenberg in its operational stance

Symposium Loosely-Bound States – From the Coldest to the Hottest Environments (SYLB)

Benjamin Dönigus
Goethe University Frankfurt am Main
Max-von-Laue-Straße 1
60438 Frankfurt am Main, Germany
b.doenigus@gsi.de

An interesting field of active research is the study of loosely-bound states that have direct connections to basic quantum physics. Such loosely-bound systems are created in many different quantum systems, namely in ultra-cold quantum gases, in nuclear physics and even in high-energy nucleus collisions, e.g. at LHC energies. One example is the hypertriton that can be seen as a bound state of a Lambda hyperon and a deuteron, with a Lambda separation energy of only 130 keV. That low energy leads to a distance between the deuteron core and the Lambda of 10.6 fm, making it the ultimate halo nucleus. This interesting object is produced copiously in heavy-ion collisions at the Large Hadron Collider at CERN, where temperatures of 156 MeV are reached, i.e. hundred thousand times hotter than the interior of the sun. The hypertriton is close to an Efimov state, i.e. a shallow 3-body bound system with universal properties. Other known halo nuclei, for instance 11Li, can also be understood as Efimov states whereas the two neutrons surround a 9Li core, these are then often called Borromean nuclei. Similar systems are also formed from atoms in magnetic traps near absolute zero temperature where the binding energy can be tuned by adjusting the magnetic field.

Overview of Invited Talks and Sessions

(Lecture hall ZHG104)

Invited Talks

SYLB 1.1	Mon	10:45–11:25	ZHG104	**Fermion Pairing and Correlation at Ultralow Temperatures** — •Philipp Preiss
SYLB 1.2	Mon	11:25–12:05	ZHG104	**The structure of loosely-bound nuclear states: when the tail wags the dog** — •Hans-Werner Hammer
SYLB 1.3	Mon	12:05–12:45	ZHG104	**Fragile Matter in Extreme Conditions: insights from the LHC** — •Francesca Bellini

Sessions

SYLB 1.1–1.3	Mon	10:45–12:45	ZHG104	**Loosely-Bound States – From the Coldest to the Hottest Environments**

Sessions

– Invited Talks –

SYLB 1: Loosely-Bound States – From the Coldest to the Hottest Environments

Time: Monday 10:45–12:45 Location: ZHG104

Invited Talk SYLB 1.1 Mon 10:45 ZHG104

Fermion Pairing and Correlation at Ultralow Temperatures — •Philipp Preiss — Max Planck Institute of Quantum Optics, Garching, Germany — Physics Institute, Heidelberg University, Heidelberg, Germany

Strongly correlated Fermi systems pose challenges across a wide range of energy scales, from quark-gluon plasmas in high-energy physics to correlated insulators in condensed matter physics.

At the lowest energies - in the microkelvin or picoelectronvolt regime - correlated fermion problems emerge in ultracold atomic gases. Reaching such ultralow temperatures presents experimental challenges but also opens opportunities: the physics unfolds at micrometer length scales and kilohertz time scales. This allows spatial resolution down to the interparticle spacing and real-time observation of dynamics.

In this talk, I will describe the toolset we have developed to microscopically study correlation and pairing effects in small two-dimensional systems of ultracold fermions. Using optical traps and fluorescence imaging, we deterministically prepare single quantum states, tune interactions, and capture particle-resolved momentum correlations in single snapshots of the wavefunction. I will show how this technique reveals Cooper-like pairs in samples containing only a few atoms and how rapid rotation induces correlations akin to Laughlin states. These results showcase the microscopic tunability of fermion pairing effects in synthetic quantum matter.

Invited Talk SYLB 1.2 Mon 11:25 ZHG104

The structure of loosely-bound nuclear states: when the tail wags the dog — •Hans-Werner Hammer — Technische Universität Darmstadt, Department of Physics, Institut für Kernphysik, 64289 Darmstadt, Germany

Loosely-bound quantum states with very different interactions at short distances can show universal behavior at large distances. These states are in the extreme quantum regime, as their constituents spend most of the time outside of the range of their interaction and the tail of the wave function determines many of their properties. They can have the peculiar property that removing one particle from a multi-body bound state can cause the whole bound state to fall apart. Such systems can be found over a large range of scales ranging from nuclear and particle physics to ultracold atoms. The talk will give an overview of current research questions and future challenges with a particular focus on nuclear systems.

Invited Talk SYLB 1.3 Mon 12:05 ZHG104

Fragile Matter in Extreme Conditions: insights from the LHC — •Francesca Bellini — Dept. of Physics and Astronomy, University of Bologna and INFN, Bologna, Italy

The formation of light nuclei and hypernuclei in high-energy collisions provides a valuable probe of nuclear structure and the strong interaction in few-body quantum systems. These nuclei, though relatively well bound in nuclear terms - the deuteron has a binding energy of 2.2 MeV are remarkably fragile when produced in extreme environments. At the CERN Large Hadron Collider, temperatures exceed 100 MeV (over a trillion Kelvin), vastly surpassing nuclear binding energies and raising fundamental questions about how loosely bound states can form and survive.

Over the past decade, the LHC has delivered a wealth of high-precision data on light nuclei and their antimatter counterparts, from deuterons to alpha particles to hypertritons. These notable results define the current experimental frontier and offer an unprecedented opportunity to confront theoretical models of nuclear formation.

Key findings are discussed in the context of recent theoretical developments, in particular focusing on the statistical hadronization and coalescence models, two quantum-mechanical frameworks that describe the production of light nuclei and hypernuclei. Comparisons between data and model predictions enable us to probe the quantum structure of matter under extreme conditions and to explore how few-body nuclear systems emerge from the underlying principles of quantum chromodynamics.

Symposium Quantum Sensing and Decoherence in Solid-State and Photonics Systems (SYQS)

Valerio Di Giulio
Max Planck Institute for
Multidisciplinary Sciences
Am Faßberg 11
37077 Göttingen, Germany
valerio.digiulio@mpinat.mpg.de

Armin Feist
Max Planck Institute for
Multidisciplinary Sciences
Am Faßberg 11
37077 Göttingen, Germany
armin.feist@mpinat.mpg.de

Claus Ropers
Max Planck Institute for
Multidisciplinary Sciences
Am Faßberg 11
37077 Göttingen, Germany
claus.ropers@mpinat.mpg.de

As quantum technologies rapidly evolve, understanding and harnessing quantum coherence at the nanoscale is becoming increasingly vital. This symposium focuses on the most recent advances in the control and sensing of quantum systems in solid-state and photonic platforms, where interactions between light and material excitations play a central role in shaping and preserving their quantum behaviour.

The session will host a distinguished lineup of invited speakers, covering a range of topics from fundamental aspects of coherence and entanglement to practical designs capable of harnessing quantum dynamics. Implementations using platforms such as photonic cavities, nanomechanical resonators, and semiconductor or superconducting devices will be discussed to foster advances in quantum computation, quantum-enhanced imaging, nanoscale sensing and manipulation, and the development of novel hybrid quantum systems for future technologies.

Overview of Invited Talks and Sessions

(Lecture hall ZHG105)

Invited Talks

SYQS 1.1	Mon	10:45–11:15	ZHG105	**Quantum Technologies for Sensing and Imaging in the Life Sciences** — •Martin B Plenio
SYQS 1.2	Mon	11:15–11:45	ZHG105	**Quantum technologies with semiconductor color centers in integrated photonics** — •Jelena Vuckovic
SYQS 1.3	Mon	11:45–12:15	ZHG105	**Towards spin-based quantum sensing in hybrid nanomechanical systems based on silicon carbide** — •Eva Weig
SYQS 1.4	Mon	12:15–12:45	ZHG105	**Quantum Sensing of Quantum Matter** — •Amir Yacoby

Sessions

SYQS 1.1–1.4	Mon	10:45–12:45	ZHG105	**Quantum Sensing and Decoherence in Solid-State and Photonics Systems**

Sessions

– Invited Talks –

SYQS 1: Quantum Sensing and Decoherence in Solid-State and Photonics Systems

Time: Monday 10:45–12:45 Location: ZHG105

Invited Talk SYQS 1.1 Mon 10:45 ZHG105
Quantum Technologies for Sensing and Imaging in the Life Sciences — •Martin B Plenio — Institute of Theoretical Physics, Ulm University, 89081 Ulm, Germany

Nuclear Magnetic Resonance (NMR), one of the most widely used spectroscopic techniques in biology and the life sciences, is inherently limited by its low sensitivity. This limitation stems from the weak nuclear spin nuclear spin polarisation in thermal equilibrium, which typically amounts to just a few parts per million, as well as the constraints of inductive NMR signal detection.

In this talk, I will discuss control techniques and signal processing methods for colour centers in diamond that enable NMR at the micron- and nanoscale. Despite these advances, enhancing the signal from the target via nuclear spin hyperpolarisation would be highly beneficial. I will explore how this enhancement might be achieved using NV centers and demonstrate that these control techniques can be transferred to parahydrogen induced polarisation, where they result in unprecedented levels if concentration and polarisation product. Interestingly, beyond the practical importance of these developments, this approach also opens up opportunities to explore chaotic dynamics and non-linear quantum physics, which hold interest for fundamental physics.

Invited Talk SYQS 1.2 Mon 11:15 ZHG105
Quantum technologies with semiconductor color centers in integrated photonics — •Jelena Vuckovic — Ginzton Laboratory, Stanford University, Stanford, CA 94305-4088, USA

Optically interfaced spin qubits based on diamond and silicon carbide color centers are considered promising candidates for scalable quantum networks and sensors. However, they can also be used to build chip-scale quantum many body systems with tunable all to all interactions between qubits enabled by photonics - useful for quantum simulation and possibly computing.

Our recent efforts have focused on tin-vacancy (SnV) color center in diamond where we have shown high fidelity microwave control of an electron-spin at 1.7K temperature, high fidelity single shot (optical) readout of an electron spin, high quality quantum photonic interface, and even heterogeneous integration with lithium niobate for frequency conversion, making this color center very interesting candidate for implementation of quantum networks. Moreover, our recent demonstration of coherent and controlled interactions of multiple qubits (silicon vacancy - VSi color centers) inside a single silicon carbide resonator has established these systems as promising candidates for other quantum technologies, including quantum simulation and possibly even quantum computing.

We also show how chip-scale Ti:sapphire laser can replace commercial tabletop lasers in our quantum optics experiments without any loss in performance, leading to truly scalable quantum systems on chip.

Invited Talk SYQS 1.3 Mon 11:45 ZHG105
Towards spin-based quantum sensing in hybrid nanomechanical systems based on silicon carbide — •Eva Weig — Technical University of Munich, Germany

Silicon carbide (SiC) has extraordinary material properties, combining some of the most favorable properties of diamond and silicon. It hosts spin-carrying color centers and exhibits high mechanical quality factors. It is thus ideally suited for the realization of advanced hybrid nano-mechanical devices incorporating atomic-scale defects. In addition, SiC crystalizes in a variety of polytypes which entails different routes towards realizing high Q mechanical resonators. Cubic 3C-SiC enables thin-film epitaxial growth on silicon. Strong tensile pre-stress is incorporated when grown on a silicon substrate oriented along the (111) direction, leading to high Q from dissipation dilution. On the other hand, hexagonal 4H-SiC is a well-established material in nanophotonics and known for its highly coherent color centers. Recently, high intrinsic Q factors exceeding 100,000 have been demonstrated in monolithic 4H-SiC. Here I will compare nanomechanical resonators made of both 3C-SiC and 4H-SiC and describe the realization of optomechanical crystals. I will discuss how to generate color centers by means of He-ion implantation, and outline the prospects of both materials for spin-mechanical and spin-optomechanical sensing.

Invited Talk SYQS 1.4 Mon 12:15 ZHG105
Quantum Sensing of Quantum Matter — •Amir Yacoby — Harvard University, Cambridge, USA

Major scientific discoveries are often enabled by new measurement capabilities that provide novel perspectives into complex physical problems. Recent advances and discoveries made on quantum materials have challenged experimentalists to come up with new ways to probe their intrinsic properties. In this talk Yacoby will discuss some of the recent work he has worked on to develop a variety of new local quantum sensing techniques and discuss how they can assist us in exploring quantum matter.

Monday Contributed Sessions (MON)

Stefan Kehrein
Fakultät für Physik
Universität Göttingen
Friedrich-Hund-Platz 1
37077 Göttingen, Germany
stefan.kehrein@theorie.physik.uni-goettingen.de

Thomas Weitz
Fakultät für Physik
Universität Göttingen
Friedrich-Hund-Platz 1
37077 Göttingen, Germany
thomas.weitz@uni-goettingen.de

Overview of Sessions

(Lecture halls ZHG001, ZHG002, ZHG003, ZHG004, ZHG006, ZHG007, ZHG008, ZHG009, ZHG101, ZHG103, ZHG104, and ZHG105; Poster ZHG Foyer 1. OG)

Sessions

MON 1.1–1.7	Mon	14:15–16:00	ZHG001	**QIP Implementations: Photons I**
MON 2.1–2.8	Mon	14:15–16:15	ZHG002	**Quantum Control**
MON 3.1–3.8	Mon	14:15–16:15	ZHG003	**Many-Body Quantum Dynamics I**
MON 4.1–4.8	Mon	14:15–16:15	ZHG004	**DPG Promotionskolleg Next Generation Computing**
MON 5.1–5.7	Mon	14:15–16:00	ZHG006	**Optical Quantum Devices**
MON 6.1–6.8	Mon	14:15–16:15	ZHG007	**QIP Implementations: Trapped Ions**
MON 7.1–7.8	Mon	14:15–16:15	ZHG008	**Foundational / Mathematical Aspects – Quantum Measurement**
MON 8.1–8.6	Mon	14:15–15:45	ZHG009	**Quantum Sensing and Decoherence: Contributed Session to Symposium I**
MON 9.1–9.8	Mon	14:15–16:15	ZHG101	**Quantum Entanglement**
MON 10.1–10.8	Mon	14:15–16:15	ZHG103	**Standard Model and Beyond**
MON 11.1–11.7	Mon	14:15–16:00	ZHG104	**Quantum Transport I**
MON 12.1–12.6	Mon	14:15–15:45	ZHG105	**Quantum Magnets**
MON 13.1–13.6	Mon	16:30–18:00	ZHG001	**QIP Implementations: Photons II**
MON 14.1–14.8	Mon	16:30–18:30	ZHG002	**QIP Implementations: Solid-State Devices I**
MON 15.1–15.7	Mon	16:30–18:15	ZHG003	**Many-Body Quantum Dynamics II**
MON 16.1–16.7	Mon	16:30–18:15	ZHG004	**Quantum Spectroscopy**
MON 17.1–17.8	Mon	16:30–18:30	ZHG006	**Quantum Communication and Networks: Theory**
MON 18.1–18.7	Mon	16:30–18:15	ZHG007	**Quantum Algorithms**
MON 19.1–19.7	Mon	16:30–18:15	ZHG008	**Foundational / Mathematical Aspects – Quantum Optics and Quantum Information**
MON 20.1–20.8	Mon	16:30–18:30	ZHG009	**Quantum Sensing and Decoherence: Contributed Session to Symposium II**
MON 21.1–21.8	Mon	16:30–18:30	ZHG103	**Quantum Materials**
MON 22.1–22.5	Mon	16:30–17:45	ZHG104	**Quantum Transport II**
MON 23.1–23.63	Mon	18:30–20:30	ZHG Foyer 1. OG	**Poster Session: Fundamental Aspects and Model Systems**

Sessions

– Contributed Talks and Posters –

MON 1: QIP Implementations: Photons I

Time: Monday 14:15–16:00 Location: ZHG001

MON 1.1 Mon 14:15 ZHG001

Boosted fusions for photonic quantum computation — •Nico Hauser[1], Matthias Bayerbach[1], Simone D'Aurelio[1], Raphael Weber[2], Matteo Santandrea[2], Shreya P. Kumar[2], Ish Dhand[2], and Stefanie Barz[1] — [1]Universität Stuttgart, Institut für funk- tionelle Materie und Quantentechnologien — [2]QC Design GmbH, Ulm

Entangling two-photon measurements, called fusions, are a fundamental requirement for photonic fusion-based quantum computation. One way of implementing such a fusion is a linear-optical Bell-state measurement. However, conventional linear-optical Bell-state measurements are limited to an overall success probability of 50%. This constraint significantly reduces the scalability of fusion-based quantum computation, where reliable fusions are needed. Here, we present a boosted fusion that surpasses this 50% success probability limit by using an entangled ancillary photon pair along with a fibre-based 4x4 multimode interferometer. By simulating fusion networks with boosted fusions, we show a significant increase in the performance of fusion-based quantum computation. We find that using boosted fusions significantly increases the robustness of fusion-based schemes to photon loss, which is one of the most prominent errors in photonic quantum technologies.

MON 1.2 Mon 14:30 ZHG001

Integrated resonant squeezer for GBS — •Jonas Sichler, Christine Silberhorn, Philip Mues, Werner Ridder, and Simone Atzeni — IQO, Universität Paderborn, Deutschland

Single-spectral-mode single-mode squeezed states are a key resource for Gaussian boson sampling (GBS) and other large-scale photonic networks. We investigate an integrated, resonator-enhanced, type-0 parametric down-conversion source in titanium-indiffused lithium niobate waveguides. By tuning the pump pulse length and tailoring the cavity geometry and mirror reflectivities correlations are suppressed and single-modeness can be achieved. The phase-matching center is set by the periodic poling and custom dielectric coatings define the cavity finesse. Achieving full single-modeness still requires external filtering in order to reject the neighboring cavity modes separated by the GHz-scale free spectral range, a demanding yet tractable task, which can be achieved, for example, with the use of filter cavities. Simulations incorporating realistic fabrication tolerances confirm that this multidimensional optimization delivers the desired joint-spectral amplitude. The resulting chip-scale Ti:LiNbO3 source provides a practical, low-loss building block for deployment in large quantum photonic networks, for example as the workhorse of GBS.

MON 1.3 Mon 14:45 ZHG001

Enhanced phase sensitivity in displacement-assisted SU(1,1) interferometer with photon recycling — Taj Kumar, Aviral Kumar Pandey, Anand Kumar, and •Devendra Kumar Mishra — Department of Physics, Institute of Science, Banaras Hindu University, Varanasi-221005, Uttar Pradesh, India

In this work, we propose a novel method to improve the phase sensitivity of the displacement-assisted SU(1,1) (DSU(1,1)) interferometer (with displacement strength γ) via photon recycling. We consider vacuum and squeezed vacuum (with squeezing parameter r) states as inputs, with a phase shift ϕ in one of the arms. This setup is modified by re-injecting the one output mode into the input mode after a phase shift θ, and the photon loss, characterized by $\sqrt{1-\mathrm{T}}$, where T is the transmission coefficient of a fictitious beam splitter. We determined the phase sensitivity of the photon recycled DSU(1,1) (PR-DSU(1,1)) interferometer under the single-intensity and homodyne detection schemes along with the quantum Cramér-Rao bound (QCRB). Then, we compared its performance with the conventional DSU(1,1) interferometer and found that the PR-DSU(1,1) interferometer can achieve improved phase sensitivity and a lower QCRB compared to the latter. Moreover, for both detection schemes, we observed the improvement in the phase sensitivity and QCRB of the PR-DSU(1,1) interferometer relative to the SNL, which further increases with an increase in T, g, $|\gamma|$, and r. Therefore, our work offers a novel approach to increase phase sensitivity via photon recycling. This work is based on our recent publication [APL Quantum 2, 016127 (2025)].

MON 1.4 Mon 15:00 ZHG001

Low-noise cascaded frequency conversion of 637.2 nm light to the telecommunication C-band in a single-waveguide device — Fabrice von Chamier, Joscha Hanel, Chris Müller, Wanrong Li, •Roger Kögler, and Oliver Benson — Humboldt-Universität zu Berlin, Institut für Physik, Newtonstraße 15, 12489, Berlin, Germany

Quantum devices and optical states often operate at disparate frequencies, making frequency conversion essential for connecting nodes in quantum networks. Here, we demonstrate a two-stage frequency conversion using an integrated device, successfully converting 637.2 nm photons emitted by nitrogen-vacancy centers in diamond into telecom wavelengths. Our system achieves low internal (external) noise spectral densities of 2.4 ± 0.8 (16 ± 5) cps/GHz, owing to the cascaded architecture, which mitigates excess noise typically introduced by spontaneous parametric down-conversion from the strong pump field.

The device is based on a periodically poled lithium niobate waveguide featuring two distinct poling sections. Remarkably, it also exhibits a phase-matched interaction between thermally generated photons and the pump field, which we investigate in detail. Additionally, we demonstrate tunable frequency conversion across the C-band by thermally controlling the phase-matching conditions of each stage. This enables wavelength targeting in the range of 1559.0 nm to 1564.9 nm, with external (internal) conversion efficiencies reaching 3.0 ± 0.1% (20.5 ± 0.8%).

MON 1.5 Mon 15:15 ZHG001

Phase stabilization of high-bandwidth squeezed and entangled states over 1km distributed optical fiber — •Sophie Verclas[1], Benedict Tohermes[1], and Roman Schnabel[2] — [1]Institut für Quantenphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]Institut für Quantenphysik & Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Quantum Key Distribution (QKD) is a technology for secure communication between two parties, using the principles of quantum mechanics. Our continuous-variable QKD experiment implements a fiber-based scheme, connecting two laboratories in two separated buildings (building A and B). We set up an EPR entanglement source in building A, consisting of two squeeze lasers and overlapped their outputs at a 50/50 beamsplitter to generate two-mode squeezed states. They are shared between A and B via a 1km optical fiber. In both buildings, the states are measured with self built balanced homodyne detectors. Due to the entanglement, the results are random but also correlated and can be used to generate a secret key. Attacks on the channel and on devices in building B reduce the entanglement strength and can thus be quantified. A major challenge in this setup is the phase stabilization and synchronization between the two buildings. Here, I will introduce the experiment, discuss the problem of phase noise and our approach to a control scheme for its compensation. As a first result, I will show measurements for the phase lock of distributed squeezed states, which is an important first step towards stabilized entanglement.

MON 1.6 Mon 15:30 ZHG001

Optical Protocol for Generating non-Gaussian state in C-band. — •Elnaz Bazzazi, Roger Alfredo Kögler, Leon Reichgardt, Marco Schmidt, and Oliver Benson — Department of Physics, Humboldt University Berlin, Berlin, Germany

Non-Gaussian states play a crucial role in fault-tolerant quantum computing, where the encoded information is protected from decoherence processes [1]. Certain classes of non-Gaussian states, however, coherent state superpositions known as cat states, pose challenges in generation due to the complexity of breeding protocols and limitations in their output states [2,3]. In this study, we explore the state engineering of squeezed coherent state superpositions (SCSS) through a catalysis protocol [4].

In this scheme, a beam splitter operation applied to two input states: a vacuum squeezed state and an m-photon Fock state, followed by photon number resolving detection in one of the output arms. Simulations results demonstrate the potential of this protocol to generate high-amplitude squeezed cat states with realistic quantum resources. We also outline an experimental implementation, and present the current progress. This research contributes to advances in quantum state engineering methods, crucial for the generation of resource states for fault-tolerant quantum computing.

[1] D. S. Schlegel et al., Phys. Rev. A 106, 022431 (2022).
[2] K. Takase et al., Phys. Rev. A 103, 013710 (2021).
[3] M. Endo et al., Opt. Express 31, 12865 (2023).
[4] R. J. Birrittella et al., J. Opt. Soc. Am. B 35, 1514 (2018).

MON 1.7 Mon 15:45 ZHG001

Topology-Optimized Integrated Photonics for Quantum Experiments — •Shiang-Yu Huang[1], Shreya Kumar[1], Jeldrik Huster[1], Yannick Augenstein[2], Carsten Rockstuhl[2,3], and Stefanie Barz[1,4] — [1]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, 70569 Stuttgart, Germany — [2]Institute of Theoretical Solid State Physics, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [3]Institute of Nanotechnology, Karlsruhe Institute of Technology, 76021 Karlsruhe, Germany — [4]Center for Integrated Quantum Science and Technology (IQST), University of Stuttgart, 70569 Stuttgart, Germany

Interference of single photons plays a central role in photonic quantum technologies as it is an essential process for creating and manipulating desired quantum states in linear optical systems. By incorporating integrated photonics, multiphoton interference can take place within on-chip interferometers featuring a minimal footprint. Furthermore, such devices can be miniaturized even further by applying inverse design methods, showing a promising path for innovating conventional integrated systems for photonic quantum technologies. Here we demonstrate the inverse-designed interferometers developed using topology optimization with an ultracompact footprint. We showcase their capabilities for quantum experiments through multiphoton interference. We also inversely design on-chip couplers to facilitate high-efficiency interconnection with an exceptionally small footprint. These topology-optimized components have great potential for building up high integration density integrated circuits for photonic quantum technologies.

MON 2: Quantum Control

Time: Monday 14:15–16:15 Location: ZHG002

MON 2.1 Mon 14:15 ZHG002

Quantum control by fast driving — •Sandro Wimberger — Department of Mathematical, Physical and Computer Sciences, Parma University — INFN, Sezione Milano-Bicocca, Parma group

We present a scheme for the systematic design of quantum control protocols based on shortcuts to adiabaticity. To fight decoherence, the adiabatic dynamics is accelerated by introducing high-frequency modulations in the control Hamiltonian, which mimic a time-dependent counterdiabatic correction. We present several applications for the high-fidelity realization of quantum state transfers and quantum gates based on effective counterdiabatic driving, in platforms ranging from superconducting circuits to Rydberg atoms [1]. We briefly sketch as well related ideas to control many-body interactions [2] and evolution errors by compensating terms in the Hamiltonian [3].

[1] F. Petiziol, F. Mintert, S. Wimberger, EPL 145, 15001 (2024); [2] S. Dengis, S. Wimberger, P. Schlagheck, PRA 111, L031301 (2025); [3] M. Delvecchio, F. Petiziol, E. Arimondo, S. Wimberger, PRA 105, 042431 (2022)

MON 2.2 Mon 14:30 ZHG002

Model predictive quantum control: A modular strategy for improving efficiency of quantum control — Eya Guizani and •Julian Berberich — Institute for Systems Theory and Automatic Control, University of Stuttgart, Germany

Model predictive control (MPC) is one of the most successful modern control methods. It relies on repeatedly solving a finite-horizon optimal control problem and applying the beginning piece of the optimal input. In this contribution, we explore the application of MPC for closed quantum systems governed by finite-dimensional Hamiltonian dynamics. Multiple MPC schemes are proposed to address different problem formulations, allowing us to trade off computational complexity with performance while retaining systems-theoretic guarantees on stability and convergence. Numerical experiments benchmark the performance of these formulations against competing approaches. Our results demonstrate the flexibility of MPC and its ability to achieve high performance in quantum optimal control problems.

MON 2.3 Mon 14:45 ZHG002

Optimization of algorithm-specific resource states for trotterized quantum dynamics and universal quantum computation — •Thierry N. Kaldenbach[1,2], Isaac D. Smith[2], Hendrik Poulsen Nautrup[2], Matthias Heller[3,4], and Hans J. Briegel[2] — [1]Institute of Materials Research, German Aerospace Center (DLR), Cologne, Germany — [2]Institute for Theoretical Physics, University of Innsbruck, Austria — [3]Fraunhofer Institute for Computer Graphics Research IGD, Darmstadt, Germany — [4]Interactive Graphics Systems Group, Technical University of Darmstadt, Germany

The direct compilation of algorithm-specific graph states in measurement-based quantum computation (MBQC) potentially leads to resource reductions in terms of circuit depth, entangling gates, and sometimes even the number of qubits. In this work, we extend previous studies on algorithm-tailored graph states to periodic sequences of Pauli rotations, which commonly appear in, e.g., trotterized quantum dynamics. We also use our approach to derive universal resource states from generating sets of Pauli unitaries, whose structure relates to the anticommutation pattern of the set. In addition, we implement a significantly enhanced annealing-based algorithm to find optimal resource states within local-Clifford MBQC. We demonstrate and compare both of our technique based on examples from quantum chemistry, binary optimization, and universal quantum computation. In particular, we showcase how graph states tailored for specific observables can lead to qubit reductions beyond the Z2 symmetries exploited in qubit tapering.

MON 2.4 Mon 15:00 ZHG002

Lower bounds for the Trotter error — •Alexander Hahn[1], Paul Hartung[2], Daniel Burgarth[2,1], Paolo Facchi[3,4], and Kazuya Yuasa[5] — [1]Center for Engineered Quantum Systems, Macquarie University, 2109 NSW, Australia — [2]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstraße 7, 91058 Erlangen, Germany — [3]Dipartimento di Fisica, Università di Bari, I-70126 Bari, Italy — [4]Istituto Nazionale di Fisica Nucleare, Sezione di Bari, I-70126 Bari, Italy — [5]Department of Physics, Waseda University, Tokyo 169-8555, Japan

In analog and digital simulations of practically relevant quantum systems, the target dynamics can only be implemented approximately. The Trotter product formula is the most common approximation scheme as it is a generic method which allows tuning accuracy. The Trotter simulation precision will always be inexact for noncommuting operators, but it is currently unknown what the minimum possible error is. This is an important quantity because upper bounds for the Trotter error are known to often be vast overestimates. Here we present explicit lower bounds on the error, in norm and on states, allowing to derive minimum resource requirements. Numerical comparison with the true error shows that our bounds offer accurate and tight estimates.

Based on Phys. Rev. A 111, 022417
https://doi.org/10.1103/PhysRevA.111.022417

MON 2.5 Mon 15:15 ZHG002

Riemannian quantum circuit optimization based on matrix product operators — •Isabel Nha Minh Le[1,2], Shuo Sun[1,2], and Christian B. Mendl[1,2,3] — [1]Technical University of Munich, School of Computation, Information and Technology, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany — [3]Technical University of Munich, Institute for Advanced Study, 85748 Garching, Germany

We significantly enhance the simulation accuracy of initial Trotter circuits for Hamiltonian simulation of quantum systems by integrating first-order Riemannian optimization with tensor network methods. Unlike previous approaches, our method imposes no symmetry assumptions, such as translational invariance, on the quantum systems. This technique is scalable to large systems through the use of a matrix product operator representation of the reference time evolution propagator. Our optimization routine is applied to various spin chains and fermionic systems described by the transverse-field Ising Hamiltonian, the Heisenberg Hamiltonian, and the spinful Fermi-Hubbard Hamiltonian. In these cases, our approach achieves a relative error improvement of up to four orders of magnitude for systems of 50 qubits. Furthermore, we demonstrate the versatility of our method by applying it to molecular systems, specifically lithium hydride, achieving an error improvement of up to eight orders of magnitude. This proof of concept highlights the potential of our approach for broader applications in quantum simulations.

MON 2.6 Mon 15:30 ZHG002

Counterdiabatic driving for random gap Landau-Zener (LZ) transitions — •Georgios Theologou[1], Mikkel F. Andersen[2,3], and Sandro Wimberger[4,5] — [1]ITP, Universität Heidelberg — [2]Department of Physics, University of Otago — [3]Dodd-Walls Centre for Photonic and Quantum Technologies — [4]Department of Mathematical, Physical and Computer Sciences, Parma University — [5]INFN, Sezione Milano-Bicocca, Parma group

The LZ model describes a two-level quantum system governed by a time-dependent Hamiltonian which undergoes an avoided crossing. In the adiabatic limit, the transition probability $\mathscr{P}_{\mathrm{LZ}}$ vanishes. To enforce an adiabatic evolution at arbitrary speed, an auxiliary control field $H_{\mathrm{CD}} = f_{\mathrm{CD}}\boldsymbol{\sigma}$ can be reverse-engineered, such that the full Hamiltonian $H + H_{\mathrm{CD}}$ drives the states transitionlessly. In the LZ case, f_{CD} takes the form of a Lorentzian pulse centered at the crossing, and the matrix $\boldsymbol{\sigma}$ is determined by the orthogonality of H_{CD} with H_{LZ} and $\dot{H}_{\mathrm{LZ}}$. Our aim is to construct a single H_{GCD} that controls an ensemble of

LZ-type Hamiltonians with a distribution of energy gaps. For a single realization, the evolution is not any more adiabatic nor the final transition probability is zero. H_{GCD} can be optimized to minimize the expectation value of a given cost function. We consider the effect of different sweeps and prefactors f_{CD}. We found a systematic trade-off between instantaneous adiabaticity and the final transition probability. As an analytically solvable limit, we examine the LZ model in the presence of a $\delta(t)$ potential and the connection to the minimization of the corresponding non-adiabatic probablity $\mathscr{P}_{\mathrm{LZD}}$.

MON 2.7 Mon 15:45 ZHG002

Spectral Control of a Noisy Quantum Emitter with Optical Pulses — •Kilian Unterguggenberger[1], Alok Gokhale[1], Aleksei Tsarapkin[1,2], Wentao Zhang[2], Katja Höflich[1,2], Herbert Fotso[3], Tommaso Pregnolato[1,2], Laura Orphal-Kobin[1], and Tim Schröder[1,2] — [1]Humboldt-Universität zu Berlin, Germany — [2]Ferdinand-Braun-Institut (FBH), Berlin, Germany — [3]University at Buffalo SUNY, Buffalo, USA

Indistinguishability of single photons gives rise to quantum interference, making it an essential ingredient for quantum information processing. Optimizing single-photon sources for indistinguishability represents an ongoing technological challenge. Solid-state emitters for instance typically exhibit inhomogenous frequency broadening due to charge noise. Current mitigation strategies such as feedback loops or post-selection introduce a large experimental overhead or drastically reduce the usable photon rate. In this work, we demonstrate a conceptually simple and efficient all-optical spectral control protocol on a nitrogen vacancy center in diamond. We observe that periodic excitation by optical π-pulses during the excited state lifetime reduces the emitter linewidth almost to the lifetime limit. Half of the spectral weight can be shifted to a target frequency selected by the pulse carrier frequency. The protocol [Fotso et al., PRL 116, 033603 (2016)] was proposed for the universal two-level system, rendering our approach applicable to a wide range of atomic and solid-state single-photon sources. Our work establishes a promising new avenue towards scalable sources of indistinguishable single photons.

MON 2.8 Mon 16:00 ZHG002

Coherent Control of a Carbon-13 nuclear spin proximal to a Tin-Vacancy Center in Diamond — •Jeremias Resch[1], Ioannis Karapatzakis[1], Philipp Fuchs[2], Marcel Schrodin[1], Michael Kieschnick[3], Julia Heupel[4], Mohamed Elshorbagy[1], Luis Kussi[1], Christoph Sürgers[1], Cyril Popov[4], Jan Meijer[3], Christoph Becher[2], Wolfgang Wernsdorfer[1], and David Hunger[1] — [1]Karlsruher Institut für Technologie — [2]Universität des Saarlands — [3]Universität Leipzig — [4]Universität Kassel

Robust quantum networks require an interface between photons and long-lived spin degrees of freedom. Due to its strong spin-orbit splitting, the Tin-Vacancy center electron spin possesses long spin lifetimes and has been shown to be able to be coherently controlled with high fidelity. In order to store information longer than the communication time between two nodes, even more long-lived nuclear spin degrees need to be coherently addressed. For high fidelity control of both electron and nuclear spin, the use of microwave fields is required. Recent work has shown the manipulation using aluminum wire bonds and on-chip gold waveguides. Both methods suffer from Ohmic losses in the microwave line, restricting coherence through heat induction. To overcome this challenge, we fabricate a superconducting coplanar waveguide made from Niobium on a diamond membrane through all-optical lithography. Using this, we demonstrate initialization of a single carbon-13 spin by optical pumping, perform high fidelity coherent manipulation, randomized benchmarking, and achieve a coherence time up to 1.3s.

MON 3: Many-Body Quantum Dynamics I

Time: Monday 14:15–16:15 Location: ZHG003

MON 3.1 Mon 14:15 ZHG003

Quantum circuit expectation values and real-time operator evolution via sparse Pauli dynamics — •Tomislav Begusic and Garnet Kin-Lic Chan — Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, California 91125, USA

We present sparse Pauli dynamics, a method for simulating quantum circuit expectation values and real-time operator evolution. We first demonstrate its performance on the example of kicked Ising model dynamics on 127 qubits, which was proposed as evidence for quantum utility of modern quantum devices. Here, we show that sparse Pauli dynamics can simulate observables orders of magnitude faster than the quantum experiment and can also be systematically converged beyond the experimental accuracy. Furthermore, we study real-time operator evolution. On the examples of energy diffusion in 1D spin chains and sudden quench dynamics in the 2D transverse-field Ising model, it is shown that this approach can compete with state-of-the-art tensor network methods. We further demonstrate the flexibility of the approach by studying quench dynamics in the 3D transverse-field Ising model which is highly challenging for tensor network methods.

MON 3.2 Mon 14:30 ZHG003

A comprehensive exploration of interaction networks—a connection between entanglement and network structure — •Yoshiaki Horiike[1,2] and Yuki Kawaguchi[1,3] — [1]Department of Applied Physics, Nagoya University, Nagoya, Japan — [2]Department of Neuroscience, University of Copenhagen, Copenhagen, Denmark — [3]Research Center for Crystalline Materials Engineering, Nagoya University, Nagoya, Japan

Recent experimental advances in various platforms for quantum simulators have enabled the realization of irregular interaction networks, which are intractable to implement with conventional crystal lattices. Another hallmark of these advances is the ability to observe the time-dependent behaviour of quantum many-body systems. However, the relationship between irregular interaction networks and quantum many-body dynamics remains poorly understood. Here, we investigate the connection between the structure of the interaction network and the eigenstate entanglement of the quantum Ising model by exploring all possible interaction networks up to seven spins. We find that the eigenstate entanglement depends on the structure of the Hilbert space diagram, particularly the structure of the equienergy subgraph. We further reveal a correlation linking the structure of the Hilbert space diagram to the number of unconstrained spin pairs. Our results demonstrate that the minimum eigenstate entanglement of the quantum Ising model is governed by the specific structure of the interaction network. (arXiv:2505.11466)

MON 3.3 Mon 14:45 ZHG003

Semiclassical Reconstruction of Many-Body Interference in the Beam Splitter — •Raphael Wiedenmann, Edoardo Carnio, and Andreas Buchleitner — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany

The beam splitter is a key optical element for observing quantum interference, most famously in the experiment of Hong, Ou and Mandel. In this talk, we investigate to what extent many-body interference effects can be captured by a semiclassical treatment. To this end, we study the approximation of the Fock-space propagator based on classical orbits in phase space.

MON 3.4 Mon 15:00 ZHG003

Single- and many-body interference in a generalized Mach- Zehnder interferometer — •Farouk Albalacy, Gabriel Dufour, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

We study the interplay of single- and many-body interference effects in a generalized Mach-Zehnder interferometer with N particles and N ports. Single-particle interference is controlled by the phase differences between the interferometer's arms. The effect of bosonic or fermionic many-body interference is singled out by tuning the distinguishability of the particles through their internal states. We analyse the output counting statistics for $N = 2$ or 3 partially distinguishable particles as a function of the interferometer phases and of the particles' internal states.

MON 3.5 Mon 15:15 ZHG003

More global randomness from less random local gates — •Ryotaro Suzuki[1], Hosho Katsura[2], Yosuke Mitsuhashi[2], Tomohiro Soejima[3], Jens Eisert[1], and Nobuyuki Yoshioka[2] — [1]Freie Universität Berlin, Berlin, Germany — [2]The University of Tokyo, Tokyo , Japan — [3]Harvard University, Cambridge, USA

Random circuits giving rise to unitary designs are key tools in quantum information science and many-body physics. In this work, we investigate a class of random quantum circuits with a specific gate structure. Within this framework, we prove that one-dimensional structured random circuits with non-Haar random local gates can exhibit substantially more global randomness compared to Haar random circuits with the same underlying circuit architecture. In particular, we derive all the exact eigenvalues and eigenvectors of the second-moment operators for these structured random circuits under a solvable condition, by establishing a link to the Kitaev chain, and show that their spectral gaps can exceed those of Haar random circuits. Our findings have applications in improving circuit depth bounds for randomized benchmarking and the generation of approximate unitary 2designs from shallow random circuits.

MON 3.6 Mon 15:30 ZHG003

Fourier analysis of partial distinguishability in many-body systems — •Gabriel Dufour and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

The dynamics of bosonic and fermionic many-body systems is sensitive to partial distinguishability arising from internal states of the particles. Indeed, although they do not participate in the dynamics, these internal states may allow to individuate the particles and thereby affect their many-body interference. We show that the Fourier transform over the group of permutations of N objects is a powerful tool to understand the effect of partial distinguishability on many-body dynamics. This generalisation of the discrete Fourier transform allows to analyse how the many-body state transforms under permutations of the particles in terms of irreducible symmetry types. Beyond the bosonic and fermionic symmetries which occur in systems of perfectly indistinguishable particles, partially distinguishable particles are characterised by the appearance of additional, mixed symmetry types.

MON 3.7 Mon 15:45 ZHG003

Exploiting emergent symmetries in disorder-averaged quantum spin systems — •Mirco Erpelding[1], Adrian Braemer[2], and Martin Gärttner[1] — [1]Institute of Condensed Matter Theory and Optics, Friedrich-Schiller-University Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

Symmetries are a key tool in understanding quantum systems and, among many other things, allow efficient numerical simulation of dynamics. Disordered systems usually feature reduced symmetries and additionally require averaging over many realizations, making their numerical study computationally demanding. However, when studying quantities linear in the time evolved state, i.e. expectation values of observables, one can apply the averaging procedure to the time evolution operator resulting in an effective dynamical map, which restores symmetry on the level of super-operators. In this work, we develop schemes for efficiently constructing symmetric sectors of the disorder-averaged dynamical map using short-time and weak-disorder expansions. To benchmark the method, we apply it to an Ising model with random all-to-all interactions in the presence of a transverse field. After disorder averaging, this system becomes effectively permutation invariant, and thus the size of the symmetric subspace scales polynomially in the number of spins allowing for the simulation of very large systems.

MON 3.8 Mon 16:00 ZHG003

Josephson-like dynamics of the low-energy crystal Goldstone mode in trapped supersolid spin-orbit-coupled Bose gases — •Kevin T. Geier, Vijay Pal Singh, Juan Polo, and Luigi Amico — Quantum Research Center, Technology Innovation Institute, PO Box 9639, Abu Dhabi, United Arab Emirates

Supersolidity is a phase of quantum matter that combines superfluidity with a solid-like crystal structure. These exotic properties are characterized by the spontaneous breaking of both phase and translational symmetry. According to Goldstone's theorem, there is a gapless mode associated with each broken symmetry. For the broken translational invariance, the Goldstone mode corresponds to a rigid translation of the supersolid pattern, which costs zero energy in an infinite system. However, in a finite system, e.g., in the presence of an external trapping potential, this motion acquires a finite energy cost and can exhibit nontrivial dynamics. Here, we show that the low-energy crystal Goldstone mode in trapped supersolid spin-orbit-coupled Bose-Einstein condensates can exhibit Josephson-like dynamics, analogous to a nonrigid pendulum. Depending on the amount of energy injected into the system by a uniform spin perturbation, the supersolid density stripes either oscillate back and forth, or undergo a unidirectional motion. We illustrate this dynamics through numerical simulations and explain the different regimes analytically under a two-mode approximation, where the equations of motion have the same structure as those governing a bosonic Josephson junction. Finally, we discuss perspectives for an observation of these effects in cold-atom experiments.

MON 4: DPG Promotionskolleg Next Generation Computing

Time: Monday 14:15–16:15 Location: ZHG004

MON 4.1 Mon 14:15 ZHG004

From Qubits to Neuromorphic Computing: Technologies Shaping the Future of Computing (Part 1) — •Jonah Elias Nitschke[1], Noah Stiehm[2], Sebastian Grossenbach[3], and Alexander Cornelius Heinrich[4] — [1]TU Dortmund university, Dortmund, Germany — [2]TU Ilmenau, Ilmenau, Germany — [3]Uni Konstanz, Konstanz, Germany — [4]QuantumBW, Stuttgart, Germany

What will the future of computing look like? Which technologies will define it, and what might succeed classical digital computation?

The technological landscape is diverse and rapidly evolving, with emerging fields such as analog and neuromorphic computing, as well as quantum computing. The German Physical Society (DPG) has launched its first Graduate Program (DPG-Promotionskolleg) to provide a structured perspective on these developments.

This initiative is not only focused on a new topic but also introduces an innovative format. The DPG Graduate School is a pilot initiative designed to encourage interdisciplinary and cross-institutional collaboration among PhD students over a period of 18 months. Participants will work alongside experts from academia, industry, and consulting to address complex questions related to the future of computing. The program emphasizes collaboration across various disciplines and encourages participants to look beyond their research topics and answer questions such as: How does my research contribute to the broader development of next generation computer technology, and why is it relevant to society?

MON 4.2 Mon 14:30 ZHG004

From Qubits to Neuromorphic Computing: Technologies Shaping the Future of Computing (Part 2) — David Ohse[1], •David Steffen[2], Julia Diana Küspert[3], Sebastian Bürger[4], and Verena Feulner[5] — [1]Uni of Bonn, Bonn, Germany — [2]DLR Institue of Engineering Thermodynamics, Ulm, Germany — [3]The European Synchrotron, Grenoble, France — [4]University of Leipzig, Leipzig, Germany — [5]University of Erlangen-Nuremberg, Erlangen, Germany

In our first session, we will introduce the DPG Graduate Program concept and share practical insights from its first cohort. Participants will present key findings from their research on emerging computing technologies, with a particular emphasis on quantum computing. We provide an overview of the status of various hardware implementations, software architectures, and algorithm development. We further discuss how the DPG Graduate Program Next Generation Computing encouraged scientific collaboration and outreach.

In the following sessions, selected participants will provide an introduction to their research topic and explain their motivation for joining the first cohort of the DPG Graduate School. In the last part, our scientific advisory board will join us for a panel discussion to address the significant challenges the field is expected to face over the next decade and how acceptance and trust in new computing technologies can be fostered in society.

MON 4.3 Mon 14:45 ZHG004

Towards a Parallel Electrical Read-Out for Spin-Wave-Based Spectrometers — •Johannes Greil[1], Felix Naunheimer[1], Valentin Ahrens[1], Manuel Wilke[1], Tobias Mohr[1], Levente Maucha[2], Ádám Papp[2], György Csaba[2], and Markus Becherer[1] — [1]Technical Universtiy of Munich, Munich, Germany — [2]Pázmány Peter Catholic University, Budapest, Hungary

This work presents the fine-tuning and electrical characterization of a demonstrator that combines a magnonic spectrometer in the Rowland circle arrangement with an RF circuit board for electrical read-out. We fabricate the Rowland circles by sputter deposition of Yttrium-Iron-Garnet (YIG) on a Gadolinium-Gallium-Garnet (GGG) substrate, followed by wet-chemical etching of the amorphous YIG film. In a subsequent lithography step, we fabricate a curved stripline transducer as input and several u-shaped transducers as local pick-ups for the output. We have achieved a mono-frequent detection resolution of around 45MHz in a usable band of 180MHz using time-resolved MOKE (trMOKE) measurements. With this system, we could successfully show that two-tone excitation and, consequently, wavefront separation is possible. The next step toward a more self-standing demonstrator device is the electrical detection of the locally picked-up magnonic signals. For this, we suggest a simple yet powerful method of power detection using RF diodes instead of RF amplifiers or mixers. To perform such measurements, we designed a circuit board providing one RF power detector per pick-up transducer, which can be read using any analog-to-digital converter (ADC).

MON 4.4 Mon 15:00 ZHG004

Quantum Computing with Trapped Ions — •Florian Ungerechts — Institut für Quantenoptik, Leibniz Universität Hannover, Germany

Trapped ions are a leading platform for quantum computing, providing high gate fidelities, long coherence times, and all-to-all connectivity between the qubits. But how does quantum computing with trapped ions work?

We begin by motivating what makes trapped ions great qubits, followed by an introduction to the basics of ion traps and how they allow for precise control of individual ions. Finally, we give a brief insight into the current status of ion-trap quantum processors in research and industry.

MON 4.5 Mon 15:15 ZHG004

Robustly optimal dynamics for active matter reservoir computing — •Mario U. Gaimann and Miriam Klopotek — Stuttgart Center for Simulation Science (SimTech), Cluster of Excellence EXC 2075, University of Stuttgart, Germany

Information processing abilities of active matter are studied in the reservoir computing (RC) paradigm to infer the future state of a chaotic signal. We uncover an exceptional regime of agent dynamics that has been overlooked previously. It appears robustly optimal for performance under many conditions, thus providing valuable insights into computation with physical systems more generally. The key to forming effective mechanisms for information processing appears in the system's intrinsic relaxation abilities. These are probed without actually enforcing a specific inference goal. The dynamical regime that achieves optimal computation is located just below a critical damping threshold, involving a relaxation with multiple stages, and is readable at the single-particle level. At the many-body level, it yields substrates robustly optimal for RC across varying physical parameters and inference tasks. A system in this regime exhibits a strong diversity of dynamic mechanisms under highly fluctuating driving forces. Correlations of agent dynamics can express a tight relationship between the responding system and the fluctuating forces driving it. As this model is interpretable in physical terms, it facilitates re-framing inquiries regarding learning and unconventional computing with a fresh rationale for many-body physics out of equilibrium. Reference: Gaimann, M. U., & Klopotek, M. (2025), arXiv:2505.05420.

MON 4.6 Mon 15:30 ZHG004

Silicon-germanium: A platform for both, spin qubit and superconducting planar qubit circuits — •Pauline Drexler and Jakob Walsh — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, D-93040 Regensburg, Germany

Silicon-germanium in principle offers a unique possibility to implement two very different types of solid-state qubits within the same materials platform: semiconductor spin qubits and superconducting flux qubits. In this approach, spin qubits are realized in Coulomb blockade-based quantum dots. Flux qubits are envisioned to be created via assemblies of gate-tunable hybrid Josephson junctions, based on a superconducting film, in proximity interaction with the semiconductor. The common basis of both types of quantum circuits is an epitaxially grown silicon-germanium quantum-confined semiconductor thin film structure. Each type of qubit then essentially relies on different planar, surface electrode circuitry layouts. In my presentation, I will discuss the epitaxy of hybrid semiconductor structures and practical aspects of the realization of both types of qubits quantum circuits. I will highlight the advantages of the planar circuit approach regarding scaling of future quantum processors and the high compatibility of the silicon-germanium platform with the current semiconductor chip industry.

MON 4.7 Mon 15:45 ZHG004

Panel discussion about Next Generation Computing and its impact on industry and society (Part 1) — •Andreas Böhm[1], Adrian Auer[2], Jeanette Lorenz[3], Hans Huebl[4], Niclas Götting[5], and Markus Hoffmann[6] — [1]Bayern Innovativ, Nuremberg, Germany — [2]IQM GmbH, Munich, Germany — [3]Fraunhofer IKS, Munich, Germany — [4]Walther-Meißner-Institut, Munich, Germany — [5]University of Bremen, Bremen, Germany — [6]FAU Erlangen-Nuremberg, Erlangen, Germany

In this panel discussion, we will focus on how to strengthen the exchange between science and industry in the dynamic field of next generation computing. Joined by our scientific advisory board consisting of Jeanette Lorenz (Fraunhofer Gesellschaft), Andreas Böhm (Bayern Innovativ), Adrian Auer (IQM), and Hans Hübl (Bavarian Academy of Sciences and Humanities), we will discuss which strategies and platforms can encourage knowledge transfer and accelerate innovation.

MON 4.8 Mon 16:00 ZHG004

Panel discussion about Next Generation Computing and its impact on industry and society (Part 2) — •Martin Mauser[1], Christoph Huettl[2], Max Mangold[3], Niclas Popp[4], and Nils-Erik Schütte[5] — [1]University of Vienna, Vieann, Austria — [2]Charité Berlin, Berlin, Germany — [3]TUM, Munich, Germany — [4]Eberhard Karl University of Tübingen, Tübingen, Germany — [5]University of Bremen, Bremen, Germany

Another key focus will be on the major challenges the field is expected to face over the next decade, ranging from technological challenges to ethical considerations. Furthermore, the discussion will address how society can be actively involved in the development and application of new computing technologies to foster acceptance and trust. Our goal is to bring together diverse perspectives and develop concrete recommendations for future-oriented collaboration.

MON 5: Optical Quantum Devices

Time: Monday 14:15–16:00 Location: ZHG006

MON 5.1 Mon 14:15 ZHG006

Magneto-optical trap of aluminium monofluoride — •Jose Eduardo Padilla-Castillo[1], Jionghao Cai[1], Russell Thomas[1], Sebastian Kray[1], Boris Sartakov[1], Stefan Truppe[2], Gerard Meijer[1], and Sidney Wright[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany — [2]Centre for Cold Matter, Imperial College, SW7 2AZ London, UK

Despite impressive progress in direct laser cooling of molecules, magneto-optical trapping has thus far been restricted to species with spin-doublet electronic ground states. These molecules are chemically reactive and only support a simple laser cooling scheme when exciting from the first rotationally excited level of the ground state.

In this talk, we will present the first magneto-optical trap (MOT) of the diatomic molecule aluminium monofluoride (AlF). This $^1\Sigma^+$ ground state molecule is amongst the most deeply bound molecules known, and even survives collision with vacuum walls of our experiment. Despite the challenging laser wavelengths required for the MOT (λ = 227.5 - 232 nm), we take advantage of the intense $A^1\Pi \leftarrow X^1\Sigma^+$ transition in AlF, which allows trapping three different rotationally excited levels of the ground via their respective Q(J) lines.

Our results set a new record for the shortest wavelength MOT, narrowly surpassing the 18 year-old milestone set by atomic Cd (λ = 228.9 nm). Similar to Cd, AlF possesses a spin-forbidden transition between its two lowest spin-singlet and triplet states. Magneto-optical trapping is a key step towards precise spectroscopy and control of the molecule via this narrow, ultraviolet transition.

MON 5.2 Mon 14:30 ZHG006

Material aspects for high-precision optical metrology — •Nico Wagner[1,2], Liam Shelling Neto[1,2], and Stefanie Kroker[1,2,3] — [1]Institut für Halbleitertechnik, Technische Universität Braunschweig, Hans-Sommer-Str. 66, Braunschweig, 38106 Germany — [2]Laboratory for Emerging Nanometrology, Langer Kamp 6a-b, Braunschweig, 38106 Germany — [3]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

High-precision optical metrology relies on materials with outstanding thermal and mechanical stability to push the limits of frequency accuracy. We explore material solutions that enhance the performance of ultra-stable optical cavities and laser systems. NEXCERA, a ceramic with a ultra-low thermal expansion coefficient at room temperature, shows reduced thermal noise compared to commonly used materials, making it ideal for cavity spacers. In mirror development, crystalline AlGaAs/GaAs coatings demonstrate lower mechanical loss than traditional amorphous coatings, though light-induced effects can introduce additional noise. We present insights into how illumination affects the mechanical loss and elasticity of GaAs. Furthermore, metamirrors—structured single-layer reflectors—offer a route to high reflectivity with significantly reduced thermal noise. For spectral-hole burning applications, the rare-earth-doped crystal Eu^{3+}:Y_2SiO_5 exhibits low cryogenic mechanical losses, making it a promising candidate for alternative laser stabilization techniques. These material innovations contribute to the advancement of robust and compact systems for future applications in optical frequency standards and precision metrology.

MON 5.3 Mon 14:45 ZHG006

Shapiro steps in driven atomic Josephson junctions — •Vijay Singh[1], E. Bernhart[2], M. Röhrle[2], H. Ott[2], G. Del Pace[3], D. Hernandez-Rajkov[3], N. Grani[3], M. Frometa Fernandez[3], G. Nesti[3], J. A. Seman[4], M. Inguscio[3], G. Roati[3], L. Mathey[5], and L. Amico[1] — [1]QRC, TII, Abu Dhabi, UAE — [2]RPTU Kaiserslautern, Germany — [3]LENS, University of Florence, Italy — [4]UNAM Mexico — [5]ZOQ and IQP, Universität Hamburg, Germany

We report the observation of Shapiro steps in atomic Josephson junctions formed by coupling two ultracold atom clouds. As predicted in the theoretical proposal, periodic modulation of the position of the tunneling barrier induces Shapiro steps in the dc current-chemical potential characteristic. Experiments on a Josephson junction of ^{87}Rb atoms display Shapiro steps in the current-potential characteristic, exhibiting universal features and providing key insight into the microscopic dissipative dynamics associated with phonon emission and soliton nucleation. Experiments with strongly-interacting Fermi superfluids of ultracold atoms also show the creation of Shapiro steps in the current-potential characteristics, with their height and width reflecting the external drive frequency and the junction nonlinear response. Direct measurements of the current-phase relationship reveal the underlying dissipation mechanism via the emission of vortex-antivortex pairs. These results establish a significant connection between superconducting and atomic Josephson dynamics, with unprecedented control and flexibility over physical parameters. Finally, our results lay the foundation for the development of new atomtronic devices and sensors.

MON 5.4 Mon 15:00 ZHG006

A Free-Electron-Driven Quantum Light Source — •F. Jasmin Kappert[1,2], Armin Feist[1,2], Guanhao Huang[3], Germaine Arend[1,2], Yujia Yang[3], Jan-Wilke Henke[1,2], Arslan Sajid Raja[3], Rui Ning Wang[3], Hugo Lourenco-Martins[1,2], Rudolf Haindl[1,2], Zheru Qiu[3], Junqiu Liu[3], Ofer Kfir[1,2], Tobias J. Kippenberg[3], and Claus Ropers[1,2] — [1]MPI for Multidisciplinary Sciences, Göttingen, Germany — [2]4th Physical Institute, University of Göttingen, Germany — [3]Institute of Physics, Swiss Federal Institute of Technology Lausanne (EPFL), Switzerland

Tailored nonclassical light is essential for photonic quantum technologies, yet generating complex optical states remains challenging. Inelastic free-electron scattering offers a promising new method for creating parametric and wavelength-tunable quantum light, particularly through coherent cathodoluminescence.

Here, we present a novel platform that efficiently couples free-electron beams to silicon nitride integrated photonics [1], enabling the generation of electron-photon pair states [2]. By post-selecting electrons with quantized energy loss, we can herald nonclassical single and multi-photon states [2,3]. This establishes a versatile source of tailored quantum light, potentially leading to a new class of hybrid quantum technology that combines electrons and photons.

[1] J.-W. Henke, FJK et al., Nature 600, 653 (2021)
[2] A. Feist, FJK et al., Science 377, 777 (2022)
[3] G. Arend et al., arXiv:2409.11300 (2024)

MON 5.5 Mon 15:15 ZHG006

Optimal quantum control and optical beam shaping for atomic gravi-gradiometer. — •Joel Gomes Baptista, Louis Pagot, Léo Rol, Niranjan Myneni, Leonid Sidorenkov, Sébastien Merlet, and Franck Pereira Dos Santos — LTE-Observatoire de Paris, Paris, France

Cold-atom interferometry-based inertial sensors represent a highly developed quantum technology, capable of achieving performances comparable to those of conventional sensors. Our sensor measures simultaneously the vertical component of the gravitational acceleration $\vec{g}$ and its gradient using a Mach-Zehnder-like interfermoter on two laser cooled ^{87}Rb atomic cloud separated by 1 m. Currently, the clouds temperature ($\approx 2\mu K$) limits the performance of the gradiometer. The Doppler detunings and the ballistic expansion at long interrogation times ($T \approx 200$ ms) reduce the efficiency of the atom-optics based on high-order Bragg transitions.

Here, we use an optimal control theory algorithm based on GRAPE method to generate dedicated evolution patterns of the coupling phase during the interrogation pulses and demonstrate the enhanced fidelity of Bragg atom-optics in our gravi-gradiometer.

In addition, we mitigate the coupling inhomogeneities originating from the usual Gaussian beam using a custom-built top-hat collimator, which generates a uniform intensity profile and maintains a stable wavefront over 3.5m propagation. We explore the integration of OCT methods with top-hat laser beam profiles to overcome key limitations of large momentum transfer atom optics for μK-range atom sources.

MON 5.6 Mon 15:30 ZHG006

Modeling and Characterization of Active Silicon Microring Resonators — •Kambiz Jamshidi, Abdou Shetewy, and Menglong He — Integrated Photonics Devices Group, Chair of RF and Photonics, Technische Universität Dresden, 01069, Dresden, Germany

Silicon ring resonators can be used for several applications in communication, signal processing, and computing. By embedding the silicon waveguide in a pn junction, it is possible to tune the free carrier lifetime of the waveguide, which provides an additional degree of freedom to tune the steady-state response of these resonators and therefore the regime in which they operate. A theoretical framework is required to model the dynamics of light evolution in these resonators, taking into account the number of free carriers in the resonator and its temperature. In this article, the nonlinear coupled equations required for this modeling will be reviewed. In addition, characterization results of the resonators, which are fabricated in a standard process using silicon-on-insulator technology, will be discussed. Finally, several applications of the resonators at different biases will also be presented.

MON 5.7 Mon 15:45 ZHG006

Leveraging Large Language Models as Qualitative Figures of Merit — •Liam Shelling Neto[1], Nico Wagner[1], and Stefanie Kroker[1,2] — [1]Technische Universität Braunschweig, Institute of Semiconductor Technology, Hans-Sommer-Str. 66, Braunschweig, 38106, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, Braunschweig, 38116, Germany

Inverse design of photonic components, particularly in quantum technology, typically relies on quantitative figures of merit (FoMs) such as efficiency, transmission, or beam waist, metrics derived from precisely defined simulation data. However, many design goals are inherently qualitative or difficult to express numerically. We propose using large language models (LLMs) as evaluators of qualitative figures of merit (qFoMs) to complement traditional FoMs. These qFoMs can assess visual or descriptive attributes of optical responses, such as field distributions, via natural language prompts and image inputs. For example, when optimizing a grating coupler to produce a Gaussian beam, early designs often yield patterns far from Gaussian, rendering quantitative fits ineffective. An LLM-based qFoM, similar to a human, can still assign a "Gaussianity" score to guide the optimizer in the right direction, even in these early, low-performance stages. By integrating qFoMs with traditional metrics, LLMs act as pseudo-intelligent agents that bridge the gap between human intuition and algorithmic evaluation, enabling more robust and flexible optimization, especially when the target functionality is poorly defined or initially unmet.

MON 6: QIP Implementations: Trapped Ions

Time: Monday 14:15–16:15 Location: ZHG007

MON 6.1 Mon 14:15 ZHG007

Quantum Information Processing with Trapped Rydberg Ions — •Katrin Bolsmann[1,2], Thiago L. M. Guedes[1,2], Joseph W. P. Wilkinson[3], Igor Lesanovsky[3,4], and Markus Müller[1,2] — [1]Institut für Quanteninformation, RWTH Aachen University — [2]PGI-2, Forschungszentrum Jülich — [3]Institut für Theoretische Physik, Universität Tübingen — [4]School of Physics and Astronomy, University of Nottingham

Combining the strong, long-range interactions of cold Rydberg atoms with the controllability of trapped ions, trapped Rydberg ions provide a promising platform for scalable quantum information processing. As demonstrated in a breakthrough experiment (Zhang et al., Nature 580, 345, 2020), microwave dressing of Rydberg states induces permanent rotating dipole moments leading to strong interactions between highly excited ions. Due to the separation of timescales, the fast electronic dynamics of Rydberg ions decouple from the slower motional modes of the linear Coulomb crystal, which typically mediate entangling gates in ground-state ion systems. Therefore, Rydberg ions enable significantly faster gate operations.

In this talk, we will discuss how the unique features of trapped Rydberg ions can be used to realize fast and high-fidelity entangling gates, along with the associated challenges and strategies to address them. We will present different types of gate protocols for two- and multi-qubit entangling gates with trapped Rydberg ions, analyze sources of infidelity, and compare the performance with other platforms based on neutral atoms and ground-state ions.

MON 6.2 Mon 14:30 ZHG007

Register-Based Trapped-Ion Quantum Processors with Near-Field Microwave Control — •Florian Ungerechts[1], Rodrigo Munoz[1], Janina Bätge[1], M.Masum Billah[1], Axel Hoffmann[1,2], Giorgio Zarantonello[1,3], and Christian Ospelkaus[1,4] — [1]Inst. f. Quantenoptik, Leibniz Universität Hannover — [2]Inst. f. Hochfrequenztechnik und Funksysteme, Leibniz Universität Hannover — [3]QUDORA Technologies GmbH — [4]Physikalisch-Technische Bundesanstalt

Trapped ions are a leading platform for quantum information processing, offering long coherence times, high gate fidelities, and unmatched quantum volume. Scalable architectures, such as the Quantum Charged Coupled Device (QCCD) architecture, enable all-to-all connectivity between atomic ion qubits in dedicated registers and can be implemented on microfabricated surface-electrode traps. However, as chip size increases, external free-space lasers become infeasible. To address this, quantum logic gates with chip-integrated microwave conductors have been demonstrated, also eliminating spontaneous emission as an intrinsic error source in laser-driven gates. Although shown individually, combining the QCCD architecture with the near-field microwave control technique into scalable devices is a current research topic. We present an overview of our recently developed surface-electrode traps for near-term quantum information processing with up to 50 atomic ion qubits. We compare the chip architectures and highlight the design of radiofrequency junctions, bucket-brigade storage registers, and chip-integrated microwave conductors.

MON 6.3 Mon 14:45 ZHG007

Framework for optimization of Paul trap design and control voltages for X-junction shuttling — •Andreas Conta, Ulrich Poschinger, and Ferdinand Schmidt-Kaler — Institut für Physik, Johannes Gutenberg-Universität Mainz

Trapped-ion quantum computing is a promising architecture for large-scale quantum computing. We aim to scale up the shuttling-based [1] approach. This requires complex multi-segmented traps that include junctions [2]. We present our work of a framework for optimization of trap designs and control voltages waveforms, with the goal of shuttling a linear crystals an X-junction. Commercially available tools are used to create parameterised models of traps and potentials of the electrodes [3]. Our custom Segmented Ion Trap CONtrol System (SITCONS) then performs a multipole expansion, thereby enabling the calculation of control voltages using quadratic programming. We analyse the influence of different trap designs and electrode shapes on the shuttling through an X-junction.

[1] Ruster et al., Phys. Rev. A 90, 033410 (2014)
[2] Delaney et al., Phys. Rev. X 14, 041028 (2024)
[3] Nullspace Inc., Nullspace ES [software], https://www.nullspaceinc.com/

MON 6.4 Mon 15:00 ZHG007

Generating arbitrary coupling matrices for multi-qubit quantum gates — •Patrick H. Huber, Dorna Niroomand, Markus Nünnerich, Patrick Barthel, and Christof Wunderlich — Department of Physics, School of Science and Technology, University of Siegen, 57068 Siegen, Germany

An always-on, all-to-all Ising-type interaction between qubits in a quantum register can be provided by the Magnetic Gradient Induced Coupling (MAGIC) approach to quantum computing with trapped ions [1,2]. In that case, the interaction strength between radio frequency(rf)-controlled qubits is determined by the trapping potential and the applied magnetic field gradient.

Here we present a novel method that allows for the tuning of the qubits' interaction without changing the trapping potential nor the magnetic field while simultaneously preserving the qubits' coherence. This method uses pulsed dynamical decoupling and is demonstrated experimentally in a quantum register of four qubits encoded into hyperfine states of the electronic ground state of laser-cooled $^{171}Yb^{+}$ ions . We synthesize an arbitrary coupling matrix within this quantum register and, furthermore, generate non-interacting subregisters. Thus, this method opens up a new path for efficiently synthesizing quantum algorithms when using an all-to-all Ising-type interaction between qubits.

[1] A. Khromova *et al.*, Phys. Rev. Lett. **108**, 220502 (2012). [2] P. Baßler *et al.*, Quantum **7**, 984 (2023).

MON 6.5 Mon 15:15 ZHG007

Fast radio frequency-driven entangling gates with trapped ions using rapid phase switching — •Markus Nünnerich, Patrick Huber, Dorna Niroomand, and Christof Wunderlich — Department of Physics, School of Science and Technology, University of Siegen, 57068 Siegen, Gemany

Entangling gates are a fundamental component of any quantum processor, ideally operating at high speeds in a robust and scalable manner. Here, we experimentally investigate a novel radio frequency (RF)-driven two-qubit gate with trapped and laser cooled $^{171}\mathrm{Yb}^{+}$ ions exposed to a static magnetic gradient field of 19 T/m that induces an effective qubit-qubit interaction (Magnetic Gradient Induced Coupling, MAGIC). The hyperfine states $|0\rangle \equiv |^2\mathrm{S}_{1/2}, \mathrm{F}=0, \mathrm{m_F}=0\rangle$ and $|1\rangle \equiv |^2\mathrm{S}_{1/2}, \mathrm{F}=1, \mathrm{m_F}=-1\rangle$ are used as qubits. We generate Bell states by applying continuously two RF driving fields, each one of them on resonance to one of the qubit transitions. By modulating the phase or amplitude of the driving fields, qubits are protected from addressing and RF amplitude fluctuations. In the experiments presented here, the phase of the driving fields varies periodically in discrete values, yielding effectively a sequence of back-to back dynamical decoupling pulses. By adjusting the Rabi frequency induced by the driving fields, the effective coupling of the qubits to the ions' motional state is changed, and the entangling gate speed can be varied between ≈ 4 ms and $\approx 300\mu s$. In currently used micro-structured traps with larger magnetic field gradients, gate speeds on par with laser-driven gates in trapped ions are expected.

MON 6.6 Mon 15:30 ZHG007

Scaling-up a trapped-ion quantum computer using MAGIC — •Saptarshi Biswas[1], Ivan Boldin[1], Benjamin Bürger[1], Friederike J. Giebel[3,4], Radhika Goyal[2], Patrick Huber[1], Eike Iseke[3,4], Lukas Kilzer[2], Nila Krishnakumar[3,4], Rodolfo Muñoz Rodriguez[1], Tobias Pootz[2], Kais Rejaibi[1], David Stuhrmann[2], Nora Daria Stahr[2,4], Jacob Stupp[2,4], Konstantin Thronberens[3,4], Celeste Torkzaban[2], Pedram Yaghoubi[1], Christian Ospelkaus[2,3,4], and Chritsof Wunderlich[1] — [1]Department of Physics, School of Science and Technology, University of Siegen, 57068 Siegen, Germany — [2]Gottfried Wilhelm Leibniz Universität, Hannover, Germany — [3]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [4]Laboratory of Nano and Quantum-Engineering, Hannover, Germany

We present the status of a cryogenic (4K) experimental set-up for quantum computing with radio frequency (rf)-controlled trapped ions. It incorporates a novel micro-structured planar Paul trap with integrated micromagnets and we report on the characterization of the first trap generation to be used in this set-up. The ions interact via magnetic gradient induced coupling (MAGIC).Also, progress in developing laser cooling techniques for mixed Yb^{+}-Ba^{+} crystals is reported.

MON 6.7 Mon 15:45 ZHG007

Efficient simulation workflow for micro-structured planar Paul traps — •Kais Rejaibi, Dorna Niroomand, Patrick Huber, and Christof Wunderlich — Department of Physics, School of Science and Technology University of Siegen, 57068 Siegen, Gemany

Trapped-ion experiments require precise control of ion motion, minimal micromotion, and stable quantum state manipulation. To support this, we developed a simulation workflow based on the Boundary Element Method (BEM), which accurately models electric fields from complex electrode layouts, including junction-type planar Paul traps and designs using Magnetic Gradient Induced Coupling (MAGIC). The method handles open boundary conditions efficiently and is suitable for iterative design.

We use a solid harmonics decomposition to analyze the simulated fields. This helps us to identify and to reduce higher-order multipole components that can cause residual micromotion. In addition, we can add specific higher-order components in a controlled way to create interaction patterns for many-body quantum systems, for instance by shaping the effective J-coupling matrix between ions.

This approach-combining simulation, field analysis, and voltage control-helps us design planar Paul traps that support reliable ion transport through regions with varying magnetic fields. It improves design efficiency and supports the development of more capable systems for quantum information experiments.

MON 6.8 Mon 16:00 ZHG007

Micro-structured ion traps with integrated magnets for quantum science — •Benjamin Bürger, Patrick Huber, and Christof Wunderlich — Department of Physics, School of Science and Technology, University of Siegen, 57068 Siegen, Germany

We present the design and implementation of quasi-two-dimensional (2D) micromagnets tailored to generate an inhomogeneous static magnetic field. This field, when integegrated into a micro-structured ion trap, enables frequency-selective addressing of ions through radio frequency radiation (RF) and conditional quantum dynamics with trapped ions. We will integrate the magnet design into a planar Paul trap that is split into two types of regions: An interaction zone and a cooling/readout zone. The micromagnets are meticulously designed to produce high field gradients while maintaining a low absolute field strength, effectively minimizing decoherence induced by magnetic field noise within the qubit interaction zones. In the cooling/readout zones, the magnets are designed to generate a small homogeneous magnetic field to facilitate efficient Doppler cooling on larger strings. Furthermore, the magnetic field orientation is optimized to support both σ and π polarized RF-driven transitions in $^{171}\mathrm{Yb}^{+}$ ions facilitating efficient cooling on the magnetic-field-insensitive π transition and utilizing the σ transition for gate operations.

MON 7: Foundational / Mathematical Aspects – Quantum Measurement

Time: Monday 14:15–16:15 Location: ZHG008

MON 7.1 Mon 14:15 ZHG008

Weak values as stereographic projections — Lorena Ballesteros Ferraz[1,3], Dominique L. Lambert[2], and •Yves Caudano[3] — [1]Present address: Lab. de Physique Théorique et Modélisation, CNRS Unité 8089, CY Cergy Paris Université, France — [2]SPS department, esphin and naXys, University of Namur, Belgium — [3]Physics department, naXys and NISM, University of Namur, Belgium

Quantum weak measurements generate a lot of fundamental and practical interest, as weakly perturbing probes or means of amplifying small effects. In a pre- and post-selected weak measurement, the experimental deflection of the measuring device depends on the real part or on the imaginary part of the weak value, a complex number. However, weak values also possess a polar representation. We have connected the argument of weak values in N-level systems to a geometric phase [1] related to a geodesic triangle in the quantum state manifold. Building on results developed for open quantum systems [2], we now demonstrate that arbitrary weak values can be interpreted as a stereographic projection of the post-selected state. This offers a comprehensive geometric interpretation of the weak value's modulus and argument, enabling its visualisation jointly with the associated quantum states. Then, the geometric phase appears as both a complex-plane angle and a solid angle on the Bloch sphere, effectively mapping the weak value onto an effective two-level system.

[1] L. B. Ferraz, D. L. Lambert, and Y. Caudano, Quantum Sci. Technol. 7 (2022) 045028. [2] L. B. Ferraz, J. Martin, and Y. Caudano, Quantum Sci. Technol. 9 (2024) 035029.

MON 7.2 Mon 14:30 ZHG008

Present status and future challenges of non-interferometric tests of collapse models — •Matteo Carlesso — University of Trieste, Strada Costiera 11, 34151 Trieste — Istituto Nazionale di Fisica Nucleare, Trieste Section, Via Valerio 2, 34127 Trieste, Italy

The superposition principle is the cornerstone of quantum mechanics, leading to a variety of genuinely quantum effects. Whether the principle applies also to macroscopic systems or, instead, there is a progressive breakdown when moving to larger scales is a fundamental and still open question. Spontaneous wavefunction collapse models predict the latter option, thus questioning the universality of quantum mechanics. Technological advances allow to increasingly challenge collapse models and the quantum superposition principle, with a variety of different experiments. Among them, non-interferometric experiments proved to be the most effective in testing these models. We provide an overview of such experiments, including cold atoms, optomechanical systems, X-ray detection, bulk heating and comparisons with cosmological observations. We also discuss avenues for future dedicated experiments, which aim at further testing collapse models and the validity of quantum mechanics.

MON 7.3 Mon 14:45 ZHG008

The role of redundant correlated records in the emergence of Objective Classical Reality — •VIshal Johnson[1,2], Ashmeet Singh[3], and Torsten Ensslin[1,2] — [1]Max Planck Institute for Astrophysics, Garching, Germany — [2]Ludwig Maximilians University, Munich, Germany — [3]Whitman College, Walla Walla, USA

Quantum measurement inevitably involves a physical system, the observer, in which the result of the measurement procedure is stored. Therefore, in the context of unitary (reversible) quantum mechanics, one has to include the observer as a physical system operating within the limits of quantum mechanics. We argue that a physical quantity (correlation) is a resource used up in each quantum measurement. We put constraints on the nature of environmental/observer states which lead to redundant, classical record formation — correlation can be provided by a GHZ-like state before or after the interaction with the measured system. A network of such measurements establishes a stable objective classical reality — the redundant agreement of several observers on the state of the measured quantum system. We verify our hypotheses by simulating the quantum measurement procedure — observer network states with a high amount of correlation gives rise to high fidelity measurement results.

MON 7.4 Mon 15:00 ZHG008

Ultradecoherence model of the measurement process — •Hai-Chau Nguyen — University of Siegen

It is proposed that measurement devices can be modelled to have an open decoherence dynamics that is faster than any other relevant timescale, which is referred to as the ultradecoherence limit. In this limit, the measurement device always assumes a definite state upto the accuracy set by the fast decoherence timescale. Further, it is shown that the clicking rate of measurement devices can be derived from its underlying parameters, not only for the von Neumann ideal measurement devices but also for photon detectors in equal footing. This study offers a glimpse into the intriguing physics of measurement processes in quantum mechanics, with many aspects open for further investigation.

MON 7.5 Mon 15:15 ZHG008

Quantifying quantum coherence and the deviation from the total probability formula — •Antoine Soulas — IQOQI Vienna, Austria

Quantum coherence is the main resource exploited by quantum computers. Unsurprisingly, over the past few years, there has been a strong interest in the task of finding appropriate measures of coherence. We propose a novel approach which, contrary to the previous ones, relies on foundational/philosophical considerations. It allows to solve two drawbacks of the resource theoretic approach: the lack of physical meaning, and the restriction to one particular basis in which to quantify coherence. In our approach, coherence is understood as the ability for a quantum system's statistics to deviate from the total probability formula.

After motivatng the importance of the total probability formula in quantum foundations, we then propose a new set of axioms that a measure of coherence should satisfy, and show that it defines a class of measures different from the previous proposals. Finally, we prove a general result about the dependence of the l2-coherence norm on the basis of interest, namely that it is well approximated by the square root of the purity in most bases. Such a behaviour (the nearly constant level of coherence in most bases) is actually expected for any measure of coherence, because of the mathematical phenomenon known as ”concentration of measure”.

MON 7.6 Mon 15:30 ZHG008

Which-way knowledge increase via feed-forward of the interfering particle's phase — •Elisabeth Meusert, Marc-Oliver Pleinert, and Joachim von Zanthier — Friedrich-Alexander Universität, Erlangen, Germany

Complementarity constitutes a central aspect of quantum theory. It manifests itself for example in a two-way interferometer, where the simultaneous observation of an interference pattern and the aquisition of which-way information are limited by an inequality, known as the duality relation.

We investigate which-way information in a double-slit interferometer. We find that, depending on the which-way detector observable chosen, the which-way information can be correlated to the interfering particle's phase at the interferometer screen, leading to a phase-dependent which-way knowledge. In specific cases, this knowledge can locally exceed the limit set by the duality relation. Based on this observation, we propose a delayed choice protocol that aims at maximizing the which-way information locally for each phase after the particle has been read out. This allows us to surpass the duality relation limit on phase-average. We present analytical results as a proof of principle of our protocol as well as numerical outcomes quantifying the amount of achievable which-way knowledge.

MON 7.7 Mon 15:45 ZHG008

The Contextual Heisenberg Microscope — •Jan-Åke Larsson — Linköpings Universitet, Linköping, Sweden

The Heisenberg microscope provides a powerful mental image of the measurement process of quantum mechanics (QM), attempting to explain the uncertainty relation through an uncontrollable back-action from the measurement device. However, Heisenberg's proposed back-action uses features that are not present in the QM description of the world, and according to Bohr not present in the world. Therefore, Bohr argues, the mental image proposed by Heisenberg should be avoided. Later developments by Bell and Kochen-Specker shows that a model that contains the features used for the Heisenberg microscope is in principle possible but must be nonlocal and contextual. In this paper we will re-examine the measurement process within a restriction of QM known as Stabilizer QM, that still exhibits for example Greenberger-Horne-Zeilinger nonlocality and Peres-Mermin contextuality, using a recent extension of stabilizer QM, the Contextual Ontological Model (COM), where the system state gives a complete description of future measurement outcomes reproducing the quantum predictions, including the mentioned phenomena. The resulting contextual Heisenberg microscope back-action can be completely described within COM; the associated randomness originates in the initial state of the pointer system, exactly as in the original description of the Heisenberg microscope. The presence of contextuality, usually seen as prohibiting ontological models, suggests that the contextual Heisenberg microscope picture can be enabled in general QM.

MON 7.8 Mon 16:00 ZHG008

Measuring the speed of quantum particles without a round-trip under non-synchronized quantum clocks — •Tomer Shushi — Ben-Gurion University of the Negev, Beer Sheva, Israel

In this talk, we show that it is possible, in principle, to measure the velocity of particles that travel at the speed of light without assuming a round-trip once we adopt a quantum mechanical description under two boundary conditions to the state of the quantum system followed by the two-state-vector formalism while assuming non-synchronized quantum clocks with unknown time dilation [1]. The weak value of velocity can be measured for a test particle that has a clock that is not synchronized with the clock of the quantum particle. Following the proposed setup, when the weak value of the velocity is known even without knowing the time states of the system, such a weak velocity is the two-way speed of light. We further explore some fundamental implications of the setup. The proposed approach opens a new avenue toward measuring the velocities of quantum particles while overcoming relativistic issues regarding the synchronization of clocks. [1] Shushi, T. (2025). Measuring the speed of quantum particles without a round-trip under non-synchronized quantum clocks. Proceedings of the Royal Society A. 481: 20240708.

MON 8: Quantum Sensing and Decoherence: Contributed Session to Symposium I

Time: Monday 14:15–15:45 Location: ZHG009

MON 8.1 Mon 14:15 ZHG009

Diamond-based quantum processors - State-of-the-art and future challenges — Lukas Antoniuk[1], Gopi Balasubramanian[1], Priya Balasubramanian[1,2], Jan Binder[1], Jason Choudhury[1], Florian Frank[1], Matthias Gerster[1], •Julian Rickert[1], Janani Sevvel[1], and Mukesh Tripathi[1] — [1]XeedQ GmbH, Augustusplatz 1-4, D-04109 Leipzig, Germany — [2]Institute for Quantum Optics, Ulm University, Albert-Einstein-Allee 11, D-89081 Ulm, Germany

Engineered colour centres within diamond have demonstrated the potential for quantum sensing, communication, and computing. Coherent control of a few qubits has been demonstrated in group-IV- and NV-centres. Currently, NV systems are the only commercially available diamond quantum processors. State-of-the-art designs couple NV centres to nearby nuclear spins and directly to other NVs. Our work employs electron-beam lithography and focused ion beam implantation to fabricate high-purity diamond chips with tailored defects. We characterize these chips by benchmarking qubit coherence, single- and two-qubit NV gate operations, NV-nuclear spin control protocols, and NV-NV entanglement. Our efforts deliver comprehensive quantum control beyond existing lab demonstrations. However, scaling beyond a few qubits is complicated by material quality, fabrication precision, and nanoscale addressability. We are working on overcoming engineering, integration, and control challenges to enable scalable networks of interlinked NV centres.

MON 8.2 Mon 14:30 ZHG009

Towards Hyperpolarization at the Solid Surface - A Progress Report — •Konstantin Herb and Christian Degen — Department of Physics, ETH Zurich, Switzerland

Traditionally, nuclear magnetic resonance (NMR) spectroscopy suffers from intrinsically low sensitivity due to the relatively weak coupling of nuclear spins to an external magnetic field. To significantly enhance the sensitivity of NMR spectroscopy, electron spins may be used as a polarizing source. Transferring nuclear spin polarization from the Nitrogen-Vacancy (NV) center to its surrounding is a long-standing goal in field. In this talk, I will present our recent progress towards achieving hyperpolarization at the solid surface. We explore the possibilities and limits of transferring polarization from NV centers to the surface of diamond. We will discuss the challenges we face in this process, including the need for efficient transfer mechanisms and the optimization of experimental conditions.

MON 8.3 Mon 14:45 ZHG009

Height Calibration of Nitrogen Vacancy Diamond Tips Using Current-Carrying Wires — Robin Abram, •Ricarda Reuter, Alexander Fernández Scarioni, Sibylle Sievers, and Hans Werner Schumacher — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Scanning Nitrogen Vacancy Microscopy (SNVM) is a measurement technique capable of resolving the spatial distribution of magnetic stray fields with nanometer and microtesla resolution, respectively. It combines optical field detection with a scanning probe-like approach, where the key component is a diamond scanning tip containing a single NV center. While magnetic field measurements are quantum-calibrated with respect to the position of the NV center, precise knowledge of the distance to the sample is required to also consider the height dependence. Unfortunately, the latter can currently only be estimated with an uncertainty of up to several nanometers, most commonly from a calibration based on the stray field detection of ferromagnetic microstructures. We propose an improved height calibration based on SNVM studies of the current-induced Oersted field in Pt wires by Lee et al.. The out of plane field component is extracted from the raw data taken along the NV spin axis, following the approach first established by Schendel et al. and later applied to SNVM by Dovzhenko et al., and fitted to a numerical model. Compared to the calibration with ferromagnets, this approach is highly adaptable in terms of both magnetic and spatial resolution, thus contributing to fully exploiting the potential of the NV center as a quantum-based magnetic field sensor.

MON 8.4 Mon 15:00 ZHG009

Exploring non-Markovian dynamics in microwave spin control of group-IV color centers coupled to a phononic bath — •Mohamed Belhassen[1], Gregor Pieplow[1], and Tim Schröder[1,2] — [1]Humboldt-Universität zu Berlin, Berlin, Germany — [2]Ferdinand- Braun-Institut, Berlin, Germany

Microwave control is a well-established technique for driving the electronic spin of diamond color centers. In our earlier work [1], we demonstrated that optimizing the orientation of the static magnetic field lifting the spin degeneracy and the polarization of the microwave field driving the spin, is essential for achieving efficient control conditions in a low strain environment. Expanding on this, we now incorporate the phononic bath, which introduces decay and decoherence to the qubit's quantum state. We examine the system dynamics using both Markovian and non-Markovian master equations, revisiting the interplay between magnetic and microwave field orientations and applied strain, with a focus on their impact on the qubit decay and decoherence times. We interpret our simulation results and compare them with the most recent experimental results. Finally, we assess the validity of the Born-Markov approximation and investigate how bath memory effects impact quantum state evolution.

[1] G. Pieplow, M. Belhassen, T. Schröder, Phys. Rev. B 109, 115409

MON 8.5 Mon 15:15 ZHG009

Nonlocal metasurface coupled to a single-photon emitter for on-chip applications — •Amitrajit Nag and Jaydeep Kumar Basu — Department of Physics, Indian Institute of Science, Bangalore, India-560012

Solid-state single-photon emitters (SPE) are indispensable in the emerging applications for qubits and photonic communications due to their higher quantum yield, spectral tunability, and scalability. All-dielectric guided mode resonant metasurfaces (GMR-MSR) are interesting photonic systems with low losses, waveguiding, and asymmetric Fano resonance features. The near-field coupling between an SPE and a GMR-MSR brings up interesting features like the resonance linewidth narrowing, directional emission, long-range photon transport, etc. In this work, we emphasize the field nonlocality property of a GMR-MSR, which controls and tunes the overall partial coherence of the coupled SPE-MSR system.

$$\mathbf{E}(\mathbf{r}_D, \omega) = \int \mathbf{G}(\mathbf{r}_D, \mathbf{r}'_d, \omega) \cdot \frac{\mathbf{P}(\mathbf{r}', \omega)}{\epsilon_0} d^3 r' \quad (1)$$

The in-plane component of this defined Green's function of the SPE-MSR system quantifies this nonlocal field behavior. Our experimental results on SPEs integrated to GMR-MSR, capable of showing field nonlocality along with an appreciable antibunching property, makes the coupled system emerge as a new platform to efficiently generate directional, high spectral purity photons with precision control parameters, and the waveguiding gives the system an additional leap as a viable platform for on-chip integrated photonic applications.

MON 8.6 Mon 15:30 ZHG009

Non-destructive characterization of ceramics using mid-infrared optical coherence tomography with undetected photons — •Felipe Gewers[1], Fabian Wendt[2], Gunnar Blume[3], Emma Pearce[1], Martin Laurowski[4], Ivan Zorin[5], Bettina Heise[5], Katrin Paschke[3], Helen Chrzanowski[1], and Sven Ramelow[1,6] — [1]Institut für Physik, Humboldt-Universität zu Berlin, Berlin, Germany — [2]Fraunhofer-Institut für Lasertechnik ILT, Aachen, Germany — [3]Ferdinand-Braun-Institut (FBH), Berlin, Germany — [4]NELA, Lahr, Germany — [5]Research Center for Non-Destructive Testing GmbH, 4040 Linz, Austria — [6]IRIS Adlershof, Berlin, Germany

Optical coherence tomography (OCT) is a non-destructive imaging technique widely used in industry and biomedicine. However, imaging ceramic micro-components is challenging due to their strong light scattering. Mid-infrared (mid-IR) wavelengths (2-4μm) can reduce scattering, but conventional OCT systems in this range are expensive, complex, and noisy.

We present a compact, low-cost OCT system based on undetected photons. Using a nonlinear interferometer and a 660nm laser, entangled photon pairs are generated: the sample is probed with mid-IR field (3.3-4.3μm), and detection occurs in the near-infrared (780-820nm) using a standard silicon spectrometer.

Our system accurately measures ceramic thickness and refractive index, and resolves subsurface structures, demonstrating its potential for affordable imaging of highly scattering materials.

MON 9: Quantum Entanglement

Time: Monday 14:15–16:15 Location: ZHG101

MON 9.1 Mon 14:15 ZHG101

Measurable entanglement lower bounds for cold atom quantum simulators using kinetic operators — •Maike Reckermann[1], Niklas Euler[1,2], and Martin Gärttner[1] — [1]Institute of Condensed Matter Theory and Optics, Friedrich-Schiller-University Jena, Germany — [2]Physikalisches Institut, Universität Heidelberg, Deutschland

The entanglement dimension plays a key role for understanding quantum many-body phenomena such as topological order, recently realized with cold atoms in lattice geometries. Although, it is challenging to measure the entanglement spectrum directly, the entanglement dimension, which is the number of non-zero values in the spectrum, can be lower bounded with measurements in two bases using fidelity witnesses. We develop a method to bound the entanglement dimension, using the information contained in the measurement of kinetic operators in double wells, which was recently pioneered with ultracold bosonic atoms in a 2D optical lattice. We also develop a method to estimate reliable error intervals for the fidelity witnesses, which are obtained using semi-definite programming. We demonstrate our scheme by showing that it can be used to detect entanglement between two attractively interacting distinguishable atoms in 1D and 2D lattice geometries.

MON 9.2 Mon 14:30 ZHG101

Analytical structures in high-dimensional entanglement — •Robin Krebs and Mariami Gachechiladze — Technische Universität Darmstadt, Darmstadt, Hesse, Germany

Efficient and generic methods for analyzing high-dimensional entanglement are crucial for scalable and resilient quantum computation and quantum communication protocols. Understanding the necessary mathematical structures requires analyzing high Schmidt number (SN) PPT states. We prove a generalization of the projection property, which relates the Schmidt number of a quantum state with its lower-dimensional projections. Then, we introduce the concept of a local extension, increasing local dimensions and entanglement content. This new method is then used to construct an extreme point of the PPT set in dimensions 4x5 with SN 3, the lowest dimensional known instance of SN 3 PPT entanglement. To accurately detect the SN for such extreme points, a sufficient and necessary generalization of the range criterion is introduced. We also present various examples of the implications of these results for the structure of high-dimensional entanglement.

MON 9.3 Mon 14:45 ZHG101

Metrological entanglement criteria — •Szilárd Szalay[1] and Géza Tóth[1,2] — [1]Wigner Research Centre for Physics, Budapest, Hungary — [2]University of the Basque Country UPV/EHU, Bilbao, Spain

We show that the quantum Fisher information in quantum metrology in a multiparticle system provides a lower bound on the average size of entangled subsystems. Before it has been known only that the quantum Fisher information puts a lower bound on the entanglement depth. We illustrate the strength of this new criterion and compare it to the previous approach.

[1] Sz. Szalay and G. Tóth, Quantum 9, 1718 (2025)
[2] Sz. Szalay, Quantum 3, 204 (2019)

MON 9.4 Mon 15:00 ZHG101

Exact steering bound for two-qubit Werner states — •Martin J. Renner — ICFO - The Institute of Photonic Sciences, 08860 Castelldefels, Barcelona, Spain

Many quantum technologies rely on nonlocality, correlations between distant particles that defy classical explanation. To harness this, it's essential to know which quantum states can or cannot display nonlocal behavior. A seminal 1989 result by Reinhard Werner showed that some entangled states can be fully explained by local models, but only under the restricted class of projective measurements. We extend this result for two-qubit Werner states to the most general class of measurements, known as positive operator-valued measures (POVMs). Our model identifies exactly which of these states can demonstrate quantum steering, the effect Einstein famously called "spooky action at a distance." Surprisingly, we find that POVMs offer no advantage over projective measurements for revealing steering in these states, resolving a long-standing open question in quantum foundations. Beyond this, our results have implications for measurement incompatibility: we determine the critical visibility under white noise at which all qubit measurements become jointly measurable.

Reference: MJ Renner, Compatibility of Generalized Noisy Qubit Measurements, Phys. Rev. Lett. 132, 250202

MON 9.5 Mon 15:15 ZHG101

Chiral Symmetries of Multiparticle Entanglement — •Sophia Denker[1], Satoya Imai[2], and Otfried Gühne[1] — [1]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Straße 3, 57068 Siegen, Germany — [2]QSTAR, INOCNR, and LENS, Largo Enrico Fermi 2, 50125 Firenze, Italy

Symmetries play a central role in physics. Particularly in entanglement theory many works investigate the separability of states with certain symmetries. However, while in bipartite systems quantum states can show symmetric or antisymmetric behavior, when exploring multipartite systems also quantum states with chiral symmetries can appear.

In this work we investigate chiral subspaces with respect to their entanglement properties. Starting with the case of three qubits we show that these subspaces are highly entangled with respect to their geometric measure of entanglement and are further related to measurements that are useful to estimate entanglement. We then consider these spaces in higher dimensions and define operators related to the structure constants of Lie algebras whose eigenspace coincides with the sum of those chiral subspaces. These operators act as strong entanglement witnesses, which can detect genuine multipartite entangled states with positive partial transpose. Moreover, while we find that these operators are sums of permutations and therefore invariant under unitary transformations, we further translate those operators to sums of permutations and their partial transposed leading to subspaces invariant under orthogonal transformations, which are even more entangled.

MON 9.6 Mon 15:30 ZHG101

Improved bounds on Quantum Max-Cut via entanglement theory constraints — •Minh Duc Tran, Lucas Vieira, and Mariami Gachechiladze — Department of Computer Science, Technical University of Darmstadt, Darmstadt, 64289 Germany

The Quantum Max-Cut (QMC) problem is a paradigmatic example in the study of many-body physics and quantum Hamiltonian complexity. While variational methods present lower bounds on the energy of the most exciting state of the given Hamiltonian, semidefinite programming (SDP) hierarchies have been used to obtain upper bounds by solving a relaxed problem. The feasible points for the solutions, which in the relaxed problem may not represent valid quantum states, are then rounded back to a valid state to obtain the approximation ratio. There are two potential venues for improvements: first, speeding up convergence of the SDP by adding extra constraints, and second, improving the rounding schemes. In this work, we present an improved SDP relaxation of QMC for arbitrary graphs by applying polynomial constraints from entanglement theory, achieving tighter bounds on the true values compared to existing approximations. We further extend this framework to the rounding schemes by using the solutions of the SDPs to obtain better initial parameters for variational algorithms.

MON 9.7 Mon 15:45 ZHG101

Symmetric extensions for the geometric measure of entanglement — •Lisa T. Weinbrenner[1], Xiao-Dong Yu[2], and Otfried Gühne[1] — [1]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Germany — [2]Department of Physics, Shandong University, Jinan 250100, China

Entanglement plays an important role in quantum information theory and is often considered to be a resource for quantum metrology, quantum cryptography or other applications. As such, there is an ongoing search for characterization and quantification techniques, measuring the amount and usefulness of entanglement in quantum states. One possible approach is given by the geometric measure of entanglement, which quantifies the entanglement of a state by its distance to the separable states. Although this measure is easily defined, it is known to be in general hard to obtain for multipartite states. The aim of this contribution is to investigate how the geometric measure can be determined by using multiple copies of the state and applying different symmetrization arguments, deriving a hierarchy for the geometric measure.

MON 9.8 Mon 16:00 ZHG101

Strong quantum nonlocality in multipartite system — •Mengying Hu[1,2], Ting Gao[1], and Fengli Yan[3] — [1]School of Mathematical Sciences, Hebei Normal University, Shijiazhuang 050024, China — [2]University of Siegen, Siegen, Germany — [3]College of Physics, Hebei Normal University, Shijiazhuang 050024, China

Strong quantum nonlocality is a stronger form of nonlocality than that manifested by locally indistinguishable quantum states. It has efficient applications in quantum information hiding and quantum secret sharing. We construct strongly nonlocal orthogonal genuinely entangled sets and strongly nonlocal orthogonal genuinely entangled bases in an N -qutrit system, which provide an answer to the open problem in Ref. [Phys. Rev. Lett. 122, 040403 (2019)]. The strongly nonlocal orthogonal genuinely entangled set we constructed in N-qutrit systems contains much fewer quantum states than previous one. When $N > 3$, our result answers the open question in Ref. [Phys. Rev. A 104, 012424 (2021)]. A sufficient and necessary condition for the strongest nonlocality in general N-partite systems is presented. We successfully construct the strongest nonlocal genuinely entangled sets in $(C^d)^{\otimes N}$ for $d \geq 4$, which have a smaller size than the existing sets as N increases.

MON 10: Standard Model and Beyond

Time: Monday 14:15–16:15 Location: ZHG103

MON 10.1 Mon 14:15 ZHG103

QCD chemistry and heavy-light diquarks — •Mikhail Shifman — William Fine Theoretical Physics Institute, University of Minnesota, MN 55455, USA

In connection with recent discoveries of heavy-quark containing exotic states publications discussing Qq diquarks (Q,q stand for a heavy and light quarks, respectively) proliferated in the literature. After a brief summary of the diquark concept I present various general reasons why the heavy-light diquark (with sufficiently heavy Q) does not exist. Then I argue (this is the focus of my talk) that the most direct way to confirm non-existence of the Qq diquarks is the study of pre-asymptotic corrections in the inclusive decays of Qqq baryons, e.g. Λb. Since the c quarks are much lighter than b, namely, the ratio (m_b)^2/(m_c^2) is of the order of 11, traces of the cq attraction in the color anti-triplet spin-0 state may or may not be present in the cqq baryons.

MON 10.2 Mon 14:30 ZHG103

Quarkonia spectroscopy in the quark-gluon plasma — •Georg Wolschin — Institute for Theoretical Physics, Heidelberg, Germany

In relativistic heavy-ion collisions at RHIC and LHC energies, the spectroscopy of heavy-quarkonia states such as J/ψ and $\Upsilon(nS)$ that are mostly produced in the initial stages of the collision is modified through the presence of the hot plasma of gluons and light quarks. Here, we investigate the in-medium effects on the Υ and χ_b states in our theoretical Heidelberg model.

It considers, in particular, screening of the real quark-antiquark potential, collisional damping through the imaginary part of this potential, gluon-induced dissociation of the six states involved below threshold, and reduction of the feed-down contribution to the $\Upsilon(1S)$ spin-triplet ground state because of the screening of the higher-lying states [1]. Centrality- and transverse-momentum dependent results are compared with CMS and STAR data for the $\Upsilon(nS)$ states, including recent CMS results [2] for $\Upsilon(3S)$. The model has also been applied to Υ physics in p-Pb collisions, where the hot-medium influence can not be neglected, although cold-matter effects are dominant – as is shown in a detailed comparison with LHCb and ALICE data.

[1] G. Wolschin, Int. J. Mod. Phys. A 35, 2030016 (2020).
[2] A. Tumasyan et al. (CMS Collaboration), Phys. Rev. Lett. 133, 022302 (2024).

MON 10.3 Mon 14:45 ZHG103

Extensions of Minimal SU(5) GUT — •Clive Reese — Georg-August Univesity, Göttingen, Germany

Grand Unified Theories (GUTs) extend the Standard Model (SM) embedding the SM gauge groups into one larger group that spontaneously breaks down to the SM at high energy scales. Thereby they predict the unification of gauge couplings and explain the charge quantization of the fermions. However, the minimal non-supersymmetric scenario based on the SU(5) group predicts too fast proton decay. In our work we extend the scalar sector of the model and study the resulting parameter space to find out if it is possible to obtain unification of the couplings at higher scale and to reconcile large masses for the proton decay mediators, while keeping the SM Higgs naturally light.

MON 10.4 Mon 15:00 ZHG103

On the Equivalence Principle in the relativistic and quantum domain — •Claus Lämmerzahl and Hansjörg Dittus — University of Bremen, Am Fallturm 1, 28359 Bremen

The Equivalence Principle (EP) states that all pointlike particles fall in the same way in a gravitational field or that inertial mass is equivalent to gravitational mass. While this is very clear in a non-relativistic classical framework there are open issues in a relativistic and quantum context. First, it is not clear how to introduce in a covariant way a violation of the EP without referring to a bi-metric theory which is ruled out with very high precision from light propagation experiments. Second, quantum states are non-local and, thus, fail to be pointlike which leads to an at least apparent violation of the EP. Here we propose a new covariant approach to violations of the EP in stationary relativistic space-times. This approach naturally includes gravitomagnetic degrees of freedom and, thus, leads to a notion of an EP including all kinds of relativistic degrees of freedom. All these various aspects in principle can be tested with, e.g., atom interferometry. However, one has to further refine the notion of an EP in the quantum domain so that apparent violations of the EP owing to the spatial extension of quantum systems can be uniquely identified. Finally, we are left with an EP which holds both in the relativistic and in the quantum domain.

MON 10.5 Mon 15:15 ZHG103

The Projected Sensitivity of the DELight Experiment — •Eleanor Fascione, Belina von Krosigk, and Francesco Toschi — Kirchhoff-Institute for Physics, Heidelberg University, Heidelberg, Germany

There is vast unexplored parameter space for dark matter masses below a few GeV, and the field of direct dark matter detection is constantly expanding to new frontiers. In particular, low mass dark matter candidates necessitate novel detector designs with lower thresholds and alternative target materials compared to e.g. the xenon-based experiments currently providing the strongest overall constraints on many dark matter models.

The Direct search Experiment for Light dark matter (DELight) will deploy a target of superfluid ^{4}He instrumented with large area microcalorimeters (LAMCALs) based on magnetic microcalorimeter (MMC) technology in a setup optimized for low mass dark matter searches. In this talk an overview of this upcoming experiment will be presented, including preliminary background models and sensitivity projections.

MON 10.6 Mon 15:30 ZHG103

Shaping DELight: signal propagation in superfluid helium-4 — •Francesco Toschi, Eleanor Fascione, and Belina von Krosigk — Kirchhoff-Institute for Physics, Heidelberg University, 69120 Heidelberg, Germany

Large dual-phase noble liquid TPCs strongly constrain the parameter space for dark matter candidates above the GeV/c^2 but can barely explore lighter candidates. Probing this low-mass regime requires ultra-low energy thresholds, which solid-state cryogenic detectors can reach by measuring phonons. However, their small target masses limit exposure and cannot scale in a monolithic way. The Direct search Experiment for Light dark matter (DELight) will use a superfluid helium-4 target instrumented with large area microcalorimeters (LAMCALs), combining the low threshold of phonon-based detection with the scalability of noble liquids. This allows DELight to explore masses down to below 100 MeV/c^2 with just 1 kg d of exposure.

DELight is in its design phase, and detailed simulations play a central role in informing the design and construction of the final detector. This talk will present the current GEANT4 simulation framework, with particular focus on the propagation of the different signal quanta deriving from an energy deposition in superfluid helium-4: photons, excimers, and quasiparticles, i.e. phonons and rotons. In particular, the role of quasiparticle collection efficiency in motivating the choice of a high aspect ratio (or 'pancake') geometry for the detector cell will be discussed.

MON 10.7 Mon 15:45 ZHG103

Towards dark matter detection with superfluid Helium: First results from the DELight Demonstrator — •Axel Brunold, Anna Bertolini, Christian Enss, and Belina von Krosig — Kirchhoff Institute for Physics, Heidelberg University

The search for light dark matter requires innovative detection techniques capable of probing weakly interacting particles with exceptional sensitivity. One promising approach involves studying elastic scattering interactions between dark matter particles and helium atoms in the superfluid phase at millikelvin temperatures.

As part of the Direct search Experiment for Light dark matter (DELight), a pilot experiment is conducted to investigate the behavior of magnetic microcalorimeters (MMCs) submerged in liquid helium referred to as DELight Demonstrator. In this setup, a small copper cell (300 ml) is cooled to below 50 mK within a *He/*He dilution refrigerator and filled with *He. The liquid helium level, during both filling and operation of the MMC, is monitored using an LC circuit-based level meter. At these temperatures, *He is deep in its superfluid phase, enabling a long mean free path for phonons and rotons. An MMC fabricated on a 5 mm * 5 mm silicon substrate and a resistive heater are submerged in the liquid helium. This experiment aims to explore the response of a small-scale athermal MMC (SAMCAL, small-area magnetic microcalorimeter) to phonons excited by the heater in the superfluid.

This contribution presents the DELight Demonstrator setup and recent developments in the project.

MON 10.8 Mon 16:00 ZHG103

Mitigating the low-energy excess in cryogenic detectors for low-mass dark matter searches: Advances from the CRESST experiment — •Anna Bertolini — Kirchhoff-Institute for Physics, Heidelberg University, Heidelberg, Germany

The low-energy excess (LEE) observed in cryogenic detectors, characterized by a steeply increasing event rate below 200 eV, poses a significant challenge to dark matter searches, particularly at low masses. The CRESST experiment has pioneered efforts to understand and mitigate this phenomenon through extensive studies of detector response, novel module designs, and innovative analysis frameworks. Recent observations highlight the time-dependent decay of the LEE rate, offering a practical mitigation strategy through long-term stable cryogenic operation. Coupled with advancements in detector technology, such as DoubleTES sensors and Mini-Beaker modules, these efforts enable a tenfold reduction in the LEE rate, significantly enhancing sensitivity to dark matter interactions. This presentation will detail the latest insights and results of the CRESST Experiment, emphasizing the critical role of detector design in pushing the boundaries of cryogenic detector performance.

MON 11: Quantum Transport I

Time: Monday 14:15–16:00 Location: ZHG104

MON 11.1 Mon 14:15 ZHG104

Scattering approach to quantum radiative heat transfer — •Matthias Hübler[1], Denis M. Basko[2], and Wolfgang Belzig[1] — [1]Universität Konstanz, Konstanz, Deutschland — [2]University Grenoble Alpes CNRS LPMMC, Grenoble, France

We formulate the problem of near-field radiative heat transfer as an effective quantum scattering theory for excitations of the matter. Built from the same ingredients as the semiclassical fluctuational electrodynamics, the standard tool to handle this problem, our construction makes manifest its relation to the Landauer-Büttiker scattering framework, which appears only implicitly in the fluctuational electrodynamics. We show how to construct the scattering matrix for the matter excitations and give a general expression for the energy current in terms of this scattering matrix. We show that the energy current has an important non-dissipative contribution that can dominate the finite-frequency noise while being absent in the average current. Our construction provides a unified description of near-field radiative heat transfer in diverse physical systems.

MON 11.2 Mon 14:30 ZHG104

Anisotropic Electrical Transport in Quasi-1D $ZrSe_3$-Stripes — •Davin Höllmann[1], Lars Thole[1], Sonja Locmelis[2], and Rolf J. Haug[1,3] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, 30167 Hannover, Germany — [2]Institut für Anorganische Chemie, Leibniz Universität Hannover, 30167 Hannover, Germany — [3]Laboratorium für Nano- und Quantenengineering, Leibniz Universität Hannover, 30167 Hannover, Germany

The anisotropy in form of quasi one-dimensional (1D) chains in transition metal trichalcogenides (TMTCs), like ZrS_3 and $ZrSe_3$, makes them stand out compared to other more conventional two-dimensional (2D) materials [1]. We investigated the electrical properties of thin stripes of TMTCs, in particular $ZrSe_3$, regarding their width and thickness. Highlighting the influence of anisotropic effective electron masses [2] in the 2D-plane. The bulk material used was fabricated by a chemical vapor transport method and then exfoliated to achieve thin stripes.

We compared narrow samples with wider samples where both have comparably similar length and thickness and found that the conductivity happens dominantly in the outer selenium atoms i.e. across the chains [3]. We confirmed this using angle dependent electrical transport measurements.

[1] J. O. Island et al., 2D Materials 4, 0220033 (2017)
[2] Y. Jin et al., Phys. Chem. Chem. Phys. 17, 18665-18669 (2015)
[3] D. Höllmann et al., ACS Appl. Electron. Mater. 7, 9, 4049-4054 (2025)

MON 11.3 Mon 14:45 ZHG104

Boundary-driven magnetization transport in the spin-1/2 XXZ chain and the role of the system-bath coupling strength — •Mariel Kempa[1], Markus Kraft[1], Sourav Nandy[2], Jacek Herbrych[3], Jiaozi Wang[1], Jochen Gemmer[1], and Robin Steinigeweg[1] — [1]University of Osnabrueck, D-49076 Osnabrueck, Germany — [2]Max Planck Institute for Physics of Complex Systems, D-01187 Dresden, Germany — [3]Wroclaw University of Science and Technology, 50-370 Wroclaw, Poland

We revisit the Lindblad equation in the context of boundary-driven magnetization transport in integrable spin-1/2 XXZ chain. In particular, we explore the influence of the system-bath coupling strength γ on the quantitative value of the diffusion constant D. Employing numerical simulations on the basis of stochastic unraveling and time-evolving block decimation, we obtain the curve $D(\gamma)$ for finite system sizes, yet outside the range of exact diagonalization. We unveil that $D(\gamma)$, as extracted from the steady state, depends significantly on γ and disagrees with the Kubo formula. We suggest a physical explanation of this disagreement.

MON 11.4 Mon 15:00 ZHG104

Scaling of diffusion constants in perturbed easy-axis Heisenberg spin chains — •Markus Kraft[1], Mariel Kempa[1], Jiaozi Wang[1], Sourav Nandy[2], and Robin Steinigeweg[1] — [1]University of Osnabrück, Department of Mathematics/Computer Science/Physics, D-49076 Osnabrück, Germany — [2]Max Planck Institute for the Physics of Complex Systems, D-01187 Dresden, Germany

Understanding the physics of the integrable spin-1/2 XXZ chain has witnessed substantial progress, due to the development and application of sophisticated analytical and numerical techniques. Since integrability is rather the exception than the rule, a crucial question is the change of infinite-temperature magnetization transport under integrability-breaking perturbations. This question includes the stability of superdiffusion at the isotropic point and the change of diffusion constants in the easy-axis regime. In our work, we study this change of diffusion constants by a variety of methods and cover both, linear response theory in the closed system and the Lindblad equation in the open system, where we throughout focus on periodic boundary conditions. In the closed system, we find evidence for a continuous change of diffusion constants over the full range of perturbation strengths. In the open system weakly coupled to baths, we find diffusion constants in quantitative agreement with the ones in the closed system in a range of nonweak perturbations, but disagreement in the limit of weak perturbations. Using a simple model in this limit, we point out the possibility of a diverging diffusion constant in such an open system.

MON 11.5 Mon 15:15 ZHG104

Andreev reflection and interferometry of integer quantum Hall edge states — •Tom Menei and Thomas L. Schmidt — Department of Physics and Materials Science, University of Luxembourg, Luxembourg

Recent experimental work has demonstrated the possibility of coupling superconductors (SCs) to quantum Hall (QH) systems at both integer and fractional filling factors. However, the theoretical modeling of such QH/SC interfaces remains challenging due to the strong magnetic fields required and the presence of disorder. In this work, we develop a theoretical framework based on QH edge state theory and incorporate realistic models of the superconductor to derive the effective coupling mechanisms at the interface. We analyze the resulting normal and Andreev reflection processes, as well as correlations probed through interference between multiple edge states across the QH/SC interface, and discuss their signatures in transport experiments.

MON 11.6 Mon 15:30 ZHG104

Unconventional Josephson Supercurrent Diode Effect Induced by Chiral Spin-Orbit Coupling — •Andreas Costa[1], Osamu Kanehira[2], Hiroaki Matsueda[2], and Jaroslav Fabian[1] — [1]University of Regensburg, Germany — [2]Tohoku University, Japan

First-principles calculations have recently predicted that chiral materials lacking mirror symmetries—such as twisted van der Waals homobilayers—can feature unconventional radial Rashba coupling with spins aligned fully parallel (instead of tangential) to momentum.

In this talk, we will address Josephson transport through vertical superconductor/ferromagnet/superconductor junctions hosting crossed (radial and tangential) Rashba fields at the interfaces and demonstrate that their interplay with ferromagnetic exchange can lead to supercurrent rectification even when the magnetization is collinear with the current. This so-called unconventional supercurrent diode effect (SDE) originates from spin precessions inside the ferromagnet, which imprint polarity-dependent transmission probabilities on the Cooper pairs being well-distinct from the conventional SDE, and provides a sensitive probe of chiral spin textures.

This work, published in Phys. Rev. B 111, L140506 (2025), has been supported by DFG Grants 454646522 and 314695032 (SFB 1277).

MON 11.7 Mon 15:45 ZHG104

Josephson vortex pinning in two-dimensional SNS-arrays — •Christian Schäfer[1,2], Justus Teller[1,2], Benjamin Bennemann[3], Matvey Lyatti[1,2], Florian Lentz[4], Detlev Grützmacher[1,2], Roman-Pascal Riwar[5], and Thomas Schäpers[1,2] — [1]Peter Grünberg Institut (PGI-9), Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA-Fundamentals of Future Information Technology, Jülich-Aachen Research Alliance, Forschungszentrum Jülich and RWTH Aachen University, Germany — [3]Peter Grünberg Institut (PGI-10), Forschungszentrum Jülich, 52425 Jülich, Germany — [4]Helmholtz Nano Facility, Forschungszentrum Jülich, 52425 Jülich, Germany — [5]Peter Grünberg Institut (PGI-2), Forschungszentrum Jülich, 52425 Jülich, Germany

We fabricated Josephson arrays by etching stacked platinum-niobium (Pt-Nb) thin films. By analyzing both small (3×3) and large (30×30 and 50×50) arrays, we examined how array size and edge effects affect the frustration patterns created by the flow of Josephson vortices. Upon cooling the arrays below 300 mK, the energy barrier for vortex motion increases, immobilizing the vortices and causing the array's behavior to resemble that of a single reference junction. In this vortex-pinned regime, we studied the switching dynamics of the arrays. To determine the distribution of single-junction critical currents within the array, we compared our experimental findings with simulations based on the resistively and capacitively shunted junction (RCSJ) model.

MON 12: Quantum Magnets

Time: Monday 14:15–15:45 Location: ZHG105

MON 12.1 Mon 14:15 ZHG105

Quantum skyrmions and antiskyrmions in monoaxial chiral magnets — Stefan Liscak, Andreas Haller, Andreas Michels, •Thomas L. Schmidt, and Vladyslav M. Kuchkin — Department of Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg, Luxembourg

Classical monoaxial chiral magnets represent a unique magnetic system that allows for the stabilization of both skyrmions and antiskyrmions of equal energy. Unlike a similar situation in frustrated magnets, the energy landscape here is much simpler, consisting of four states: the saturated ferromagnetic state, spin-spiral, skyrmion, and antiskyrmion. This simplicity makes such systems interesting for potential applications that rely on manipulating these states. We study the quantum analog of the already established classical theory by investigating the low-energy excitation spectra of a spin-1/2 quantum Heisenberg model with monoaxial Dzyaloshinskii-Moriya interaction. Using the density matrix renormalization group method, we establish that such a model supports the existence of skyrmion and antiskyrmion states of equal energy. This degeneracy allows for the existence of a mesoscopic Schrödinger cat state exhibiting properties of both skyrmion and antiskyrmion. To characterize this superposition, we calculate two-point correlation functions that can be measured in neutron scattering experiments. Finally, we introduce a perturbation in the form of a magnetic field gradient to induce a non-trivial time evolution of the superposition state. We study this time evolution using both a numerical variational method and the collective coordinates approach.

MON 12.2 Mon 14:30 ZHG105

Revealing Magnetic Chirality in Non-Collinear Kagome Antiferromagnets through Spin-Seebeck Measurements — •Feodor Svetlanov Konomaev, Mithuss Tharmalingam, and Kjetil Magne Dørheim Hals — Department of Engineering Sciences, University of Agder, 4879 Grimstad, Norway

Non-collinear antiferromagnets (NCAFMs) are attractive for antiferromagnetic spintronics, as they combine the advantages of collinear antiferromagnets with novel emergent phenomena arising from their complex spin textures. One such phenomenon is the intrinsic chirality of the ground-state spin configuration, which strongly influences the spin-wave excitation spectrum. In this work, we investigate an NCAFM with a kagome lattice structure interfaced with a normal metal and demonstrate that the ground-state chirality can be probed via measurements of the spin Seebeck effect (SSE). Starting from a microscopic spin Hamiltonian, we derive the corresponding bosonic Bogoliubov-de Gennes (BdG) Hamiltonians for the distinct chiral configurations. Using linear response theory, we obtain a general expression for the spin current thermally pumped into the normal metal due to the SSE. Our results show that a substantial in-plane spin current arises only when the NCAFM is in the negative chiral state, offering a clear experimental signature for real-time detection of chirality switching in kagome NCAFMs.

MON 12.3 Mon 14:45 ZHG105

The effect of Rashba on the magnetic field dependence of Ising superconductors — •Joren Harms, Michael Hein, and Wolfgang Belzig — Fachbereich Physik, Universität Konstanz, Konstanz, Germany

Ising superconductors are transition metal dichalgogenides which can withstand large in-plane external magnetic fields. To a large extent, the protection of the superconducting state from the external magnetic *eld comes from the presence of Ising spin-orbit coupling (ISOC). Since ISOC breaks inversion symmetry and not time-reversal symmetry (TR) it could protect against external magnetic fields. In this work, we study the influence of Rashba SOC on the magnetic field dependence of Ising superconductors.

MON 12.4 Mon 15:00 ZHG105

Thermoelectric response in Altermagnets — •Javad Vahedi[1], Martin Gärttner[1], and Ali Moghaddam[2] — [1]Institute of Condensed Matter Theory and Optics, Friedrich-Schiller-University Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Computational Physics Laboratory, Physics Unit, Faculty of Engineering and Natural Sciences, Tampere University, FI-33014 Tampere, Finland

We study the thermoelectric properties of altermagnets using semiclassical Boltzmann transport theory with constant relaxation time. Altermagnets, with zero net magnetization but spin-split bands from staggered magnetic order, enable exploration of unconventional transport. Using a 2D tight-binding model with spin-independent hopping, altermagnetic exchange, and spin-orbit coupling, we analyze both Drude and Berry curvature contributions. Without a magnetic field, longitudinal conductivities σ_{xx} and α_{xx} vary strongly with spin-orbit coupling λ and exchange J, peaking at intermediate λ. Symmetry-induced Berry curvature cancellation suppresses transverse responses σ_{xy} and α_{xy}. A weak out-of-plane magnetic field breaks these symmetries, inducing notable transverse transport tied to band topology. Finite doping leads to complex Berry curvature patterns and sharp peaks in the anomalous Nernst signal α_{xy}, reflecting resonant entropy transport. The transport behavior as a function of μ, λ, and J highlights the interplay between spin-orbit coupling, magnetic order, and topology. Our findings position altermagnets as tunable platforms for topological and spintronic applications.

MON 12.5 Mon 15:15 ZHG105

V_2Se_2O and Janus V_2SeTeO: Monolayer altermagnets for the thermoelectric recovery of low-temperature waste heat — •Shubham Rakesh Singh, Paresh C. Rout, Mohammed Ghadiyali, and Udo Schwingenschlögl — Physical Science and Engineering Division (PSE), King Abdullah University of Science and Technology (KAUST), Thuwal 23955-6900, Saudi Arabi

We determine the thermoelectric properties of the V_2Se_2O and Janus V_2SeTeO monolayer altermagnets with narrow direct band gaps of 0.74 and 0.26 eV, respectively. Monte Carlo simulations reveal Néel temperatures of 800 K for V_2Se_2O and 525 K for Janus V_2SeTeO. The electrical conductivity is higher for p-type charge carriers than for n-type charge carriers due to lower effective masses. The presence of heavy Te atoms in Janus V_2SeTeO results in lower phonon group velocities, higher phonon scattering rates, and higher lattice anharmonicity than in the case of V_2Se_2O, leading to an almost 19-fold reduction of the lattice thermal conductivity at 300 K. The thermoelectric figure of merit of V_2Se_2O reaches 0.4 (0.1) and that of Janus V_2SeTeO reaches 2.7 (1.0) just below the Néel temperature at the optimal p-type (n-type) charge carrier density, demonstrating that altermagnets have excellent potential in the thermoelectric recovery of low-temperature waste heat.

MON 12.6 Mon 15:30 ZHG105

Katsura-Nagaosa-Balatskiy magnetoelectricity in molecular magnets: Bipartite entanglement transfer with the aid of electric field. — •Zhirayr Adamyan[1,2], Vadim Ohanyan[1,2], Ani Chobanyan[1], Hamid Arian Zad[3], Jozef Strecka[3], Azadeh Ghannadan[4], and Saeed Haddadi[4,5] — [1]Laboratory of Theoretical Physics, Yerevan State University, 1 Alex Manoogian, 0025 Yerevan, Armenia — [2]Synchrotron Research Institute, 31 Acharyan Str., 0040 Yerevan, Armenia — [3]Department of Theoretical Physics and Astrophysics, Faculty of Science, P. J. Safarik University, Park Angelinum 9, 041 54 Kosice, Slovak Republic — [4]Saeeds Quantum Information Group, P.O. Box 19395-0560, Tehran, Iran — [5]Faculty of Physics, Semnan University, P.O. Box 35195-363, Semnan, Iran

The quantum entanglement of spin states in molecular magnets has important applications in quantum information technologies. Currently, qubit models based on magnetic molecules are being developed to advance quantum computation and communication technologies. In this study, we examine a molecular magnet consisting of a spin-1/2 triangular configuration, with a Katsura-Nagaosa-Balatsky(KNB) mechanism to couple spin degrees of freedom with an external electric field. Thanks to the KNB mechanism, the system allows for extensive control over quantum entanglement through the magnitude and direction of the electric field. By utilizing a rotating configuration of the KNB-coupled electric field where the field magnitude remains fixed while its direction rotates-the controllable transfer of bipartite entanglement between different pairs of spins in the model is demonstrated.

MON 13: QIP Implementations: Photons II

Time: Monday 16:30–18:00 Location: ZHG001

MON 13.1 Mon 16:30 ZHG001

Distinguishability, mixedness and symmetry in multiphoton quantum interference — •Shreya Kumar[1], Alex E Jones[2], Matthias Bayerbach[1], Simone D'Aurelio[1], Nico Hauser[1], and Stefanie Barz[1] — [1]Institute for Functional Matter and Quantum Technologies, and IQST, University of Stuttgart, 70569 Stuttgart, Germany — [2]2QET Labs, University of Bristol, Bristol BS8 1FD, UK

Quantum interference is fundamental to many quantum technologies and is governed by properties such as distinguishability, mixedness, and the symmetry of quantum states. Here, we present how these properties influence multiphoton scattering statistics. In particular, we demonstrate that three photons can exhibit distinct scattering statistics depending on whether they are in pure or mixed states, even when they display identical pairwise Hong-Ou-Mandel (HOM) interference. This highlights that pairwise HOM interference is insufficient to fully characterise multi-photon quantum interference. We further investigate the role of quantum state symmetry in quantum interference. Together, these results provide new fundamental insights into the nature of quantum interference and highlight the role of distinguishability, mixedness, and symmetry in multiphoton interference. Apart from providing fundamental insight into the nature of quantum interference, our results have significant implications for quantum technologies that rely on photonic interference, including quantum computing and quantum simulation.

MON 13.2 Mon 16:45 ZHG001

Switching, Amplifying, and Chirping Diode Lasers with Current Pulses for High Bandwidth Quantum Technologies — •Gianni Buser, Roberto Mottola, Suyash Gaikwad, and Philipp Treutlein — Universität Basel, Departement Physik, Klingelbergstrasse 82, 4056 Basel, Schweiz

High-bandwidth asynchronous (fast and triggered) operation is key to establishing the technological relevance of current proof-of-principle quantum devices. Therein, achieving sufficient speed and contrast in amplitude and phase modulation of light is a widespread performance limitation. For instance, quantum memories storing photons in collective matter excitations by optical control often suffer from unintentional readout due to leaking control light during the storage time [1,2]. Moreover, the control intensities are regularly such, that two-photon process like read/write operations technically require chirped pulses to remain on resonance over the course of their dynamics because of induced atomic level shifts. This talk describes direct current modulation methods that grant independent phase and amplitude control over diode lasers. A system capable of producing watt power level, nanosecond duration optical pulses with 60 dB intensity contrast between their on and off states and simultaneous chirps at rates up to 150 MHz/ns on demand [3] is presented, and application to high bandwidth quantum technology is discussed. [1] PRX Quantum 3, 020349 (2022), [2] PRL 131, 260801 (2023), [3] RSI 95, 123001 (2024).

MON 13.3 Mon 17:00 ZHG001

Applications of boosted Bell-state measurements — Matthias J. Bayerbach[1,2], •Simone E. D'Aurelio[1,2], and Stefanie Barz[1,2] — [1]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, Stuttgart, Germany. — [2]Center for Integrated Quantum Science and Technology (IQST), University of Stuttgart, Stuttgart, Germany

Bell-state measurements are a key component to realize in many quantum communication and computing applications. They are at the heart of quantum repeaters or measurement-device-independent quantum key distribution protocols and essential in the generation of larger entangled state in measurement-based quantum computing. Linear optical implementations are favourable due to their simplicity, but limited in their success rates. Boosting the success rate of these measurements with ancillary photons allow one to overcome this flaw, while keeping the advantages of linear optics.

In this talk, we present experimental implementations of such a scheme. We demonstrate boosted quantum teleportation and boosted entanglement swapping, both critical components of a quantum repeater. Using single photon sources at 1550 nm, our system is compatible with existing telecommunication infrastructure. Our work demonstrated the practicality and usefulness of ancillary state boosting for any application relying on Bell-state measurements.

MON 13.4 Mon 17:15 ZHG001

Generation a 3-mode NOON state with heralding — •Sukhjit Singh, Emanuele Polino, Farzad Ghafari, Simon White, Geoff Pryde, Sergei Slussarenko, and Nora Tischler — Queensland Quantum and Advanced Technologies Institute and Centre for Quantum Computation and Communication Technology, Griffith University, Yuggera Country, Brisbane, QLD 4111, Australia

The preparation of photonic entangled states is generally probabilistic, and their successful generation is mainly verified by destructively measuring them (post-selection), making them impractical for many large-scale applications. This problem can be avoided by heralding, which means creating the entangled state with additional photon(s) in ancilla modes, and upon only measuring these modes, the desired state's successful generation can be verified.

Multi-mode NOON states, a coherent superposition of N photons in one mode and none in the other d modes, are optimal probes for multiphase sensing and key resources for phase imaging in optical microscopy. However, it must be generated in a heralded manner. Only then can it be used efficiently to perform phase sensing, without reducing the Fisher information due to failed state generation attempts.

Using single photons, linear optics and SNSPDs, we have experimentally created for the first time a 3-mode NOON state whose successful generation can be verified by detecting one and only one auxiliary photon in an additional mode: (|2,0,0> + |0,2,0> + |0,0,2>)|1>.

MON 13.5 Mon 17:30 ZHG001

Homodyne detection of pulsed squeezed states of light for Gaussian Boson Sampling — •Florian Lütkewitte[1], Sanaz Haddadian[2], Mikhail Roiz[1], Kai Hong Luo[1], Jan-Lucas Eickmann[1], J. Christoph Scheytt[2], Benjamin Brecht[1], Michael Stefszky[1], and Christine Silberhorn[1] — [1]Paderborn University, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Str. 100, 33098, Paderborn, Germany — [2]System and Circuit Technology Group, Heinz Nixdorf Institute, Paderborn University, 33102 Paderborn, Germany

With the advent of complex, hybrid photonic networks such as Gaussian Boson Sampling (GBS), it becomes increasingly important to produce high-quality single-spectral-mode single-mode squeezed states of light (SMSS), requiring precise engineering of spectral properties. Here, SMSS are generated by interfering the modes of a decorrelated, spectrally indistinguishable two-mode squeezed state.

Naturally, one also needs to verify the quality of these states, which can be done using single-shot homodyne detection, requiring tailored electronics and optics. This detection scheme also enables time-multiplexed architectures and measurement of complex heralded quantum states by post-selection. Here, we will show the suitability of single-shot homodyne detection for characterizing single-spectral-mode single-mode squeezed states for GBS

MON 13.6 Mon 17:45 ZHG001

Demonstration of free-electron-photon entanglement — •Jan-Wilke Henke[1,2], Hao Jeng[1,2], Murat Sivis[1,2], and Claus Ropers[1,2] — [1]Max Planck Institute for Multidisciplinary Sciences, Göttingen, Germany — [2]University of Göttingen, 4th Physical Institute, Göttingen, Germany

Most emerging quantum technologies including quantum computation and sensing rely on quantum entanglement. Verifying the entanglement between different quantum system is thus of high relevance. While the interaction of free electrons with optical fields is expected to induce free electron-photon entanglement [1,2], its proof has been an outstanding challenge.

Here, we demonstrate quantum entanglement between free electrons and photons [3]. Harnessing a quantum eraser-type setup [4], we employ dual electron beams in a transmission electron microscope that generate photons of distinct polarisation at a nanostructure. The joint electron-photon state is reconstructed from measurements in different bases and shown to violate the Peres-Horodecki entanglement criterion by more than 7 standard deviations. This proof of electron-photon entanglement will be a cornerstone of free electron quantum optics, enabling quantum-enhanced sensing in electron microscopy.

[1] O. Kfir, Phys. Rev. Lett. 123, 103602 (2019);
[2] A. Konecńa, F. Iyikanat, and F. J. García de Abajo, Sci. Adv. 8, eabo7853 (2022);
[3] J.-W. Henke et al., arXiv:2504.13047 (2025);
[4] J.-W. Henke, H. Jeng & C. Ropers, Phys. Rev. A 111, 012610 (2025)

MON 14: QIP Implementations: Solid-State Devices I

Time: Monday 16:30–18:30 Location: ZHG002

MON 14.1 Mon 16:30 ZHG002

Fast quantum gates for exchange-only qubits using simultaneous exchange pulses — •Irina Heinz[1], Felix Borjans[2], Matthew J. Curry[2], Roza Kotlyar[2], Florian Luthi[2], Mateusz T. Mądzik[2], Fahd A. Mohiyaddin[2], Nathaniel Bishop[2], and Guido Burkard[1] — [1]Department of Physics, University of Konstanz, Konstanz, Germany — [2]Intel Technology Research, Intel Corporation, Hillsboro, OR, USA

The benefit of exchange-only qubits compared to other spin qubit types is the universal control using only voltage controlled exchange interactions between neighboring spins. As a compromise, qubit operations have to be constructed from non-orthogonal rotation axes of the Bloch sphere and result in rather long pulsing sequences. We theoretically develop a faster implementation of single-qubit gates using simultaneous exchange pulses and manifests their potential for the construction of two-qubit gates. We introduce faster pulse sequences and show that subsequences on three spins in two-qubit gates could be implemented in fewer steps. We experimentally demonstrate and characterize a simultaneous exchange implementation of X rotations in a SiGe quantum dot device and compare to the state of the art with sequential exchange pulses. Our findings can particularly speed up gate sequences for realistic idle times between sequential pulses and we show that this advantage increases with more interconnectivity of the quantum dots. We further demonstrate how a phase operation can introduce a relative phase between the computational and some of the leakage states, which can be advantageous for the construction of two-qubit gates.

MON 14.2 Mon 16:45 ZHG002

Sub-harmonic control of a fluxonium qubit via a Purcell-protected flux line — •Christian Schneider[1,2], Johannes Schirk[1,2], Florian Wallner[1,2], Longxiang Huang[1,2], Ivan Tsitsilin[1,2], Niklas Bruckmoser[1,2], Leon Koch[1,2], Klaus Liegener[1,2], and Stefan Filipp[1,2,3] — [1]Walther-Meißner-Insitut, Bayerische Akademie der Wissenschaften, 85748 Garching — [2]Technische Universität München, TUM School of Natural Sciences, 85748 Garching — [3]Munich Center for Quantum Science and Technology (MCQST), 80799 München

Isolating qubits from environmental noise while maintaining fast, high-fidelity control is a central challenge in quantum information processing. In this talk, I present our findings on isolating a superconducting fluxonium qubit from its noisy control environment while maintaining fast, high-fidelity control. We achieve this by adding a low-pass filter below the qubit frequency, which suppresses resonant coupling between the qubit and the control channel. Although this prevents resonant qubit control, we overcome the limitation by driving the qubit at integer fractions of its transition frequency, allowing us to achieve Rabi oscillations through the Purcell-protected channel. We demonstrate coherent control using up to 11-photon processes through driving the qubit at 1/11 of its resonant frequency and have developed an effective Hamiltonian model using a Magnus expansion, which accurately predicts the observed behavior. These results open a scalable approach for fluxonium control via a single Purcell-protected channel, preserving intrinsic qubit coherence while allowing for fast, high-fidelity control.

MON 14.3 Mon 17:00 ZHG002

Transmon-based thermometrics through integrated control of cryo-system parameters and automated quantum chip diagnostics — •Thorsten Last, Adam Lawrence, Koushik Kumaran, Gerben Erens, Kelvin Loh, and Adriaan Rol — Orange Quantum Systems, Elektronicaweg 2, 2628 XG Delft, NL

Thermometric analysis of superconducting qubits gives valuable insights into their environment such as the quantum processor, the I/O unit they are connected to, and the steadily increasing number of components required for scaling the cryogenic part of the quantum system. Analyzing their various decoherence channels and minimizing their thermal load becomes increasingly important. Hence, here we report on the development of an quantum chip test setup in which cryogenic and quantum control units are fully integrated to enable efficient and automated quantum chip testing and qualification. Purpose-built cryogenic and quantum control hardware systems are integrated under a unified control software platform which provides an application-specific operating system for quantum chip control. This integrated quantum test setup offers a practical advantage in the optimization of quantum chip characterization. The unified software interface allows for intelligent feedback between quantum control parameters and cryogenic control and monitoring. We will show that this enables novel features for the prevention, diagnostics and mitigation of a range of practical issues that can occur in cryogenic chip benchmarking, as well as providing a unified interface for quantum experiments involving cryogenic parameters for utility-scale quantum processors.

MON 14.4 Mon 17:15 ZHG002

Optimized flip chip bonding for 3D integrated superconducting quantum circuits — •Lea Richard[1,2], Julius Feigl[1,2], Niklas Bruckmoser[1,2], Leon Koch[1,2], Lasse Södergen[1,2], and Stefan Filipp[1,2] — [1]Technical University of Munich — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften

In order to use quantum computing to tackle classically intractable problems, quantum processors must grow to larger scales. Yet, in current planar architectures, routing multiple lines to an increasing number of qubits while minimizing crosstalk remains a significant challenge. 3D-integration techniques, such as flip-chip bonding enable more efficient connectivity. However, implementing a novel circuit geometry introduces challenges, including maintaining high coherence and preserving precise parameter targeting. Flip-chip bonding relies on indium bump bonds to mechanically and galvanically connect two separate chips. The additional fabrication steps can lead to new loss channels and degrade overall system performance. Moreover, in superconducting quantum circuits, capacitances and inductances are determined by the design of the electrodes. In a flip-chip assembly, these parameters depend on the gap separating the bonded chips and variations during the bonding process can limit accurate parameter targeting. To address these challenges, we present the fabrication of high-thickness indium bumps and the development of an optimized flip-chip bonding process for high-coherence quantum circuits. Additionally, we introduce a method for improving interchip spacing control and parameter targeting using polymer spacers.

MON 14.5 Mon 17:30 ZHG002

Passive leakage removal unit based on a disordered transmon array — •Gonzalo Martín-Vázquez[1,2], Taneli Tolppanen[2], and Matti Silveri[2] — [1]Departamento de Física Aplicada II, Universidad de Sevilla, E-41012 Seville, Spain — [2]Nano and Molecular Systems Research Unit, University of Oulu, FI-90014 Oulu, Finland

Leakage out from the qubit subspace compromises standard quantum error correction protocols and poses a challenge for practical quantum computing. We propose a passive leakage removal unit based on an array of coupled disordered transmons and last-site reset by feedback-measurement or dissipation. We find that the unit effectively removes leakage with minimal effect to the qubit subspace by taking advantage of energy level disorder for qubit subspace and resonant leakage energy levels. There are two optimal measurement rates for removing leakage, which we show analytically to correspond to characteristic time scales of leakage propagation and disintegration in the system. The performance of the leakage removal unit depends on the strength of disorder, coupling between the transmons, and the length of the array. We simulate the system under experimentally feasible parameters and present an optimal configuration. Our approach is readily compatible with existing superconducting quantum processors considering realistic conditions.

MON 14.6 Mon 17:45 ZHG002

Josephson Qubits with a DC Voltage Drive — •Florian Höhe[1], Ciprian Padurariu[1], Björn Kubala[1,2], and Joachim Ankerhold[1] — [1]ICQ and IQST, Ulm University, Ulm, Germany — [2]Institute of Quantum Technologies, German Aerospace Center (DLR), Ulm, Germany

Superconducting qubits utilize a Josephson junction as a nonlinear element to create a non-linear oscillator with unequally spaced energy levels. Coherent AC pulses, resonant with the transition frequency between the two lowest energy eigenstates, $|0\rangle$ and $|1\rangle$, enable quantum gate operations while leaving higher energy states largely unaffected.

In Josephson-photonics devices, a DC-biased Josephson junction generates excitations within a microwave LC resonator. Although the resonator's energy levels are equally spaced, the intrinsic nonlinearity of the drive can be exploited to suppress the $|1\rangle \rightarrow |2\rangle$ transition. This effectively turns the system into a two-level qubit that can be controlled by tuning the Josephson energy through a SQUID, eliminating the need for AC pulses.

In this work, we propose a method for implementing both single- and multi-qubit gates for qubits based on DC-biased Josephson junctions. The typically large Josephson energy in these devices may allow for fast and efficient gate operations.

MON 14.7 Mon 18:00 ZHG002

Robust, fast and high-fidelity composite single-qubit gates for superconducting transmon qubits — •Hristo Tonchev[1], Boyan Torosov[2], and Nikolay Vitanov[1] — [1]Center for Quantum Technologies, Department of Physics, Sofia University, James Bourchier 5 blvd., 1164 Sofia, Bulgaria — [2]Institute of Solid State Physics, Bulgarian Academy of Sciences, 72 Tsarigradsko chaussee, 1784 Sofia, Bulgaria

We introduce a novel quantum control method for superconducting transmon qubits that significantly outperforms conventional techniques in precision and robustness against coherent errors. Our approach leverages composite pulses (CP) to effectively mitigate system-specific errors, such as qubit frequency and anharmonicity variations. By utilizing CP, we demonstrate both complete and partial population transfers between qubit states, as well as the implementation of two essential single-qubit quantum gates. Simulations reveal substantial reductions in common error rates and gate durations. The effectiveness of our method is validated through four independent verification techniques, underscoring its potential for advancing quantum computing with superconducting qubits.

MON 14.8 Mon 18:15 ZHG002

Characterization of Impedance-Matched Broadband Josephson Parametric Amplifier — •Maria-Teresa Handschuh[1,2], Kedar E. Honasoge[1,2], Florian Fesquet[1,2], Simon Gandorfer[1,2], Achim Marx[1,2], Rudolf Gross[1,2,3], and Kirill G. Fedorov[1,2,3] — [1]Walther-Meissner-Institute, 85748 Garching, Germany — [2]School of Natural Sciences, Technische Universität München, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology, 80799 Munich, Germany

Josephson parametric amplifiers (JPAs) are essential tools in experiments involving superconducting quantum circuits due to their near quantum-limited performance. However, traditional JPAs suffer from narrow bandwidths and limited compression powers, which restricts their applicability in systems requiring broader frequency range and higher signal powers. In this talk, we present the design and characterization measurements of a broadband JPA that integrates an on-chip impedance-matching circuit based on two coupled resonators. Gain measurements reveal a spectral bandwidth enhancement of nearly two orders of magnitude, as compared to conventional JPAs. In addition, we present the noise performance across a wider frequency range, highlighting the amplifier's suitability for advanced quantum applications.

MON 15: Many-Body Quantum Dynamics II

Time: Monday 16:30–18:15 Location: ZHG003

MON 15.1 Mon 16:30 ZHG003

Towards a Many-Body Generalization of the Wigner-Smith Time Delay — •Georg Maier[1], Carolyn Echter[2], Juan Diego Urbina[1], Caio Lewenkopf[3], and Klaus Richter[1] — [1]Institut für Theoretische Physik Universität Regensburg, Regensburg, Germany — [2]Fakultät für Mathematik, Universität Regensburg, 93040 Regensburg, Deutschland — [3]Instituto de Física, Universidade Federal do Rio de Janeiro, 21941-972 Rio de Janeiro, RJ, Brazil

Many body systems with a large number of degrees of freedom are usually described by statistical physics on the theoretical side while experiments usually relay on scattering (e.g. particle physics). Is it possible to relate scattering and statistical physics, or to measure scattering-related observables which directly relate to quantities of statistical physics? At least for single particle systems a close relation exists between the well known Wigner-Smith delay time in scattering theory and the density of states of the scattering system.

I will present a novel ansatz relating a many-body version of dwell-/Wigner-Smith delay time and many body density of states based on the famous Birman-Krein-Friedel-Loyd formula connecting scattering theory and statistical observables in the many-body context. Due to the flexibility of this ansatz it can be used to investigate a wide variety of MB systems. I will discuss interesting scaling behaviors for different systems, like the harmonic trap[1] or the free particle together with the different behavior of bosons, fermions and indistinguishable particles.

[1] C. Echter et. al 2409.08696

MON 15.2 Mon 16:45 ZHG003

Equilibrium, Relaxation and Fluctuations in homogeneous Bose-Einstein Condensates: Linearized Classical Field Analysis — •Nils A. Krause[1,2] and Ashton S. Bradley[1,2] — [1]Department of Physics, University of Otago, Dunedin, New Zealand — [2]Dodd-Walls Centre for Photonic and Quantum Technologies

We present a thorough analysis of the linearized stochastic projected Gross-Pitaevskii equation (SPGPE) describing finite temperature in Bose-Einstein condensates (BECs). Our study reveals an optimal choice for the cut-off that divides the Bose gas into a low energy coherent region forming a classical wave and a high energy thermal cloud acting as a reservoir. Moreover, it highlights the relevance of energy damping, the number conserving scattering between thermal and coherent atoms. We analyze the equilibrium properties and near equilibrium relaxation of a homogeneous BEC in one, two and three dimensions at high phase space density. Simulations of the full nonlinear SPGPE are in close agreement, and extend our arguments beyond the linear regime. Our work suggests the need for a re-examination of decay processes in BECs studied under the neglect of energy damping.

MON 15.3 Mon 17:00 ZHG003

Creating NOON Wavepackets via Resonance and Chaos-Assisted Tunneling of Ultracold Atoms in a Ring — •Diego Morachis and Peter Schlagheck — CESAM Research Unit, University of Liège, 4000 Liège, Belgium

A way to generate microscopic quantum superpositions for repulsively interacting ultracold atoms confined in a ring-shaped trap is proposed. Periodically driving the system renders a mixed phase space where chaotic dynamics coexist with stable resonant islands. These islands act as effective double-well potentials, enabling the confinement of atoms in distinct wavepackets with the possibility of achieving states in a perferctly balanced superposition known as a NOON state. We explore the creation of such states by studying the evolution of experimentally feasible coherent states as initial wavepackets. Parameter sets enabling the self-trapping regime are identified, which suppresses individual tunneling and promotes collective tunneling as the dominant mechanism. By performing exact numerical simulations of the many-body dynamics, we characterize NOON state formation timescales for distinct particle numbers. Preliminary results suggest specific driving windows where this resonance and chaos-assisted approach may generate nonclassical states in atomic traps.

MON 15.4 Mon 17:15 ZHG003

NOON entanglement via quantum control in Bose-Hubbard systems — •Simon Dengis[1], Sandro Wimberger[2,3], and Peter Schlagheck[1] — [1]CESAM Research Unit, University of Liege, 4000 Liege, Belgium — [2]Istituto Nazionale di Fisica Nucleare (INFN), Sezione Milano Bicocca, Gruppo collegato di Parma, Italy — [3]Dipartimento di Matematica, Fisica e Informatica, Università di Parma, Parco Area delle Scienze 7/A, 43124 Parma, Italy

A quantum control protocol is proposed for the creation of NOON states with N ultracold bosonic atoms on two modes, corresponding to the coherent superposition $|N,0\rangle + |0,N\rangle$. This state can be prepared by using a third mode where all bosons are initially placed and which is symmetrically coupled to the two other modes. Tuning the energy of this third mode across the energy level of the other modes allows the adiabatic creation of the NOON state. While this process normally takes too much time to be of practical usefulness, due to the smallness of the involved spectral gap, it can be drastically boosted through counterdiabatic driving which allows for efficient gap engineering. We then extend this entanglement protocol to the realization of multi-mode NOON states by employing a generic star-shaped Bose-Hubbard model with an arbitrary number of modes. We demonstrate that this process can be implemented in terms of static parameter adaptations that are experimentally feasible with ultracold quantum gases using Geodesic Counterdiabatic Driving, which saturates the quantum speed limit.

MON 15.5 Mon 17:30 ZHG003

Stability of Floquet sidebands and quantum coherence in 1D strongly interacting spinless fermions — •Karun Gadge and Salvatore R Manmana — Institute for Theoretical Physics, Georg-August-University Goettingen, Germany

For strongly correlated quantum systems, fundamental questions about the formation and stability of Floquet-Bloch sidebands (FBs) upon periodic driving remain unresolved. Here, we investigate the impact of electron-electron interactions and perturbations in the coherence of the driving on the lifetime of FBs by directly computing time-dependent single-particle spectral functions using exact diagonalization (ED) and matrix product states (MPS). We study interacting metallic and correlated insulating phases in a chain of correlated spinless fermions. At high-frequency driving we obtain clearly separated, long-lived FBs of the full many-body excitation continuum. However, if there is significant overlap of the features, which is more probable in the low-frequency regime, the interactions lead to strong heating, which results in a significant loss of quantum coherence and of the FBs. Similar suppression of FBs is obtained in the presence of noise. The emerging picture is further elucidated by the behavior of real-space single-particle propagators, of the energy gain, and of the momentum distribution function, which is related to a quantum Fisher information that is directly accessible by spectroscopic measurements.

Ref: arXiv:2502.12643

MON 15.6 Mon 17:45 ZHG003

Transport in quantum wires: Fractional charges and non-linear Luttinger liquids — •Sebastian Eggert[1], Flávia B. Ramos[1], Imke Schneider[1], and Rodrigo G. Pereira[2] — [1]University of Kaiserslautern-Landau — [2]Universidade Federal do Rio Grande do Norte, Natal

This talk will address the question about how a right-moving unit charge propagates along an interacting spinless wire. Using adaptive time-dependent DMRG, we observe that the charge spontaneously separates into three distinct parts: a fractional charge with free particle dynamics and left- and right-moving parts. As we will show the results are in full agreement with the non-linear Luttinger theory and provide deep insights into the universal correlated nature of these emergent particles. Corresponding out-of-equilibrium transport measurements offer a direct method to extract the interaction parameters governing correlations in the system even at higher energies.

MON 15.7 Mon 18:00 ZHG003

Many-body interference of anyons on a one-dimensional lattice — •Peter Robert Förderer[1], Gabriel Dufour[1], and Andreas Buchleitner[1,2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg, Germany — [2]EUCOR Centre for Quantum Science and Quantum Computing, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg, Germany

In addition to bosons and fermions, one- or two-dimensional systems can host anyons with non-trivial exchange phase φ. Here, we theoretically explore the dynamics of anyons on a one-dimensional lattice. This anyon-Hubbard model can be mapped onto a generalized Bose-Hubbard model with an occupation-dependent tunneling phase. In particular, we study the Hong-Ou-Mandel interference of two anyons scattering on a potential barrier. We show that the anyonic phase not only enables to interpolate between bosonic bunching and fermionic antibunching but also introduces new effects such as the formation of bound states and preferential scattering in one direction.

MON 16: Quantum Spectroscopy

Time: Monday 16:30–18:15 Location: ZHG004

MON 16.1 Mon 16:30 ZHG004

Two-photon excitation spectroscopy of high pressure xenon- noble gas mixtures — •Eric Boltersdorf, Thilo vom Hövel, Frank Vewinger, and Martin Weitz — Institut für Angewandte Physik, Bonn, Deutschland

When confined to a dye-filled optical microcavity, photons can exhibit Bose-Einstein condensation upon thermalization after repeated absorption and (re-)emission processes on the dye molecules. This has been experimentally demonstrated first in 2010.

In this work, an experimental approach is investigated to realize a Bose-Einstein condensate of vacuum-ultraviolet photons (100nm - 200nm) by absorption and (re-)emission cycles between xenon's $5p^6$ and $5p^5 6s$ (J = 1) state in dense xenon-noble gaseous ensembles. Here, we show the results of two-photon excitation spectroscopy to higher lying electronic states. We report on excitation spectra with excitation wavelengths ranging from 220nm to 260nm. The collected emission around 147nm is attributed to the decay of the $5p^5 6s$ (J = 1) state which is proposedly populated via collisional deactivation from the higher lying excited states. We show data for xenon-krypton as well as for xenon-helium mixtures.

MON 16.2 Mon 16:45 ZHG004

Sensitivity and Bandwidth Trade-Off in Rydberg Atom Sensors: A Superheterodyne-Homodyne Approach — •Dixith Manchaiah[1,2], Nikunjkumar Prajapati[1], and Christopher L Holloway[1] — [1]National Institute of Standards and Technology, Boulder, US — [2]University of Colorado, Boulder, US

Rydberg atom-based electric field sensors are emerging as powerful alternative to conventional antennas, offering high sensitivity and a broad frequency response. In this work, we explore the bandwidth and sensitivity of such sensors using Rydberg electromagnetically induced transparency (EIT) in rubidium vapor cell. The bandwidth of Rydberg sensors is typically limited by atomic transit time and the Rabi frequency of the coupling laser. While reducing beam size can increase bandwidth, it often leads to reduced signal strength and lower sensitivity.

To address this trade-off, we employ a radio frequency(RF) superheterodyne technique combined with optical homodyne detection. This approach allows us to optimize the relationship between bandwidth and sensitivity of the sensor. We further explore the effects of probe and coupling Rabi frequencies, and modulation schemes with different symbol rates and beatnote frequencies to understand the sensor performance. These findings demonstrate a practical path toward developing high bandwidth, high sensitivity Rydberg sensors suitable for applications in communication, radar, and metrology.

MON 16.3 Mon 17:00 ZHG004

Retrieving lost atomic information of an optical quantum system — •Laura Orphal-Kobin[1], Gregor Pieplow[1], Alok Gokhale[1], Kilian Unterguggenberger[1], and Tim Schröder[1,2] — [1]Department of Physics, Humboldt-Universität zu Berlin, Berlin, Germany — [2]Ferdinand-Braun-Institut, Berlin, Germany

The precise characterization of quantum systems is critical for exploring fundamental questions and for assessing their potential in quantum technologies. Many characterization methods and prospective quantum applications rely on the detection of single photons and are therefore often time-consuming and resource-intensive. In this work, we leverage statistical Monte Carlo simulations to retrieve information from undersampled experimental data [1].

We perform a photoluminescence excitation spectroscopy measurement to estimate the optical linewidth of a quantum emitter, here a single nitrogen-vacancy center in diamond. We emulate regimes of high and low photonic signals by adding a neutral density filter in the detection path of the setup. In a regime of weak signals, standard data analysis methods result in unphysically narrow linewidths. Using a Monte Carlo method, synthetic data is generated with different input parameters, here linewidth and detected photon number. The comparison of the simulations with experimental data sets allows to determine the system parameters with high accuracy even when the experimental data are undersampled. Therefore, the Monte Carlo method unlocks new experimental regimes in quantum optics.

[1] L. Orphal-Kobin et al., arXiv:2501.07951 (2025).

MON 16.4 Mon 17:15 ZHG004

Quantum interference effects in cathodoluminescence — •Hebrew Benhur Crispin and Nahid Talebi — Christian-Albrechts-Universität, Kiel, Germany

Free electrons have emerged as a versatile tool for investigating the quantum properties of light at a nanoscale level. Recent advances in electron microscopy have made it possible to observe quantum optical phenomena, such as photon antibunching and superbunching, through the excitation of quantum emitters by an electron beam. This has sparked significant interest in understanding photon statistics and electron-emitter interactions in cathodoluminescence. Previous studies have largely relied on classical models, focusing on electron excitations of two-level quantum systems only.

Here, we introduce a theoretical model for cathodoluminescence from a multi-level quantum emitter. We derive a quantum optical master equation for the system by treating the free-electron beam excitation as an incoherent, broad-band pump driving the emitter. We demonstrate that the existence of numerous transition pathways can result in quantum interference effects that significantly modify both the emitter dynamics and the time-resolved cathodoluminescence spectra. We demonstrate that the excitation rate, initial coherence and energy spacing between excited states are crucial parameters determining the influence of interference. Our work sheds light on free-electron-induced quantum interference in cathodoluminescence emission, providing a general framework with which to investigate quantum optical effects in the electron-beam excitation of multi-level quantum emitters.

MON 16.5 Mon 17:30 ZHG004

Attosecond pulse generation in laser-assisted radiative recombination — •Katarzyna Krajewska[1], Deeksha Kanti[1], Jerzy Z. Kaminski[1], and Liang-You Peng[2] — [1]University of Warsaw, Warsaw, Poland — [2]Peking University, Beijing, China

Electron-ion radiative recombination in the presence of a bicircular laser pulse is analyzed beyond the dipole approximation [1]. A bicircular pulse consists of two counter-rotating circularly polarized laser pulses with commensurate carrier frequencies. It is demonstrated that the broad bandwidth radiation can be generated in the process and that its spectrum can be significantly enhanced by tailoring the laser field [2]. A special emphasis is put on analyzing temporal properties of generated radiation, which is released as either an isolated attosecond pulse or an attosecond pulse train.

[1] D. Kanti et al., Phys. Rev. A 110, 043112 (2024).
[2] D. Kanti et al., Photonics 12, 320 (2025).

MON 16.6 Mon 17:45 ZHG004

Nondipole effects in multiphoton ionization — •Katarzyna Krajewska and Jerzy Z. Kaminski — University of Warsaw, Warsaw, Poland

We study nondipole effects in multiphoton ionization of a two-dimensional hydrogen-like atom by a flat-top laser pulse. To this end, we solve numerically the Schrodinger equation treating a propagating laser pulse exactly in the entire interaction region [1]. We demonstrate a directional dependence of the energy-angular photoelectron distributions for propagating laser pulses of moderate and high intensities. It is analytically interpreted based on the leading order relativistic expansion of the electron Volkov state, showing a significant contribution of the electron recoil to that behavior. In contrast, the retardation correction originating from the space- and time-dependence of the laser field leads to a tiny redshift of the photoelectron energy spectra. Other features of ionization distributions are also analyzed, including the sidelobes and the double-hump structures of multiphoton peaks, or their disappearance for intense propagating laser pulses [2].

[1] M. C. Suster et al., Phys. Rev. A 107, 053112 (2023).
[2] K. Krajewska, J. Z. Kaminski, Phys. Rev. A (submitted) (2025).

MON 16.7 Mon 18:00 ZHG004

Control of laser-assisted radiative recombination beyond the dipole approximation — Deeksha Kanti[1], •Mateusz Majczak[1], Jerzy Kamiński[1], Liang-You Peng[2], and Katarzyna Krajewska[1] — [1]Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, Warsaw, 02-093, Poland — [2]State Key Laboratory for Mesoscopic Physics and Frontiers Science Center for Nano-optoelectronics, School of Physics, Peking University, Beijing, 100871, China

We present a comprehensive theoretical description of laser-assisted radiative recombination (LARR) in the presence of short laser pulses, that accounts for nondipole corrections of the leading order in $1/c$. They are derived systematically by the relativistic reduction, enabling us to follow the origin of various nondipole contributions. As it follows from our numerical analysis, the most important of them originates from the electron recoil off the laser pulse. We recognize that it results in extension of the LARR high-energy plateau and is a cause of an asymmetry of energy distributions of generated radiation with respect to the polar angle of the recombining electron. As we show, the remaining nondipole corrections of the leading order in $1/c$ turn out to be less significant.

In addition, we analyze ways to control the LARR radiation using external laser pulses. Despite the aforementioned nondipole effects which arise entirely from the presence of the laser field, we investigate the possibility of manipulating the intensity of the cutoff portion of LARR by chirping the accompanying laser pulse.

MON 17: Quantum Communication and Networks: Theory

Time: Monday 16:30–18:30 Location: ZHG006

MON 17.1 Mon 16:30 ZHG006

Resolution of Holevo's Conjecture on Classical-Quantum Channel Coding via Uncertainty Relations — •Joseph M. Renes — Institute for Theoretical Physics, ETH Zurich, Switzerland

The notion of complementarity is fundamental to quantum theory, as evidenced by the uncertainty principle. In quantum information theory complementarity and uncertainty relations have become important tools in designing and analyzing information processing protocols, e.g. in quantum key distribution. Here I report on another use, in determining the error exponent of classical-quantum (CQ) channels.

The error exponent of a given channel W and rate R is the constant $E(W, R)$ which governs the exponential decay of decoding error when using ever larger optimal codes of fixed rate R to communicate over ever more (memoryless) instances of a given channel W. Here I show a lower bound on the error exponent of communication over arbitrary CQ channels which matches Dalai's sphere-packing upper bound for rates above a critical value, exactly analogous to the known results for the case of classical channels. This resolves a conjecture made by Holevo in 2000 from his investigation of the problem.

Unlike the classical case, however, the argument does not proceed via a refined analysis of a suitable decoder, but instead by leveraging a bound by Hayashi on the error exponent of the cryptographic task of privacy amplification. This bound is then related to the coding problem via tight entropic uncertainty relations, providing another illustration of their use in quantum information theory.

MON 17.2 Mon 16:45 ZHG006

No-Go Theorem for Generic Simulation of Qubit Channels with Finite Classical Resources — •Sahil Gopalkrishna Naik[1], Nicolas Gisin[2,3,4], and Manik Banik[1] — [1]S. N. Bose National Center for Basic Sciences, Kolkata, India — [2]University of Geneva, 1211 Geneva 4, Switzerland. — [3]Constructor University, Bremen, Germany. — [4]Constructor Institute of Technology, Geneva, Switzerland.

The mathematical framework of quantum theory, though fundamentally distinct from classical physics, raises the question of whether quantum processes can be efficiently simulated using classical resources. For instance, a sender (Alice) possessing the classical description of a qubit state can simulate the action of a qubit channel through finite classical communication with a receiver (Bob), enabling Bob to reproduce measurement statistics for any observable on the state. Here, we contend that a more general simulation requires reproducing statistics of joint measurements, potentially involving entangled effects, on Alice's system and an additional system held by Bob. We establish a no-go result, demonstrating that such a general simulation for the perfect qubit channel is impossible with finite classical communication. Furthermore, we show that entangled effects render classical simulation significantly more challenging compared to unentangled effects. On the other hand, for noisy qubit channels with depolarizing noise, we demonstrate that general simulation is achievable with finite communication. Notably, the required communication increases as the noise decreases, revealing that large classical resources are necessary for its classical simulation.

MON 17.3 Mon 17:00 ZHG006

Extending Entropic Uncertainty Relations in QKD to multiple measurements — •Maik Romancewicz and Ramona Wolf — Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Straße 3, 57068 Siegen, Germany

Uncertainty is a fundamental property of quantum mechanics, and entropic uncertainty relations (EURs) provide a means to quantify and use it for various applications. EURs play a central role in analysing the security of quantum key distribution (QKD) protocols, especially in the finite-size regime. For the case of two different measurement settings, many useful relations are well-established and have been used to analyse QKD protocols such as BB84, obtaining high key rates and strong security guarantees. However, their applicability to study more complex QKD protocols, employing multiple measurements, such as the six-state-protocol, or higher dimensional systems, remains limited. In this work we study how to extend these relations, aiming to provide new results that can be useful in analysing the security of more complex QKD protocols.

MON 17.4 Mon 17:15 ZHG006

Quantum Conference Key Agreeement with Pre-shared Basis Choice — •Yien Liang, Anton Trushechkin, Hermann Kampermann, and Dagmar Bruss — Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf, Germany

Quantum conference key agreement is a quantum protocol that distributes a secret key among more than two parties. The participants of the protocol share an entangled quantum state and they measure it in the same basis to obatin the secret key. However, as the number of parties increases, the probability of all participants independently randomly choosing the same basis decreases exponentially. In previous literature, key pre-sharing is mentioned as a possible solution to increase the output of the protocol: here, the participants share a secret basis choice. However, no details were given about how to perform basis pre-sharing. In our work, we show how we can securely perform practical basis-sharing without introducing loopholes in the security proof.

MON 17.5 Mon 17:30 ZHG006

Quantum conference key agreement in pair-entangled networks: Fundamental bounds — •Anton Trushechkin, Justus Neumann, Hermann Kampermann, and Dagmar Bruss — Heinrich Heine University Düsseldorf, Faculty of Mathematics and Natural Sciences, Institute for Theoretical Physics III, Universitätsstr. 1, Düsseldorf 40225

Networks of nodes connected by sources of bipartite entangled states are in focus. The nodes can perform collective measurements on the particles coming from different sources. After many repetitions of such rounds, the nodes post-process the obtained data to agree on a secret conference key. This scenario is relevant to future quantum networks. We derive fundamental bounds on the conference key generation rate based on properties of the graph of the network. In particular, the bounds can reveal global bottleneck structures in the network, i.e., node partitions that set tightest restrictions the conference key rate.

MON 17.6 Mon 17:45 ZHG006

Merging-based Quantum Repeater — Maria Flors Mor-Ruiz[1], Jorge Miguel-Ramiro[1], •Julius Wallnöfer[1], Tim Coopmans[2,3], and Wolfgang Dür[1] — [1]Institute for Theoretical Physics, University of Innsbruck, Austria — [2]QuTech, Delft University of Technology, The Netherlands — [3]EEMCS, Delft University of Technology, The Netherlands

We introduce an alternative approach for the design of quantum repeaters based on generating entangled states of growing size. The scheme utilizes quantum merging operations, also known as fusion type-I operations, that allow the reintegration and reuse of entanglement. Unlike conventional swapping-based protocols, our method preserves entanglement after failed operations, thereby reducing waiting times, enabling higher rates, and introducing enhanced flexibility in the communication requests. Through proof-of-principle analysis, we demonstrate the advantages of this approach over standard repeater protocols, highlighting its potential for practical quantum communication scenarios.

MON 17.7 Mon 18:00 ZHG006

Unlocking Quantum Advantage in Distributed Communication Networks — •Ananya Chakraborty[1], Ram Krishna Patra[1], Kunika Agarwal[1], Samrat Sen[1], Pratik Ghosal[1], Sahil Gopalkrishna Naik[1], Manik Banik[1], Mir Alimuddin[3], Edwin Peter Lobo[2], and Amit Mukherjee[4] — [1]Department of Physics of Complex Systems, S. N. Bose National Center for Basic Sciences, Block JD, Sector III, Salt Lake, Kolkata 700106, India. — [2]Laboratoire d'Information Quantique, Universite libre de Bruxelles (ULB), Av. F. D. Roosevelt 50, 1050 Bruxelles, Belgium. — [3]ICFO-Institut de Ciencies Fotoniques, The Barcelona Institute of Science and Technology, Av. Carl Friedrich Gauss 3, 08860 Castelldefels (Barcelona), Spain — [4]Indian Institute of Technology Jodhpur, Jodhpur 342030, India

In this work (Phys.Rev.A,vol.111,032617(2025)), we show a quantum advantage in multipartite communication complexity using n+1 partite GHZ states, enabling perfect evaluation of a global Boolean function with an n-1 bit reduction over classical protocols. Even for noisy GHZ states this advantage persists.For n = 3 and 4, genuine multipartite entanglement is necessary; for n greater than 4, inseparable states can suffice, broadening the range of useful quantum resources. In this work(New J. Phys. 27 023027), we show that qubit communication can outperform classical strategies in simulating MACs, without shared entanglement, bypassing the Frenkel-Weiner bound via joint quantum decoding. Our protocol links to nonlocality without entanglement,semi-device-independent certification of entangled measurements.

MON 17.8 Mon 18:15 ZHG006

Emergent statistical mechanics in holographic random tensor networks — •Shozab Qasim, Alexander Jahn, and Jens Eisert — Dahlem Center for Complex Quantum Systems, Freie Universitat Berlin, 14195 Berlin, Germany

Random tensor networks, formed by contracting locally random tensors chosen from the unitary Haar measure, define a class of ensembles of quantum states whose properties depend on the tensor network geometry. Of particular interest are random tensor networks on hyperbolic geometries, leading to properties resembling those of critical boundary states of holographic bulk-boundary dualities. In this work, we elevate this static picture of ensemble averages to a dynamic one, leveraging earlier work on random matrix product state to show that random tensor network states exhibit equilibration of time-averaged operator expectation values under a highly generic class of Hamiltonians with non-degenerate spectra. We show that random tensor networks on hyperbolic geometries equilibrate faster than on flat ones, consistent with the expectation that the former describe highly chaotic holographic boundary theories, and that equilibration is further accelerated by the insertion of high- bond dimension black hole tensors in the network, consistent with previous holographic constructions. These results show that random tensor network techniques can describe aspects of holographic boundary dynamics without the explicit construction of a boundary Hamiltonian.

MON 18: Quantum Algorithms

Time: Monday 16:30–18:15 Location: ZHG007

MON 18.1 Mon 16:30 ZHG007

Simulation of IQP circuits with hypergraph states — •Matthias Heller[1], Paul Haubenwallner[1], and Mariami Gachechiladze[2] — [1]Fraunhofer Institut für Graphische Datenverarbeitung IGD, Darmstadt, Germany — [2]Techniche Universität Darmstadt, Darmstadt, Germany

Instantaneous quantum polynomial (IQP) circuits have recently gained a significant amount of attention due to their special structure, which allows for fault-tolerant implementation in the near future. It has been argued that classical sampling from these circuits is computationally hard, making this task a prime candidate for demonstrating quantum advantage. In this talk, we discuss the connection between IQP circuits and hypergraph states and show how graphical rules can be used to simulate these circuits. We test our approach for hypercube IQP circuits, a fault-tolerant instance of IQPs that has been introduced recently in the literature. Finally, we identify IQP structures which are easy to simulate.

MON 18.2 Mon 16:45 ZHG007

Variational quantum algorithms for continuum modelling of batteries — •Albert Pool[1,2], Michael Schelling[1,2], and Birger Horstmann[1,2,3] — [1]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Wilhelm-Runge-Str. 10, 89081 Ulm — [2]Helmholtz Institute Ulm, Helmholtzstr. 11, 89081 Ulm — [3]Department of Physics, Ulm University, Albert-Einstein-Allee 11, 89081 Ulm

We present variational quantum algorithms (VQAs) for continuum models in electro-chemical energy-storage-systems, focusing on transport equations in batteries. Our method uses a space-time encoding with time evolution based on the Feynman-Kitaev Hamiltonian, as introduced in [1]. We show how to implement the non-linear terms of the transport equations and discuss efficient quantum circuits to evaluate the terms of this Hamiltonian, and to realize suitable boundary conditions. Further, we present an adaptive optimisation strategy to find the ground state, which represents the solution to a differential-algebraic system of equations.

[1] Pool et al. Phys. Rev. Research 6, 033257 (2024).

MON 18.3 Mon 17:00 ZHG007

Influence of different feature maps on solving partial differential equations on quantum computers — •David Steffen[1,2], Michael Schelling[1,2], Felix Schwab[1,2], and Birger Horstmann[1,2,3] — [1]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Wilhelm-Runge-Str. 10, 89081 Ulm — [2]Helmholtz Institute Ulm, Helmholtzstr. 11, 89081 Ulm — [3]Department of Physics, Ulm University, Albert-Einstein-Allee 11, 89081 Ulm

Differentiable quantum circuits (DQCs) [1] are variational algorithms to solve partial differential equations on quantum computers. We investigate the potential of this method to solve systems of coupled partial differential equations as they occur in the simulation of electrochemical systems, e.g., fuel cells and batteries. A crucial part of DQCs is the feature space in which the input variables are encoded into quantum states. Possible choices are a Chebyshev feature map or a Fourier feature map, that generate a set of corresponding basis functions to fit the desired model. We show results on the influence of different feature maps on the expressibility and trainability for spatiotemporal models, on the use case of transport equations from battery simulation.

[1] Kyriienko, O. et al., Phys. Rev. A 2021, 103, 052416

MON 18.4 Mon 17:15 ZHG007

Bridging wire and gate cutting with ZX-calculus — •Marco Schumann[1,2], Tobias Stollenwerk[1], and Alessandro Ciani[1] — [1]Forschungszentrum Jülich GmbH, Peter Grünberg Institute, Quantum Computing Analytics (PGI-12), 52425 Jülich, Germany — [2]Theor. Physics, Saarland University, 66123 Saarbrücken, Germany

Wire cuts and gate cuts allow one to reduce the required number of qubits for evaluating expectation values of the output states of quantum circuits. This comes at the price of a sampling overhead. While throughout the literature, wire and gate cutting are mostly seen as two independent methods for circuit cutting, our contribution in this work [1] is to establish a connection between them. We find that, since in ZX-calculus only connectivity matters, many known gate cuts can be obtained by cutting wires in these gates. Furthermore, we obtain a decomposition of the multi-qubit controlled-Z gate with decreased sampling overhead. Our work gives new ways of thinking about circuit cutting that can be particularly valuable for finding decompositions of large unitary gates. Besides, it sheds light on the question of why exploiting classical communication decreases the sampling overhead of a wire cut but does not do so for certain gate decompositions. In particular, using wire cuts with classical communication, we obtain gate decompositions that do not require classical communication.

[1] M. Schumann, T. Stollenwerk, A. Ciani, Bridging wire and gate cutting with ZX-calculus (2025). arXiv: 2503.11494.

[2] C. Ufrecht et al., Cutting multi-control quantum gates with zx calculus, Quantum 7, 1147 (2023).

MON 18.5 Mon 17:30 ZHG007

Optimizing ZX-diagrams with deep reinforcement learning — •Maximilian Nägele[1,2] and Florian Marquardt[1,2] — [1]Max Planck Institute for the Science of Light, Staudtstraße 2, 91058 Erlangen, Germany — [2]Physics Department, Friedrich-Alexander-Universität Erlangen-Nürnberg, 91058 Erlangen, Germany

ZX-diagrams are a powerful graphical language for the description of quantum processes with applications in fundamental quantum mechanics, quantum circuit optimization, tensor network simulation, and many more. The utility of ZX-diagrams relies on a set of local transformation rules that can be applied to them without changing the underlying quantum process they describe. These rules can be exploited to optimize the structure of ZX-diagrams for a range of applications. However, finding an optimal sequence of transformation rules is generally an open problem. In this work, we bring together ZX-diagrams with reinforcement learning, a machine learning technique designed to discover an optimal sequence of actions in a decision-making problem and show that a trained reinforcement learning agent can significantly outperform other optimization techniques like a greedy strategy, simulated annealing, and state-of-the-art handcrafted algorithms. The use of graph neural networks to encode the policy of the agent enables generalization to diagrams much bigger than seen during the training phase.

MON 18.6 Mon 17:45 ZHG007

Quantum Text Generation with Quantum Context-Sensitive Word Embeddings: A Comparative Architecture and Experimental Analysis — •Charles Varmantchaonala M.[1], Niclas Götting[1], Nils-Erik Schütte[1], J. L. E Fendji[2,3], and Christopher Gies[1] — [1]Institut für Physik, Fakultät V, Carl von Ossietzky Universität Oldenburg, 26129 Oldenburg — [2]Department of Computer Engineering University Institute of Technology University of Ngaoundéré, Ngaoundere, Cameroon — [3]Stellenbosch Institute for Advanced Study (STIAS) Wallenberg Research Centre at Stellenbosch University Stellenbosch, South Africa

Quantum machine learning has recently gained attention for its potential to enhance natural language processing tasks[1,2]. In this talk, we present a quantum-based text generation architecture that incorporates a quantum-native word embedding method using parameterized quantum circuits. This approach encodes classical contextual information into quantum states by designing specific quantum circuits, resulting in word embeddings that leverage quantum properties. These embeddings are then used in a prototype text generation model. To assess its effectiveness, we perform a comparative analysis against a classical model using small-scale and controlled datasets. The talk highlights both the current limitations and the potential of quantum word embeddings in language modeling. We conclude with a discussion on outlooks toward near-term quantum language tasks.

1. C. Varmantchaonala M. et al., IEEE Access 12, 99578 (2024)
2. J. Shi et al., IEEE TNNLS, 1 (2024)

MON 18.7 Mon 18:00 ZHG007

yquant - Typesetting quantum circuits in a human-readable language — •Benjamin Desef — DLR e.V., Ulm, Germany

After many months of intense work, you want to write down your results in a presentable way. Working in quantum information, it may well be that your paper will contain one, two, or many quantum circuits—either to quickly visualize something that is said in the main text anyway or because it is an integral part of your work. Of course, the result should look nice and embed well with the rest of your document, so you would rather not use some external tools to generate a picture. But you also don't want to spend hours trying to bring it to the tabular form that is required by qcircuit and quantikz. In fact, it would be nice if by looking at the LaTeX source code, you could directly understand the circuit and make modifications without going back to whatever tool generated this fify-column table.

To answer these—my own—demands, I developed yquant, which allows to write quantum circuits in a human-readable language directly in LaTeX, with no external tools involved. In this talk, I will give a quick overview, demostrate you can even use the package for your quick-and-not-dirty-at-all sketches, answer questions, and collect ideas for future features.

MON 19: Foundational / Mathematical Aspects – Quantum Optics and Quantum Information

Time: Monday 16:30–18:15 Location: ZHG008

MON 19.1 Mon 16:30 ZHG008

Operational theory for photonic circuits: the Hong-Ou-Mandel effect — •Ismael Septembre[1], Matthias Kleinmann[1], and Martin Plavala[2] — [1]University of Siegen, Germany — [2]University of Hannover, Germany

In this presentation, I will introduce a method that allows studying photonic circuits in a general operational probability theory in position-momentum space (phase space). We use our method to thoroughly study beam splitters. We show that the Hong-Ou-Mandel dip (often cited as a truly quantum effect) is a universal feature of all theories with no state preparation uncertainty, such as classical optics. We then discuss where does the 50% visibility of standard classical optics come from and construct alternative classical theories that reproduce the 100% visibility of quantum optics. Our work paves the way to the study of photonic quantum computing in a generalised setting and the origin of its alleged computing advantage.

MON 19.2 Mon 16:45 ZHG008

Preventing the Breakdown of the Tight Binding Approximation in Waveguide Quantum Optics — •Konrad Tschernig[1], Florian Huber[2], Janik Wolters[1,3], and Jasmin Meinecke[2,3] — [1]Deutsches Zentrum für Luft- und Raumfahrt, Institut für Weltraumforschung, Berlin, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany — [3]Technische Universität Berlin, Berlin, Germany

Many scientific advancements rely on the tight-binding approximation, which simplifies the description and prediction of complex system behaviors. In waveguide quantum optics, this approximation describes the dynamics of the single photon field by examining the coupling between the guided modes of individual single-mode waveguides. However, a crucial and often overlooked assumption in this framework is the mutual orthogonality of the guided modes. This assumption can fail when the waveguides are positioned very close to each other. We analyze the breakdown of the tight-binding approximation in scenarios involving small distances and then introduce the solution called Symmetric Löwdin Orthogonalization (SLO). By using SLO, we restore the orthogonality of the guided modes, leading to a closer alignment with the full continuous theory and improved agreement with experimental data compared to the standard tight-binding approach. Additionally, we explore the origin of nonreciprocal coupling in detuned waveguide systems within the SLO framework, which has previously been attributed to non-Hermitian effects.

MON 19.3 Mon 17:00 ZHG008

Causal influences in quantum many-body systems — •Leonardo Silva Vieira Santos and Otfried Gühne — Universität Siegen

In this contribution, I will present a quantum information-theoretic framework for consistently formulating cause-and-effect in quantum many-body systems. We define an operational measure of quantum causal influence, which quantifies how information and correlations propagate through the system. This reveals a causal interpretation of the 2nd law of thermodynamics, arising from the monogamy of entanglement and thus with no counterpart in classical physics. Finally, we show how causality constrains quantum dynamics and can be used to infer properties of many-body Hamiltonians, formulating a "converse Lieb-Robinson problem".

MON 19.4 Mon 17:15 ZHG008

Projective simulability of noisy SIC-POVMs — Raphael Brinster, Hermann Kampermann, Dagmar Bruss, and •Nikolai Wyderka — Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf, Germany

Generalized measurements, i.e., POVMs, are known to yield an advantage over usual projective measurements in tasks like state discrimination, state tomography and entanglement detection. While any POVM can be realized as a projective measurement using auxiliary systems, some of them can be simulated through the process of classical randomization of projective measurements in the original system. Such POVMs are called projectively simulable, and every POVM becomes simulable if enough noise is added to it. While the exact amount of required noise (a quantity related to the so-called critical visibility) is in general unknown, it was conjectured that symmetric informationally complete POVMs (SIC-POVMs) are most robust against becoming simulable.

By employing a hierarchy of semidefinite programs together with constructing specific simulable decompositions for classes of noisy SIC-POVMs, we significantly enlarge the collection of POVMs for which exact critical visibilities are known. Finally, we show that there are POVMs which are more robust than certain SIC-POVMs.

MON 19.5 Mon 17:30 ZHG008

Understanding quantum theory — •Adán Cabello — University of Sevilla, Sevilla, Spain

"Nobody understands quantum mechanics" in the sense that nobody can "reduce it to the freshman level". Here, we ague that John Bell's observation that quantum theory is about "experiments" (rather than about "measurements"), together with a convenient rephrasing of four technical results, two of them about general theories of experiments [taken from G. Chiribella et al., Phys. Rev. Res. 2, 042001(R) (2020)] and two of them about sets of correlations in general physical theories [taken from B. Amaral et al., Phys. Rev. A 89, 030101(R) (2014) and A. Cabello, Phys. Rev. A 100, 032120 (2019)] provide a compelling narrative for understanding quantum theory and "where does it come from".

MON 19.6 Mon 17:45 ZHG008

Outcome communication cannot explain nonlocality — Carlos Vieira[1], •Carlos de Gois[2,3], Sébastien Designolle[4], Pedro Lauand[5], Lucas E. A. Porto[5,6], and Marco T. Quintino[6] — [1]IMECC, Unicamp, Brazil — [2]Naturwissenschaftlich-Technische Fakultät, Uni Siegen, Germany — [3]Inria, Université Paris-Saclay, France — [4]Zuse Institute Berlin, Germany — [5]IFGW, Unicamp, Brazil — [6]LIP6, Paris, France

Sixty years ago it was established that quantum theory cannot be completed by local hidden variables. This fact implies a fundamental separation between classical and quantum systems, and has since become a central aspect of quantum information. However, it does not rule out the possibility of non-local completions. In particular, it is known that local hidden variable models augmented with two bits of classical communication can explain the correlations of any two-qubit state. Would this still hold if communication is restricted to measurement outcomes? We show that any qubit-qudit state can be explained by outcome communication if and only if it is local. In other words, outcome communication does not help explain qubit-qudit correlations. In contrast to the standard local model, where only rank-1 measurements must be reproduced, the outcome communication model must explicitly account for full-rank measurements. This is not a limitation of our proof, but a general fact. To prove this, we construct an explicit outcome-local model for all rank-1 measurements on a nonlocal state, thus showing that the equivalence between the two models does not hold for these measurements alone.

MON 19.7 Mon 18:00 ZHG008

Lie Meets von Neumann for Symmetry Characterisation of Compact Lie Algebras — Emanuel Malvetti[1], Robert Zeier[2], and •Thomas Schulte-Herbrüggen[1] — [1]Technical University of Munich (TUM) — [2]Forschungszentrum Jülich GmbH, Peter Grünberg Institute, Quantum Control (PGI-8)

Von Neumann's celebrated double-centraliser theorem completely characterises an operator algebra by its symmetries/commutant. How can this idea be taken over to symmetry-characterise all simple compact Lie algebras (i.e. subalgs of $\mathfrak{u}(N)$) in finite dimension N?

Early contributions (inspired by Noether, Artin, van-der-Waerden) see group algebras to (regular representations of) finite groups as first incarnations of von Neumann algebras—still in finite dimensions.

For compact Lie groups and their Lie algebras, we elucidate the add-ons to central isotypic projections (via the commutant to the adjoint representation) that allow for such a full symmetry characterisation. We thus give a general algorithm that identifies a compact simple Lie algebra just from a given set of generators based on its joint symmetries thus substantially driving our earlier work [1-3] to a full classification.

Our algorithmic approach can be applied to problems in various fields such as measurement-based quantum computing, stabiliser design via Clifford algebras, phases of many-body systems—and last but not least quantum control.

[1] *J. Math. Phys.* **52**, 113510 (2011)
[2] *Phys. Rev. A* **92**, 042309 (2015)
[3] *J. Math. Phys.* **56**, 081702 (2015)

MON 20: Quantum Sensing and Decoherence: Contributed Session to Symposium II

Time: Monday 16:30–18:30 Location: ZHG009

MON 20.1 Mon 16:30 ZHG009

Ultrastable multicolor laser system with 10^-20-level frequency stability for quantum computing, sensing and timing applications — •Thomas Quenzel[1], Michele Giunta[1,2], Martin Wolferstetter[1], Maurice Lessing[1], Wolfgang Hänsel[1], Michael Mei[1], Marc Fischer[1], and Ronald Holzwarth[1,2] — [1]Menlo Systems GmbH, Bunsenstraße 5, D-82152 Martinsried, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching bei München, Germany

Photonics-based quantum technologies often require ultrastable and ultralow phase noise lasers that are turn-key operated. Here we present such an ultrastable laser system with multiple wavelengths based on a continuous-wave (CW) laser referenced to an optical reference system (ORS), an optical frequency comb (OFC), and application-dependent CW lasers, supporting 20 digits of fractional stability measurements.

The ORS guarantees sub-Hz linewidth performance and fractional frequency stability of <7x10^-16 in 1 second. The OFC is based on a femtosecond fiber laser operating ~1560 nm, which is modelocked using the figure 9 technique. The stabilized CW laser serves as optical input to the OFC, and by a direct high-bandwidth phase lock the stability and narrow linewidth of this laser can be copied to every single comb line of the OFC. Finally, multiple CW lasers are locked to the corresponding comb lines extending from the UV to the Mid-IR, depending on the application. The outcome is a multicolor, ultrastable laser system, with fractional stability on the 10^-18 level in one second, and 10^-20 in 1,000 seconds.

MON 20.2 Mon 16:45 ZHG009

Top-Hat Laser Beams for Accurate Quantum Gravity Sensing — •Niranjan Myneni[1], Joël Gomes Baptista[1], Sébastien Merlet[1], Leonid Sidorenkov[1], Camille Janvier[2], and Franck Pereira Dos Santos[1] — [1]LTE, Observatoire de Paris, Université PSL, Sorbonne Université, Université Lille, LNE, CNRS, Paris, France. — [2]Exail, Quantum Sensors, Gradignan, France.

Within the FIQUgS (Field Quantum Gravity Sensors) project, we investigate the use of top-hat laser beams to improve the performance of atom interferometers in precision inertial sensing. This work extends earlier efforts [1] demonstrating the benefits of flat-top beams towards evaluating systematic errors. We analyze both measured (Shack-Hartmann wavefront sensing) and simulated intensity and wavefront profiles, studying their propagation stability and aberration sensitivity over relevant distances. Atomic simulations quantify their impact on interferometric contrast, phase stability and accuracy. We explore beam-reducing/expanding optics to adapt top-hat beams to the required beam size for various sensor architectures. Simulations are conducted for both the FIQUgS instruments and other experimental platforms [2] available at LTE (formerly SYRTE). The results of these simulations will be benchmarked against the performance of the FIQUgS instruments evaluated during an extensive metrological campaign. This work contributes to advance compact, high-precision quantum gravimeters [3] and enhance their robustness for field deployment.

1. Appl. Phys. Lett., 113 (16), 161108(2018). 2. Phys. Rev. A 106, 013303 (2022). 3. Phys. Rev. A 105, 022801 (2022).

MON 20.3 Mon 17:00 ZHG009

Coherent feedback for quantum expander in gravitational wave observatories — •Niels Böttner, Joe Bentley, Roman Schnabel, and Mikhail Korobko — Institut für Quantenphysik und Zentrum für Optische Quantentechnologien, Universität Hamburg

The observation of gravitational waves from binary neutron star mergers offers insights into properties of extreme nuclear matter. However, their high-frequency signals in the kHz range are often masked by quantum noise of the laser light used. We propose the "quantum expander with coherent feedback", a new detector design that features an additional optical cavity in the detector output and an internal squeeze operation. This approach allows to boost the sensitivity at high frequencies, at the same time providing a compact and tunable design for signal extraction. It allows to tailor the sensitivity of the detector to the specific signal frequency range. We demonstrate that our design allows to improve the sensitivity of the high-frequency detector concept NEMO (neutron star extreme matter observatory), increasing the detection rates by around 14%. Our approach promises new level of flexibility in designing the detectors aiming at high-frequency signals.

MON 20.4 Mon 17:15 ZHG009

Geometry of variational qubit dynamics with its applications on quantum control and sensing — •Xiu-Hao Deng — Shenzhen International Quantum Academy — Hefel National Lab

Quantum systems are fragile to perturbations from their environment. The variation of parameters brings deviation to the qubit dynamics. These variations may originate from noises, parameter uncertainty and weak signals to detect. We discover that the variational part of the qubit dynamics has beautiful geometric properties on its manifold, which includes space curves and areas. By applying the geometric theory to suppress the errors generated by noise, we find that the space curves on the manifold of the variational quantum dynamics should be close and encircle vanishing areas. Using this theory, we have obtained very robust quantum gates and quantum circuits. On the other hand, to obtain enhanced sensing, the curves should be far from the origin. We have also demonstrated enhanced signal precision and sensitivity. I will also present some experimental results in this talk.

MON 20.5 Mon 17:30 ZHG009

Phonon Dynamics and Quasi-Particle Interactions in Proximitized 2D Systems — •Zamin Mamiyev, Narmina O.Balayeva, Dietrich R.T. Zahn, and Christoph Tegenkamp — Institut für Physik, Technische Universität Chemnitz

Understanding and controlling phonon behavior in two-dimensional (2D) materials is crucial for tailoring their electronic, optical, thermal, and mechanical properties. In this context, confinement epitaxy serves as a versatile approach to create chemically protected, atomically thin 2D materials while enabling the study of proximity interactions in stacked structures [1]. In this work, we investigate phonon dynamics in epitaxial graphene (EG) intercalated with H, Sn, and In, using a combination of variable-wavelength and temperature-dependent Raman spectroscopy, complemented by electron energy loss spectroscopy. Our results demonstrate that intercalation is not merely a doping mechanism but an effective route to tune vibrational properties in EG via proximity effects [2]. Detailed analysis reveals that the primary mechanism influencing phonon behavior is the modification of electron-phonon coupling (EPC), governed by charge transfer or the strength and nature of interfacial interactions. While band filling and strain induce rigid phonon shifts, altered EPC impacts phonon group velocity. Furthermore, we show that beyond atomic-scale effects, interface engineering also significantly influences the thermal conductivity of EG.

[1] Z. Mamiyev et al., 2D Materials. 11 (2024) 025013
[2] Z. Mamiyev et al, Carbon 234 (2025) 120002

MON 20.6 Mon 17:45 ZHG009

Optomechanical cooling using a nonlinearly-driven cavity — Surangana Sengupta[1], Björn Kubala[1,2], Joachim Ankerhold[1], and •Ciprian Padurariu[1] — [1]Institute for Complex Quantum Systems and IQST, Ulm University — [2]German Aerospace Center (DLR), Institute for Quantum Technologies, Ulm

Conventional optomechanics combines a harmonic cavity mode with a mechanical element that modulates the cavity frequency [1]. The limitation of the method arises due to back-action of the cavity on the mechanical mode. This results in a residual heating effect that sets a limit to the lowest phonon occupation that can be reached via optomechanical cooling.

In this talk, I will show how driving the cavity in a nonlinear fashion can alleviate the residual heating effect, increasing the overall cooling. This method allows cooling down to orders of magnitude lower phonon occupation. As an example, the talk will focus on the case when the nonlinear drive is implemented in a superconducting circuit setup, using a Josephson junction as the nonlinear element.

In the semiclassical regime, our cooling method shows a significant advantage both in the regime where the nonlinearly-driven cavity shows multi-stable states, as well as below the threshold for multi-stability. In the future, a nonlinear cavity drive could be combined with other methods to improve the performance of optomechanical cooling, such as using intrinsically nonlinear cavity modes [2].

[1] F. Marquardt *et al.*, Phys. Rev. Lett. **99**, 093902 (2007).
[2] D. Zoepfl *et al.*, Phys. Rev. Lett. **130**, 033601 (2023).

MON 20.7 Mon 18:00 ZHG009

Amplification and Detection of Single Itinerant Microwave Photons — Lukas Danner[1,2], Ciprian Padurariu[2], Max Hofheinz[3], Joachim Ankerhold[2], and •Björn Kubala[1,2] — [1]German Aerospace Center (DLR), Institute of Quantum Technologies, Ulm (Germany) — [2]Institute for Complex Quantum Systems and IQST, University of Ulm, Ulm (Germany) — [3]Institut Quantique, Université de Sherbrooke, Sherbrooke, Québec (Canada)

The detection of single microwave photons plays a crucial role in a wide range of technological applications using quantum microwaves. Standard readout techniques relying on linear amplification [1] add noise, limiting the chance of identifying single photons. Here, we propose schemes to amplify single itinerant mircowave photons using highly-nonlinear Josephson photonics devices [2]. These devices consist of a dc-voltage biased Josephson junction, connected in series with two microwave cavities. By tuning the dc voltage, various resonances can easily be accessed, such that, e.g., a Cooper pair tunneling through the junction enables a coherent transfer between one excitation in the first cavity and n excitations in the second cavity. Using a recently developed formalism [3], we describe how a single photon pulse is absorbed by the device to trigger the leakage of multiple photons from the second cavity that can subsequently be detected, and calculate performance parameters, such as detection probabilities and dark count rates.

[1] C. M. Caves, Phys. Rev. D 26, 1817 (1982)
[2] J. Leppäkangas et al., Phys. Rev. A 97, 013855 (2018)
[3] AH. Kiilerich and K. Mølmer, Phys. Rev. Lett. 123, 123604 (2019)

MON 20.8 Mon 18:15 ZHG009

Quantum imaging with undetected photons enabled by position correlation — •Balakrishnan Viswanathan[1], Gabriela Lemos[2], and Mayukh Lahiri[3] — [1]Optics and Quantum Information Group, The Institute of Mathematical Sciences, Chennai 600113, India — [2]Instituto de Fisica, Universidade Federal do Rio de Janeiro, Av. Athos da Silveira Ramos 149, Rio de Janeiro, CP 68528, Brazil — [3]Department of Physics, 145 Physical Sciences Bldg., Oklahoma State University, Stillwater, OK 74078, USA

Quantum imaging with undetected photons (QIUP) is a novel interferometric technique in which the light that illuminates the object is not detected. The image is constructed from the single-photon interference pattern of the photon that never interacted with the object. The basic ingredients of QIUP are two identical pairs of correlated photons and the Zou-Wang-Mandel interferometer. This imaging technique exploits the absence of path information to induce interference. We develop a theory of QIUP in which both the object and the camera are placed in the near-field with respect to the sources. It turns out that in this configuration, the imaging is enabled by the position correlation between the twin photons. Furthermore, we also investigate the resolution limit in the near-field configuration of QIUP.

MON 21: Quantum Materials

Time: Monday 16:30–18:30 Location: ZHG103

MON 21.1 Mon 16:30 ZHG103

Directional Control of Fermi Arcs via Pseudo-Magnetic Fields — Sachin Vaidya[1], •Alaa Bayazeed[2], Adolfo Grushin[3], Marin Soljačić[1], and Christina Jörg[2] — [1]1Department of Physics, Massachusetts Institute of Technology, Cambridge, MA, USA — [2]Physics Department and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [3]Univ. Grenoble Alpes, CNRS, Grenoble INP, Institut Néel, France

Weyl materials are three-dimensional topological systems characterized by Weyl points, which are band crossings in momentum space that act as sources or sinks of Berry curvature. These points give rise to surface states known as Fermi arcs, connecting Weyl points of opposite chirality. Under a magnetic field, the bulk band structure reorganizes into quantized Landau levels (LL), with the zeroth LL inheriting the chirality of the associated Weyl point. We investigate how pseudo-magnetic fields, arising from engineered spatial variations, influence such systems. These fields couple differently to Weyl points of opposite chirality, enabling all zeroth LLs to exhibit the same group velocity. Coating the surfaces with photonic bandgap materials, we suppress this radiation and reveal topological surface states that restore the balance of chirality. We experimentally demonstrate this in a photonic multilayer analogue of Weyl semimetals with tailored layer thicknesses and partially reflective Bragg mirrors. Our system maps complex topological physics of strained Weyl semimetals onto an accessible photonic platform.

MON 21.2 Mon 16:45 ZHG103

Emergent quantum phenomena in a two-dimensional magnet — •Ying-Jiun Chen[1], Tzu-Hung Chuang[2], Jan-Philipp Hanke[1], Markus Hoffmann[1], Gustav Bihlmayer[1], Yuriy Mokrousov[1,3], Stefan Blügel[1], Claus Michael Schneider[1,4], and Christian Tusche[1,4] — [1]Forschungszentrum Jülich — [2]National Synchrotron Radiation Research Center, Taiwan — [3]Johannes Gutenberg University Mainz — [4]University of Duisburg-Essen

Quantum phenomena that result from the breaking of time-reversal symmetry offer an innovative platform for nonvolatile switching of physical properties by controlling the direction of the sample magnetization. Magnetic order serves as an ideal means to create on-demand topological phase transitions and significantly alter the topology of the electronic states. In this talk, we present emergent quantum phenomena and magnetic control in a two-dimensional magnet by momentum microscopy. We show that giant open Fermi arcs are created at the surface of an ultrathin hybrid magnet, composed of two iron monolayers, where the Fermi-surface topology is substantially modified by hybridization with the heavy-metal substrate tungsten [1]. The interplay between magnetism and topology allows us to control the shape and the location of the Fermi arcs by tuning the magnetization direction, which dominates spin and charge transport as well as magneto-electric coupling effects [2]. Our findings not only provide a knob to tune the physical properties in a solid, but also offer a platform for prospective quantum devices. [1] Y.-J. Chen et al., Nat. Commun. 13, 5309 (2022). [2] Y.-J. Chen et al., Appl. Phys. Lett. 124, 093105 (2024).

MON 21.3 Mon 17:00 ZHG103

Strong Spin-Magnon coupling between paramagnetic ion GdW10 and VdW antiferromagnet CrSBr — •Jorge Perez-Bailon, David Garcia-Pons, Xavier del Arco-Fargas, David Zueco, and Maria Jose Martinez-Perez — Instituto de Nanociencia y Materiales de Aragón CSIC-Universiad de Zaragoza, Calle Pedro Cerbuna 12, 50009, Zaragoza, España

Cavity Quantum Electrodynamics (QED) has proven to be a highly powerful platform for manipulating and interrogating qubits. In these systems, strong coupling between qubits and quantized fields, typically photons, forms the basis for applications ranging from quantum sensing of individual spins to coherent qubit interactions. However, the reliance on photons in conventional electromagnetic cavities imposes intrinsic limitations on the maximum achievable coupling strengths and the accessible regimes of quantum physics.

Here we study the magnon-spin interaction between the layered van der Waals antiferromagnet CrSBr and the paramagnetic ion crystal GdW10 using microwave absorption spectroscopy at millikelvin temperatures. Analysis of macroscopic samples revealed multiple CrSBr resonances, attributed to phase differences among its layers, while an anticrossing at low power indicates strong coupling, which disappears at higher power as the paramagnet saturates. These findings suggest that CrSBr and similar materials could serve as magnonic platforms in hybrid quantum systems.

MON 21.4 Mon 17:15 ZHG103

Impurity scattering in one-dimensional cavity QED systems — •Lukas I. Krieger[1] and Peter P. Orth[2] — [1]Department of Physics, Saarland University, 66123 Saarbrücken — [2]Department of Physics, Saarland University, 66123 Saarbrücken

We consider the effects of impurity scattering in materials strongly coupled to high-finesse electromagnetic cavities. We focus on the regimes of deep to extremely strong coupling between light and matter degrees of freedom, where perturbative methods to cavity QED break down. We use an unitary transformation introduced by Ashida et al. [PRL 126, 153603 (2021)], the asymptotic decoupling (AD) transformation, which shifts the minimal coupling of the vector potential to the momentum to the potential terms describing the influence of periodic crystal lattice and impurities. We consider one-dimensional models of electrons subject to the AD frame light-matter interaction and we analyze the influence of the light-matter coupling to the scattering of electron waves at an impurity site. The impurity scattering will be tackled by perturbation theory in the impurity potential at low orders and by a Green's function treatment to sum up the relevant diagrams contributing to scattering.

MON 21.5 Mon 17:30 ZHG103

Orbital Topology of Chiral Crystals for Orbitronics — Kenta Hagiwara[1,2], Ying-Jiun Chen[1], Dongwook Go[3], Xin Liang Tan[1,2], Sergii Grytsiuk[1], Kui-Hon Ou Yang[4], Guo-Jiun Shu[5], Jing Chien[4], Yi-Hsin Shen[4], Xiang-Lin Huang[5], Iulia Cojocariu[1], Vitaliy Feyer[1], Minn-Tsong Lin[4,6], Stefan Blügel[1], Claus Michael Schneider[1,2], Yuriy Mokrousov[1,3], and •Christian Tusche[1,2] — [1]Forschungszentrum Jülich — [2]University of Duisburg-Essen — [3]Johannes Gutenberg University Mainz — [4]National Taiwan University, Taiwan — [5]National Taipei University of Technology, Taiwan — [6]Academia Sinica, Taiwan

Chirality is ubiquitous in nature and manifests in a wide range of phenomena including chemical reactions, biological processes, and quantum transport of electrons. In quantum materials, the chirality of fermions, given by the relative directions between the electron spin and momentum, is connected to the electronic band topology. Here, we show that in structurally chiral materials like CoSi, the orbital angular momentum (OAM) serves as the main driver of a nontrivial band topology in this new class of unconventional topological semimetals, even when spin-orbit coupling is negligible. A nontrivial orbital-momentum locking of multifold chiral fermions in the bulk leads to a pronounced OAM texture of helicoid Fermi arcs at the surface [1]. Our findings highlight the pivotal role of the orbital degree of freedom for the chirality and topology of electron states, in general, and pave the way towards the application of topological chiral semimetals in orbitronic devices. [1] Hagiwara et al., Adv. Mater. 2418040 (2025).

MON 21.6 Mon 17:45 ZHG103

Mechanism of the electrochemical hydrogenation of graphene — •YUCHIAN SOONG — Department of Physics and Astronomy, The University of Manchester, Manchester M13 9PL, UK

The electrochemical hydrogenation of graphene has been recently shown to induce a robust and reversible conductor-insulator transition, which is of strong interest in logic and memory applications. However, its mechanism remains unknown. Here we show that it proceeds as a reduction reaction in which proton adsorption competes with a process attributable to the formation of H2 molecules. Graphene*s electrochemical hydrogenation is up to 6 orders of magnitude faster than alternative hydrogenation methods and is fully reversible via the oxidative desorption of protons. We demonstrate that the proton reduction rate in defect-free graphene can be enhanced by an order of magnitude by the introduction of nanoscale corrugations in its lattice and that the substitution of protons for deuterons results both in lower potentials for the hydrogenation process and in a more stable compound. Our results pave the way to investigating the chemisorption of ions in 2D materials at high electric fields, opening a new avenue to control these materials* electronic properties.

MON 21.7 Mon 18:00 ZHG103

Shadow Wall Epitaxy - Towards the all-in-situ fabrication of ZnSe-based Quantum Devices — •Christine Falter[1,2], Yurii Kutovyi[1,2], Nils von den Driesch[1,2], Denny Dütz[2,3], Lars R. Schreiber[2,3], and Alexander Pawlis[1,2] — [1]Peter Grünberg Institute, Forschungszentrum Jülich GmbH, 52428 Jülich, Germany — [2]JARA-FIT, Jülich Aachen Research Alliance, Forschungszentrum Jülich and RWTH Aachen University, Germany — [3]JARA-Institute for Quantum Information, RWTH Aachen University, 52074 Aachen, Germany

Wide band-gap semiconductors such as ZnSe offer a wide range of unique properties making them well-suited for a variety of quantum devices. However, in standard fabrication schemes, surface states and defects introduced during ex-situ applied processing steps can limit the performance of the final device. With this in mind, we have developed a Shadow Wall technique for molecular beam epitaxy (MBE), which allows for all-in-situ device fabrication making all post processing steps obsolete. The technique relies on the pre-patterning of vertical walls on the substrate and the precise alignment of material fluxes during deposition. In our contribution, we focus on the realization of an all-in-situ ZnSe-based field effect transistor (FET). We demonstrate the MBE growth of high quality ZnSe layers on pre-patterned substrates, the in-situ realization of well-defined spatially separated metal contacts and the electrical characterization of the final device. The optimization of the ZnSe FET platform is a first step towards the realization of qubits based on gate defined quantum dots in ZnSe.

MON 21.8 Mon 18:15 ZHG103

Low-density InAs quantum dots grown by local droplet etching for telecom O-band single-photon emission — •Elias Kersting, Nikolai Spitzer, Severin Krüger, Hans Georg Babin, Andreas Wieck, and Arne Ludwig — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany

InAs quantum dots (QDs) grown by molecular beam epitaxy (MBE) are promising candidates for single-photon sources (SPS). Emission in the telecom O-band (1260 - 1360 nm) is particularly desirable due to the low transmission loss in optical fibers. However, conventional Stranski-Krastanov (SK) InAs QDs face challenges in achieving low and well-controlled densities in the suitable range of 0.1-10 QDs/μm^2, as well as in precisely tuning the emission wavelength.

We present an alternative approach based on local droplet etching (LDE), in which nanoholes in a GaAs matrix are filled with InAs to form QDs. The dot density is determined by the nanohole pattern, enabling precise and scalable control. A strain-reducing layer (SRL) enables shifting of the emission wavelength into the telecom O-band. Homogeneous QD growth is achieved through shutter-synchronized deposition, making this approach well-suited for scalable SPS fabrication. We detail the fabrication method and present structural and optical characterization results.

MON 22: Quantum Transport II

Time: Monday 16:30–17:45 Location: ZHG104

MON 22.1 Mon 16:30 ZHG104

Ultralow Lattice Thermal Conductivity and Colossal Thermoelectric Figure of Merit of the Room Temperature Antiferromagnet CsMnBi — •shubham Rakesh Singh[1], Nirpendra Singh[2], and Udo Schwingenschlögl[1] — [1]Physical Science and Engineering Division (PSE), King Abdullah University of Science and Technology (KAUST), Thuwal 23955-6900, Saudi Arabia — [2]Department of Physics, Khalifa University of Science and Technology, Abu Dhabi-127788, United Arab Emirates

We study the experimentally synthesized layered material CsMnBi using first-principles calculations and the linearized electron and phonon Boltzmann transport equations. CsMnBi is found to be a semiconductor with a indirect bandgap of 0.9 eV and to realize C-type antiferromagnetism, which is energetically favorable by 187 meV per formula unit over ferromagnetism. Energetical overlap between the acoustic and low-frequency optical phonon modes enhances the phonon-phonon scattering. Combined with low group velocities and high lattice anharmonicity this results in an ultralow lattice thermal conductivity of 0.07 $Wm^{-1}K^{-1}$ at 300 K. A high thermoelectric figure of merit of 2.2 (1.7) is achieved at 300 K at a hole (electron) density of 6.0×10^{18} (1.0×10^{18}) cm^{-3}.

MON 22.2 Mon 16:45 ZHG104

Transport characteristics of quantum dots for single-electron pumps — •Johannes C. Bayer, Thomas Gerster, Dario Maradan, Niels Ubbelohde, Klaus Pierz, Hans W. Schumacher, and Frank Hohls — Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany

An elegant and direct way to generate accurate currents is given by applying a periodic signal to a tunable barrier quantum dot. Such a device is called a single-electron pump (SEP) and emits a well defined number of n electrons per cycle of an external drive, resulting in a current of $I = nef$, with elementary charge e and driving frequency f. While individual SEPs can already achieve sub-ppm accuracy [1], the extension to systems operating multiple well-performing SEPs, e.g. in parallel to achieve larger currents, is still challenging. Our SEP devices are based on quantum dots formed electrostatically in a GaAs/AlGaAs two-dimensional electron gas. Based on multiple quantum dot devices, we characterize the DC transport properties and analyze relations to the dynamic SEP operation toward achieving robust, reproducible and scalable devices [2].

[1] F. Stein, et. al., Metrologia 54, S1-S8 (2017).
[2] T. Gerster, et. al., Metrologia 56, 014002 (2019)

MON 22.3 Mon 17:00 ZHG104

Quantum electrical current sources for metrological application based on silicon qubit technology — •Dustin Wittbrodt[1], Johannes C. Bayer[1], Janne S. Lehtinen[2], Lars R. Schreiber[3], Marcelo Jaime[1], and Frank Hohls[1] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Deutschland — [2]SemiQon Technologies Oy, Espoo, Finnland — [3]3JARA Institute for Quantum Information, Forschungszentrum Juelich,Juelich, Germany

In 2019, the redefinition of the SI system of units introduced fixed values to fundamental constants such as the elementary charge (e) and the Planck constant (h). While the units Ohm and Volt are well established, the ampere has yet to reach the same level of accuracy. The most commonly used concept of Ampere realization has been the Single Electron Pumps (SEPs), which generate quantized currents in the fA-pA range with a precision of as low as 0.2 ppm. To increase the current level of such single electron-based quantum current standards into the nA range, parallelization of several SEPs is required. To explore this task a high level of reproducibility and scalability is necessary, which is available in industrial CMOS processes. As part of the EU-funded AQuanTEC project, different Si and Si-Compound Spin Qubit Technology platforms are being tested as SEPs focusing on their accuracy and pumping behavior. To benchmark their accuracy, AC modulated pumping experiments are conducted. The results of this effort are presented here, offering a perspective into the possible employment of Qubit technology for the broader usage as quantum metrological instruments.

MON 22.4 Mon 17:15 ZHG104

Influence of Electron Density on Giant Negative Magnetoresistance — •Lina Bockhorn[1], Christian Reichl[2], Werner Wegscheider[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Germany — [2]Laboratorium für Festkörperphysik, ETH Zürich, Switzerland

Ultra-high mobility two-dimensional electron gases often exhibit a remarkably robust negative magnetoresistance at zero magnetic field. Below 800 mK, this phenomenon divides into two distinct parts [1-4]: a temperature-independent narrow peak around $B = 0$ T, arising from the interplay of smooth disorder and elastic scattering at macroscopic defects [2, 3], and a temperature-dependent giant negative magnetoresistance (GNMR) at higher magnetic fields. The theoretical understanding of the GNMR remains an open question, as it involves several independent parameters in addition to electron-electron interaction, possibly leading to hydrodynamic transport effects. To gain insights into the nature of GNMR, we investigate this effect as a function of electron density at various temperatures and currents. Our results show a significant dependence of GNMR on electron density [4], suggesting that variations in scattering potentials [5] are not considered appropriately in theoretical models.

[1] L. Bockhorn et al., Phys. Rev. B 83, 113301 (2011).
[2] L. Bockhorn et al., Phys. Rev. B 90, 165434 (2014).
[3] L. Bockhorn et al., Appl. Phys. Lett. 108, 092103 (2016).
[4] L. Bockhorn et al., Phys. Rev. B 109, 205416 (2024).
[5] Y. Huang et al., Phys. Rev. Materials 6, L061001 (2022).

MON 22.5 Mon 17:30 ZHG104

Decoding undesired charge dynamics in gated GaAs quantum dots — •Lena Klar[1], Kai Hühn[1], Arne Ludwig[2], Andreas Wieck[2], Jens Hübner[1], and Michael Oestreich[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany

Single semiconductor quantum dots (QDs) exhibit high potential as single-photon sources and are promising candidates for solid state qubits [1,2]. However, fluctuations in their charge state and in the surrounding semiconductor matrix significantly affect their optical absorption and emission spectra, even for gated quantum dots. Using two-colour resonance fluorescence spectroscopy, we investigate these fluctuations in a gated GaAs/(AlGa)As-QD in dependence on the QD charge state, temperature, and laser intensity. The experiment reveals not only standard telegraph noise but also subtle noise contributions from the QD's environment, which deteriorate single photon QD sources. Calculations and numerical simulations based on light induced charge dynamics and an alternating occupation of charge traps surrounding the QD are in good agreement with the experimental results and show optimisation perspectives for GaAs QD single photon emitters.

[1] Y. Arakawa, M. J. Holmes, Appl. Phys. Rev. **7**, 021309 (2020).
[2] A. Chatterjee et al., Nat. Rev. Phys. **3**, 157-177 (2021).

MON 23: Poster Session: Fundamental Aspects and Model Systems

Time: Monday 18:30–20:30 Location: ZHG Foyer 1. OG

MON 23.1 Mon 18:30 ZHG Foyer 1. OG

Heisenbergs Artikel von 1925 erklärt von Studierenden für Studierende — •Noah Stiehm[1,2], Bernward Lauterbach[1], Aaron Flötotto[1] und Osamah Sufyan[1] — [1]junge DPG, Regionalgruppe Ilmenau — [2]FFNI e.V., c/o Technische Universität Ilmenau, Weimarer Straße 32, 98693 Ilmenau

Mit seinem Artikel „Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen." legt Heisenberg 1925 den Grundstein für die Formulierung der Quantenmechanik. Der Inhalt ist prinzipiell für Physikstudierende schon früh im Studium (Kenntnisse über Fourier-Reihen und theoretische Mechanik sind nötig) greifbar. Gewissermaßen haben Studierende heute, durch Kenntnisse über Matrizen und Intuition zu diskreten Zuständen und Übergängen, bereits einen Vorsprung.

Dennoch ist der Zugang zu Heisenbergs Argumenten und Folgerungen größtenteils schwierig, z.B. aufgrund ad-hoc eingeführter, ungewohnter und inkonsistenter Notation, verkürzt dargestellten Gedankengängen, sowie fehlendem historischen Kontext. An der TU Ilmenau hat sich eine Gruppe Studierender damit beschäftigt, den Artikel nachzuvollziehen, um ihn im Anschluss ihren Kommiliton:innen nahe zu bringen. Aus diesem Prozess haben wir Kommentare und Gedankenstützen destilliert, und zusammen mit historischem Begleitmaterial zu einer Poster-Ausstellung geformt. Anhand dieser können interessierte Studierende die Entstehung der Quantenmechanik miterleben.

MON 23.2 Mon 18:30 ZHG Foyer 1. OG

A Short Story of Linear Quantum Mechanic AI and Global Relativistic Electrodynamics (1826-1925) — •Ulrich Christian Fischer — Alumni of the MPIBC Göttingen

Riemann's collected papers contain a 5-d Potential $Vehxyz$, with the irreducible dimension ezh of mass eh with the quantization $\alpha(eh)$ of the electron [arXiv:1609.05218]. We consider a finite motion of the hydrogen Molecule H_2, with the order Parameter ($n = 1e$) of one proton and a molecular weight ($m = 2$), against the chemiosmotic Proton motive force $\left[Pmf = \frac{1}{4}eV\right]$. V acts as Activation barrier $A\left(v = \frac{h}{4}\right)$ against the permutation of a Hydrogen molecule in a polymeric String S_n of Hydrogen molecules. A string S_n consists of a number n of Proton - Electron Pairs. The Quaternion $P_{2n} = Q_{eh}^2 he$ [M.Atiah] with a number k of Neutrons has a molecular weight $P_{2n} = P_{m-k} = S(n) = \frac{n}{m}Q_{eh}^{2he}$. With the Prime number P_n, this leads to the Mathematical Proof of the reciprocity principle of Max Born's Q-Physics, or of the Prime numbers P_n, and the order Parameter n, and the proof of Riemann's Hypothesis on the real Part $\left(x_{n0} = \frac{1}{2}\right)$ of the Zero of the [Zeta-function] $Z_0(x + iy) = \left[x_0 = \frac{1}{P_1} = \frac{1}{2} = \frac{n}{2P_n}\right] = x_{0n} = \frac{1}{2} = Z_{0n}^2 - \left[\frac{n}{2P_n}\right]^2 = 0$.

MON 23.3 Mon 18:30 ZHG Foyer 1. OG

Influence of longitudinal laser modes on the generation of time varying interference pattern — •Jelena Jovanović, Saša Ivković, and Bratislav Obradović — University of Belgrade, Faculty of Physics, 11001 Belgrade, Serbia

The primary goal of this work was to explain the interesting effect of time varying interference obtained using a birefringent crystal and an unstabilized He-Ne laser. Used laser operates in two longitudinal modes with mutually orthogonal polarizations. These modes represent the range of allowed discrete frequency values that a laser resonator can support, each corresponding to a quantized energy level within the laser cavity. The intensities of the modes vary in time, resulting that interference patterns also change in time: interference fringes appear, then disappear and appear again, but with changed positions. To explain this phenomenon, a simple analysis of the polarization states of the laser modes, which propagate through the crystal as ordinary and extraordinary rays was performed. This experiment not only demonstrates classical interference and polarization effects, but also offers an accessible way to explore the quantum nature of longitudinal modes. It highlights how quantum principles manifest in seemingly classical optical setups, providing students with a hands-on opportunity to investigate fundamental aspects of quantum optics using an interesting experiment.

MON 23.4 Mon 18:30 ZHG Foyer 1. OG

An educational setup for measuring photons and particles with modern detectors — Anja Bitar, Andrea Brogna, Fabian Piermaier, Steffen Schönfelder, Stefan Schoppmann, and •Quirin Weitzel — PRISMA Detektorlabor, Johannes Gutenberg-Universität Mainz, 55128 Mainz, Germany

In quantum and particle physics, highly sensitive and complex detectors are used, which always reflect the latest technological standards. To introduce students to these, practical experiments for training purposes are required in addition to specialized lectures. In this work, we describe the construction of a small fully working particle detector for demonstration in educational context. It is based on a state of the art scintillator, read out with optical fibers attached to a Silicon Photomultiplier (SiPM), and can be used to detect, for example, muons from cosmic rays. Furthermore, SiPMs are excellent photon counting sensors allowing to explore the quantum nature of light when exposed to repeated fast flashes on the nanosecond scale. An adjustable Light Emitting Diode (LED) pulser is used here for this purpose. Our setup can be constructed with relatively moderate effort, provided that in addition a 3D-printer and suitable readout electronics (at least an oscilloscope) are available.

MON 23.5 Mon 18:30 ZHG Foyer 1. OG

Partial distinguishability in the interference of Gaussian states in linear unitary networks — •Matheus Eiji Ohno Bezerra and Valery Shchesnovich — Universidade Federal do ABC, Santo André, State of São Paulo, 09210-170 Brazil

Partial distinguishability of the photons is a fundamental property of the quantum interference and an important source of noise in photonic quantum information protocols, particularly in Boson Sampling schemes. It originates from the imperfect overlap in the internal degrees of freedom of the photons (polarization, spectral profile, arrival time, etc). This effect was first demonstrated in the Hong-Ou-Mandel experiment, where two single photons interfere in a beam splitter and the coincidence events vanish when they are perfectly indistinguishable. Let $|\psi_k\rangle$ the internal states of the photons, with overlaps given by $\langle\psi_i|\psi_j\rangle = r_{ij}e^{i\theta_{ij}}$. When looking to the partial distinguishability, in the two-photon interference, only the modulus r_{ij} is important; while in the interference of three and more single photons, the phases θ_{ij} play an important role. However, these effects of partial distinguishability have not been fully explored in the interference of Gaussian states. In this work, we investigate how the partial distinguishability and these internal phases influence the interference of Gaussian states, specifically coherent and squeezed states, when the photons from each source are partially distinguishable. We find that the coherent states exhibit a classical dependence on the individual phases θ_{ij}, whereas squeezed states display an additional collective dependence of the phase, reminiscent of the behavior seen in the single-photon interference.

MON 23.6 Mon 18:30 ZHG Foyer 1. OG

Proposed Experiments on Adequate Frames — •Jannik Fiege[1] and Hans-Otto Carmesin[1,2,3] — [1]Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade — [2]Bahnhofstraße, 5 — [3]Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen

The International Astronomical Union, IAU, realized, that the frames provided by general relativity are insufficient for space flight. As a provisional approximate solution, the IAU proposed reference systems for the purpose of space flight.

For instance, the IAU proposed a geocentric celestial reference system, GCRS, for space travel near Earth. In contrast, for space travel in the planetary system, the IAU recommended a barycentric (essentially heliocentric) celestial reference system. More generally and fundamentally, the concept of adequate frames has been proposed, adequate frames have been derived, and exact space navigation for each location in spacetime has been developed (Carmesin 2025). These results are predictive and should be tested. For it, we propose various experiments and observations, suited for different equipment.

H.-O. Carmesin (2025): On the Dynamics of Time, Space and Quanta - Essential Results for Space Flight and Navigation. Berlin: Verlag Dr. Köster.

MON 23.7 Mon 18:30 ZHG Foyer 1. OG

Volume Portions Provide the Map of the Exact Quantum Frames of the Planetary System — •Hans-Otto Carmesin — Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen — Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade

A space paradox shows that space is an average of microscopic volume portions. These imply the quantum postulates, as well as gravity and curvature in spacetime. It is very valuable and insightful that the volume portions show how the quantum postulates are derived from spacetime and how they are applied to spacetime: In this manner, exact quantum frames of spacetime are derived for each location in the planetary system (Carmesin 2025). These frames are represented in a new map of the planetary system. Moreover, these frames provide the absolute zero of the kinematic time dilation. Predictions are derived, have been tested empirically, and can additionally be tested by space flights in various manners.

MON 23.8 Mon 18:30 ZHG Foyer 1. OG

Analysis of the Evolution of Universal Time Dilation and Dark Energy — •Jacky David Yang[1] and Hans-Otto Carmesin[1,2,3] — [1]Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen — [2]Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — [3]Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade

We analyze the concept and the universal/global evolution of time. Our elaboration uses the global Euclidean geometry of the universe. We model the universe on the basis of homogeneity (ΛCDM model) and of heterogeneity (linear growth theory). Measurement values of cosmological parameters are used, see Planck Collaboration (2020). Hereby, the model of the heterogeneous universe depends on the volume dynamics (Carmesin 2024). Thereby, we take care of the Hubble tension. The aim is the analysis of the universal time dilation. We transform the calculable H_0 - values into calendar dates. Moreover, differences between respective times of both models are derived, in order to determine the time dilation. The results are presented by graphs, tables and formulas, so our results are visualized intuitively. Therefrom, the time evolution and the age of the universe are obtained, Furthermore, the time evolution of the dark energy Ω_Λ is analyzed and visualized. It is derived from the time evolution of the universal/global time dilation.

H.-O.Carmesin (2024): How Volume Portions Form and Found Light, Gravity and Quanta. Berlin: Verlag Dr. Köster.
Planck Collaboration (2020): Planck 2018 results. VI. Cosmological parameters. Astronomy and Astrophysics, pp 1-73.

MON 23.9 Mon 18:30 ZHG Foyer 1. OG

Comparative Investigation of the Newtonian Gravitational Field and the Exact Gravitational Field — •Amboer Jiaer Li[1] and Hans-Otto Carmesin[1,2,3] — [1]Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen — [2]Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — [3]Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade

Understanding gravitational fields is fundamental to celestial mechanics and space exploration. This project investigates the differences between the classical Newtonian gravitational field and the relativistic exact gravitational field (Carmesin 2024, 2025), using Mercury as a test case. The gravitational acceleration is computed for both models over varying distances, using Python. Preliminary findings aim to assess the validity of Newtonian gravity in practical applications and explore the necessity of relativistic corrections in scenarios requiring high accuracy. This research provides insights into the limitations of classical mechanics in planetary science and informs future computational approaches for interplanetary missions.

MON 23.10 Mon 18:30 ZHG Foyer 1. OG

Factorization of multimeters: a unified view on nonclassical quantum phenomena — •Tim Achenbach[1,2], Andreas Bluhm[3], Leevi Leppäjärvi[2], Ion Nechita[4], and Martin Plávala[5] — [1]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Straße 3, 57068 Siegen, Germany — [2]Faculty of Information Technology, University of Jyväskylä, 40100 Jyväskylä, Finland — [3]Univ. Grenoble Alpes, CNRS, Grenoble INP, LIG, 38000 Grenoble, France — [4]Laboratoire de Physique Théorique, Université de Toulouse, CNRS, UPS, France — [5]Institut für Theoretische Physik, Leibniz Universität Hannover, Hannover, Germany

Quantum theory exhibits various nonclassical features, such as measurement incompatibility, contextuality, steering, and Bell nonlocality, which distinguish it from classical physics. These phenomena are often studied separately, but they possess deep interconnections. This work introduces a unified mathematical framework based on commuting diagrams that unifies them. By representing collections of measurements (multimeters) as maps to the set of column-stochastic matrices, we show that measurement compatibility and simulability correspond to specific factorizations of these maps through intermediate systems. We apply this framework to put forward connections between different nonclassical notions and provide factorization-based characterizations for steering assemblages and Bell correlations, including a perspective on the CHSH inequality witnessing measurement incompatibility.

MON 23.11 Mon 18:30 ZHG Foyer 1. OG

Development and Study of an Optical Quantum Processing Unit, OQPU — •Ruder Jannes[1] and Hans-Otto Carmesin[1,2,3] — [1]Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen — [2]Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — [3]Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade

The ongoing advancement of optical technologies opens new possibilities for enhancing the performance of classical computer architectures. This contribution presents the design and current status of implementation of a novel computer chip called the OQPU. The aim of this chip is to combine the advantages of optical computations, particularly the processing of information through light with quantum mechanical principles, to enable more efficient data processing. The OQPU utilizes laser beams whose states can be precisely manipulated and exhibit properties similar to qubits. Unlike single-photon approaches, this method provides a cost- and resource-efficient alternative while still harnessing quantum effects such as superposition and interference. The OQPU aims to overcome practical limitations in scalability, temperature and stability faced by many quantum devices. The development process focuses on validating the physical principles and optimizing the device structure. Challenges such as maintaining coherence and integrating optical components with classical electronics are addressed. Potential applications range from quantum-enhanced algorithms for complex problem-solving to faster optical data transmission systems. This work represents a significant step towards practical quantum-enhanced computing devices.

MON 23.12 Mon 18:30 ZHG Foyer 1. OG

Higher-dimensional entanglement detection and quantum channel characterization using moments of generalized positive maps — •Bivas Mallick[1], Ananda G. Maity[1,2], Nirman Ganguly[3], and Archan S. Majumdar[1] — [1]S. N. Bose National Centre for Basic Sciences, Block JD, Sector III, Salt Lake, Kolkata 700 106, India — [2]Networked Quantum Devices Unit, Okinawa Institute of Science and Technology Graduate University, Onna-son, Okinawa 904 0495, Japan — [3]Department of Mathematics, Birla Institute of Technology and Science Pilani, Hyderabad Campus, Hyderabad, Telangana-500078, India

Higher-dimensional entanglement is a valuable resource for several quantum information processing tasks, and is often characterized by the Schmidt number and specific classes of entangled states beyond qubit-qubit and qubit-qutrit systems. We propose a criterion to detect high-dimensional entanglement, focusing on determining the Schmidt number of quantum states and identifying significant classes of PPT and NPT entangled states. Our approach relies on evaluating moments of generalized positive maps which can be efficiently simulated in real experiments without the requirement of full-state tomography. We demonstrate the effectiveness of our detection scheme through various illustrative examples. As an application, we explore the implications of our moment-based detection schemes in identifying useful quantum channels such as non-Schmidt number breaking channels. Finally, we present an operational implication of our proposed moment criterion through its manifestation in channel discrimination tasks.

MON 23.13 Mon 18:30 ZHG Foyer 1. OG

Splitting and connecting singlets in atomic quantum circuits — •Lars Fischer, Zijie Zhu, Yann Kiefer, Samuel Jele, Marius Gächter, Giacomo Bisson, Konrad Viebahn, and Tilman Esslinger — Institute for Quantum Electronics & Quantum Center, ETH Zurich, 8093 Zurich, Switzerland

Large scale quantum computation relies on the configurable connection of qubits by system-wide error free transportation of quantum states. In this talk we present one way to coherently shuttle and manipulate quantum states in optical dynamical superlattices. By preparing atomic spin singlet pairs of fermionic potassium-40 in a lattice potential, we use a bi-directional quantized Thouless pump to transport, coherently split, and separate atomic pairs. We report a single-shift fidelity in our pumping mechanism of 99.78(3)% over 50 lattice sites.

Additionally, we implement tunable $(\mathrm{SWAP})^\alpha$-gates with strongly repulsive interactions. When atoms moving in opposite directions meet on a double well, they undergo a superexchange interaction that continuously swaps their internal spin states. We use this gate set to coherently manipulate the quantum states in our system and interconnect large fractions of spin-singlet pairs. By applying a

magnetic field gradient we observe multi-frequency singlet-triplet oscillations, which reveal complex final states from controlled quantum circuits. The presented scheme can be used as a tool to study full-system entanglement, quantum processing and sensing, and atom interferometry in optical lattices.

MON 23.14 Mon 18:30 ZHG Foyer 1. OG

Efficient detection of genuine multipartite entanglement using moments of positive maps — •Saheli Mukherjee[1], Bivas Mallick[1], Sahil Gopalkrishna Naik[1], Ananda G. Maity[1,2], and Archan S. Majumdar[1] — [1]S.N. Bose National Centre for Basic Sciences, Kolkata-700106, West Bengal, India — [2]Networked Quantum Devices Unit, Okinawa Institute of Science and Technology Graduate University, Onna-son, Okinawa 904-0495, Japan

Genuine multipartite entanglement (GME) represents the strongest form of entanglement in multipartite systems, providing significant advantages in various quantum information processing tasks. In this work, we propose an efficient and experimentally feasible scheme for detecting GME, based on the truncated moments of positive maps. Our method avoids the need for full state tomography, making it scalable for larger systems. We provide illustrative examples of both pure and mixed states to demonstrate the efficacy of our formalism in detecting inequivalent classes of tripartite genuine entanglement. Finally, we present a proposal for realising these moments in real experiments.

MON 23.15 Mon 18:30 ZHG Foyer 1. OG

Scalable Entanglement Quantification in Quantum Many-Body Systems with a Graph Neural Network — •Susanna Bräu, Martina Jung, and Martin Gärttner — Institut für Festkörpertheorie und Optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena

Entanglement is a fundamental feature of quantum mechanics and plays a central role in quantum computing, quantum communication, and quantum information theory. Quantifying entanglement between different parts of a system - via measures such as entanglement entropy or quantum mutual information - usually requires full knowledge of the quantum state. However, due to the curse of dimensionality, quantum state tomography is infeasible for larger systems, limiting the accessible system sizes. Therefore, we propose a supervised machine learning approach to estimate entanglement features based on a set of measurement snapshots of the system. For that, we develop a permutation invariant graph neural network (GNN) that is parameter-efficient, being linear in the system size. Our scalable GNN incorporates the mini-set architecture, developed by Kim et al. [1], who divided the input into smaller sets which the model processes in parallel. By attending the output of each mini-set in a permutation invariant manner, high order correlations can be extracted. In this way, we aim to improve the scaling such that the GNN can be applied to larger data sets or be used to increase the time over which the model can accurately predict entanglement features in the future.

[1] Kim, H. et al. arXiv:2405.11632 [quant-ph] (Nov. 2024).

MON 23.16 Mon 18:30 ZHG Foyer 1. OG

Quenching on the circle: how compactification curbs entanglement growth in coupled rotors — •Stefan Aimet[1] and Spyros Sotiriadis[2] — [1]Freie Universität Berlin, Berlin, Germany — [2]University of Crete, Heraklion, Greece

Compact topology fundamentally constrains quantum dynamics. After a global frequency quench to zero, coupled harmonic oscillators display unbounded entanglement growth because their position variables live on the real line and the associated metastable zero modes diffuse indefinitely. Recasting these variables instead as angular coordinates compactified on a circle maps the system to coupled quantum rotors whose phase-space support and hence entanglement entropy saturates at late times. We analyse how compactification curbs entanglement growth. Our findings identify compactification as a generic mechanism that tames entanglement divergence and motivate experimental realisations.

MON 23.17 Mon 18:30 ZHG Foyer 1. OG

Photonic simulation optimized for quantum field dynamics — •Robin Alexander Strahlendorf, Mauro D'Achille, and Martin Gärttner — Institut für Festkörpertheorie und Optik, Friedrich-Schiller-Universität Jena, Max-Wien Platz 1 07743 Jena

Photonic multimode systems offer great potential as quantum simulators of quantum field theories. The dynamics of free field theories, corresponding to quadratic Hamiltonians, can be decomposed into a sequence of passive optical elements and squeezing transformation. It is difficult to scale an optical circuit to large number of modes and depths due to the inherent loss of the optical elements.

We tackle this problem by exploiting the freedom in designing an optical circuit for a given unitary evolution. In particular, we aim to minimize the number of gates, thereby reducing the overall simulation error. For this, we simulate realistic noise models and compare the robustness of the different decomposition schemes with respect to common types of errors.

MON 23.18 Mon 18:30 ZHG Foyer 1. OG

Fractal Zeta Universe and Atoms — •Otto Ziep — 13089 Berlin — Independent Research

Fractal universes and atoms are assigned to k-components or stable orbiting laps of simplest cycles of elliptic invariants. Cosmological redshift, expansion of the universe, origin of cosmic rays, cosmic microwave background, quantum entanglement and the cosmological constant problem are resolvable easily by fractal universes of bifurcating spacetime. Quantum entanglement is explainable by a highly correlated pseudo-congruent k-component in bifurcating spacetime. A one-dimensional complex contour around nontrivial zeros of zeta and L- functions is capable to create a zero-energy universe- action functional. Gauge coupling parameter fit into Gaussian periods of fixpoints. Many experiments in natural history support a fractal zeta universe.

[1] O. Ziep, A quantum entangled fractal superfluid universe, Journal of High Energy Physics, Gravitation and Cosmology, vol. 11, 3, (2025)
[2] O. Ziep, Fractal Universe and Atoms, Scholars Journal of Physics, Mathematics and Statistics, Vol.12, No. 4 (2025)
[3] O. Ziep, Cosmic Rays, Aerosol-Photosynthesis and Vegetational Air Ions, Manuscript in preparation, 2025

MON 23.19 Mon 18:30 ZHG Foyer 1. OG

Fully Dynamical Analysis of Coulomb Breakup Experiments for the Determination of the α(d, γ)6Li cross section — •Monica Sanjinez Ortiz and Pierre Capel — Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, D-55099 Mainz, Germany

In the modelling of Big Bang nucleosynthesis, the cross sections of reactions leading to the formation of light nuclei play a fundamental role. For the synthesis of 6Li, in particular, the radiative capture process α(d, γ)6Li is of utmost importance. From experiments, the direct determination of the cross section is difficult at low energy, and there exists only one set of direct measurements in the energy range of interest. Coulomb breakup has been considered as an alternative method to infer the low-energy cross section of reactions for astrophysics as it corresponds to the time reversed process of radiative captures. In the past, two experiments of 6Li breakup onto 208Pb have been performed: at 26A MeV and at 150A MeV. With a fully dynamical reaction model based on the eikonal approximation, we report here on a new theoretical analysis of this breakup reaction. Our results indicate that the breakup cross section at 150A MeV is nuclear dominated with marked interferences with the Coulomb component. Accordingly, it is difficult to infer radiative capture cross sections from data at this energy. Similarly, the analysis of the reaction at 26A MeV points towards a nuclear dominated contribution at forward angles. Nevertheless, at low beam energy and large scattering angles, the reaction seems Coulomb dominated, suggesting a way to overcome the aforementioned difficulty.

MON 23.20 Mon 18:30 ZHG Foyer 1. OG

Floquet-Engineering of Feshbach Resonances in Ultracold Lithium Gases — •Louisa Marie Kienesberger, Alexander Guthmann, Felix Lang, and Artur Widera — Physics Department and Research Center OPTIMAS, University of Kaiserslautern

Magnetic Feshbach resonances are a key tool for tuning interactions in ultracold atomic systems. In our recent work [1], we demonstrate that periodic modulation of the magnetic field enables the creation of Floquet-Feshbach resonances in a two-component gas of fermionic lithium-6, providing dynamic control over resonance positions.

We experimentally map out the structure of Floquet-dressed scattering states and confirm the theoretical predictions for their positions and widths. Our observations include clear signatures of higher-order resonances, revealing a rich spectrum of interaction control not accessible via static fields alone. Additionally, we show that inelastic atom losses can be strongly suppressed by introducing a second modulation frequency at exactly the second harmonic.

In conclusion, Floquet-Engineering of Feshbach resonances opens new pathways for precise control of scattering in ultracold gases. As a prominent application, it enables the realization of Bound States in the Continuum (BICs) through interference at avoided crossings between Floquet-Feshbach resonances, which will be discussed in a separate talk.

[1] A. Guthmann, F. Lang, L. M. Kienesberger, S. Barbosa, A. Widera , Floquet-Engineering of Feshbach Resonances in Ultracold Gases, arXiv 2503.05454 (2025).

MON 23.21 Mon 18:30 ZHG Foyer 1. OG

Hydrodynamic Effects in Cryogenic Buffer Gas Cells — •Nick Vogeley[1], Bernd Bauerhenne[2], and Daqing Wang[1] — [1]Institut für angewandte Physik, Uni Bonn — [2]Experimentalphysik I, Uni Kassel

We report a screening of design geometries for cryogenic buffer gas beam cells operating in the hydrodynamic extraction regime with moderate throughput $J \approx 50$ sccm. We performed steady-state slip-flow simulations for helium at $T = 4.5$ K and included a localized heat source to represent the ablation or injection point of the species of interest. In a subsequent direct-simulation Monte Carlo diffusion model we tracked the trajectories of these particles to compare the performance for different buffer gas injection geometries. While most prior studies focused on box-like or cylindrical cells, we investigated hydrodynamic effects such as vortex formation within a spherical cell and assessed whether these could be utilized to improve extraction efficiency. In addition to the observed enhancement in extraction yield and reduced deposition on inner walls, we identified indicators for experimental verification of these effects in time-of-flight measurements.

MON 23.22 Mon 18:30 ZHG Foyer 1. OG

Controlling the rotational quantum states of chiral molecules — •Elahe Abdiha, JuHyeon Lee, Shilpa Yadav, Sejun An, Boris G Sartakov, Gerard Meijer, and Sandra Eibenberger-Arias — Fritz-Haber-Institut der Max-Planck-Gesellschaft; Berlin, 14195, Germany

We present recent experimental advances targeted at full enantiomer-specific control of the quantum states of chiral molecules using enantiomer-specific state transfer (ESST). In theory, ESST can reach 100We will also present our ongoing efforts to address the intrinsic limitation of ESST due to orientational degeneracy of the rotational states by incorporating theoretically tailored pulse schemes [4].

[1] Eibenberger et al., Phys. Rev. Lett. 118, 123002 (2017)
[2] Pérez et al., Angew. Chem. Int. Ed. 56, 12512 (2017)
[3] Lee et al., Nat. Commun. 15, 7441 (2024)
[4] Leibscher et al. Commun. Phys. 5, 110 (2022).

MON 23.23 Mon 18:30 ZHG Foyer 1. OG

Hanbury Brown-Twiss interference of electrons in free space — •Florian Fleischmann[1], Mona Bukenberger[2], Anton Classen[3], Marc-Oliver Pleinert[1], and Joachim von Zanthier[1] — [1]Friedrich-Alexander- Universität Erlangen-Nürnberg, Quantum Optics and Quantum Information, 91058 Erlangen, Germany — [2]ETH Zürich, Depart- ment of Environmental Systems Science, 8092 Zürich, Switzerland — [3]University of Utah, Health Science Core, UT 84112 Salt Lake City, USA

We investigate the spatial second-order correlation function of two electrons originating from two nanotips in a Hanbury Brown-Twiss like setup. First, we consider semi-classically the effects of the Pauli exclusion principle and Coulomb repulsion on the expected correlation pattern. This is followed by a full quantum-mechanical treatment of the problem, where we separate the system into relative and center-of-mass coordinates in analogy to the Hydrogen atom ansatz. While the center-of-mass system is described as a free particle, the relative system contains the Coulomb scattering process which translates into an effective one-particle problem. We expand the respective initial state of the electrons in the eigenstates of the corresponding Hamiltonian and evolve the system in time. After the scattering process, the function is evaluated in the far field. We present the formal solution of the problem and discuss the current state of the numerical investigations.

MON 23.24 Mon 18:30 ZHG Foyer 1. OG

Photon Bose-Einstein Condensates: Polarization properties and tailored potential landscapes — •Sven Enns[1], Julian Schulz[1], Kirankumar Karkihalli Umesh[2], Frank Vewinger[2], and Georg von Freymann[1,3] — [1]Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Institute of Applied Physics, University of Bonn, 53115 Bonn, Germany — [3]Fraunhofer Institute for Industrial Mathematics ITWM, 67663 Kaiserslautern, Germany

We experimentally investigate polarization properties of harmonically trapped photon gases in a dye-filled microcavity and their dependence on the polarization of the pump beam. Our results demonstrate the interplay between the timescales of thermalization, rotational diffusion of the dye molecules and photon lifetime in the cavity. In agreement with previous theoretical work [1], we show that symmetry breaking occurs when stimulated emission becomes the dominating process.

Furthermore, we investigate photon gases in potential landscapes using the technology of Direct-Laser-Writing (DLW), a 3D laser lithography technology that enables the fabrication of three-dimensional polymer structures at the submicron scale. By printing these structures onto the cavity mirrors potential landscapes for the photon gas are created. This allows for the investigation of many fields, such as quantum thermodynamics [2] and properties of coupled photon gases.

[1] R. I. Moodie, P. Kirton, and J. Keeling, Phys. Rev. A 96 (2017).
[2] Karkihalli Umesh, K., J. Schulz, J. Schmitt, M. Weitz, G. von Freymann and F. Vewinger, Nature Physics 20, 1810-1815, (2024).

MON 23.25 Mon 18:30 ZHG Foyer 1. OG

Rabi-like mode conversion in nonlinear photonic meta atoms — •Oliver Melchert[1,2], Shihao Zhang[1,2], Ihar Babushkin[1,2], Uwe Morgner[1,2], and Ayhan Demircan[1,2] — [1]Institute of Quantum Optics, Leibniz Universität Hannover, Hannover, Germay — [2]PhoenixD, Leibniz Universität Hannover, Hannover, Germay

We investigate the interaction dynamics of optical pulses in the higher-order nonlinear Schrödinger equation with mixed domains of normal and anomalous dispersion. This system enables one-dimensional nonlinear photonic meta atoms, i.e. composite solitary waves that support direct optical analogues of quantum mechanical bound states: the stationary atom potential is defined by the refractive index change induced by a fundamental soliton; its bound modes are realized by a weak co-propagating pulse. Coupling of both pulses is achieved via cross-phase modulation accross a vast frequency gap. Here, we demonstrate Rabi-like transfer of energy between the bound modes, driven by periodic oscillations of the atom potential in terms of a nonfundamental soliton. Coupled-mode theory shows that the underlying resonance phenomenon is reversible and parity maintaing. Beyond the quantum analogy we observe phase-matched coupling to resonant radiation, resulting in exponentially slow decay of the bound energy.

MON 23.26 Mon 18:30 ZHG Foyer 1. OG

The effects of Casimir interactions in experiments on gravitationally-induced entanglement — •Jan Bulling, Marit O. E. Steiner, Julen S. Pedernales, and Martin B. Plenio — Institut für Theoretische Physik, Ulm, Germany

The detection of gravitationally induced entanglement between two macroscopic bodies has recently emerged as a promising approach to probe the non-classical nature of gravity. Experimental proposals typically suggest placing the center-of-mass of two levitated particles in spatially delocalized Schrödinger-cat states or squeezed Gaussian states. According to standard arguments, a quantum theory of gravity is expected to generate entanglement between their positional degrees of freedom due to the gravitational interaction between the two masses. To ensure that the observed entanglement arises solely from gravity, all other interactions - particularly electromagnetic forces - must be suppressed. Therefore, the use of a conductive Faraday shield between the particles is often proposed.

In this work, we investigate the impact of short-range Casimir forces arising between the particles and the newly introduced shield on the entanglement generation. We show that stochastic variations in the initial state preparation across multiple experimental runs, as well as thermal vibrations of the shield, can destroy measurable entanglement.

MON 23.27 Mon 18:30 ZHG Foyer 1. OG

Testing two cornerstones of quantum theory with multi-particle interference — •Marc-Oliver Pleinert and Joachim von Zanthier — Quantum Optics and Quantum Information Group, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 1, 91058 Erlangen, Germany

From the start, quantum mechanics has been questioned due to its counter-intuitive aspects. One example is the use of complex numbers, one building block of quantum theory, which has been criticised already by Schrödinger. Another example is Born's rule relating detection probabilities to the modulus square of the wave function, which initially was only added as a footnote.

Altogether, quantum theory permits interference between indistinguishable paths but, at the same time, restricts its order. Single-particle interference, for instance, is limited to the second order, that is, to pairs of single-particle paths. Recently, we introduced particular multi-particle interference tests of these two cornerstones of quantum mechanics: (i) generalised Sorkin tests of the order of interference and thus Born's rule [1,2] and (ii) generalised Peres tests for the dimensionality of the number system with the aim of questioning whether complex numbers are sufficient for quantum theory [3].

[1] Phys. Rev. Research 2, 012051(Rapid Comm.) (2020)
[2] Phys. Rev. Lett. 126, 190401 (2021)
[3] Phys. Rev. Lett. 134, 060201 (2025)

MON 23.28 Mon 18:30 ZHG Foyer 1. OG

Probing High-Order Susceptibilities of monolayer MoS_2 via High Harmonic Generation: TDDFT approach — Yeganeh Alvankar[1,2], •Elnaz Irani[2], Hamid Talkhabi[2], and Mohammad Monfared[3] — [1]3ICMM, Centro Superior de Investigaciones Cientficas, Sor Juana Ines de la Cruz, 3 Cantoblanco, 28049 Madrid, Spain — [2]Department of Physics, Faculty of Basic Sciences, Tarbiat Modares University, P.O. Box 14115-175, Tehran, Iran — [3]Institute of Theoretical Physics, Leibniz University Hannover, Appelstraße 2, 30167 Hannover, Germany

High-harmonic generation (HHG) is a powerful method for probing high-order nonlinear optical responses in solids, across both perturbative and non-perturbative regimes.

Here, we use time-dependent density functional theory (TDDFT) to calculate the nonlinear susceptibilities ($\chi^{(5)}, \chi^{(7)}, \chi^{(9)}$) of monolayer MoS_2 via HHG. Simulations employ intense ultrafast laser pulses (λ_0 = 600, nm) with peak intensities from 0.2-1.2 TW/cm^2.

Our results exhibit power-law scaling $\text{Yield}_N = A_N I^N$ and interband polarization, enabling direct extraction of higher-order susceptibilities. We also observe strong crystal orientation dependence, with anisotropic behavior across harmonic orders, emphasizing the role of polarization control in 2D material characterization.

Unlike previous methods (e.g., attosecond streaking) that inferred lower-order susceptibilities indirectly, HHG directly reveals higher-order responses without broad spectra or indirect analysis. Quantifying such nonlinearities is key to advancing ultrafast photonics.

MON 23.29 Mon 18:30 ZHG Foyer 1. OG

Limits of the anomalous-velocity description for currents in solid state systems driven by ultrafast pulses — •Jelena Schmitz, Adrian Seith, Jan Wilhelm, and Ferdinand Evers — Institute of Theoretical Physics and Regensburg Center for Ultrafast Nanoscopy, University of Regensburg, Germany

The current response of solids to electric fields $\mathbf{E}(t)$ is often described using a quasi-classical current approximation including an anomalous velocity term containing the Berry curvature $\mathbf{\Omega}_n(\mathbf{k})$ [1],

$$\mathbf{j}(t) = \int_{BZ} \frac{d\mathbf{k}}{(2\pi)^d}\ q \sum_n (\partial \epsilon_n(\mathbf{k})/\partial_{\mathbf{k}} + q\,\mathbf{E}(t) \times \mathbf{\Omega}_n(\mathbf{k}))\, f_n^{(0)}(\mathbf{k})\,, \qquad (2)$$

where $f_n^{(0)}(\mathbf{k})$ denote the (initial) band occupations and $\epsilon_n(\mathbf{k})$ the dispersion. To test the limits of the quasi-classical descriptions for ultrafast and strong driving fields, we compare Eq. (1) with results from a quantum mechanical calculation using the Semiconductor Bloch equations (SBE) [2,3]. By deriving Eq. (1) from the SBE, we determine the parametric regime of validity of the quasi-classical description. The small dimensionless parameters that control the domain of applicability are weak fields and slow driving in comparison to the system dependent effective gap. We confirm our analytic predictions by comparing Eq. (1) to numerically exact solutions of the SBE using a two band massive Dirac Hamiltonian as our model system. [1] Xiao, D. et. al., Rev. Mod. Phys. 82, 1959 (2010) [2] Schmitt-Rink, S. et. al., Phys. Rev. B 37, 941 (1988) [3] Wilhelm, J. et. al., Phys. Rev. B 103, 125419 (2021) [4] https://github.com/ccmt-regensburg/CUED/

MON 23.30 Mon 18:30 ZHG Foyer 1. OG

Entering the overcritical regime of nonlinear Breit-Wheeler pair production by superintense, tightly focused laser pulses colliding with bremsstrahlung γ-rays — •Ingo Elsner, Alina Golub, Selym Villalba-Chavez, and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf

Nonlinear Breit-Wheeler pair production in collisions of a tightly focused high-intensity laser pulse with GeV bremsstrahlung photons is theoretically studied in an overcritical field regime, where the quantum nonlinearity parameter substantially exceeds unity [1]. We investigate under which conditions the attenuation of the γ-beam due to the production process must be taken into account and how much the second generation of created pairs contributes to the total yield. In the considered interaction regime, it is shown that the relevant range of bremsstrahlung frequencies is generally very broad and that – for sufficiently large values of the quantum nonlinearity parameter – an optimum domain of frequencies far below the spectral end point emerges. We also demonstrate that it is beneficial for achieving optimum pair yields to increase the interaction volume by a wider laser focus at the expense of decreased field intensity.

[1] I. Elsner, A. Golub, S. Villalba-Chávez and C. Müller, Phys. Rev. D 111, 096012 (2025)

MON 23.31 Mon 18:30 ZHG Foyer 1. OG

Universal Behavior of Tunneling Time and Disentangling Tunneling Time and Barrier Time-Delay in Attoclock Experiments — •Ossama Kullie[1] and Igor Ivanov[2] — [1]Department of Mathematics and Natural Sciences. University of Kassel, 34132 Kassel, Germany. — [2]Department of Fundamental and Theoretical Physics, Australian National University, Australia

In previous work [1,2,3], we have shown in our model that the (tunnel-ionization) time-delay measured in the attoclock experiment can be precisely described in the adiabatic and nonadiabatic field calibrations. Furthermore, the barrier (tunneling) time-delay itself can be determined from the difference between the time-delays of the adiabatic and nonadiabatic tunnel-ionization, which shows excellent agreement with the experimental results. Remarkably, the tunneling time-delay exhibits a universal behavior with disentangled contributions. Furthermore, we find that in the weak measurement limit, the barrier time-delay corresponds to the Larmor-clock time-delay and the interaction time within the barrier region [1]. We further discuss quantum superluminality in the framework of the attoclock [4].

[1] O. Kullie, J. Phys, Commun. 9, 015003 (2025).
[2] O. Kullie and I. Ivanov, Annals of Physics 464, 169648 (2024).
[3] O. Kullie, Annals of Physics 389, 333 (2018).
[4] O. Kullie and I. A. Ivanov, in preparation.

MON 23.32 Mon 18:30 ZHG Foyer 1. OG

Kondo effect with singular baths: the role of electron-phonon interaction — •Max Fischer[1], Emin Moghadas[2], Niklas Witt[1], Alessandro Toschi[2], and Giorgio Sangiovanni[1] — [1]Institut für Theoretische Physik und Astrophysik and Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg, 97074 Würzburg, Germany — [2]Institute of Solid State Physics, TU Wien, 1040 Vienna, Austria

In the context of dynamical mean-field theories, the hybridization function of the associated impurity model becomes singular at the Fermi level whenever the density of states vanishes at the Fermi level. One examples is the prominent twisted bilayer graphene where the flat bands form a 2D Dirac cone yielding a peak in the bath of the corresponding periodic Anderson model. This is at odds with standard examples of Kondo systems in which the hybridizations are assumed to be regular and well-behaved around the Fermi energy. By means of quantum Monte Carlo and renormalization group we study the crossover from Kondo to the local-moment regime solving an Anderson impurity model which combines a regular part with a tunable peak at the Fermi level. Furthermore, we couple the impurity electrons to a local Holstein-like degree of freedom and analyze the effect of the oscillator on the Kondo feature. We also investigate in which way the singularity in the bath influences the effects of retardation.

MON 23.33 Mon 18:30 ZHG Foyer 1. OG

DMRG on arbitrary geometries using Belief Propagation — •Hendrik Kühne[3] and Christian B. Mendl[1,2] — [1]School of Computation, Information and Technology, Technical University of Munich — [2]Munich Center for Quantum Science and Technology — [3]School of Natural Sciences, Technical University of Munich

Tensor networks have recently attracted much attention as a powerful tool for modeling systems in quantum many-body physics. Their contraction is a significant challenge however, especially in highly connected networks, as memory requirements become prohibitive and the optimal contraction order is increasingly hard to find. The belief propagation algorithm has emerged as an alternative to exact contraction. It offers great flexibility, being completely independent of the geometry in question, however its accuracy suffers in the presence of loops. On the other hand, in Quantum Chemistry, the DMRG algorithm is regarded as the gold standard in solving the ground state problem. Its behavior is well-understood in 1D, however maintaining the necessary canonical forms in higher dimensions becomes increasingly complex. This work proposes to combine Belief Propagation and DMRG, thereby extending DMRG to higher dimensions and arbitrary system geometries. We demonstrate the viability of BP-DMRG on the transverse-field Ising model, where it yields ground states reliably with high fidelity. We also discuss limitations that we incur by using belief propagation, and possible future directions for improving the accuracy and controllability of BP-DMRG.

MON 23.34 Mon 18:30 ZHG Foyer 1. OG

Quantum spin system as reservoir for quantum reservoir computing — •Lara Celine Ortmanns — Deutsches Zentrum für Luft- und Raumfahrt e.V., Linder Höhe, 51147 Köln, Germany

Reservoir computing (RC) is a well-known framework of machine learning, which is used to solve temporal learning tasks, such as temporal pattern recognition and prediction. So far, a variety of physical systems have been considered to implement the reservoir of the RC-scheme [1]. In this project, we investigate a quantum spin system as possible candidate for a quantum reservoir. More specifically, the system is described by the transverse-field Ising model with long-range spin-spin interaction. Additionally, we allow for transverse disorder. Depending on the ratio of involved coupling strengths (interaction and disorder), the system exhibits two dynamical phases, an ergodic and an MBL phase. We raise the question whether counteracting tendencies associated with the vicinity of the phase transition can increase the reservoir performance w.r.t. the ergodic phase for certain tasks.

[1] G. Tanaka et al., Neural Networks 115, 100-123 (2019)

MON 23.35 Mon 18:30 ZHG Foyer 1. OG

Topological insulator single electron transistor — •Omargeldi Atanov, Junya Feng, and Yoichi Ando — Physics Institute II, University of Cologne, Cologne, Germany

When a topological insulator (TI) Josephson junction is driven through a topological phase transition, the ground-state parity of the system is expected to change, potentially due to the fusion of Majorana bound state (MBS) pairs. Measuring the individual parity of MBS pairs is a critical step in understanding the mechanisms behind these parity changes and for more complex braiding operations. We present the successful fabrication and characterization of single electron transistors (SETs) based on bulk-insulating BiSbTeSe2 flakes, which also serve as the material for TI Josephson junctions. This approach simplifies the process flow of the devices and improves fabrication yield. Initial characterization of devices demonstrates well-formed Coulomb diamonds that confirms the robust charge quantization and SET performance. These results pave the way for integrating SETs with TI Josephson junctions and measuring MBS parity in the near future.

MON 23.36 Mon 18:30 ZHG Foyer 1. OG

Realization of topological Thouless pumping in a synthetic Rydberg dimension — •Johannes Deiglmayr[1], Martin Trautmann[1], and Inti Sodemann Villadiego[2] — [1]Felix-Bloch Institute, Leipzig University, Linnéstraße 5, 04103 Leipzig, Germany — [2]Institute for Theoretical Physics, Leipzig University, Brüderstraße 16, 04103 Leipzig, Germany

Synthetic dimensions provide the opportunity to investigate regimes outside those of more traditional quantum many-body platforms. Rydberg states of atoms are a particularly promising platform to engineer Hamiltonians in such synthetic dimensions due to the large number of states and the readily available technologies for manipulating their couplings and for detecting them.

We will present the realization of topological quantum pumping in a synthetic dimension by engineering a one-dimensional Rice-Mele chain within the Rydberg states of cesium atoms [1]. The Thouless protocols for topological pumping is implemented, and the adiabaticity of transport is investigated.

[1] M. Trautmann, I. Sodemann Villadiego, and J. Deiglmayr, Phys. Rev. A **110**, L040601 (2024)

MON 23.37 Mon 18:30 ZHG Foyer 1. OG

Illumination dependent hot polaron photovoltaics in strongly correlated perovskite manganites — •Annika Dehning, Birte Kressdorf, Jörg Hoffmann, and Christian Jooss — Institute of Materials Physics, University of Göttingen, Germany

Highly correlated materials offer new pathways to stabilize hot-carriers after optical excitation and thus might enable overcoming the Shockley-Queisser (SQ) limit. In metal-oxide perovskites excited polaronic states can be stabilized up to ns-lifetime through the enhanced coupling between phonons and charges in the charge/orbital (CO) ordered state. Understanding the mechanisms behind hot polaron photovoltaics (PV) challenges because of the complex interplay between electronic degrees of freedom and structure. It requires knowledge about the cold quantum ground state and how it is affected by lattices, temperature and excitations. Light induced excitations are studied here in dependence of temperature, photon energy and power in $Pr_{1-x}Ca_xMnO_3$ and Ruddlesden-Popper $Pr_{1-x}Ca_{1+x}MnO_4$ (RP-PCMO). Single-crystalline epitaxial thin films are prepared on $Nb:SrTiO_3$ substrates with ion beam sputtering. XRD, AFM, SEM, EDX and TEM are employed to characterize the films, their ordering and the p-n junction. It is demonstrated that the PV response correlates with the appearance of CO order and it is measured up to 320K in RP-PCMO. The characteristic PV-parameters reveal spectral and power density dependencies that do not follow the SQ-theory. An approach to describe the PV-response based on hot carrier contributions via scaling laws is presented.

MON 23.38 Mon 18:30 ZHG Foyer 1. OG

Testing Nonlinear Quantum Theories with PHIP-Based Nuclear Spin Ensembles — •Xiaoyi Yang, Martin Korzeczek, and Martin B. Plenio — Ulm University, Institute of Theoretical Physics, Albert-Einstein-Allee 11, 89081 Ulm, Germany

We propose and analyze a quantum simulation of nonlinear quantum dynamics inspired by gravitational interaction models and a mathematical framework due to Weinberg, using parahydrogen-induced polarization (PHIP) NMR. The platform leverages hyperpolarized hydrogen and carbon-13 nuclei to realize an effective Hamiltonian incorporating both linear J-coupling and nonlinear mean-field self-interaction. Under specific initial conditions and symmetry constraints, the system reproduces the dynamics predicted by a nonlinear quantum gravity-inspired model. The resulting evolution exhibits Duffing-type behavior and transitions between dynamical topologies, with solutions described by Jacobi elliptic functions. Notably, the presence of controlled nonlinearity reveals an amplified sensitivity to small differences between quantum states, offering a potential mechanism for distinguishing nonorthogonal states within a closed quantum system. Our results highlight PHIP NMR as a viable experimental testbed for probing nonlinear extensions to quantum mechanics, with potential applications in quantum information processing, metrology, and foundational tests of quantum theory.

MON 23.39 Mon 18:30 ZHG Foyer 1. OG

Towards low-energy structured coherent electron and ion beams — •Prosenjit Majumder, Matias Eriksson, and Robert Fickler — Physics Unit, Photonics Laboratory, Tampere University, Tampere, Finland

In recent years, structured matter waves particularly structured electron beams have attracted growing interest due to their potential in advanced microscopy and quantum experiments. Spatially coherent field-emission electron sources are well-established, enabling precise control over electron beam wavefronts and facilitating developments in electron microscopy and spectroscopy. Our research focuses on developing a tunable low-energy source capable of structuring both electron and ion beams. The setup features a cryogenically cooled nanotip field/gas field ion emission source followed by a 2-meter free propagation region. This configuration is designed to generate transversely coherent beams, with coherence lengths of several micrometers for ions suitable for shaping with nanofabricated electrostatic elements.

We aim to investigate the physics of low-energy vortex electrons and ions using electrostatic chopsticks as a minimally invasive shaping tool. Housed in a custom-built vacuum chamber, the setup includes electrostatic lenses, deflectors, and full-length magnetic shielding to suppress ambient magnetic interference. Realizing a spatially coherent ion source would mark a major advance, enabling new studies in composite charged wave systems and pushing the frontiers of ion-based microscopy and quantum technologies.

MON 23.40 Mon 18:30 ZHG Foyer 1. OG

Cavity QED experiments and lasing with cold trapped Yb atoms — •Ke Li[1], Saran Shaju[1], Gabriel Dick[1], Simon B. Jäger[2], and Jürgen Eschner[1] — [1]Universität des Saarlandes, Physik, 66123 Saarbrücken, Germany — [2]Universität Bonn, Physikalisches Institut, 53115 Bonn,Germnay

Cavity quantum electrodynamics with cold atoms enables the controlled interactions between atoms and photons, providing advanced applications in quantum technologies and fundamental science. In our research, 10^4 to 10^6 Ytterbium-174 atoms are magneto-optically trapped, using the ${}^1S_0$-${}^1P_1$ transition at 399 nm, inside a high-finesse cavity that couples to the ${}^1S_0$-${}^3P_1$ intercombination transition. We have observed lasing action in both single- and multi-mode emission [1]. Additionally, the collective strong coupling leads to complex atom-field dynamics and scattering phenomena, including vacuum Rabi splitting accompanied by additional fluorescence at atomic resonance [2]. Future research will be extended to studying the quantum dynamics of atom-cavity interactions on the ${}^1S_0$-${}^3P_0$ clock transition.

[1] H. Gothe et al., Physical Review A 99.1 (2019) 013415.
[2] S. Shaju et al. , arXiv:2404.12173 (2024).

MON 23.41 Mon 18:30 ZHG Foyer 1. OG

Coherent interactions of quantum emitters in a dielectric waveguide — •Grigory Kornilov, Alok Gokhale, Gregor Pieplow, Tim Schröder, Kurt Busch, and Francesco Intravaia — Humboldt-Universität zu Berlin, Berlin, Germany

Robust theoretical modeling of quantum emitters in dielectric media is crucial for predicting their behavior in practical applications. Existing models often simplify the system to a one-dimensional regime, thereby failing to accurately capture the influence of quantum noise and radiative losses on the emitters' intrinsic properties and overall system performance. Especially in nanoscopic devices, such as photonic integrated circuits with embedded solid-state quantum emitters, these effects can significantly impact measurement outcomes.

Utilizing a Green's-tensor approach in combination with the theory of open quantum systems, we present a fully three-dimensional quantum electrodynamics description of a quantum emitter embedded in a dielectric structure. Specifically, we investigate negatively charged nitrogen vacancy centers (NVs) in a cylindrical diamond waveguide. We explore the interaction of a single NV with an incident light field as well as waveguide-mediated coherent interactions between multiple emitters. In particular, the latter analysis may inform future experiments seeking to harness such collective effects. We also show how our explicit treatment of phonon-mediated NV decay affects simulated experiments beyond a simple modification of the NV-waveguide coupling strength.

MON 23.42 Mon 18:30 ZHG Foyer 1. OG

Spin and energy dynamics in the disordered spin-1/2 XX ladder — •Lukas Peinemann, Kadir Çeven, and Fabian Heidrich-Meisner — Institut für Theoretische Physik, Georg-August-Universität Göttingen, Germany

Understanding the relaxation dynamics of closed many-body quantum systems is a central goal in the study of non-equilibrium quantum physics. Within linear response theory, we numerically calculate the spin and energy diffusion coefficients in the disordered two-leg spin-1/2 XX ladder at infinite temperature, employing the concept of quantum typicality. Using exact diagonalization, we determine the disorder-induced finite-size crossover from delocalized to many-body localized regime by analyzing the gap ratio and the von Neumann entanglement entropy. We examine how the hierarchy of spin and energy diffusion constants in the delocalized regime compares to that in other non-integrable spin models, such as the XXZ chain with a staggered magnetic field. Our numerical findings reveal an atypical hierarchy in the XX ladder, where spin diffusion exceeds energy diffusion - in contrast to the behavior observed in the other studied models. This reversed hierarchy persists throughout the entire delocalized regime, with both diffusion constants decreasing systematically as disorder is increased. Moreover, our results suggest that increasing the inter-leg coupling leads to a convergence of the spin and energy diffusion coefficients.

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MON 23.43 Mon 18:30 ZHG Foyer 1. OG

Ultrastrong coupling limit to quantum mean force Gibbs state for anharmonic environment — •Prem Kumar and Sibasish Ghosh — Optics and Quantum Information Group, The Institute of Mathematical Sciences, C.I.T. Campus, Taramani, Chennai 600113, India.

The equilibrium state of a quantum system can deviate from the Gibbs state if the system-environment (SE) coupling is not weak. An analytical expression for this mean force Gibbs state (MFGS) is known in the ultrastrong coupling (USC) regime for the Caldeira-Leggett (CL) model that assumes a harmonic environment. Here, we derive analytical expressions for the MFGS in the USC regime for more general SE models. For all the generalized models considered here, we find the USC state to be diagonal in the basis set by the SE interaction, just like in the CL case. While for the generic model considered, the corresponding USC-MFGS is found to alter from the CL-result, we do identify a class of models more general than the CL model for which the CL-USC result remains unchanged. We also provide numerical verification for our results. These results provide key tools for the study of strong coupling quantum thermodynamics and several quantum chemistry and biology problems under more realistic SE models, going beyond the CL model.

MON 23.44 Mon 18:30 ZHG Foyer 1. OG

Minimal quantum models and non-standard heat transport — Helen Dorausch and •Carsten Henkel — Universität Potsdam, Institut für Physik und Astronomie

As the building blocks of coupled thermodynamical systems get smaller, quantum physics introduces curious challenges. We study simple examples based on oscillators coupled to heat baths. (1) A single, strongly damped oscillator driven by a laser provides a model for the plasmon resonance of a single particle. We study it with a quantum jump simulation that provides a quite different steady-state picture with strong spikes in the local bath temperature (the electron gas in the particle itself). (2) A two-site oscillator chain connected to baths with different temperatures permits to dis-spell a purported violation of the second law [1, 2]. We analyse carefully the role of the rotating-wave approximation adopted in the coupling (or not). The symplectic (canonical) group Sp(4) is instrumental in getting a global picture.

[1] A. Levy and R. Kosloff, Europhys. Lett. 107 (2014) 20004
[2] C. Henkel, Ann. Phys. (Berlin) 533 (2021) 2100089

MON 23.45 Mon 18:30 ZHG Foyer 1. OG

Accessing Metastable Triplet States of Aromatic Molecular Emitters — •Max Masuhr, Bo Deng, Babak Behjati, Hazem Hajjar, and Daqing Wang — Institute of Applied Physics, University of Bonn, Wegelerstrasse 8, 53115 Bonn, Germany

Aromatic hydrocarbon molecules embedded in solid-state matrices have been shown to be an excellent platform for quantum optics applications. The triplet states of these molecules offer additional magnetic degrees of freedom, which are potentially interesting for quantum sensing and information. Here, we present our recent work focused on combined optical and microwave characterization of metastable triplet states of several molecule-host combinations.

MON 23.46 Mon 18:30 ZHG Foyer 1. OG

Exploring Electrical Transport in the 2D Quantum Material $FePSe_3$ — •Paul Perl[1], Lars Thole[1], Sonja Locmelis[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, 30167 Hannover, Germany — [2]Institut für Anorganische Chemie, Leibniz Universität Hannover, 30167 Hannover, Germany

Thin-layer systems of the quantum 2D material iron phosphorus triselenide ($FePSe_3$) exhibit promising potential for use in innovative devices [1]. In this study, we investigate the electrical properties of flakes with thicknesses ranging from 14 nm to 28 nm, including activation energy and Schottky barriers with various contact materials, to develop a deeper understanding of the material's behavior. The bulk crystals were synthesized via chemical vapor transport, and the thin flakes were then exfoliated using the scotch tape method. Electrical contacts for the exfoliated flakes were created using electron beam lithography followed by physical vapor deposition. Additionally, we observe a memory effect induced by the application of a backgate voltage, suggesting potential for $FePSe_3$ in memory devices.

[1] Z. Zhao et al., npj 2D Mater. Appl. 9, 30 (2025)

MON 23.47 Mon 18:30 ZHG Foyer 1. OG

Novel Medium- and High-Entropy Telluride Thin Films via Hybrid Pulsed Laser Deposition — •Niklas Kohlrautz, Pia Henning, Helmut Klein, Heidrun Sowa, and Jasnamol Palakkal — Institute of Materials Physics, University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

Medium- and high-entropy materials (MEMs and HEMs) are known for their great multifunctional properties, ranging from catalytic activity to magnetic order [1]. Moreover, tellurides (e.g., CrTe, FeGeTe, and CrGeTe) have gained large interest for their highly tunable magnetic properties, including room-temperature ferromagnetism and perpendicular magnetic anisotropy [2]. Toward the goal of synthesizing novel HEMs, we designed a hybrid Pulsed Laser Deposition (PLD) technique with Te molecular beam source attached. After primarily establishing the growth of $Cr_{(1+\delta)}Te_2$, we synthesized a novel MEM telluride, FeCrNiTe (FCNT), using a PLD target containing the transition metals and supplying Te via the beam source. Growth parameter optimization yielded high-quality epitaxial thin films. We present a detailed structural and physical characterization of a series of FCNT thin films deposited on $SrTiO_3(100)$ substrates. Orthorhombic crystal structure, highly homogeneous surface, semiconducting behavior, and a low magnetoresistance at low temperatures were identified in these novel MEM tellurides. This work pioneers the synthesis of many novel MEM and HEM tellurides that have potential in future spintronics devices.

[1] N. Oueldna, Materials Horizons 2024, 11(10), 2323-2354.
[2] A. Tschesche et al., R.S., doi.org/10.21203/rs.3.rs-4861088/v1.

MON 23.48 Mon 18:30 ZHG Foyer 1. OG

Deterministic single ion-implantation of Er into thin film lithium niobate — •Maranatha Andalis, Reiner Schneider, and Klaus D. Jöns — Institute for Photonic Quantum Systems (PhoQS), Center for Optoelectronics and Photonics Paderborn (CeOPP) and Department of Physics, Paderborn University, 33098 Paderborn, Germany

Incorporating rare earth ions (REIs) into lithium niobate-on insulators (LNOI) is of great interest in scalable photonic integrated circuits (PIC), enhancing the potential of LNOI with added functionalities enabled by the REIs. Erbium ions can be incorporated into LNOI using ion implantation and implemented at telecom wavelengths. Together with Ionoptika Ltd., we have customized a single ion implantation system called Q-One with up to 40 kV acceleration voltage. For most quantum applications, the site-selective implantation of a single REI is required. Our results show single Er ion implantation into LNOI with 85% efficiency using secondary electron emission detection. The Q-One single ion implanter, with its high-resolution mass-filtered focused ion beam, nanometer-precision stage, and choice of ion source, holds significant potential in deterministic ion implantation, crucial for scalable quantum technologies with REIs.

MON 23.49 Mon 18:30 ZHG Foyer 1. OG

Probing Ultrafast Lattice Dynamics of Quantum Material Surfaces — •Alp Akbiyik[1], Felix Kurtz[1], Hannes Böckmann[1], and Claus Ropers[1,2] — [1]Max Planck Institute for Multidisciplinary Sciences, Göttingen, Germany — [2]4th Physical Institute, University of Göttingen, Germany

Correlated phenomena among quantum materials have attracted considerable interest in recent decades. However, their potential applications require a better understanding of and ability to manipulate the lattice dynamics coupled to electronic phenomena. Ultrafast LEED probes the surfaces of bulk or two-dimensional materials to observe structural phase transitions and lattice thermalization with a time resolution down to 1 ps [1]. While some bulk CDW systems, such as TaS2 and TiSe2 have been studied extensively in ULEED, our ongoing studies focus more on mono- and few-layer van der Waals (vdW) materials to investigate intriguing phonon dynamics and novel structural changes owing to dimensionality effect.

[1] G. Storeck et al., Structural Dynamics 7, 034304 (2020).

MON 23.50 Mon 18:30 ZHG Foyer 1. OG

Controlling Indistinguishability of cascaded emissions from QDs through an Open Cavity system — •Francesco Salusti[1], Mark Hogg[2], Timon Luca Baltisberger[2], Malwina Anna Marczak[2], Nils Heinisch[1], Rüdiger Schott[3], Sascha René Valentin[3], Andreas Dirk Wieck[3], Arne Ludwig[3], Stefan Schumacher[1], Richard Warburton[2], and Klaus Jöns[1] — [1]PhoQS Institute, CeOPP, and Department of Physics, Paderborn University, Paderborn, Germany — [2]Philosophisch-Naturwissenschaftliche Fakultät, Departement Physik, Basel, Switzerland — [3]Ruhr Universität Bochum, Faculty of Physics and Astronomy, Bochum, Germany

Cavity structures are effective tools for enhancing quantum light emitters. Tunable open cavities can be adapted to emitters like quantum dots, supporting key features for quantum communication such as on-demand emission, low multiphoton probability, and indistinguishable photons. Here we show that a tunable microcavity enhances photon pair generation from the biexciton exciton cascade, overcoming the limits of poor indistinguishability due to non-separability and time-correlation. We control exciton and biexciton emission rates via selective Purcell enhancement of the transitions using our tunable cavity. By imbalancing the lifetime ratio between biexciton and exciton photons (as suggested in E. Schöll et al. Phys.Rev.Lett.125, 233605(2020)), we achieve high Hong-Ou-Mandel visibility values for both photons emitted in the cascade. We show that the HOM visibility follows $V=(\tau_X)/(\tau_X+\tau_{XX})$, matching with theoretical predictions.

MON 23.51 Mon 18:30 ZHG Foyer 1. OG

Topological Phenomena in Folded Bilayer Graphene Heterostructures — •Hannes Kakuschke, Lina Bockhorn, and Rolf Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, 30167 Hannover, Germany

Mono- and bilayer systems of graphene have been extensively researched due to their unique magnetic and electronic transport properties. In more recent work, folded graphene [1, 2] heterostructures exhibit fascinating phenomena. This is due to the topology of the folded region, causing effects such as snake states and zero line modes. However, in transport measurements of self-assembled, folded graphene [3, 4, 5], multiple effects occur simultaneously, complicating the analysis of individual contributions. To solve this problem, we use the dry transfer method to fold graphene around hBN, decoupling the overlapping graphene regions. In such heterostructures we observe topologically protected transport behaviour in the folded region.

[1] J. C. Rode et al., Ann. Phys. 529, 1700025 (2017).
[2] J. C. Rode et al., 2D Mater. 6, 015021 (2018).
[3] L. Bockhorn et al., Appl. Phys. Lett. 118, 173101 (2021).
[4] S. J. Hong et al., 2D Materials 8, 045009 (2021).
[5] S. J. Hong et al., Phys. Rev. B 105, 205404 (2022).

MON 23.52 Mon 18:30 ZHG Foyer 1. OG

Giant Stark-shift of a defect emitter in a strained WSe_2 monolayer — Felix Schaumburg[1], Fabian Stechemesser[1], Hendrik Mannel[1], Jeniffer König[2], Cornelius Dietrich[2], Corinne Steiner[3], Patricia Pesch[3], Axel Lorke[1], •Günther Prinz[1], Martin Geller[1], and Annika Kurzmann[2] — [1]Universität Duisburg-Essen, Duisburg, Deutschland — [2]Universität zu Köln, Köln, Deutschland — [3]RWTH Aachen, Aachen, Deutschland

The search for quantum emitters for quantum technologies is one of today's fastest-growing fields in research worldwide. Here, we investigate the electrical-field dependent optical emission of a two-dimensional (2D) heterostructure, based on tungsten diselenide (WSe_2). Hexagonal boron nitride layers provide electrical isolation, and few-layer graphene acts as a backgate electrode. The heterostructure was placed on a silicon substrate with SiO_2 nanopillars to create local strain. In the WSe_2 layer, defects have been introduced by 100 kV electron irradiation. μ-Photoluminescence (PL) measurements of single emitters show narrow emission lines and single photon emission.

By applying voltages to the graphene and the metallic top gate, an electric field can be introduced across the WSe_2. We will present μ-PL spectra of emitters depending on the gate voltage and observe a giant shift in wavelength up to 6 nm, when the gate voltage is changed by 1.5V. Additionally, the intensity of the emitters is strongly dependent on the absolute value of the gate voltage. The combination of defect engineering, strain-induced localization, and electric field control offers a promising route toward scalable quantum emitter platforms.

MON 23.53 Mon 18:30 ZHG Foyer 1. OG

Epitaxial Growth of Van der Waals Magnets $Cr_{1+\delta}Te_2$ — •Pia Henning, Anna Tschesche, Laura Pflügl, Tobias Meyer, and Jasnamol Palakkal — Institute of Material Physics, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077, Göttingen

Tunable magnetic materials in 3D and as well as in lower dimensions, exhibiting ferromagnetism and perpendicular magnetic anisotropy (PMA) are highly desired for application in future spintronic devices. In the course of that, thin films of transition metal dichalcogenides $Cr_{1+\delta}Te_2$ gained an increased interest, due to their highly tunable magnetic anisotropy and ferromagnetism with T_C ranging from 150 K to 350 K [1]. The stoichiometry, i.e. the intercalation of Cr species (δ) in between $CrTe_2$ layers, is the reason for the highly variable magnetic properties [1]. This makes the need for a sensitive control of δ in combination with a high-quality thin film growth critical. A hybrid deposition was used for growing $Cr_{1+\delta}Te_2$ thin films with various δ, combining Pulsed Laser Deposition (PLD) and Molecular Beam Epitaxy (MBE). Structural, magnetic and transport properties of the samples were evaluated, whereby Room-temperature ferromagnetism, PMA, anisotropic magnetoresistance and anomalous Hall effect are observed, showing a high tunability of properties relative to δ. This work emphasizes the potential of this hybrid deposition technique for growing transition metal dichalcogenide thin films paving the way for possible device applications.

[1] A. Tschesche, P. Henning, et al., Preprint on Research Square, https://doi.org/10.21203/rs.3.rs-4861088/v1

MON 23.54 Mon 18:30 ZHG Foyer 1. OG

Quantum Dynamics of Spin Polarization Transfer in NV-diamond Systems Probed by In-Situ ^{13}C NMR — •Tilen Knaflič, Mario Grüneberg, Enrique Sánchez-Ibáñez, Claudius Mullen, and Jaka Pribošek — Silicon Austria Labs, Villach, Austria

Dynamic nuclear polarization (DNP) is a powerful technique that significantly boosts nuclear spin polarization in solids, amplifying the sensitivity of nuclear magnetic resonance (NMR), which can serve as a foundation for new-generation quantum sensors. Several DNP mechanisms - such as the Overhauser effect, the solid effect and the cross effect - rely on quantum interactions between electron and nuclear spins, mediated by microwave-driven transitions and spin diffusion. These processes exploit the large thermal polarization of electron spins and efficient polarization transfer to nuclear spins, enabling quantum control over spin ensembles and enhancing signal detection in high-resolution spectroscopy and imaging.

In this work, we explore DNP in negatively charged nitrogen-vacancy (NV^-) centers in diamond, a quantum system with optically addressable spin states and long coherence times. We study the field dependence of the DNP process by performing hyperpolarization and in-situ inductive NMR detection of ^{13}C nuclei at different magnetic fields in the range between 10 mT and 1 T. Our results provide insights into the quantum dynamics of spin polarization transfer in NV-diamond systems and demonstrate the potential of DNP for enhancing NMR sensitivity across a range of magnetic field strengths.

MON 23.55 Mon 18:30 ZHG Foyer 1. OG

Geometrically Constrained Quantum Dynamics: A Numerical Study on a Comb — •Ognen Kapetanoski and Irina Petreska — Ss. Cyril and Methodius University in Skopje, Faculty of Natural Sciences and Mathematics, Institute of Physics, Skopje, Macedonia

We investigate the quantum dynamics of a particle constrained by a two-dimensional comb-like geometry using the time-dependent Schrödinger equation. This structure consists of a backbone and branching fingers, which models transport phenomena in heterogeneous and anisotropic media. Geometric constraints are implemented by implementing a Dirac delta function into the kinetic energy operator, approximated by a Gaussian. Spatial discretization is done using a finite-difference scheme and time evolution is computed with a fourth-order Runge-Kutta method. We compare Gaussian and comb-like wave functions to study how initial conditions affect the evolution of the probability density. The comb-like initial state shows strong localization near the backbone in early stages of time evolution. At later times, this localization disappears and the resulting probability distribution becomes similar to that of the Gaussian case. Numerical results are compared with analytical solutions, showing excellent agreement for short to intermediate time intervals. This method allows quantum transport modeling in finite domains and complex initial conditions where analytical solutions do not exist.

[1] O. Kapetanoski and I. Petreska, *Phys. Scr.* **100**, 025254 (2025).

MON 23.56 Mon 18:30 ZHG Foyer 1. OG

Geometrically Constrained Quantum Dynamics: A Numerical Study on a Comb — •Ognen Kapetanoski and Irina Petreska — Ss. Cyril and Methodius University in Skopje, Faculty of Natural Sciences and Mathematics, Institute of Physics, Skopje, Macedonia

We investigate the quantum dynamics of a particle constrained by a two-dimensional comb-like geometry using the time-dependent Schrödinger equation. This structure consists of a backbone and branching fingers, which models transport phenomena in heterogeneous and anisotropic media. Geometric constraints are implemented by implementing a Dirac delta function into the kinetic energy operator, approximated by a Gaussian. Spatial discretization is done using a finite-difference scheme and time evolution is computed with a fourth-order Runge-Kutta method. We compare Gaussian and comb-like wave functions to study how initial conditions affect the evolution of the probability density. The comb-like initial state shows strong localization near the backbone in early stages of time evolution. At later times, this localization disappears and the resulting probability distribution becomes similar to that of the Gaussian case. Numerical results are compared with analytical solutions, showing excellent agreement for short to intermediate time intervals. This method allows quantum transport modeling in finite domains and complex initial conditions where analytical solutions do not exist.

[1] O. Kapetanoski and I. Petreska, *Phys. Scr.* **100**, 025254 (2025).

MON 23.57 Mon 18:30 ZHG Foyer 1. OG

Towards a Quantitative Framework for Capacitance-Voltage Spectroscopy in Quantum Dot Ensembles — •Phil Julien Badura[1], Nico Frédéric Brosda[1], Ismail Bölükbaşı[1], Ibrahim Engin[1], Patrick Lindner[1], Sascha René Valentin[1], Andreas Dirk Wieck[1], Björn Sothmann[2], and Arne Ludwig[1] — [1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [2]Fakultät für Physik and CENIDE, Universität Duisburg-Essen, Lotharstraße 1, D-47048 Duisburg, Germany

This study investigates an inhomogeneous ensemble of quantum dots coupled to a charge reservoir using capacitance-voltage spectroscopy. Experimental measurements reveal shifts in capacitance peak positions influenced by AC frequency and temperature, with frequency-dependent shifts remaining unexplained by existing models. To address this, we develop a master equation-based theoretical model incorporating energy-dependent tunneling effects, which successfully reproduces the experimental data. Our findings emphasize the role of energy-dependent tunneling in distinct regimes: at low temperatures, energy level dispersion dominates, while at high temperatures and frequencies, shifts arise from optimized sequences of in- and out-tunneling events.

MON 23.58 Mon 18:30 ZHG Foyer 1. OG

Magnetotransport measurements of magic angle twisted bilayer graphene — •Monica Kolek Martinez de Azagra and Thomas Weitz — 1. Institute of Physics, Georg-August University of Göttingen

Magic angle twisted bilayer graphene (MATBG) has in recent years been established as a powerful platform for exploring strongly correlated electron phenomena in two-dimensional materials [1]. The rich phase diagram of two graphene layers stacked on top of each other with a precise twist angle of 1.1° has been widely studied with a special emphasis on investigating the robust superconducting state, whose exact nature and origin have yet to be determined [2,3]. Here, we present our recent progress in the fabrication and electric characterization of high-quality, encapsulated MATBG devices, highlighting key experimental observations.

[1] R.Bistritzer, A. H. MacDonald, PNAS 108, 12233(2011).
[2] Y. Cao et al., Nature 556, 80 (2018).
[3] Y. Cao et al., Nature 556, 43 (2018).

MON 23.59 Mon 18:30 ZHG Foyer 1. OG

Autonomous conversion of particle exchange to quantum self-oscillations — •Sofia Sevitz[1], Federico Cerisola[2], Karen Hovhannisyan[1], and Janet Anders[1,2] — [1]University of Potsdam, Germany — [2]University of Exeter, UK

Particle-exchange autonomous machines continuously convert electronic transport into heat transfer between fermionic reservoirs. In typical set-ups, to collect the generated electrical power, an external resistive load is connected that inevitably yields some dissipation. To overcome these losses, we couple a mechanical resonator as an internal degree of freedom to the particle exchange machine hosted in a quantum dot. This way, part of the exchanged energy can be converted into self-oscillations. Here we explore the slow transport regime making use of a recently developed quantum model. Our analysis goes well beyond all previous work, which was limited to semiclassical treatment of the fast transport regime. First, we show that quantum self-oscillations are present in this slow regime and can be measured via the electrical particle current acting as a witness. Next, we study the thermodynamics of the setup and find that, under realistic conditions, self-oscillations occur only when the machine operates as a heater. Lastly, we establish an experimentally measurable performance metric which reveals that, counterintuitively, strong coupling between dot and resonator is detrimental to the conversion quality. The framework developed in this work can be readily implemented in a variety of nanoscale devices such as a suspended carbon nanotube with an embedded quantum dot.

MON 23.60 Mon 18:30 ZHG Foyer 1. OG

Electronic Phase Diagram of Rhombohedral-Stacked Thin Graphene Layers — •Sirri Batuhan Kalkan, Caroline Scheper, David Urbaniak, Monica Kolek Martinez de Azagra, Isabell Weimer, and Thomas Weitz — I. Institute of Physics, Georg-August University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

Twisted bilayer graphene has emerged as a powerful system for studying flat band induced exotic quantum phase transitions, offering valuable insights into quantum phenomena [1]. However, the fixed angle between layers in this system limits the tunability of electronic correlations, prompting researchers to explore alternative approaches. Naturally occurring few-layer graphene systems provide a promising solution, as stacking failures in these systems can result in rhombohedral stacking. This configuration enables continuous control of interactions through external electric fields, offering a versatile platform for studying quantum phase transitions [2-3]. By identifying rhombohedral domains, fabricating devices, and conducting electrical characterization, in this work we discuss its electronic phase diagram that encompasses both superconducting and magnetic phase transitions.

[1] Yuan Cao et al. , Nature 556.7699 (2018): 43
[2] Haoxin Zhou et al., Nature 598.7881 (2021): 434
[3] Tonghang Han et al. , arXiv preprint arXiv:2408.15233 (2024).

MON 23.61 Mon 18:30 ZHG Foyer 1. OG

Towards magnetotransport measurements in rhombohedral multi-layer graphene — •David Paul Urbaniak, Christian Eckel, Sirri Batuhan Kalkan, and Thomas Weitz — 1st Institute of Physics, Faculty of Physics, Georg-August University Göttingen, Germany

The flat bandstructure of rhombohedral multilayer graphene enables the investigation of a variety of correlation-driven effects, including the fractional quantum Hall effect and its anomalous counterpart, recently observed in rhombohedral pentalayer graphene [1]. Recent observations have additionally revealed signatures of chiral superconductivity in rhombohedral tetra- and pentalayer graphene, along with the unprecedented discovery of a superconductor phase within an anomalous Hall phase in rhombohedral hexalayer graphene [2, 3]. This work presents the necessary steps for the fabrication of an in hexagonal boron nitride (hBN) encapsulated, dual gated device for the investigation of the aforementioned effects during magnetotransport measurements in the milli Kelvin regime. The fabrication techniques employed consist of Raman spectroscopy, scattering near field optical microscopy (SNOM), a nanolithography technique based on an atomic force microscope (AFM), and a dry transfer technique. Conclusively, preliminary measurements are presented.

[1] Zh. Lu et al., Nature 626, 759 (2024).
[2] T. Han et al., arXiv:2408.15233 (2024).
[3] E. Morissette et al., arXiv:2504.05129 (2025).

MON 23.62 Mon 18:30 ZHG Foyer 1. OG

Vacancies and Stone-Wales Defects in Twisted Bilayer Graphene: A Comparative Theoretical Study — •Fabian Dietrich and Eduardo Cisternas — Departamento de Ciencias Físicas, Universidad de La Frontera, Temuco, Chile

Twisted bilayer graphene (TBG) has emerged as a cornerstone in the exploration of strongly correlated electronic systems, exhibiting tunable quantum phenomena such as superconductivity and Mott insulating states. In this study, we present a comparative theoretical investigation of two key classes of structural defects - monovacancies and Stone-Wales (SW) defects - introduced into a TBG system with different twist angles.

Using density functional theory (DFT), we analyze the energetic stability, local geometric reconstruction, and electronic structure of these defects. Our results show that both types of defects significantly alter the local density of states (LDOS), introducing mid-gap states and modifying the flat bands characteristic of TBG. Notably, the influence of the defect type is highly sensitive to its registry within the Moiré supercell, with SW defects inducing less mid-gap perturbation than vacancies but more extensive topological rearrangements.

Our findings offer new insights into defect engineering in twisted van der Waals systems and have implications for designing quantum devices based on TBG with tailored electronic properties.

[1] F. Dietrich, U. Guevara, A. Tiutiunnyk, D. Laroze, E. Cisternas, Flatchem. 41 (2023) 100541.

MON 23.63 Mon 18:30 ZHG Foyer 1. OG

Parent State Modeling of Correlated and Topological Quantum Phases in Rhombohedral Multilayer Graphene — •Robert Schneider[1], David Urbaniak[1], Chiho Yoon[2], Sirri Batuhan Kalkan[1], Fan Zhang[2], and Thomas Weitz[1] — [1]1st Physical Institute, Faculty of Physics, University of Göttingen, Göttingen, Germany — [2]Department of Physics, University of Texas at Dallas, Richardson, TX, USA

Recently, a number of novel correlated and topological quantum phases in N-layer ABC-stacked graphene systems have been identified. Among them are anomalous Hall crystals with a non-trivial Chern number at vanishing magnetic field (Nature 608, 298-302), as well as chiral p-wave superconducting states that persist to unconventionally high magnetic fields (arXiv: 2408.15233). Even though they are fundamentally many-body quantum phenomena, the theoretical determination of the single-particle bands hosting these quantum phases is important in understanding the interplay between quantum geometry and many-body interactions. Examples of relevant effects are the formation of flat bands, the generation of a tunable band gap, and the possibility of a topological Lifshitz transition due to trigonal warping. This work shows how the parent states of these correlated and topological quantum phases can be accurately modeled using various computational methods including tight-binding models and density functional theory (arXiv: 2502.17555v1). Finally, an outlook into the interpretation of the obtained results for different rhombohedral multilayer graphene systems is presented.

Symposium Correlated Quantum Matter – From Cold Atoms to the Solid State (SYCQ)

Silke Bühler-Paschen
TU Wien
Wiedner Hauptstraße 8-10
1040 Wien, Austria
silke.buehler-paschen@tuwien.ac.at

Philipp Hauke
University of Trento
Via Sommarive 14
38123 Povo TN, Italy
philipp.hauke@unitn.it

Elke Scheer
University of Konstanz
Universitaetsstrasse 10
78464 Konstanz, Germany
elke.scheer@uni.kn

Correlated quantum matter displays some of the most intriguing phenomena - from strange metallicity and quantum spin liquid behavior to topological order - that escape our understanding. Massive or long-range entanglement might be a common characteristic of the underlying states but the verification is challenging, in particular in condensed matter systems. New approaches inspired by quantum information have the potential to boost progress. This symposium will bring together experts from the fields of ultracold atoms, mesoscopic systems, and quantum materials, to stimulate cross-talk between the communities, generate new ideas, and contribute to establishing a new field at the junction between correlated matter and quantum information.

Overview of Invited Talks and Sessions

(Lecture hall ZHG008)

Invited Talks

SYCQ 1.1	Tue	10:45–11:15	ZHG008	**New synthetic quantum systems with ultracold fermions in optical lattices** — •Leonardo Fallani
SYCQ 1.2	Tue	11:15–11:45	ZHG008	**Realization of Andreev-molecules** — •Szabolcs Csonka
SYCQ 1.3	Tue	11:45–12:15	ZHG008	**Giant transverse magnetic fluctuations at high fields in UTe_2** — •Kimberly Modic, Valeska Zambra, Amit Nathwani, Brad Ramshaw
SYCQ 1.4	Tue	12:15–12:45	ZHG008	**Emerging platforms to answer basic theoretical questions about correlated quantum matter** — •Joel Moore

Sessions

SYCQ 1.1–1.4	Tue	10:45–12:45	ZHG008	**Correlated Quantum Matter – From Cold Atoms to the Solid State**

Sessions

– Invited Talks –

SYCQ 1: Correlated Quantum Matter – From Cold Atoms to the Solid State

Time: Tuesday 10:45–12:45 Location: ZHG008

Invited Talk SYCQ 1.1 Tue 10:45 ZHG008

New synthetic quantum systems with ultracold fermions in optical lattices — •Leonardo Fallani — Università degli Studi di Firenze, Sesto Fiorentino, Italy

Ultracold atoms trapped in optical lattices provide a powerful technological platform for studying solid-state phenomena with ample tunability of the system parameters. In this quantum-simulation perspective, it is possible to control the atomic state to provide direct realizations of microscopic models and achieve "extreme" states of matter with no counterpart in conventional materials. I will discuss some recent developments in this field that are opened by the coherent manipulation of internal states in strongly interacting 173Yb fermions.

I will discuss the realization of multi-component SU(N) Fermi-Hubbard systems, where a coherent laser coupling between internal states can induce a controlled breaking of the global interaction symmetry and lead to a flavour-selective Mott localization, in connection with the physics arising in strongly correlated materials from the coupling of different orbitals.

I will also discuss recent experiments where we have measured Hall transport in interacting synthetic ladders, where the laser coupling implements the action of a strong external magnetic field on effectively charged particles. I will show a strong dependence of the Hall response upon changing atom-atom interactions and discuss the direct measurement of Hall voltages and resistances, which provide a direct connection between cold-atom quantum simulators and the measurement of electric-like quantities in solid-state systems.

Invited Talk SYCQ 1.2 Tue 11:15 ZHG008

Realization of Andreev-molecules — •Szabolcs Csonka — MTA-BME Superconducting Nanoelectronics Momentum Research Group, Department of Physics, Budapest University of Technology and Economics

Understanding the spectrum of individual atoms set the start of quantum mechanics 100 years ago and the learnt new concepts helped to understand more complex quantum systems like molecules, solids or superconductors. Present technologies allow us to realize artificial atoms and try to couple them one-by-one to create synthetic state-of-matters. In this talk I will present special molecules, so called Andreev-molecules, which are built up from artificial atoms coupled by superconductors. We will explain the basic properties of an artificial atom coupled to a superconductor; describe the role of crossed Andreev-reflection when more atoms are coupled. Finaly we will present experimental realization of two types of Andreev-molecule: the analog of H_2 and H_2O molecule. The polymerization of such superconducting molecules into a 1D chain is an exciting direction, which holds the promise to realize a topological superconducting system, the Kitaev-chain.

Invited Talk SYCQ 1.3 Tue 11:45 ZHG008

Giant transverse magnetic fluctuations at high fields in UTe_2 — •Kimberly Modic[1], Valeska Zambra[1], Amit Nathwani[1], and Brad Ramshaw[2] — [1]Institute of Science and Technology Austria, 3400 Klosterneuburg, Austria — [2]Cornell University, Ithaca, NY USA

Superconductors offer a rare glimpse into quantum mechanics at a macroscopic scale, making them powerful candidates for next-generation quantum technologies. While most superconducting qubits still rely on conventional materials like aluminum, a new class of unconventional superconductors-featuring exotic properties such as time-reversal symmetry breaking and nodal gaps-could enable new functionalities in quantum devices. Among these, UTe_2 stands out for its extraordinary behavior: it regains its superconducting state at ultra-high magnetic fields above 40 tesla, after initially being suppressed around 10 tesla–a phenomenon known as re-entrant superconductivity. One proposed explanation involves transverse fluctuations of a ferromagnetic order parameter. Yet, UTe_2 shows no clear signs of ferromagnetic order or strong fluctuations in standard magnetization measurements. To probe deeper, we developed a new technique to measure the transverse magnetic susceptibility in pulsed magnetic fields up to 60 tesla. In a manner reminiscent of the transverse field Ising model, large external magnetic fields applied along the b-axis lead to a huge increase in the transverse susceptibility–over 30 times greater than the longitudinal response. These findings suggest that the highly-unusual, magnetic field-enhanced superconductivity of UTe_2 is closely linked to this anisotropic magnetic response.

Invited Talk SYCQ 1.4 Tue 12:15 ZHG008

Emerging platforms to answer basic theoretical questions about correlated quantum matter — •Joel Moore — University of California, Berkeley — Lawrence Berkeley National Laboratory

New insights into correlated quantum materials have been achieved using a variety of experimental platforms and computational approaches that did not exist a few years ago. This talk begins with the example of the quantum Heisenberg chain and its unusual spin superdiffusion at high temperatures, which following initial theoretical predictions has now been observed in neutron scattering off crystals (2021), quantum emulators of ultracold atoms (2022), and gate-based superconducting quantum computers (2023-2024). One can ask more generally which problems in quantum materials are likely to be amenable to new approaches and which are likely to remain challenging at least in the near term. Using examples drawn from different materials classes, particularly spin systems and two-dimensional electronic materials, a guess at the possible sequence of progress in this area is presented.

Symposium Quantum Computing and Communication: Early Days and New Developments (SYCC)

Guido Burkard
University of Konstanz
Universitaetsstrasse 10
78464 Konstanz, Germany
guido.burkard@uni-konstanz.de

Quantum mechanics has transformed our understanding of the physical world. In the last four decades, there has also been an increasing awareness of the implications that quantum physics has for information science and technology. This has led to the thriving field of quantum information science. This symposium brings together some of the pioneers and leading researchers in this field.

Overview of Invited Talks and Sessions

(Lecture hall ZHG010)

Invited Talks

SYCC 1.1	Tue	10:45–11:25	ZHG010	**Founding Concepts for Solid State Quantum Computers** — •David DiVincenzo
SYCC 1.2	Tue	11:25–12:05	ZHG010	**Semiconductor spin qubits - vision, opportunities and challenges** — •Lieven Vandersypen
SYCC 1.3	Tue	12:05–12:45	ZHG010	**Perspectives on Control and Characterization of Temporally Correlated Nonclassical Noise** — •Lorenza Viola

Sessions

SYCC 1.1–1.3	Tue	10:45–12:45	ZHG010	**Quantum Computing and Communication: Early Days and New Developments**

Sessions

– Invited Talks –

SYCC 1: Quantum Computing and Communication: Early Days and New Developments

Time: Tuesday 10:45–12:45 Location: ZHG010

Invited Talk SYCC 1.1 Tue 10:45 ZHG010

Founding Concepts for Solid State Quantum Computers — •David DiVincenzo — QuTech, TU Delft; RWTH Aachen

From 1994 onwards, the question always has been, "when will we have a quantum computer?" The answer was mostly, "a long time from now." But within a few years, new concepts from quantum information came into being that would transform the subject of quantum device physics. Over time, what once were physics experiments have morphed into installations. I will discuss the fact that, throughout these thirty years, the dreams about the "installation" have, time and again, fueled novel scientific insights, both about the nature of quantum computing, but also about the solid-state physics underlying our qubits.

Invited Talk SYCC 1.2 Tue 11:25 ZHG010

Semiconductor spin qubits - vision, opportunities and challenges — •Lieven Vandersypen — QuTech and Kavli Institute of Nanoscience, Delft University of Technology, Delft, Netherlandds

Quantum computation has captivated the minds of many for several decades. For much of that time, it was seen mostly as an extremely interesting scientific problem. In the last few years, we have entered a new phase as the belief has grown that a large-scale quantum computer can actually be built. Quantum bits encoded in the spin state of individual electrons in silicon quantum dot arrays, have emerged as a highly promising direction. In this talk, I will present our vision of a large-scale spin-based quantum processor, and ongoing work to realize this vision.

Recent steps include the realization of high-fidelity multi-qubit registers, novel qubit control schemes, high-fidelity shuttling of electron spins, two-qubit gates implemented on mobile spins, two-qubit gates acting on spins separated by 250 micron. When combined, the progress along these various fronts can lead the way to scalable networks of high-fidelity spin qubit registers for computation and simulation.

Invited Talk SYCC 1.3 Tue 12:05 ZHG010

Perspectives on Control and Characterization of Temporally Correlated Nonclassical Noise — •Lorenza Viola — Dartmouth College, Hanover, NH 03755, USA

Accurate characterization and control of realistic open-quantum system dynamics is vital for exploiting the full potential of quantum technologies. Over the past decade, substantial progress has been made in developing qubit-based quantum noise spectroscopy techniques, which have revealed how realistic noise often exhibits strong correlations both in space and time. Still, even in the simplest setting of a single qubit exposed to pure-dephasing noise, understanding the full implications of modeling the environment as a genuinely quantum, as opposed to a classical system, remains surprisingly subtle. I will revisit the use of dynamical decoupling to protect a single-qubit gate in the presence of dephasing noise that is both temporally correlated and nonclassical, and show how the evolution of the quantum bath statistics causes the gate fidelity to depend strongly on the applied control history even if the system-side error propagation is fully removed through perfect reset operations. As a result, the fidelity can saturate at a value substantially lower than the one achievable with no intervening history. Only if decoupling can keep the qubit highly pure over a timescale larger than the noise correlation time, the bath is shown to approximately re-equilibrate to its original statistics and a stable-in-time control performance is recovered. I will conclude by discussing ongoing extensions to multi-qubit settings and implications for fault-tolerant quantum computation.

Symposium Quantum Physics in Strong Fields (SYSF)

Holger Gies
Friedrich Schiller University Jena
Fröbelstieg 1
07743 Jena, Germany
holger.gies@uni-jena.de

Ralf Schützhold
Helmholtz-Zentrum Dresden-Rossendorf
Bautzner Landstraße 400
01328 Dresden, Germany
r.schuetzhold@hzdr.de

Ultra-strong electromagnetic fields offer a new regime for studying novel fundamental quantum phenomena. They give access to an as yet unexplored territory of physics in addition to the high-energy frontier. The symposium "Strong-field physics" will review recent theoretical and experimental developments in this fascinating area.

Overview of Invited Talks and Sessions

(Lecture hall ZHG104)

Invited Talks

SYSF 1.1	Tue	10:45–11:25	ZHG104	**Nuclear physics with strong electromagnetic fields** — •Adriana Pálffy
SYSF 1.2	Tue	11:25–12:05	ZHG104	**Strong fields and fundamental physics** — •Anton Ilderton
SYSF 1.3	Tue	12:05–12:45	ZHG104	**Weakly coupled new physics in strong fields** — •Babette Döbrich

Sessions

SYSF 1.1–1.3	Tue	10:45–12:45	ZHG104	**Quantum Physics in Strong Fields**

Sessions

– Invited Talks –

SYSF 1: Quantum Physics in Strong Fields

Time: Tuesday 10:45–12:45 Location: ZHG104

Invited Talk SYSF 1.1 Tue 10:45 ZHG104

Nuclear physics with strong electromagnetic fields — •Adriana Pálffy — University of Würzburg, Institute for Theoretical Physics and Astrophysics, 97074 Würzburg

Strong laser-matter interaction traditionally deals with the response of atoms, molecules, and plasmas to external electromagnetic fields. Atomic nuclei have very small dipole moments and show limited response to even the strongest available optical fields. However, progress towards laser sources with increasingly high intensities and higher frequencies opens new opportunities for direct or indirect laser-nucleus interactions.

The talk will review some recent achievements in direct nuclear excitation using laser sources in the vacuum ultraviolet [1] and x-ray regimes [2]. The question on whether strong electromagnetic fields can influence nuclear processes such as alpha decay [3] or fusion [4,5] will be also addressed. Considering indirect and plasma-mediated effects, the prospects of laser-induced secondary reactions or excitation in nuclei and possible future developments will be discussed.

[1] C. Zhang *et al.*, Nature **636**, 603 (2024)
[2] Y. Shvyd'ko *et al.*, Nature **622**, 471 (2023)
[3] A. Pálffy and S. V. Popruzhenko, Phys. Rev. Lett. **124**, 212505 (2020)
[4] F. Queisser and R. Schützhold, Phys. Rev. C **100**, 041601(R) (2019)
[5] N. Thomson, L. Moschini and A. Diaz-Torres, Phys. Rev. C **110**, 034614 (2024)

Invited Talk SYSF 1.2 Tue 11:25 ZHG104

Strong fields and fundamental physics — •Anton Ilderton — Higgs Centre, University of Edinburgh, UK

Strong electromagnetic fields are produced by modern intense laser systems, are found in astrophysical environments, and can be created in collisions of dense particle bunches.

Such strong fields are essentially classical, yet they can be used to probe quantum physics, including properties of the quantum vacuum itself, through processes such as vacuum birefringence. There are even hints that in sufficiently strong fields, quantum electrodynamics may behave very differently compared to how we understand it today.

In this talk I will give an overview of some current activities in the use of strong fields to study fundamental physics, both in electrodynamics and in gravity, where strong-field methods can be applied to the scattering of black holes in the extreme-mass-ratio regime.

Invited Talk SYSF 1.3 Tue 12:05 ZHG104

Weakly coupled new physics in strong fields — •Babette Döbrich — Max Planck Institute for Physics

Strong electromagnetic fields are an exquisite ingredient in searches for weakly coupled physics. Such physics is proposed to extend the Standard Model of particle physics, among else to help to explain Dark Matter. In my talk, I will exemplify this statement and will highlight how axions over a wide set of mass scales can be searched exploiting their coupling to two photons: From laboratory setups to the use of large-scale accelerator infrastructure.

Symposium The Charm of Unconventional Hadrons (SYUH)

Sebastian Neubert
University of Bonn
Nussallee 14-16
53115 Bonn, Germany
neubert@hiskp.uni-bonn.de

The strong interaction is the dominating force inside the atomic nucleus, binding quarks into nucleons and determining the dynamics of nuclear matter. Recent years have seen the discovery of multiple objects, where quarks are bound into unconventional configurations, beyond the long established quark model. This symposium will trace how experiments with heavy quarks have lead to spectacular breakthroughs and shed new light on long standing questions on the physics of quarks.

Overview of Invited Talks and Sessions

(Lecture hall ZHG105)

Invited Talks

SYUH 1.1	Tue	10:45–11:00	ZHG105	**The social life of quarks** — •Marek Karliner
SYUH 1.2	Tue	11:00–11:15	ZHG105	**The enigmatic strong interaction** — •Christoph Hanhart
SYUH 1.3	Tue	11:15–11:30	ZHG105	**Paving the future: new experimental approaches to subatomic forces** — •Chiara Pinto
SYUH 1.4	Tue	11:30–11:45	ZHG105	**Tracks and Tetraquarks** — •Mikhail Mikhasenko

Sessions

SYUH 1.1–1.5	Tue	10:45–12:30	ZHG105	**The Charm of Unconventional Hadrons**

Sessions

– Invited Talks and Discussions –

SYUH 1: The Charm of Unconventional Hadrons

Time: Tuesday 10:45–12:30 Location: ZHG105

Invited Talk SYUH 1.1 Tue 10:45 ZHG105

The social life of quarks — •Marek Karliner — School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel

In the recent years experiments in high energy accelerators have discovered a large number of unusual heavy ”cousins” of the proton, i.e. strongly-interacting particles, collectively known as hadrons. Ordinary hadrons are either baryons, containing three quarks, or mesons containing a quark and an anti-quark. The new unusual hadrons contain either two quarks and two antiquarks, in which case they are known as tetraquarks, or four quarks and an antiquark, and are known as pentaquarks. They are often referred to as multiquark, or exotic hadrons. With the large number of such exotics discovered so far, it becomes increasingly important to discuss what additional multiquark states are likely to be observed and how are quarks organized in these exotic hadrons. In my talk I will discuss both questions, providing some guidelines about essential differences between the two types of exotics.

Invited Talk SYUH 1.2 Tue 11:00 ZHG105

The enigmatic strong interaction — •Christoph Hanhart — IAS-4, Forschungszentrum Jülich, Jülich

It is the strong interaction that is responsible for forming nuclei, the cores of atoms, by binding protons and neutrons together. The same force, albeit with a quite different mechanism, is also creating protons and neutrons themselves by forming bound states of quarks and gluons. The strong interaction still is the least understood part of the Standard Model*even though the underlying theory, Quantum Chromodynamics (QCD), has been known for several decades. In this presentation the key features of QCD are reviewed and observable consequences presented.

Invited Talk SYUH 1.3 Tue 11:15 ZHG105

Paving the future: new experimental approaches to subatomic forces — •Chiara Pinto — CERN, Geneva, Switzerland

Investigating the strong interaction among hadrons remains one of the central challenges in modern nuclear and particle physics. In recent years, innovative experimental techniques have been developed to probe this fundamental force. Among them, femtoscopy enables the study of particle correlations at femtometer scales, while the measurement of hypernuclei -nuclei containing a strange baryon- offers unique insights into the strong interaction in systems beyond ordinary matter. This contribution presents the current status of these measurements at the Large Hadron Collider, along with an outlook on upcoming experimental programs aimed at advancing our understanding of the structure and dynamics of subatomic systems.

Invited Talk SYUH 1.4 Tue 11:30 ZHG105

Tracks and Tetraquarks — •Mikhail Mikhasenko — Ruhr Universität Bochum, Germany

Over the past century, our ability to observe the quantum world has progressed from foggy trails in bubble chambers to sharp images of fleeting subatomic events. The Large Hadron Collider and its dedicated beauty experiment, LHCb, represent the pinnacle of this technological evolution—machines that have grown ever larger and more precise, driving forward both fundamental science and technological innovation. Among the most intriguing results are exotic hadrons—unusual combinations of quarks that challenge the traditional view of how matter is bound. This talk will trace the experimental journey that led to the discovery of this growing zoo of heavy exotic particles and explore how the long-standing dream of observing a tetraquark stable under the strong interaction is becoming less elusive.

Discussion SYUH 1.5 Tue 11:45 ZHG105

Charmed by hadrons - a flavorful debate — •Sebastian Neubert[1], Chiara Pinto[2], Christoph Hanhart[3], Marek Karliner[4], and Mikhail Mikhasenko[5] — [1]Universität Bonn — [2]CERN — [3]Forschungszentrum Jülich — [4]Tel Aviv University — [5]Ruhr Universität Bochum

The interplay between theory and experimental efforts is crucial for the advancement of our understanding of the strong interaction and its complex spectrum of bound states. The scientific discourse of the field is not only driven by the search for new methodologies, but also by the quest for the most useful paradigms and degrees of freedom to describe the world of quarks. It is often characterized by debates on seemingly disparate concepts of the nature of hadrons. Subatomic molecules or compact multiquark systems can all explain part of the phenomena observed, but a unifying picture seems elusive. The four speakers of this symposium will engage in a panel discussion and bring this debate to the audience, to share the intrigue around those fascinating quantum systems and discuss avenues into future research of the most mysterious of the fundamental interactions.

Tuesday Contributed Sessions (TUE)

Stefan Kehrein
Fakultät für Physik
Universität Göttingen
Friedrich-Hund-Platz 1
37077 Göttingen, Germany
stefan.kehrein@theorie.physik.uni-goettingen.de

Thomas Weitz
Fakultät für Physik
Universität Göttingen
Friedrich-Hund-Platz 1
37077 Göttingen, Germany
thomas.weitz@uni-goettingen.de

Overview of Sessions

(Lecture halls ZHG001, ZHG002, ZHG003, ZHG004, ZHG006, ZHG007, ZHG008, ZHG009, ZHG101, ZHG103, ZHG104, and ZHG105)

Sessions

TUE 1.1–1.7	Tue	14:15–16:00	ZHG001	**QIP Implementations: Photons III**
TUE 2.1–2.8	Tue	14:15–16:15	ZHG002	**Quantum Networks: Technologies**
TUE 3.1–3.7	Tue	14:15–16:00	ZHG003	**Quantum Field Theory**
TUE 4.1–4.7	Tue	14:15–16:00	ZHG004	**Education and Outreach**
TUE 5.1–5.7	Tue	14:15–16:00	ZHG006	**QIP Certification and Benchmarking**
TUE 6.1–6.7	Tue	14:15–16:00	ZHG007	**Quantum Computing and Communication: Contributed Session I (Algorithms & Theory)**
TUE 7.1–7.6	Tue	14:15–15:45	ZHG008	**Entanglement and Complexity: Contributed Session to Symposium I**
TUE 8.1–8.7	Tue	14:15–16:00	ZHG009	**Correlated Quantum Matter: Contributed Session to Symposium I**
TUE 9.1–9.8	Tue	14:15–16:15	ZHG101	**Quantum Physics in Strong Fields: Contributed Session to Symposium**
TUE 10.1–10.8	Tue	14:15–16:15	ZHG103	**Foundational / Mathematical Aspects – Rigorous Results**
TUE 11.1–11.8	Tue	14:15–16:15	ZHG104	**Quantum Optics and Quantum Computation**
TUE 12.1–12.7	Tue	14:15–16:00	ZHG105	**Quantum Sensing and Decoherence: Contributed Session to Symposium III**

Sessions

– Talks –

TUE 1: QIP Implementations: Photons III

Time: Tuesday 14:15–16:00 Location: ZHG001

TUE 1.1 Tue 14:15 ZHG001

Bose-Einstein Condensation of Photons in Lattice Potentials — •Andreas Redmann, Christian Kurtscheid, Niels Wolf, Frank Vewinger, Julian Schmitt, and Martin Weitz — Institut für Angewandte Physik, Universität Bonn, Germany

Thermalization of radiation by contact to matter is a well-known concept, but the application of thermodynamic methods to complex quantum states of light remains a challenge. Using a controlled mirror surface delamination technique to imprint micro-wells in different lattice geometries [1,2], we study thermalization of light in a dye-filled microcavity at room temperature in variable trapping potentials.

In recent work, we have demonstrated Bose-Einstein condensation of photons in a four-site quantum ring [3]. We observe macroscopic accumulation of photons in the ground state with no phase winding above a critical photon number. In other work, we have thermalised photons in a double well system, realizing the textbook-character problem of N bosons populating a two-state system.

[1] C. Kurtscheid et al., Science 366, 894-897 (2019)
[2] C. Kurtscheid et al., EPL 130, 54001 (2020)
[3] A. Redmann et al., Phys. Rev. Lett. 133, 093602 (2024)

TUE 1.2 Tue 14:30 ZHG001

Hollow-core light cages: Towards scalable multiplexed quantum memories — •Esteban Gómez-López[1], Dominik Ritter[1], Jisoo Kim[2], Harald Kübler[3], Markus A. Schmidt[2,4], and Oliver Benson[1] — [1]Humboldt-Universität zu Berlin, Berlin, Germany — [2]Leibniz Institute of Photonic Technology, Jena, Germany — [3]Universität Stuttgart, Stuttgart, Germany — [4]Otto Schott Institute of Material Research, Jena, Germany

Quantum memories play a fundamental role in synchronizing quantum network nodes. Using electromagnetically induced transparency (EIT) in hot atomic vapors provides easy-to-handle systems capable of storing light for up to seconds [1]. Employing a novel photonic structure -a nanoprinted hollow-core light cage (LC)- can enhance the effects of EIT when interfaced with Cs vapor, offering the advantage of faster atomic diffusion inside the core compared to other hollow-core structures [2]. In this work, we show the storage of faint coherent light pulses in the atomic medium confined within the core of the LC for hundreds of nanoseconds. The intrinsic efficiency of the memory was optimized by performing a parameter scan on the signal bandwidth and control power driving the memory [3]. This paves the way towards an on-chip integrated module for quantum memories and as a platform for coherent interaction of light and warm atomic vapors. [1] Katz, O. and Firstenberg, O., Nat. Commun. 9, 2074 (2018). [2] Davidson-Marquis, F., et al., Light. Sci. Appl. 10, 114 (2021). [3] Gómez-López, E., et al., Preprint: arXiv:2503.22423 (2025).

TUE 1.3 Tue 14:45 ZHG001

Storage of single photons from a semiconductor quantum dot in a room-temperature atomic vapor memory with on-demand retrieval — •Benjamin Maass[1,2], Avijit Barua[2], Norman Vincenz Ewald[1], Elizabeth Jane Robertson[1], Kartik Gaur[2], Suk In Park[3], Sven Rodt[2], Jin-Dong Song[3], Stephan Reitzenstein[2], and Janik Wolters[1,2,4] — [1]Institute of Space Research, German Aerospace Center (DLR), Germany — [2]Institutes of Physics, Technische Universität Berlin, Germany — [3]Korean Institute of Technology, Seoul, Republic of Korea — [4]Einstein Center Digital Future (ECDF), Berlin, Germany

On-demand storage and retrieval of single photons in coherent light-matter interfaces is a key requirement for distributing quantum information. Here, we demonstrate storage of single photons from a semiconductor quantum dot device in a room-temperature atomic vapor memory and their on-demand retrieval [1]. A deterministically fabricated InGaAs quantum dot light source emits single photons at the cesium D1 transition wavelength (895 nm) with a linewidth of 5.1(7) GHz which are subsequently stored in a low-noise ladder-type cesium vapor memory. We show control over the interaction between the single photons and the atomic vapor, allowing for variable retrieval times of up to 19.8(3) ns and a maximum internal efficiency of $\eta_{\text{int}} = 0.6(1)\%$. This QD-memory interface provides an unprecedented level of control over the temporal mode of the single-photon emitter and represents a step towards heterogeneous platforms for quantum network nodes.

[1] B.Maaß et al. arXiv:2501.15663 (2025)

TUE 1.4 Tue 15:00 ZHG001

Stark Effect Limitations in Optical Addressing of Phosphorus Donors in Si-28 — •Nico Eggeling[1], Jens Hübner[1], Michael Oestreich[1], and N.V. Abrosimov[2] — [1]Leibniz Universität Hannover, Germany — [2]IKZ Berlin, Germany

Phosphorus donors in isotopically pure Si-28 serve as powerful qubits in electrical measurements. Combining these donors with optical methods seems highly promising[1]. However, surprisingly, spectral hole-burning experiments have not yet achieved Fourier-limited line shapes, a crucial requirement for efficient optical addressing[2]. For the first time on Si-28, we employ time-resolved spectral hole-burning spectroscopy to demonstrate that the primary cause is a random quadratic Stark-Effect, rooted in the formation of ionized donor-acceptor pairs. Monte Carlo simulations validate that the unavoidable acceptor background doping in silicon is responsible for this limitation and open a method to suppress the influence of these acceptors efficiently. This approach not only improves the optical performance of phosphorus-doped Si-28 but also paves the way for the further advancement of solid-state qubits.

[1] Sauter et al., Phys. Rev. Lett. **126**, 137402 (2021)
[2] Yang et al., Appl. Phys. Lett. **95**, 122113 (2009)

TUE 1.5 Tue 15:15 ZHG001

Experimental quantum metrology for fast-varying systems — •Lukas Rückle[1,2] and Stefanie Barz[1,2] — [1]Institute for Functional Matter and Quantum Technologies, Universitity of Stuttgart, 70569 Stuttgart, Germany — [2]Center for Integrated Quantum Science and Technology (IQST), University of Stuttgart, 70569 Stuttgart, Germany

The use of quantum states for metrology tasks has been proven to surpass classical limits on the precision of estimating parameters. Recently, the framework of probably approximate correct (PAC) metrology has been introduced. It not only enables the estimation of a parameter in an arbitrarily big parameter space without prior knowledge, but also gives bounds for few- and single-shot metrology settings. It thus bridges the rather theoretical case of performing infinitely many measurements and practical metrology tasks.

Here, we present experimental results in a photonic metrology setting. We show how to use different states and measurements and how for each case to optimize the prediction strategy of the parameter that shall be estimated. Our work shows how to implement the given new framework of PAC metrology and thus helps improving the precision of applications that only allow for a few measurements, e.g. when measuring fast varying systems.

TUE 1.6 Tue 15:30 ZHG001

Hetero-integration of diamond nanostructures on AlGaN-based photonic circuits — •Domenica Romina Bermeo Alvaro[1,2], Sinan Gündogdu[1,2], Lea M. Rektorschek[2], Pascal Frehle[2], Marco E. Stucki[1,2], Maarten H. van der Hoeven[2], Julian M. Bopp[2,1], Tim Kolbe[2], Sylvia Hagedorn[2], Markus Weyers[2], Tommaso Pregnolato[1,2], and Tim Schröder[2,1] — [1]Ferdinand-Braun-Institut (FBH), Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany — [2]Department of Physics, Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Germany

Spin-photon interfaces are crucial for the development of large quantum networks. A highly efficient spin-photon interface can be achieved when diamond color centers are embedded in photonic crystal cavities, which enhance the light-matter interaction and boost the emission rate of photons generated by the coherent zero-phonon-line transition. While the diamond substrate allows for the nanofabrication of such devices, achieving a monolithic platform that will take advantage of those photonic crystal cavities on a large scale remains a challenge. To overcome these limitations, we propose the hetero-integration of diamond nanostructures into AlGaN-based photonic circuits. By embedding diamond nanostructures within AlGaN-based circuits, we aim to create highly efficient, scalable spin-photon interfaces. Our approach involves the design, fabrication and characterization of a low-loss coupling section between diamond and AlGaN waveguides. Finally, we show the first integration on an AlGaN-based photonic circuit of a Sawfish cavity, our newly proposed photonic crystal cavity.

TUE 1.7 Tue 15:45 ZHG001

Experimental Quantum Strong Coin Flipping using a Deterministic Single-Photon Source — •Koray Kaymazlar[1], Daniel Vajner[1], Fenja Drauschke[2], Lucas Rickert[1], Martin von Helversen[1], Shulun Li[3], Zhichuan Niu[3], Anna Pappa[2], and Tobias Heindel[1] — [1]Institute of Physics and Astronomy, Technische Univeristät Berlin, Germany — [2]Electrical Engineering and Computer Science Department, Technische Univeristät Berlin, Germany — [3]Institute of Semiconductors, Chinese Academy of Sciences, Beijing, China

Strong coin flipping (SCF) is a fundamental cryptographic protocol allowing two distrustful parties to agree on randomly generated bit. In this work, we report the first implementation of a quantum strong coin flipping protocol that yields a quantum advantage compared to both its classical counterpart and an implementation using weak coherent pulses [1]. The quantum advantage is enabled by employing a state-of-the-art deterministic single-photon source based on a quantum dot embedded in a high-Purcell microcavity. Using a fiber-based electro-optic modulator (EOM) we realize fast dynamic, random polarization-state encoding at 80 MHz clock-rate. Our QSCF implementation enables a coin flipping rate of 1.5 kHz and an average quantum bit error ratio (QBER) below 3%, sufficient to realize a quantum advantage.

[1] D. A. Vajner, K. Kaymazlar, F. Drauschke, L. Rickert, M. von Helversen, H. Liu, S. Li, H. Ni, Z. Niu, A. Pappa, T. Heindel, Single-Photon Advantage in Quantum Cryptography Beyond QKD, arXiv:2412.14993 (2024)

TUE 2: Quantum Networks: Technologies

Time: Tuesday 14:15–16:15 Location: ZHG002

TUE 2.1 Tue 14:15 ZHG002

Quantum Dots for Quantum Networks — •Klaus D. Jöns — PhoQS Institute, CeOPP, and Department of Physics, Paderborn University

Germany has started more than a decade ago to invest in a platform-agnostic approach to quantum repeaters, funding multiple technological pathways, including semiconductor-based quantum dots as one of the brightest quantum light sources. I will highlight some of the remarkable achievements based on quantum dots and discuss the feasibility of on-demand generation of entangled photon pairs for quantum repeaters architectures that integrate external quantum memories. I will critically discuss bottlenecks and challenges to deploy quantum dots and put our results in a broader perspective.

TUE 2.2 Tue 14:30 ZHG002

Development of Site-Controlled Quantum Dot Arrays for Multicore-Fiber-Coupled Quantum-Communication Source Modules — •Martin Podhorský[1], Maximilian Klonz[1], Lux Böhmer[1], Sebastian Kulig[1], Phillip Manley[2], Martin Hammerschmidt[2], Stefan Link[3], Gunnar Böttger[3], Henning Schröder[3], Nikolay Ledentsov[4], Vitaly Shchukin[4], Sven Rodt[1], and Stephan Reizenstein[1] — [1]Institut für Physik und Astronomie, Technische Universität Berlin, Hardenbergstraße 36, D-10623 Berlin, Germany — [2]JCMwave GmbH, Bolivarallee 22, 14050 Berlin, Germany — [3]Fraunhofer IZM, G.-Meyer-Allee 25, 13355 Berlin, Germany — [4]VI Systems GmbH, Hardenbergstr. 7, 10623 Berlin, Germany

Fiber-based optical quantum communication is emerging as a robust alternative for traditional secure data transfer. We propose a monolithic device in which classical and quantum communication channels can be realised simultaneously using semiconductor quantum dots embedded in resonant cavities. We report on growth of positioned InGaAs quantum dots via the buried stressor method, achieving high precision, uniformity and reproducibility of the quantum dot placement. A detailed statistical analysis shows controlled quantum dot density variation and positioning accuracy. Furthermore, we present a micro-manufactured glass holder design for a passive multicore-fiber-coupling process, enabling scalable, efficient, and practical utilisation in quantum communication networks.

TUE 2.3 Tue 14:45 ZHG002

Building Blocks for Hybrid Quantum Repeaters — •Marlon Schäfer, Tobias Bauer, Pascal Baumgart, Max Bergerhoff, Christian Haen, Dennis Herrmann, David Lindler, Jonas Meiers, Robert Morsch, Jürgen Eschner, and Christoph Becher — Universität des Saarlandes, Fachrichtung Physik, Campus E2 6, 66123 Saarbrücken

Large-scale quantum networks require the development of quantum repeaters capable of high-fidelity entanglement distribution over long distances. We report progress toward heterogeneous quantum repeater nodes that integrate solid-state and atomic platforms. Specifically, tin-vacancy (SnV) centers in diamond and trapped calcium ions ($^{40}Ca^+$) are employed as quantum memories, with quantum frequency conversion bridging their respective emission to the low-loss telecom band. We demonstrate frequency conversion of indistinguishable photons from SnV centers and $^{40}Ca^+$ ions, and present results on quantum interference between photons emitted by these systems. To evaluate performance under realistic conditions, we operate a 14 km-long urban fiber testbed with a stable frequency reference frame distributed over the fiber link. These results represent critical steps toward scalable, hybrid quantum repeater architectures.

TUE 2.4 Tue 15:00 ZHG002

Automated Large-Scale Characterization of Solid-State Color Centers for Quantum Communication — •Julian M. Bopp[1,2], Maarten H. van der Hoeven[1], Marco E. Stucki[1,2], Tommaso Pregnolato[1,2], and Tim Schröder[1,2] — [1]Department of Physics, Humboldt-Universität zu Berlin, 12489 Berlin, Germany — [2]Ferdinand-Braun-Institut (FBH), 12489 Berlin, Germany

Extending quantum networks toward a global quantum internet requires the serial-production of standardized building blocks, including highly efficient spin-photon interfaces. Due to variations in the local environment of optically active solid-state spin qubits, like diamond color centers, their quality differs spatially across sample substrates. Consequently, all spin qubits have to be characterized thoroughly before incorporating them into quantum network building blocks. However, characterization experiments are time-consuming since they regularly involve addressing qubits manually with a confocal microscope.

Paving the way toward the deterministic fabrication of quantum network building blocks on the wafer scale, we present the fully automated large-scale characterization of such solid-state qubits employing a combined widefield and confocal microscope. Moreover, we employ means of artificial intelligence to classify hundreds of acquired spectra and second-order correlation functions. Our approach enables the automated selection of qubits that are best suitable for quantum networking and the statistical investigation of sample treatment effects on the qubits [1].

[1] E. Corte et al., Adv. Photonics Res. 3, 2100148 (2021)

TUE 2.5 Tue 15:15 ZHG002

Quantum networking with microfabricated atomic vapor cells — •Roberto Mottola, Gianni Buser, Suyash Gaikwad, and Philipp Treutlein — Universität Basel, Basel, Schweiz

Quantum memories for photons are building blocks of quantum networks. Memories implemented in hot alkali vapor are attractive as they operate due to their technological simplicity and have been proven to perform well in a multitude of figures of merit [1]. In [2] we report on an elementary, hybrid network interconnect. We combine a low-noise quantum memory implemented in hot Rb vapor based on electromagnetically induced transparency with a tailored downconversion source. By spin polarizing the atomic ensemble and exploiting polarization selection rules we were able to significantly reduce the noise of the memory. This allowed us to observe for the first time a non-classical $g^{(2)}_{ret}$ for photons stored and retrieved in a broadband, ground-state alkali vapor quantum memory - yielding a measured $g^{(2)}_{ret} = 0.177(23)$ well below the classical limit of 1. Realistic visions of large-scale networks require a scalable and mass-producible platform. In this respect, microfabricated vapor cells are very promising. MEMS fabrication techniques have already been successfully used to miniaturize atomic quantum sensors, as atomic clocks, magnetometers, and gyroscopes. We report on the first implementation of an alkali vapor memory in microfabricated Rb cells compatible with wafer-scale mass production [3] - a crucial step towards scalability. [1] C. Simon et al., *Eur. Phys. J. D* **58**, 1–22 (2010). [2] G. Buser et al., *PRX Quantum* **3**, 020349 (2022). [3] R. Mottola et al., *Phys. Rev. Lett.* **131**, 260801 (2023).

TUE 2.6 Tue 15:30 ZHG002

Evaluating Cavity-enhanced Telecom-wavelength Quantum Dot Single-photon Sources for Quantum Cryptography — •Robert Behrends[1], Koray Kaymazlar[1], Mareike Lach[1], Martin v. Helversen[1], Pratim Saha[1], Daniel Vajner[1], Jochen Knaupp[2], Yorick Reum[2], Tobias Huber-Loyola[2], Sven Höfling[2], Andreas Pfenning[2], and Tobias Heindel[1] — [1]Institute of Physics and Astronomy, Technische Univeristät Berlin, 10623 Berlin, Germany — [2]Technische Physik, Physikalisches Institut and Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Great advances are made in the fabrication of telecom-wavelength quantum light sources based on semiconductor quantum dots (QDs)[1]. Yet, further progress is needed towards practical applications. Here, we evaluate QD-based single-photon sources for applications in quantum cryptography in the telecom C-band. Exploiting cavity-enhanced devices with embedded InAs/InAlGaAs QDs, we achieve emitter lifetimes of 500 ps and g(2)(0)=0.044 under pulsed quasi-resonant excitation. Employed in a quantum cryptography testbed, we investigate dynamic polarization-state encoding using a customized fiber-coupled electro-optic modulator in single-pass configuration, which is controlled by an arbitrary waveform generator. The random preparation of four polarization states with low loss and low quantum bit error ratio thereby is crucial for applications in quantum key distribution and beyond[2].

[1] Holewa et al., Nanophotonics, 10.1515/nanoph-2024-0747 (2025)
[2] Vajner et al., arXiv:2412.14993 (2024)

TUE 2.7 Tue 15:45 ZHG002

Integrated quantum network nodes — •Jonas C. J. Zatsch[1,2], Tim Engling[1,2], Jeldrik Huster[1,2], Louis L. Hohmann[1,2], Shreya Kumar[1,2], and Stefanie Barz[1,2] — [1]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, 70569 Stuttgart, Germany — [2]Center for Integrated Quantum Science and Technology (IQST)

Quantum networks require both local quantum information processing and the transmission of quantum information across the network. Integrated photonic circuits are promising candidates for quantum nodes, as they offer a compact footprint and scalability, while optical fibres allow for low-loss transmission between such nodes. A key challenge is the transfer of quantum states generated or manipulated on-chip to the network; and vice versa. Here, we present a silicon-on-insulator integrated photonic circuit capable of high-fidelity preparation of two-qubit states, which can be transferred to optical networks. In turn, quantum states sent over an optical network can be analysed using the same chip. We demonstrate its functionality by preparing different two-qubit states on-chip and transferring them to fibres. Additionally, we show its reverse operation by using the chip as a two-qubit quantum state tomography unit for an off-chip prepared state. This bidirectional operation makes our chip a versatile platform for the implementation of quantum networked protocols.

TUE 2.8 Tue 16:00 ZHG002

Synchronization of remote Time Taggers for quantum communication applications — •Mickey Martini, Edoardo Mornacchi, Timon Eichhorn, Jan Bruin, and Mirco Kolarczik — Swabian Instruments GmbH, Stuttgart, Germany

Synchronous detection of photon events at large distances is a key enabler for quantum communication. While local Time Taggers reach a timing resolution below 2 ps, synchronization of Time Taggers on the scale of kilometers at a comparable resolution level is a challenge. The precise correlation between photon streams and characterization of single events within the stream allows for advanced filtering mechanisms that can target for suppression of background noise as well as for recognition of attacks on the communication channel. The impact of these approaches depends strongly on the effective timing resolution of the synchronized time-tagging system.

In this presentation, we give an overview of software components that contribute to a flexible and easy-to-use synchronization solution. As a first level of synchronization, we demonstrate the use of commercially available White Rabbit (WR) technology for clock distribution. WR promises sub-nanosecond accuracy (clock offsets) at picosecond precision (clock stabilization). We demonstrate that the additional jitter of such a system is below 4 ps. To handle the data from remote sites, we present a merging solution based on standard network protocols. Finally, we provide insights into the development of a second synchronization layer that aligns the photon streams.

TUE 3: Quantum Field Theory

Time: Tuesday 14:15–16:00 Location: ZHG003

TUE 3.1 Tue 14:15 ZHG003

Photonic simulation of quantum field dynamics — •Mauro D'Achille[1], Martin Gärttner[1], and Tobias Haas[2] — [1]Friedrich-Schiller-Universität Jena — [2]Universität Ulm

Photonic multimode systems are an emerging quantum simulation platform ideally suited for emulating non-equilibrium problems in quantum field theory.

I will present a new decomposition for the time evolution generated by a large class of field-theoretic quadratic Hamiltonians in terms of optical elements. The peculiarity of this decomposition consists in the way the time parameter is taken into account. Indeed, for such a class, it is always possible to decouple the time evolution in time-dependent phase shifters by means of a proper time-independent symplectic transformation composed by squeezers and beam splitters.

I will conclude with physically relevant examples and applications aimed to analyze and simulate how the entanglement entropy associated to local and non-local theories spreads over time.

TUE 3.2 Tue 14:30 ZHG003

Topologically Charged Vortices at Superconductor/Quantum Hall Interfaces — •Enderalp Yakaboylu and Thomas L Schmidt — Department of Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg

We explore interface states between two paradigmatic mesoscopic many-body quantum phases: a type-II s-wave superconductor (SC) and a Chern insulator in the $\nu = 1$ quantum Hall (QH) regime. We show that effective interactions at the SC/QH boundary give rise to two emergent Abelian Higgs fields, representing paired electrons localized at the interface. These fields couple through a Chern-Simons term originating from the QH sector, which induces a topological mass for photons and imparts a fractional topological charge to the interface vortices. These findings, particularly the emergence of vortices carrying fractional charge, corresponding to Abelian anyons, bridge topological condensed matter physics and quantum information science, suggesting a new platform for engineering anyonic excitations and advancing toward fault-tolerant topological quantum computation.

TUE 3.3 Tue 14:45 ZHG003

Quark confinement due to unified magnetic monopoles and vortices reduced from symmetric instantons with holography — •Kei-Ichi Kondo — Chiba University, Chiba 263-8522, Japan

We present a new rigorous scheme for understanding quark confinement based on the non-perturbative vacuum disordered by some topological defects. We start from the 4-dim. Euclidean Yang-Mills theory and require the conformal equivalence between the 4-dim.Euclidean space and the possible curved spacetimes with some compact dimensions. This requirement forces us to restrict the gauge configurations of 4-dim.Yang-Mills instantons to those with some space symmetries (called symmetric instantons) which are identified with magnetic monopoles and vortices living in the lower-dimensional curved spacetime with non-zero curvature through the dimensional reduction. The new scheme gives the direct built-in equivalence between (3-dim.hyperbolic) magnetic monopoles (of Atiyah type) and (2-dim.hyperbolic) vortices (of Witten-Manton type), which have been assumed without any rigorous proof to be the dominant contributors to quark confinement. This unified treatment of two topological defects is shown to give the semi-classical picture for quark confinement in the sense of Wilson. At the same time, this scheme caused by the dimensional reduction give a holographic description of magnetic monopole dominance on AdS3 in the rigorous way without any further assumptions. Moreover, the asymptotic freedom is also shown to be derived by performing the pertutbative deformation on the vacuum with these topological defects. [Paper in preparation to be submitted to ArXiv]

TUE 3.4 Tue 15:00 ZHG003

Spinorial Superspaces and Supersymmetric Yang-Mills Theories — •Johannes Moerland — University of Göttingen

In physics literature about supersymmetry, many authors refer to "super Minkowski spaces". These spaces are extensions of ordinary Minkowski spaces by spinorial directions. More abstractly, super Minkowski spaces are affine supermanifolds (i.e., locally ringed spaces with a $\mathbb{Z}_2$-graded algebra of functions) with distinguished spin structures.

In this talk, we formalise these spin structures, allowing us to generalise the setup to curved supermanifolds. Apart from the possibility of formulating field theories on topologically non-trivial superspaces, our approach bears two advantages: Firstly, the language of graded geometry allows for a global and inherently coordinate-free formulation of field theories on the superspace. Secondly, the approach to superspaces via graded geometry endows many algebraic manipulations with a concise geometric meaning. For example, the Dirac γ matrices can be identified with the torsion of the superspace along the spinorial directions.

After exploring the geometric properties of spinorial superspaces, we apply the rather general theory to $\mathcal{N} = 1$ super Yang-Mills theories on curved superspaces of space-time dimensions 3 and 4 and show that the effective theory on an embedded ordinary space-time manifold, obtained by integrating over the spinorial directions, reproduces a coupled system of Yang-Mills and twisted Dirac Lagrangians.

TUE 3.5 Tue 15:15 ZHG003

A short review of the worldline approach to strong-field QED — •Christian Schubert — Facultad de Ciencias Físico-Matemáticas, Universidad Michoacana de San Nicolás de Hidalgo, Avenida Francisco J. Mújica, 58060 Morelia, Michoacán, Mexico

The worldline formalism offers an alternative to the standard Feynman diagram approach in QED that has been found particularly efficient for processes in external field, primarily because it avoids the segmenting of fermion lines or loops into individual propagators. Here I will give a short summary of the method and its present range of applications, with examples ranging from Schwinger pair creation in various types of electric fields to photon-graviton conversion in a magnetic field.

TUE 3.6 Tue 15:30 ZHG003

Measurement of the Casimir force during free fall — •Sascha Kulas — International University of Applied Sciences (IU), Hannover, Germany

The Casimir force still has a lot of unknown aspects. Here this force is measured in a tuning fork experiment during free fall and compared with a measurement on ground. It seems like the Casimir force is strongly suppressed during fall. This is a hint that the Casimir force does not have its origin in the Van der Waals force, which would not change in reduced gravity. Independent drop tower experiments have to validate these results. Further conclusions concerning gravity and Dark Energy are raised by establishing a first phenomenological approach based on the measurement results and Verlindes entropic gravity. The main conclusion is that Dark Energy is coupled to baryonic matter.

TUE 3.7 Tue 15:45 ZHG003

Forward Physics at the LHC — •Rainer Schicker — Phys. Institute, Heidelberg University

Quantum-Chromodynamics (QCD) was formulated 50 years ago as a gauge theory for describing the interaction between quarks and gluons. The underlying SU(3) symmetry of the color degree of freedom leads to self-couplings of gluons, which results in two very intriguing features of QCD, confinement and asymptotic freedom. A perturbative treatment of QCD processes is only possible for large momentum transfers Q^2. The nonperturbative sector of QCD still carries many mysteries which are very poorly understood, or not at all. Many of these enigmas reveal their nature in soft interactions which are experimentally accessible in forward and very forward measurements at the LHC.

I will outline how future forward measurements at the LHC could contribute to shed light on the many unsolved mysteries of nonperturbative QCD.

TUE 4: Education and Outreach

Time: Tuesday 14:15–16:00 Location: ZHG004

TUE 4.1 Tue 14:15 ZHG004

Shaping Quantum Education: National Networks, European Programs, and the CFQT — •Franziska Greinert and Rainer Müller — Technische Universität Braunschweig, Institut für Fachdidaktik der Naturwissenschaften

As quantum technologies approach industrial application, education systems face increasing pressure to respond to emerging skill demands. This talk outlines current initiatives – from a German educator network to European programs – aimed at building quantum competences across sectors. A central focus lies on the European Competence Framework for Quantum Technologies (CFQT), developed through iterative research and stakeholder engagement. The CFQT provides a structured model for mapping and comparing competences, supporting curriculum planning and workforce development. The talk introduces the CFQT with selected use cases, highlighting its role in aligning education with evolving quantum workforce needs.

TUE 4.2 Tue 14:30 ZHG004

Heisenberg's Philosophy of Quantum Mechanics: A Road to Pragmatic Positivism — •Kanan Purkayastha — The Philosophical Society, Oxford, United Kingdom

One of the key figures in the development of quantum mechanics was Werner Heisenberg (1901-1976). Heisenberg developed both the first quantum mechanical mathematical framework, matrix mechanics. He also outlined the philosophical basis underpinning it, named thereafter the *uncertainty principle.*

On the other hand, a central contribution to the understanding of science in general and physics in particular, is the naturalistic analysis of the subject by philosopher Willard Van Orman Quine (1908-2000). This is evident in Quine*s works on the nature of language. Within Heisenberg*s writings there is a substantial attention directed to analysing nature of language, and especially its relation to epistemic questions within science.

This paper argues that in spite of Heisenberg being a physicist working in an area of quantum mechanics and Quine being an analytic philosopher concerned with the broader questions of epistemology both of them are led to strikingly similar conclusions about the nature of reality. Also, the abstract account of how science progresses that Quine provides matches closely with the Heisenberg's philosophical ideas of how science in general and physics in particular makes crucial advances. The paper concludes that both Heisenberg and Quine opt for a pragmatic positivism rather than logical positivism.

TUE 4.3 Tue 14:45 ZHG004

Quantencomputer in der Oberstufe: Unterrichtsmaterial für MINT-Fächer und für einen Projektkurs im Abitur — •Jörg Gutschank[1,3] und Jörg Thorwart[2,4] — [1]Leibniz Gymnasium, Dortmund, Germany — [2]Albert-Einstein-Gymnasium, Ulm, Germany — [3]Science on Stage Germany, Berlin, Germany — [4]European School Brussels II, Belgium

Quantencomputer sind mehr als ein technologischer Trend - sie eröffnen neue Perspektiven für die physikalische, mathematische und informatische Bildung. Im Rahmen einer internationalen Zusammenarbeit von Lehrkräften aus Physik, Mathematik und Informatik wurde unter der Koordination von *Science on Stage* Unterrichtsmaterial entwickelt, das Lehrkräfte einsetzen können, um Schüler:innen der Sekundarstufe II einen praxisnahen Zugang zum Quantencomputing zu ermöglichen.

Das Projekt befindet sich aktuell in der Abschlussphase; die Materialien werden in Kürze online verfügbar sein unter: https://www.science-on-stage.eu/quantumcomputing

Die Materialien wurden von Lehrkräften für Lehrkräfte entwickelt und bieten vielfältige Zugänge - von Schülerexperimenten und Online-Animationen bis zu Programmieraufgaben und eigenständigen Arbeitsformen. Sie eignen sich für einzelne MINT-Fächer und projektorientierte Abiturkurse.

Im Vortrag werden das interdisziplinäre Material und Umsetzungsbeispiele aus den MINT-Fächern vorgestellt. Ziel ist es, das Potenzial für fächerverbindenden Unterricht zum Quantencomputing aufzuzeigen.

TUE 4.4 Tue 15:00 ZHG004

Mehr als Chemie: Die Kontakte von Carl Auer von Welsbach zu Niels Bohr & Co — •Gerd Löffler — Carl Auer von Welsbach Museum, Althofen, Österreich

Carl Auer von Welsbach ermöglichte durch seine hochreinen chemischen Präparate fundamentale experimentelle Bestätigungen in der frühen Quantenphysik. Niels Bohr hatte auf Basis seines Atommodells vorausgesagt, dass Lutetium das letzte Element der Lanthanoidreihe sei und diamagnetische Eigenschaften aufweise. Der experimentelle Nachweis dieser Vorhersagen gelang erst durch Welsbachs exzellente Lutetiumpräparate, die Stefan Meyer in Wien erfolgreich einsetzte. Die hohe chemische Reinheit war entscheidend für die Reproduzierbarkeit der magnetischen Messungen. Aufbauend auf diesen experimentellen Grundlagen entwickelte Friedrich Hund 1925 sein quantenmechanisches Modell der Elektronenkonfiguration, das als *Hundsche Regel* bekannt wurde. Diese Modellbildung stand in enger Übereinstimmung mit den empirischen Ergebnissen aus Wien. Darüber hinaus bestimmte Auer von Welsbach die Atomgewichte von Ytterbium und Lutetium mit außergewöhnlicher Genauigkeit – ein beachtlicher Erfolg angesichts der damaligen analytischen Möglichkeiten. Seine Arbeiten bilden eine zentrale Schnittstelle zwischen präparativer Chemie und theoretischer Quantenphysik und trugen wesentlich zum Verständnis der magnetischen Eigenschaften seltener Erden bei.

Weitere Informationen finden Sie auf der Webseite des Museums https://www.auer-von-welsbach-museum.at/de/unser-museum/ vortraege-veroeffentlichungen

TUE 4.5 Tue 15:15 ZHG004

Modular Setup for Coherent Control Experiments on NV Centers in Diamond — •David Ahlmer[1], Dennis Stiegekötter[1], Jonas Homrighausen[2], Marina Peters[2,3], Markus Gregor[2], and Peter Glösekötter[1] — [1]Department of Electrical Engineering and Computer Science, FH Münster, 48565 Steinfurt, Germany — [2]Department of Engineering Physics, FH Münster, 48565 Steinfurt, Germany — [3]Experimentalphysik, Universität des Saarlandes, 66123 Saarbrücken, Germany

Hands-on access to quantum state control experiments is often limited by cost and complexity. Initially kits allowing for experiments with NV centers have been presented. [1,2] We introduce a modular, 3D printable teaching platform that performs key experiments on colour centres in bulk diamond within a modular setup for educational purposes. The complete hardware costs about €500 split among electronics, cabling and optical components, making the system affordable for schools and undergraduate laboratories. The platform supports experiments to investigate optically detected magnetic resonance (ODMR), coherent Rabi oscillations, longitudinal relaxation (T1) and spin-echo coherence (T2) measurements on nitrogen-vacancy (NV) centres. Pulse sequences are generated by a microcontroller with a timing resolution of 53 ns [3]. By tuning the microwave drive power, the $\pi/2$-pulse duration can be set to integer multiples of this step size, enabling robust coherent spin control. [1] Stegemann, J. et al. Eur. J. Phys.44, 35402 (2023). [2] Haverkamp, N. et al. EPJ Quantum Technol. 12, 27 (2025). [3] Stiegekötter, D. et al. Sensors. 24, 3138 (2024).

TUE 4.6 Tue 15:30 ZHG004

Interaktive Spiele zur Vermittlung der Quantenmechanik in der Grund- und Sekundarbildung: Eine forschungsbasierte Entwicklung mit Scratch, Python, CSS und JavaScript — •João Marcos Brandet, Gabriel da Silva Cardoso, Fabrício Lorenzo Monfernatti Ramos und Vinicius Sanches da Luz — SEED, Londrina, Brazil

Diese Forschung präsentiert die Entwicklung und Validierung interaktiver Lernspiele zur Einführung der Quantenmechanik auf verschiedenen Ebenen der Grund- und Sekundarbildung. Die Spiele wurden kollaborativ von Lehrkräften und Schülern mithilfe von visueller Blockprogrammierung (Scratch) sowie textbasierten Programmiersprachen (Python, CSS und JavaScript) entwickelt. Ziel ist es, komplexe Konzepte der Quantenphysik durch spielerische und partizipative Methoden verständlich zu machen. Der Entwicklungsprozess basiert auf konstruktivistischen und konstruktionistischen Ansätzen und folgt den Prinzipien des Game-Based Learning sowie der Maker-Pädagogik. Die Validierung erfolgte durch Expertenanalysen, Usability-Tests und Pilotanwendungen in realen Unterrichtsszenarien. Erste Ergebnisse zeigen, dass die Spiele sowohl die Motivation als auch das konzeptuelle Verständnis der Schülerinnen und Schüler signifikant fördern. Dieses Projekt stellt einen innovativen Beitrag zur naturwissenschaftlichen Bildung dar und zeigt Wege auf, wie abstrakte Inhalte durch digitale Werkzeuge und kreative Lernumgebungen zugänglich gemacht werden können.

TUE 4.7 Tue 15:45 ZHG004

Über die Quantenkompetenz hinaus: Zukunft der Bildung in einer vernetzten Welt — •Zrinka Stimac — Leibniz-Institut für Bildungsmedien, Freisestr. 1, 38118 Braunschweig

Mit diesem Vortrag stelle ich das interdisziplinäre Projekt "Neue Menschenbilder, neues Denken? Quantentechnologie als Herausforderung der Bildung" vor und frage, ob quantenphilosophische Perspektiven die Zukunft der Bildung mitgestalten können. Im deutschen Kontext und aus geistes- und sozialwissenschaftlicher Perspektive analysiert das Projekt, wie Bildungssysteme auf die wachsende Präsenz von Quantentechnologien reagieren - insbesondere im Hinblick auf analoge und digitale Bildungsmedien sowie die Bedürfnisse der Bildungsakteure. Die Studie geht über die Vermittlung von Quantenkompetenz hinaus und untersucht, ob Konzepte wie Indeterminiertheit, Verschränkung und Relationalität neue Impulse für das fächerübergreifende Lernen geben können. Theoretisch stützt sie sich auf Arbeiten von Karen Barad, Ernst Cassirer, Matthias Jung und Lev Wygotsky. Statt einen konkreten pädagogischen Wandel zu fordern, eröffnet die Präsentation einen Raum für Reflexion: Könnten die konzeptuellen Rahmen der Quantentheorie dazu beitragen, Lehren, Lernen und Welterschließung anders zu denken? Anknüpfend an UNESCOs Vision von Wissenskonvergenz und zukünftigen Kompetenzen wird gefragt, was es bedeutet, Bildungskonzepte für eine vernetzte, nichtlineare und komplexe Zukunft zu gestalten.

TUE 5: QIP Certification and Benchmarking

Time: Tuesday 14:15–16:00 Location: ZHG006

TUE 5.1 Tue 14:15 ZHG006

Photonic Fidelity Witnesses — •Riko Schadow[1], Naomi Spier[2], Stefan N van den Hoven[2], Malaquias C Anguita[2], Redlef B G Braamhaar[2], Sara Marzban[2], Jens Eisert[1], Jelmer J Renema[2], and Nathan Walk[1] — [1]Freie Universität Berlin — [2]University of Twente

Certification and benchmarking represent a key challenge across all platforms for quantum information science and technology. A fundamental task in this regard is the verifiable creation of a particular quantum state. This can be accomplished via a fidelity witness - an empirical procedure that verifies with high probability that the experimentally prepared state has at least a certain fidelity with a desired target state. A promising avenue for experiments and applications is photonics, specifically the manipulation of photon number states through linear optics, which can directly demonstrate a quantum computational advantage via BosonSampling and, combined with adaptivity, universal, fault-tolerant quantum computation. Here, we design several sample-complexity efficient fidelity witnesses tailored to photonic systems and implement them on multi-photon entangled states generated by spontaneous parametric down-conversion sources injected into an integrated waveguide chip. We compare the witnesses in terms of required assumptions, closeness to the true fidelity and overall experimental effort. Using the best witnesses we certify sufficiently fidelities with highly entangled target states to verify the generated entanglement structure. We expect these tools to have further applications for quantum communication, computation and metrology.

TUE 5.2 Tue 14:30 ZHG006

Characterizing multimode linear optical devices via Scattershot Boson Sampling — •Cheeranjiv Pandey[1], Robert Schade[2], Jan-Lucas Eickmann[1], Jonas Lammers[1], Florian Lütkewitte[1], Fabian Schlue[1], Kai Hong Luo[1], Simone Atzeni[1], Mikhail Roiz[1], Christian Plessl[2], Benjamin Brecht[1], Michael Stefszky[1], and Christine Silberhorn[1] — [1]Paderborn University, Integrated Quantum Optics, Institute of Photonic Quantum Systems (PhoQS) Warburger Str. 100, 33098, Paderborn, Germany — [2]Paderborn Center for Parallel Computing, Paderborn University, Warburger Str. 100, 33098 Paderborn, Germany

Photonics has recently emerged as a promising platform for implementing various quantum computational and communication schemes. At the heart of many such schemes lie multimode linear optical devices, composed of integrated arrays of beam splitters and phase shifters. Previous work has demonstrated that any arbitrary unitary matrix can be decomposed into an array of these components. Consequently, these devices can implement any unitary transformation between their input and output channels by precisely controlling the beam splitter transmissivities and phase shifter values. However, real devices often deviate from their ideal behavior due to fabrication imperfections and thermal crosstalk, making accurate device characterization essential. We showcase our ongoing research focused on developing characterization techniques that will allow us to reconstruct the unitary matrix implemented by such devices using data obtained from Scattershot Boson Sampling (SBS) experiments.

TUE 5.3 Tue 14:45 ZHG006

Probing Continuous Variable Quantum Interference with Photon Counting — •Fabian Schlue[1], Patrick Folge[1], Takefumi Nomura[2], Philip Held[1], Federico Pegoraro[1], Michael Stefszky[1], Benjamin Brecht[1], Stephen M. Barnett[3], and Christine Silberhorn[1] — [1]Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Paderborn University, Paderborn, Germany — [2]Department of Applied Physics, School of Engineering, The University of Tokyo, Tokyo, Japan — [3]School of Physics and Astronomy, University of Glasgow, Glasgow G4 8QQ, UK

The interference of squeezed quantum states on a balanced beam splitter is the most fundamental element in hybdrid photonic quantum computing circuits such as Gaussian boson sampling, where photon counting is deployed at the output of the circuit.

We demonstrate the generation of two independent single-mode squeezed states from the interference of two modes of a two-mode squeezed state from a dispersion-engineered parametric down-conversion source on a balanced beam splitter. We measure the joint photon-number statistics by using photon-number resolved coincidence detection. If the two modes are indistinguishable, the photon statistics become decorrelated, which we prove with different statistical measures. On the other hand, partial distinguishability gives rise to a richer structure that cannot be explained in a standard single-mode picture anymore.

Our investigations shed important insight into the inner workings of hybrid quantum photonic networks with many photons.

TUE 5.4 Tue 15:00 ZHG006

Benchmarking of Large Photonic Systems — •Jan-Lucas Eickmann[1], Jonas Lammers[1], Mikhail Roiz[1], Kai-Hong Luo[1], Simone Atzeni[1], Florian Lütkewitte[1], Fabian Schlue[1], Cheeranjiv Pandey[1], Timon Schapeler[2], Benjamin Brecht[1], Tim J. Bartley[2], Michael Stefszky[1], and Christine Silberhorn[1] — [1]Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Paderborn University, Warburger Str. 100, Paderborn 33098, Germany — [2]Department of Physics & Institute for Photonic Quantum Systems (PhoQS), Paderborn University, Warburger Str. 100, Paderborn 33098, Germany

Photonics is a promising platform for noisy intermediate-scale quantum technologies due to its scalability and room-temperature operation. Taking advantage of deterministic squeezed state generation in parametric down-conversion, Gaussian boson sampling (GBS) has been proven to be a scalable approach towards photonic quantum simulation. The scheme consists of many single-mode squeezed states that are sent into an interferometer, before measuring the photon-number outputs. However, many factors impact the performance, like photon loss, interference quality, and spectral single-modeness of the quantum light source, requiring detailed system characterization. We present methods to characterize large photonic quantum systems, focusing on benchmarking quantum state generation and interference as well as estimating total system efficiency. We apply these methods to characterize the Paderborn Quantum Sampler (PaQS), a 12-mode Gaussian boson sampling device that incorporates many integrated components.

TUE 5.5 Tue 15:15 ZHG006

Certifying Quantum Gates via dimensional advantage — •Anna Schroeder[1,2], Jan Nöller[1], Nikolai Miklin[3], Lucas B. Vieira[1], and Mariami Gachechiladze[1] — [1]Department of Computer Science, Technical University of Darmstadt, Darmstadt, Germany — [2]Merck KGaA, Darmstadt, Germany — [3]Institute for Quantum-Inspired and Quantum Optimization, Hamburg University of Technology, Germany

Certifying individual quantum devices efficiently and with minimal assumptions remains a significant challenge. Traditional device-independent approaches often rely on space-like separation or computational hardness assumptions, which are both difficult to realize in practice. Recently, a robust certification framework,*Quantum System Quizzing (QSQ),*has been introduced under the sole assumption of bounded dimension. This protocol uniquely identifies the underlying quantum model for a universal gate set.*Leveraging concepts from automata theory, we explore the dimension gap between classical and quantum models in deterministic protocols and characterize the classical simulation cost of the observed deterministic*responses. We identify a family of certification schemes that exhibit increasing quantum advantage and analyze their robustness in the presence of noise on quantum hardware.*Our approach shifts the focus from spatial correlations to deterministic tests in temporal scenarios, which are more amenable to implementation on NISQ devices, paving the way for reliable and resource-efficient quantum certification protocols.

TUE 5.6 Tue 15:30 ZHG006

SPAM-free sound certification of quantum gates via quantum system quizzing — •Nikolai Miklin[1], Jan Nöller[2], Martin Kliesch[1], and Mariami Gachechiladze[2] — [1]Hamburg University of Technology — [2]Technical University of Darmstadt

The rapid advancement of quantum hardware necessitates the development of reliable methods to certify its correct functioning. However, existing certification tests often fall short: they either rely on flawless state preparation and measurement, or fail to provide soundness guarantees, meaning that they do not ensure the correct implementation of the target operation by a quantum device. We introduce an approach, which we call quantum system quizzing, for certification of quantum gates in a practical server-user scenario, where a classical user tests the results of exact quantum computations performed by a quantum server. Importantly, this approach is free from state preparation and measurement (SPAM) errors. For a wide range of relevant gates, including a gate set universal for quantum computation, we demonstrate that our approach offers soundness guarantees based solely on the dimension assumption. Additionally, for a highly-relevant single-qubit phase gate - which corresponds experimentally to a pi/2-pulse - we prove that the method's sample complexity scales inverse-linearly relative to the average gate infidelity. By combining the SPAM-error-free and sound notion of certification with practical applicability, our approach paves the way for promising research into efficient and reliable certification methods for quantum computation.

TUE 5.7 Tue 15:45 ZHG006

A digital twin of atomic ensemble quantum memories — •Elizabeth Robertson[1], Benjamin Maass[1], Konrad Tschernig[1], and Janik Wolters[1,2,3,4] — [1]Institute of Space Research, German Aerospace Center, Berlin, Germany — [2]nstitutes of Physics, Technische Universität Berlin, Berlin, Germany — [3]Einstein Center Digital Future (ECDF) Berlin, Germany — [4]AQLS UG Haftungsbeschränkt, Germany

Performance estimation of experimentally demonstrated quantum memories is key for their deployment in quantum communication and quantum computing networks [1]. While existing platforms like Qiskit and Strawberry Fields enable quantum simulations, they do not natively account for the lossy and noisy nature of physical devices. We present a practical framework for modeling ensemble-based atomic quantum memories using the quantum channel formalism. By representing several state-of-the-art experimental memories with Kraus operators, we highlight key performance metrics of each of the memories and enable direct comparison between them. We further demonstrate the utility of this approach by simulating a memory-assisted quantum token protocol for authentication, for different experimentally demonstrated memories [2]. [1] Gündoğan, M. et al. Proposal for space-borne quantum memories for global quantum networking. npj Quantum Inf 7, 128 (2021) [2] Manuscript in preparation.

TUE 6: Quantum Computing and Communication: Contributed Session I (Algorithms & Theory)

Time: Tuesday 14:15–16:00 Location: ZHG007

TUE 6.1 Tue 14:15 ZHG007

Measurement-driven quantum advantages in shallow circuits — •Chenfeng Cao[1] and Jens Eisert[1,2] — [1]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, 14109 Berlin, Germany

Quantum advantage schemes probe the boundary between classically simulatable quantum systems and those that computationally go beyond this realm. Here, we introduce a constant-depth measurement-driven approach for efficiently sampling from a broad class of dense instantaneous quantum polynomial-time circuits and associated Hamiltonian phase states, previously requiring polynomial-depth unitary circuits. Leveraging measurement-adaptive fan-out staircases, our "dynamical circuits" circumvent light-cone constraints, enabling global entanglement with flexible auxiliary qubit usage on bounded-degree lattices. Generated Hamiltonian phase states exhibit statistical metrics indistinguishable from those of fully random architectures. Additionally, we demonstrate measurement-driven globally entangled feature maps capable of distinguishing phases of an extended SSH model from random eigenstates using a quantum reservoir-computing benchmark. Technologically, our results harness the power of mid-circuit measurements for realizing quantum advantages on hardware with a favorable topology. Conceptually, we highlight their power in achieving rigorous computational speedups.

TUE 6.2 Tue 14:30 ZHG007

A quantum protocol for applying arbitrary phase transformations — Siavash Davani[1,2] and •Falk Eilenberger[3,1,2] — [1]Institute of Applied Physics, Abbe Center of Photonics, Friedrich Schiller University Jena, 07745 Jena, Germany — [2]Max Planck School of Photonics, 07745 Jena, Germany — [3]Fraunhofer-Institute for Applied Optics and Precision Engineering, 07745 Jena, Germany

The standard approach to developing algorithms for quantum computers involves constructing a sequence of unitary gates to manipulate a quantum register. We show an alternative approach that directly uses quantum information stored in memory as instructions and performs a transformation on a register based on the state of the instruction state. This enables programming quantum computers by encoding different instructions as quantum information in the memory. The approach unifies the role of memory in quantum computers as containing both data and software similar to the von Neumann architecture in classical computers. Using this technique, we introduce a protocol capable of arbitrary phase transformations on wavefunctions, allowing for the simulation of large classes of Hamiltonians on quantum computers. The protocol functions by temporarily entangling the instruction and data registers, and it consumes the instruction state during the process.

TUE 6.3 Tue 14:45 ZHG007

Quantum Approximate Optimization via Weak Measurements — •Tobias Stollenwerk[1] and Stuart Hadfield[2] — [1]Forschungszentrum Jülich — [2]NASA Quantum Artificial Intelligence Laboratory

Algorithms based on non-unitary evolution have attracted much interest for ground state preparation on quantum computers. One recently proposed method makes use of ancilla qubits and controlled unitary operators to implement weak measurements related to imaginary-time evolution. In this work we specialize and extend this approach to the setting of combinatorial optimization. We first generalize the algorithm from exact to approximate optimization. We then show how to modify the paradigm to the setting of constrained optimization for a number of important classes of hard problem constraints. For this we adapt the algorithm to penalty-based approaches and elucidate the resource overhead. As an alternative approach we show how one may design and employ operators that preserve the subspace of feasible problem solutions in order to to avoid the overhead of penalty terms. In particular, we show that mixing operators from the quantum alternating operator ansatz may be directly imported, both for the necessary eigenstate scrambling operator and for initial state preparation, and discuss quantum resource tradeoffs. Finally, we consider the effects of hardware noise and propose further algorithmic variants towards ameliorating its effects.

TUE 6.4 Tue 15:00 ZHG007

State Specific Measurement Protocols for the Variational Quantum Eigensolver — •Davide Bincoletto — University of Augsburg, Augsburg, Germany

A central roadblock in the realization of variational quantum eigensolvers on quantum hardware is the high overhead associated with measurement repetitions, which hampers the computation of complex problems, such as the simulation of mid- and large-sized molecules. In this work, we propose a novel measurement protocol which relies on computing an approximation of the Hamiltonian expectation value. The method involves measuring cheap grouped operators directly and estimating the residual elements through iterative measurements of new grouped operators in different bases, with the process being truncated at a certain stage. The measured elements comprehend the operators defined by the Hard-Core Bosonic approximation, which encode electron-pair annihilation and creation operators. These can be easily decomposed into three self-commuting groups which can be measured simultaneously. Applied to molecular systems, the method achieves a reduction of 30% to 80% in the number of measurement and gates depth in the measuring circuits compared to state-of-the-art methods. This provides a scalable and cheap measurement protocol, advancing the application of variational approaches for simulating physical systems.

TUE 6.5 Tue 15:15 ZHG007

A complexity theory for non-local quantum computation — •Simon Höfer[1], Andreas Bluhm[1], Alex May[2,3], Mikka Stasiuk[2], Philip Verduyn Lunel[4], and Henry Yuen[5] — [1]Univ. Grenoble Alpes, CNRS, Grenoble INP, LIG — [2]Perimeter Institute for Theoretical Physics — [3]Institute for Quantum Computing, Waterloo, Ontario — [4]Sorbonne Université, Paris — [5]Columbia University

Non-local quantum computation (NLQC) replaces a local interaction between two systems with a single round of communication and shared entanglement.

Despite many partial results, it is known that a characterization of entanglement cost in at least certain NLQC tasks would imply significant breakthroughs in complexity theory, so we take an indirect approach to understanding resource requirements in NLQC, by studying the relative hardness of different NLQC tasks by identifying resource efficient reductions between them.

Most significantly, we prove that f-measure and f-route, the two best studied NLQC tasks, are in fact equivalent under reductions, with only constant overhead in the entanglement cost, regardless of the function f.

This result simplifies many existing proofs in the literature and extends several new properties to f-measure, such as sub-exponential upper bounds on entanglement cost.

Beyond this, we study a number of other examples of NLQC tasks and their relationships.

TUE 6.6 Tue 15:30 ZHG007

Application of quantum computing in Life Sciences - a Case Study — •Klaus Mayer, Artemiy Burov, Clément Javerzac-Galy, and Oliver Mülken — School of Life Sciences, FHNW Fachhochschule Nordwestschweiz, Hofackerstr. 30, 4132 Muttenz, Switzerland

We study the practical application of currently available intermediate-scale Quantum Computers in the Life Sciences context [1]. Among the various conceivable applications where quantum utility or even advantage may be achieved, Hamiltonian simulation is among the most relevant.

As a concrete example, we explore the applicability of modern quantum computing algorithms (such as Qubitization and Quantum Signal Processing) to the simulation of nuclear magnetic resonance (NMR) spectra, which are highly relevant, for instance, in the field of protein characterization for drug discovery or in the material sciences. To this end, a Heisenberg Hamiltonian for liquid-state NMR is mapped to a higher-dimensional unitary which can be implemented in a Quantum Computer. We investigate resource scaling of the implementation and compare our results to product formula implementations [2].

[1] K. Mayer, A. Burov, C. Javerzac-Galy, O. Mülken (2025), *to be submitted*
[2] A. Burov, O. Nagl, C. Javerzac-Galy (2024), *arXiv:2404.17548*

TUE 6.7 Tue 15:45 ZHG007

Beyond Classical Approximation Guarantees in the NISQ Era — •Chinonso Onah[1,2] and Kristel Michielsen[2,3] — [1]Volkswagen Group, Germany — [2]Department of Physics, RWTH Aachen, Germany — [3]Forschungszentrum Jülich, Germany

We present the first constant-low-depth, ancilla-free constrained QAOA variant that (1) provably concentrates inverse-polynomial probability on the target bit-strings, (2) exponentially outperforms generic QAOA at any depth by massively boosting the probability of legal solutions, (3) amplifies any generic QAOA parameter set by a super-exponential factor, and (4) serves as the quantum core of an Exact Hybrid Quantum*Classical solver that is a fully-polynomial randomized approximation scheme whose success probability*and additive-gap performance under Hungarian repair*cannot be matched by any polynomial-time classical sampler unless NP is contained in BPP. On the QOPTLib TSP benchmark (all instances up to one hundred qubits that fit on today*s superconducting hardware), our solver recovers or improves upon every previously published tour*achieving up to a 12.3 percent shorter route on the hardest instance. This dramatic gain on the most challenging benchmarks underlines the practical promise of our approach on near-term devices.

TUE 7: Entanglement and Complexity: Contributed Session to Symposium I

Time: Tuesday 14:15–15:45 Location: ZHG008

TUE 7.1 Tue 14:15 ZHG008

Experimental Demonstration of Electron-Photon Entanglement — •Sergei Bogdanov[1,2], Alexander Preimesberger[1,2], Isobel C. Bicket[1,2], Phila Rembold[1], and Philipp Haslinger[1,2] — [1]Vienna Center for Quantum Science and Technology, Atominstitut, TU Wien, Vienna, Austria — [2]University Service Centre for Transmission Electron Microscopy (USTEM), TU Wien, Vienna, Austria

Quantum entanglement, a fundamental resource for quantum technologies, describes correlations between particles that cannot be explained by classical physics. While transmission electron microscopes (TEMs) are well-established tools with exceptional spatial resolution, their potential for exploring quantum correlations remains largely underexplored. In this study, we demonstrate entanglement between electrons and photons generated via cathodoluminescence inside a TEM. To produce correlated electron-photon pairs we use a TEM working at 200 keV to illuminate a 50 nm silicon membrane. Inelastic scattering of electrons may lead to the emission of cathodoluminescent coherent photons. Due to energy and momentum conservation, transmitted electrons and emitted photons are correlated in position and momentum. A custom-made parabolic mirror directs the photons out of the TEM to an optical detection system. To perform coincidence measurements, an absorptive grating mask is used as the object for ghost image formation. We reconstruct near- and far-field "ghost" images of the periodic masks and show a violation of the classical uncertainty bound. Hence, we demonstrate position-momentum entanglement of electron-photon pairs, bridging quantum optics and electron microscopy.

TUE 7.2 Tue 14:30 ZHG008

Experimental measurement and a physical interpretation of quantum shadow enumerators — •Daniel Miller[1,7], Kyano Levi[1], Lukas Postler[2], Alex Steiner[2], Lennart Bittel[1], Gregory A.L. White[1], Yifan Tang[1], Eric J. Kuehnke[1], Antonio A. Mele[1], Sumeet Khatri[1,3,4], Lorenzo Leone[1], Jose Carrasco[1], Christian D. Marciniak[2], Ivan Pogorelov[2], Milena Guevara-Bertsch[2], Robert Freund[2], Rainer Blatt[2,5], Philipp Schindler[2], Thomas Monz[2,6], Martin Ringbauer[2], and Jens Eisert[1] — [1]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany — [2]Universität Innsbruck, Institut für Experimental- physik, Technikerstrasse 25, 6020 Innsbruck, Austria — [3]Department of Computer Science, Virginia Tech, Blacksburg, Virginia 24061, USA — [4]Virginia Tech Center for Quantum Information Science and Engineering, Blacksburg, Virginia 24061, USA — [5]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, 6020 Innsbruck, Austria — [6]Alpine Quantum Technologies GmbH, 6020 Innsbruck, Austria — [7]Institute for Theoretical Nanoelectronics (PGI-2), Forschungszentrum Jülich, 52428 Jülich, Germany

We show that Rains' shadow enumerators are the same as triplet probabilities in two-copy Bell sampling. We measure them in experiments.

TUE 7.3 Tue 14:45 ZHG008

Why Quantum Mechanics needs 'Hidden' Variables — •Wolfgang Paul — Martin-Luther-Universität Halle-Wittenberg, Institut für Physik, 06099 Halle

One early culmination point of the discussion on whether the Hilbert space description of quantum mechanics can be considered complete or not are the famous breakfast and dinner conversations between Bohr and Einstein during the 5th Solvay Conference 1927. While Einstein thought that it should be augmented by ontological objects (hidden variables) Bohr insisted that this can not be done.

Bohr was well aware that he declared the death of a good part at the heart of physics as it had been established for the preceding 300 years: his position denied quantum physics the ability to model the measurement process and reduced it to the accounting of measurement results.

Based on Nelson's stochastic mechanics approach [1], one can formulate a model of particles with spin as possessing position and orientation degrees of freedom and describe the measurement process in the Stern Gerlach experiment as well as the Einstein-Podolski-Rosen-Bohm thought experiment [2]. The outcome statistics agree with the Hilbert space quantum mechanical predictions, even reproducing the violation of Bell's inequalities, but in addition the complete measurement process can be followed in a time-resolved manner, so there is no measurement problem any more.

[1] E. Nelson, Phys. Rev. **150**, 1079 (1966)
[2] M. Beyer, W. Paul, Found. Phys. **54**, 20 (2024)

TUE 7.4 Tue 15:00 ZHG008

The dynamic meaning of the Lorentz transforms of mass and time — •Grit Kalies[1] and Duong D. Do[2] — [1]HTW University of Applied Sciences, Dresden, Germany — [2]The University of Queensland, Brisbane, Australia

We describe acceleration as a complex process in which a particle or body changes several of its properties, not just its momentum. Consequently, during acceleration, several forms of energy of an object change, not just its motion energy, which means that its so-called rest energy becomes Lorentz-variant. This insight is made possible by representing particles as physical waves and by applying thermodynamic principles to individual quantum objects, whose property changes are described by several simultaneously occurring forms of quantum work. The results form the basis for the emerging field of quantum-process thermodynamics.

TUE 7.5 Tue 15:15 ZHG008

Role of Nonstabilizerness in Quantum Optimization — •Chiara Capecci[1,2], Gopal Chandra Santra[1,2], Alberto Bottarelli[1,2], Emanuele Tirrito[3], and Philipp Hauke[1,2] — [1]Pitaevskii BEC Center, CNR-INO and Department of Physics, University of Trento, Via Sommarive 14, I-38123 Trento, Italy — [2]INFN-TIFPA, Trento Institute for Fundamental Physics and Applications, Via Sommarive 14, I-38123 Trento, Italy — [3]The Abdus Salam International Centre for Theoretical Physics (ICTP), Strada Costiera 11, 34151 Trieste, Italy

Quantum optimization is a promising method for tackling complicated classical problems using quantum devices. However, the extent to which these algorithms exploit genuine quantum resources and the role of these resources remain open questions. We investigate the resource requirements of the Quantum Approximate Optimization Algorithm (QAOA) using nonstabilizerness measurements. We demonstrate that nonstabilizerness increases with circuit depth, reaches a maximum, then decreases approaching the solution state — creating a barrier that limits algorithm's capability for shallow circuits. We find that curves for different depths collapse under simple rescaling and uncover a relationship between final nonstabilizerness and success probability. A similar barrier is found in quantum annealing. These results clarify how quantum resources influence quantum optimization.

TUE 7.6 Tue 15:30 ZHG008

Rethinking Quantization: Toward a Local, Realistic Interpretation — •Falk Rühl — D52159 Roetgen, Auf der Alm 14

More than a century after the birth of quantum theory, its formalism has matured, but its interpretation remains entangled with the early 20th-century notion of 'early quantization'. In this conventional view, central to the Copenhagen interpretation, proposed by A. Einstein and N. Bohr, quanta are treated as discrete property carrying objects, generated at sources and transmitted without loss to distant targets.

In this talk, I will present an alternative framework: 'late quantization'. Here, quantum phenomena arise not from the emission, transfer, and absorption of discrete quanta, but from the interaction of radiation from all possible sources, with continuously evolving states of the targets themselves. This shift allows for a local and realistic interpretation of quantum processes, dispensing with the need for non-locality, wave-function collapse, or quantum jumps.

A key feature of this approach is that efficient detection of sources only occurs, when the source radiation drives closed cycles in the target's state space. This makes only a small subset of the continuously evolving 'beable' states of sources 'observable' states.

This new interpretation not only provides conceptual clarity but also eliminates longstanding quantum puzzles within a fully local and deterministic framework.

TUE 8: Correlated Quantum Matter: Contributed Session to Symposium I

Time: Tuesday 14:15–16:00 Location: ZHG009

TUE 8.1 Tue 14:15 ZHG009

Optical signatures of dynamical excitonic condensates — •Alexander Osterkorn[1], Yuta Murakami[2], Tatsuya Kaneko[3], Zhiyuan Sun[4], Andrew J. Millis[5,6], and Denis Golež[1,7] — [1]Jožef Stefan Institute, Ljubljana, Slovenia — [2]RIKEN, Wako, Japan — [3]Osaka University, Toyonaka, Japan — [4]Tsinghua University, Beijing, P.R. China — [5]Columbia University, New York, USA — [6]Flatiron Institute, New York, USA — [7]University of Ljubljana, Ljubljana, Slovenia

Excitons, or bound electron-hole pairs, can condense into an excitonic insulator state, similarly to Cooper pairs in superconductors. A non-equilibrium carrier concentration, such as the one transiently induced by photo-doping or sustained by a tuneable bias voltage in bilayers, can create a dynamical excitonic insulator state. However, proving phase coherence in such setups remains challenging. We examine the condensate phase behavior theoretically and show that optical spectroscopy can distinguish between phase-trapped and phase-delocalized dynamical regimes. In the weak-bias regime, trapped phase dynamics result in an in-gap absorption peak nearly independent of bias voltage, while at higher biases its frequency increases approximately linearly. In the large bias regime, the response current grows strongly under the application of a weak electric probe leading to negative weight in the optical response, which we analyze relative to predictions from a minimal model for the phase. This work opens new avenues for experimentally probing coherence in excitonic condensates and the detection of their dynamical regimes. Preprint: arXiv:2410.22116

TUE 8.2 Tue 14:30 ZHG009

Dissipative loading of ultracold atom tweezer arrays — •Lara Giebeler[1], Alexander Schnell[1], Monika Aidelsburger[2,3,4], and André Eckardt[1] — [1]Institute for Physics and Astronomy, Technical University Berlin — [2]Munich Center for Quantum Science and Technology — [3]Max-Planck-Institut für Quantenoptik — [4]Fakultät für Physik, LMU Munich

Using ultracold atoms in quantum computing and simulation often requires arbitrary single-atom control, typically achieved with optical tweezer arrays. However, defect-free loading of large-scale arrays remains challenging due to the slow speed of adiabatic preparation methods.

To overcome these limitations, in this work we introduce a dissipative scheme for loading fermionic atoms into tweezers, mediated by lasercoupled interactions with a fermionic bath. In particular, we explore the trade-off between loading time and efficiency depending on the system bath coupling and the impact of reservoir size and temperature.

TUE 8.3 Tue 14:45 ZHG009

A general scheme for detecting phases of lattice-confined ultracold atomic clouds — •Niklas Euler[1,2], Christof Weitenberg[3], and Martin Gärttner[1] — [1]Institut für Festkörpertheorie und Optik, FSU Jena, Jena — [2]Physikalisches Institut, Universität Heidelberg, Heidelberg — [3]Fakultät Physik, TU Dortmund, Dortmund

Over the past decade, quantum-gas microscopes have become an invaluable tool for cold-atom experiments, delivering unprecedented single-site resolution. The now available high-precision density measurements have been used successfully to probe strongly correlated quantum matter, perform quantum simulation tasks, or investigate out-of-equilibrium dynamics, among other applications. However, reconstructing phase distributions of ultracold atomic clouds from matter-wave images has remained challenging, especially for large phase fluctuations. Here, we propose a new measurement scheme that reliably reconstructs initial-state phases and density fluctuations from a single matter-wave inference image in an efficient manner. Our method works by decomposing the initial state into individual spatially localized modes and evolving them independently, which is well justified in the regime of weak nonlinear interactions. Furthermore, by comparing the reconstructed image with measurement data, the plausibility of the resulting distributions can easily be verified. Finally, we show first numerical results, demonstrating that our method is robust under typical experimental conditions.

TUE 8.4 Tue 15:00 ZHG009

Modelling of collisional spin entanglement beyond the Born-Markov approximation — •Robert Weiss[1], Scott Parkins[2,3], Mikkel F. Andersen[3,4], and Sandro Wimberger[5,6] — [1]Institut für theoretische Physik, Universität Heidelberg — [2]Department of Physics, University of Auckland — [3]Dodd-Walls Centre for Photonic and Quantum Technologies — [4]Department of Physics, University of Otago — [5]Department of Mathematical, Physical and Computer Sciences, Parma University — [6]INFN, Sezione Milano-Bicocca, Parma group

It was shown experimentally that colliding cold atoms produce entanglement between their spin states [1]. A thorough theoretical foundation and prediction was restricted in modelling the internal and external atomic degrees of freedom due to computational constraints. We demonstrate why established analytical techniques restricting to the spins only and relying on the Born-Markov approximation fail to reproduce the experimental results. The Markov approximation is not applicable because the correlations in the motional degree of freedom do not decay on a short enough time scale. The Born approximation is questionable as the interatomic interaction is too strong. Numerical models are presented which capture the observed dynamics well including non-Markovian effects and the relative motion.

[1] P. Sompet et. al., Nat. Comm. **10**, 1889 (2019)

TUE 8.5 Tue 15:15 ZHG009

Universal theory for heavy impurities in ultracold Fermi gases — •Eugen Dizer, Xin Chen, Emilio Ramos Rodriguez, and Richard Schmidt — Institut für Theoretische Physik, Universität Heidelberg, D-69120 Heidelberg, Germany

Single impurities immersed in a degenerate Fermi gas exhibit fascinating many-body phenomena, such as the polaron-to-molecule transition and Anderson's orthogonality catastrophe (OC). It is known that mobile impurities of finite mass can be described as quasiparticles, so called Fermi polarons. In contrast, Anderson showed in 1967 that the ground state of a static, infinitely heavy impurity in a Fermi sea is orthogonal to the ground state of the system without impurity - a hallmark of the OC and a fundamentally non-perturbative effect. As a result, conventional variational approaches or path integral methods fail to capture this phenomenon accurately. Despite decades of research, a unified approach connecting the quasiparticle description of Fermi polarons with Anderson's OC has remained elusive. In this work, we present a theoretical framework for arbitrary-mass impurities in a Fermi sea that incorporates Anderson's OC, the polaron-to-molecule transition and the quasiparticle picture. Our theory provides new insights into the nature of impurity physics and many-body correlations, describing how quasiparticle behavior and the polaron-to-molecule transition emerge from the OC.

TUE 8.6 Tue 15:30 ZHG009

Quantum phases of bosonic mixture with dipolar interaction — •Rukmani Bai and Luis Santos — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstrasse 2, D-30167 Hannover, Germany

Ultracold dipoles in optical lattices, characterized by strong inter-site interactions, open new possibilities for ground-state phases as well as an intriguing dynamics. Recent experiments on dipolar mixtures of magnetic lanthanide atoms are especially interesting, not only due to the dipolar interaction, but also because these atoms are particularly suitable for realizing component-dependent lattices. Using a combination of DMRG and cluster Gutzwiller methods, we study the ground-state physics that may result when the two components experience mutually intertwined optical lattices, which resemble interacting bilayer geometries.

TUE 8.7 Tue 15:45 ZHG009

Static impurity in a mesoscopic system of SU(N) fermionic matter-waves — •Juan Polo[1], Wayne Chetcuti[1], Andreas Osterloh[1], Anna Minguzzi[3], and Luigi Amico[1,2] — [1]Quantum Research Center, Technology Innovation Institute, Abu Dhabi 9639, UAE — [2]Dipartimento di Fisica e Astronomia Ettore Majorana University of Catania, Via S. Sofia 64, 95123 Catania, Italy — [3]Université Grenoble Alpes, CNRS, LPMMC, 38000 Grenoble, France

We investigate the effects of a static impurity, modeled by a localized barrier, in a one-dimensional mesoscopic system comprised of strongly correlated repulsive SU(N)-symmetric fermions. For a mesoscopic sized ring under the effect of an artificial gauge field, we analyze the particle density and the current flowing through the impurity at varying interaction strength, barrier height and number of components. We find a non-monotonic behaviour of the persistent current, due to the competition between the screening of the impurity, quantum fluctuations, and the phenomenon of fractionalization, a signature trait of SU(N) fermionic matter-waves in mesoscopic ring potentials. This is also highlighted in the particle density at the impurity site. We show that the impurity opens a gap in the energy spectrum selectively, constrained by the total effective spin and interaction. Our findings hold significance for the fundamental understanding of the localized impurity problem and its potential applications for sensing and interferometry in quantum technology.

TUE 9: Quantum Physics in Strong Fields: Contributed Session to Symposium

Time: Tuesday 14:15–16:15 Location: ZHG101

TUE 9.1 Tue 14:15 ZHG101

LUXE: a high-precision experiment to study non-perturbative QED in electron-laser and photon-laser collisions — •Tom Blackburn — Department of Physics, University of Gothenburg, 41296 Gothenburg, Sweden

The Laser Und XFEL Experiment (LUXE), in planning at DESY Hamburg, is intended to study quantum electrodynamics (QED) in strong electromagnetic fields, and in particular the transition from perturbative to non-perturbative. In the non-perturbative regime, electron-positron pairs tunnel out of the vacuum in a manner akin to the Schwinger process. The experiment will make precision measurements of the photon and positron rates in collisions between a high-intensity laser pulse and the 16.5 GeV electron beam of the European XFEL, or the high-energy secondary photons it produces. This talk will provide an overview and update on the work of the LUXE collaboration, as the experiment moves towards implementation.

TUE 9.2 Tue 14:30 ZHG101

The Quantum Superluminality of Tunnel-ionization — •Ossama Kullie[1] and Igor Ivanov[2] — [1]Department of Mathematics and Natural Sciences. University of Kassel, 34132 Kassel, Germany. — [2]Department of Fundamental and Theoretical Physics, Australian National University, Australia

Tunneling is one of the most interesting phenomena in quantum physics. In our tunnel-ionization model [1, 2, 3], we have shown that the time-delay of the adiabatic and nonadiabatic tunnel-ionization determines the barrier time-delay in a good agreement with the attoclock measurement and that it corresponds to the dwell time and the interaction time. In the present work, we show that the barrier time-delay for H-like atoms with a large nuclear charge can be superluminal (quantum superluminality), which can be experimentally validated using the attoclock scheme. Furthermore, we accompany our model with the numerical integration of time-dependent Schödinger equation (NTTDSE), where we expect good agreement with our model as in earlier work [2]. We investigate the quantum superluminality for the different experimental calibrations (adiabatic and nonadiabatic tunnel-ionization) of the attoclock [4] and discuss its interpretation. [1] O. Kullie, J. Phyis. Commun. 9, 015003, (2025). [2] O. Kullie and I. Ivanov, Annals of Physics 464, 169648 (2024). [3] O. Kullie, Annals of Physics 389, 333 (2018). [4] O. Kullie and I. A. Ivanov, Quantum superluminality of Tunnel-Ionization. In preparation.

TUE 9.3 Tue 14:45 ZHG101

Theoretical strong-field quantum physics in Dresden: An Overview — •Christian Kohlfürst — Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany

We provide an overview of the research area of strong-field quantum electrodynamics, focusing particularly on the topics covered by the Strong-Field research group within the Institute of Theoretical Physics at the Helmholtz-Zentrum Dresden Rossendorf. Special emphasis is placed on non-equilibrium quantum dynamics and the scattering of light by light.

TUE 9.4 Tue 15:00 ZHG101

Femtosecond and attosecond correlations in multi-electron pulses — •Rudolf Haindl[1,2], Valerio Di Giulio[1,2], Armin Feist[1,2], and Claus Ropers[1,2] — [1]Max Planck Institute for Multidisciplinary Sciences, Göttingen, Germany — [2]4th Physical Institute, University of Göttingen, Göttingen, Germany

Correlations between electrons are at the core of numerous phenomena in atomic, molecular, and solid-state physics. In femtosecond electron emission from nanoscale field emitters, Coulomb interactions result in structured few-electron states with strong correlations in energy [1,2], transverse momentum [2], and time[3].

In this contribution [4], we combine femtosecond-gated, event-based detection with inelastic electron-light scattering to directly map the photoelectron phase-space distribution of two-electron states. Our experiments demonstrate a bimodal structure in longitudinal phase space, with distinct contributions from interparticle interaction and dispersion. Moreover, we theoretically reveal that global phase modulation coherently shapes the few-electron phase-space distribution to exhibit attosecond temporal correlations. This controlled phasing of few-electron states leads to a multi-electron quantum walk and can be harnessed to produce tailored excitations and super-radiance via two-electron energy post-selection.

[1] R. Haindl et al., *Nat. Phys.* **19**, 1410-1417 (2023).
[2] S. Meier et al., *Nat. Phys.* **19**, 1402-1409 (2023).
[3] J. Kuttruff et al., *Sci. Adv.* **10**, eadl6543 (2024).
[4] R. Haindl et al., *arXiv*, arXiv:2412.11929 (2024).

TUE 9.5 Tue 15:15 ZHG101

Quantum simulation of strong field phenomena and curved spaces in deformed optical lattices — •Nikodem Szpak — Faculty of Physics, University of Duisburg-Essen

Low energy excitations in specially designed optical lattice systems can behave like relativistic particles. Inhomogeneous perturbations of these lattices can give rise to effective coupling to artificial electromagnetic fields and curvature. We give a review of interesting strong field phenomena, like spontaneous pair creation or graviational lensing, still not accessible in direct experiments, which can be simulated with cold atoms in finite size optical lattices.

TUE 9.6 Tue 15:30 ZHG101

Scattering matrix approach to dynamical Sauter-Schwinger process: vortex- vs. spiral structures — •Mateusz Majczak, Katarzyna Krajewska, Jerzy Kamiński, and Adam Bechler — Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, Pasteura 5, 02-093 Warsaw, Poland

The dynamical Sauter-Schwinger mechanism of electron-positron (e^-e^+) pair creation by electric field pulses is considered using the S-matrix approach and reduction formulas. They lead to the development of framework that treats the external electric field to all orders and is based on the solutions of the Dirac equation with the so-called Feynman- or anti-Feynman boundary conditions. The asymptotic properties of those solutions are linked to the electron and positron spin(helicity)-resolved probability amplitudes. Most importantly, the corresponding spin- or helicity-resolved distributions, when summed over spin or helicity configurations, reproduce the momentum distributions of created particles calculated with other methods that are typically used in this context, such as the DHW function approach. In contrast to those approaches, however, the S-matrix method provides the information about the phase of the probability amplitude of e^-e^+ pair creation. Therefore, it allows one to study the vortex- and spiral structures in momentum distributions of produced particles. As it follows from our numerical studies, a momentum spiral is created as a result of the vortex-antivortex annihilation. Moreover, as we show, in order to observe such annihilation one has to drive the pair creation with electric field pulses of the time reversal symmetry.

TUE 9.7 Tue 15:45 ZHG101

Vortex Structures and Spin Effects in Dynamical Schwinger Process
— •Wojciech Smialek[1], Mateusz Majczak[1], Adam Bechler[1], Jerzy Kamiński[1], Carsten Müller[2], and Katarzyna Krajewska[1] — [1]Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, Poland — [2]Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf, Germany

The dynamical Schwinger effect offers a unique opportunity to probe the nonperturbative regime of QFT under controlled conditions. While the spectra and yields of particles created in this process have been studied in great detail, the currently dominant tools for nonperturbative analysis of this process within QED do not allow for a full examination of the spin properties of the created pairs.

In order to study the angular momentum effects in the dynamical Schwinger process, we present a novel S-matrix-based formalism that grants access to the full information about the state of the created pairs through spin-resolved probability amplitudes. This formalism has been adapted to Dirac and Klein-Gordon fields to provide further insight into spin effects.

Our numerical analysis reveals the occurrence of vortical phase singularities in the complex probability amplitude of spinor and scalar pairs when the QED vacuum is exposed to a circularly polarized electric field. The occurrence of phase vortices is linked to a nonvanishing orbital angular momentum carried by the particles, and as we show, the structure of vortices for fermionic and bosonic pairs complies with the principle of angular momentum conservation.

TUE 9.8 Tue 16:00 ZHG101

Photon-graviton conversion in a magnetic field — •Naser Ahmadiniaz — Helmholtz Zentrum Dresden Rossendorf, Dresden, Germany

In this talk, I will first give a brief overview of the worldline formalism, a first-quantized approach to quantum field theory that streamlines the computation of scattering amplitudes in gauge theory and gravity. This method is particularly well suited to incorporating background fields non-perturbatively and reveals the underlying geometric structure of amplitudes. The main focus will be on photon–graviton conversion in an external magnetic field. While this process is typically studied at tree level, one-loop corrections due to scalar and spinor fields have also been computed. Unlike the tree-level result, the one-loop amplitude exhibits a dependence on the photon polarization, leading to vacuum dichroism. I will present a worldline-based derivation of this one-loop effect and show how the formalism naturally captures the emergence of dichroism. Furthermore, I will discuss the role of a previously neglected tadpole contribution. Although such diagrams often vanish in conventional treatments, we find that in this context the tadpole gives a finite contribution to the amplitude that must be included to obtain a complete result.

TUE 10: Foundational / Mathematical Aspects – Rigorous Results

Time: Tuesday 14:15–16:15 Location: ZHG103

TUE 10.1 Tue 14:15 ZHG103

Classicality enforced by consistent value assignments — •Giuseppe Antonio Nisticò — University of Calabria, Rende, Italy

The problem of the "emergence of classicality", in rough synthesis, consists in explaining why "macroscopic" systems behave obeying classical laws rather than quantum laws. The present work pursues an approach to this problem alternative to the typical approaches in the literature. The basic step is to identify the deepest origin of non-classicality in the empirically ascertained impossibility of a simultaneous value assignment to all quantum observables. Specific macrosopicity conditions are introduced, which characterize the physical system as rigid homogeneous body. These conditions enforce the possibility of extending the value assignment provided by actually performed measurements to both the position and the velocity of the center of mass of the body, without loosing empirical and quantum theoretical consistency. This made possible by the use of the quantum concept of "evaluation" developed in [Int.J.Theor.Phys., 55 1798 (2016)]. Under regularity conditions for the interaction, it is proved that a center of mass trajectory can be consistently assigned by quantum theory, which satisfies the classical laws of motion.

TUE 10.2 Tue 14:30 ZHG103

In a closed universe, orbital angular momentum has non-integer values — •Daniel Burgarth[1] and Paolo Facchi[2] — [1]Friedrich Alexander University — [2]Bari University

We show that the spectrum of orbital angular momentum in quantum mechanics is the union of two parts when the underlying space has periodic boundaries. While the first part corresponds to the usual textbook integer quantized values, the second is a continuous band arising from the edge of space with respect to the center of rotation. The spectrum thus contains not only half-integer values (often thought impossible for orbital angular momentum), but even irrational ones. This effect is independent of the size of space. We argue that such spectral components would be invisible in the laboratory but might nonetheless have observable consequences on the cosmic scale.

TUE 10.3 Tue 14:45 ZHG103

Proof of the ionization conjecture for Engel-Dreizler atoms — •Heinz Siedentop — Mathematisches Institut, Ludwig-Maximilians-Universität München, Theresienstr. 39, 80333 München

We show that the number of electrons that an atom described by the relativistic density functional introduced by Engel and Dreizler is bounded uniformly in Z. The presentation is based on joined work with Rafael Benguria, Santiago, Chile.

TUE 10.4 Tue 15:00 ZHG103

Robust quantification of spectral transitions in perturbed quantum systems
— Zsolt Szabó[1,2], Stefan Gehr[3], Paolo Facchi[4,5], Kazuya Yuasa[6], Daniel Burgarth[3], and •Davide Lonigro[3] — [1]School of Mathematical and Physical Sciences, Macquarie University, NSW 2109, Australia — [2]ARC Centre of Excellence for Engineered Quantum Systems, Macquarie University, NSW 2109, Australia — [3]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstraße 7, 91058 Erlangen, Germany — [4]Dipartimento di Fisica, Università di Bari, I-70126 Bari, Italy — [5]INFN, Sezione di Bari, I-70126 Bari, Italy — [6]Department of Physics, Waseda University, Tokyo 169-8555, Japan

A quantum system subject to an external perturbation can experience leakage between uncoupled regions of its energy spectrum separated by a gap. To quantify this phenomenon, we present two complementary results. First, we establish time-independent bounds on the distances between the true dynamics and the dynamics generated by block-diagonal effective evolutions constructed via the Schrieffer-Wolff and Bloch methods. Second, we prove that, under the right conditions, this leakage remains small eternally. That is, we derive a time-independent bound on the leakage itself, expressed in terms of the spectral gap of the unperturbed Hamiltonian and the norm of the perturbation, ensuring its validity for arbitrarily large times. Our approach only requires the existence of a finite spectral gap, thus accommodating continuous and unbounded spectra.

Based on arXiv:2505.19904.

TUE 10.5 Tue 15:15 ZHG103

Lie symmetries and ghost-free representations of the Pais-Uhlenbeck model
— •Alexander Felski — Max Planck Institute for the Science of Light, Erlangen, Germany

Ghost-ridden quantum systems manifest in various forms. Typically, this means that parts of their spectra are not bounded from below or that they contain non-normalisable states, leading to a violation of unitarity. We investigate the Pais-Uhlenbeck model, a prominently ghost-ridden system and paradigmatic example of a higher time-derivative theory, by identifying the Lie symmetries of its associated fourth-order dynamical equation. Exploiting these symmetries in conjunction with the model's Bi-Hamiltonian structure, we construct distinct Poisson bracket formulations that preserve the system's dynamics. This allows us to recast the Pais-Uhlenbeck model in a positive definite manner, offering a solution to the long-standing problem of ghost instabilities. Furthermore, we systematically explore a family of transformations that reduce the Pais-Uhlenbeck model to equivalent first-order, higher-dimensional systems. Our approach yields a unified framework for interpreting and stabilizing higher time-derivative dynamics through a symmetry analysis.

TUE 10.6 Tue 15:30 ZHG103

Macroscopic Hall-Current Response in Infinite-Volume Systems — •Marius Wesle[1], Giovanna Marcelli[2], Tadahiro Miyao[3], Domenico Monaco[4], and Stefan Teufel[1] — [1]Universität Tübingen, Germany — [2]Università di Roma Tre, Italy — [3]Hokkaido University, Japan — [4]Sapienza Università di Roma, Italy

Given a 2-dimensional system of interacting fermions, the Hall-conductivity is defined as the linear response coefficient that is associated to the current induced in one direction when applying a homogeneous electric field in the perpendicular direction.

In this talk I will explain how in infinitely-extended periodic systems of interacting lattice fermions with a spectral gap, one can rigorously realise the linear response definition of the Hall-conductivity described above. By using the NEASS (Non-Equilibrium Almost-Stationary State) approach to linear response theory we can rigorously control the induced Hall-current, despite the fact that even a very small homogeneous electric field closes the spectral gap. Our proof recovers a many-body version of the double-commutator formula for the Hall-conductivity and shows, that the current response is purely linear with no polynomial corrections. It also allows for a simple argument that shows that the

Hall-conductivity is constant within topological phases. This talk is based on arXiv:2411.06967.

TUE 10.7 Tue 15:45 ZHG103

Particle propagation bounds for bosonic lattice systems with long range interactions — •Carla Rubiliani[1], Marius Lemm[1], and Jingxuan Zhang[2] — [1]University of Tübingen, Germany — [2]Tsinghua University, China

We study the quantum time evolution of a system of bosons on a lattice generated by a long-range Hamiltonian with power-law decaying terms. We establish the first thermodynamically stable particle propagation bound in this setting, thus showing the finiteness of the speed of boson transport across the lattice. The main novelty in our proof is a multi-scale adaptation of the adiabatic space-time localisation observable method, which allows removing the dependence of the error term from far-away particles. Following this strategy, we were also able to control higher moments of the number operator. This opens the door to proving the first thermodynamically stable Lieb-Robinson bounds for bosonic systems with long-range hopping. This talk is based on arxiv:2310.14896

TUE 10.8 Tue 16:00 ZHG103

Quantum Incompatibility in Parallel *vs* Antiparallel Spins — Ram K Patra[1], •Kunika Agarwal[1], Biswajit Paul[2], Snehasish R Chowdhury[1], Sahil G Naik[1], and Manik Banik[1] — [1]Department of Physics of Complex Systems, S. N. Bose National Center for Basic Sciences, Block JD, Sector III, Salt Lake, Kolkata 700106, India — [2]Department of Mathematics, Balagarh Bijoy Krishna Mahavidyalaya, Balagarh, Hooghly-712501, West Bengal, India

We investigate the joint measurability of incompatible quantum observables on ensembles of parallel and antiparallel spin pairs. In parallel configuration, two systems are identically prepared, whereas in antiparallel configuration each system is paired with its spin-flipped counterpart. We demonstrate that the antiparallel configuration enables exact simultaneous prediction of three mutually orthogonal spin components*an advantage unattainable in the parallel case. As we show, this enhanced measurement compatibility in antiparallel configuration is better explained within the framework of generalized probabilistic theories, which allow a broader class of composite structures while preserving quantum descriptions at the subsystem level. Furthermore, this approach extends the study of measurement incompatibility to more general configurations beyond just the parallel and antiparallel cases, providing deeper insights into the boundary between physical and unphysical quantum state evolutions. To this end, we discuss how the enhanced measurement compatibility in antiparallel configuration can be observed on a finite ensemble of qubit states, paving the way for an experimental demonstration of this advantage.

TUE 11: Quantum Optics and Quantum Computation

Time: Tuesday 14:15–16:15 Location: ZHG104

TUE 11.1 Tue 14:15 ZHG104

Collective photon emission of correlated atoms in free space — •Joachim von Zanthier[1], Stefan Richter[1], Sebastian Wolf[2], and Ferdinand Schmidt-Kaler[2] — [1]Universität Erlangen-Nürnberg, 91058 Erlangen — [2]Universität Mainz, 55128 Mainz

Superradiance is one of the enigmatic problems in quantum optics since Dicke introduced the concept of coherent spontaneous emission by an ensemble of identical atoms in highly entangled Dicke states [1]. While single excited Dicke states have been investigated, the production of Dicke states with higher number of excitations remains a challenge. We generate these states via successive measurement of photons at particular positions in the far field starting from the fully excited system [2]. In this case, the collective system cascades down the ladder of symmetric Dicke states each time a photon is recorded. We apply this scheme to demonstrate directional super- and subradiance with two trapped Ca+ ions [3]. The arrangement for preparing the Dicke states and subsequently recording directional super- and subradiance corresponds to a generalized HBT setup. This shows that the two fundamental phenomena of quantum optics, Dicke superradiance and HBT interference, are two sides of the same coin. We also outline how to map the symmetric Dicke states onto the long-lived ground state Zeemann-levels of the Ca+ ions [4].

[1] R. H. Dicke, Phys. Rev. 93, 99 (1954).
[2] S. Oppel et al., PRL 113, 263606 (2014).
[3] S. Richter et al., PRR 5, 013163 (2023).
[4] M. Verde et al., ArXiv 2404.12513.

TUE 11.2 Tue 14:30 ZHG104

Training non-linear optical neural networks with Scattering Backpropagation — •Nicola Dal Cin[1,2], Florian Marquardt[1,2], and Clara Wanjura[1] — [1]Max Planck Institute for the Science of Light, Staudtstraße 2, 91058 Erlangen, Germany — [2]Department of Physics, University of Erlangen-Nuremberg, 91058 Erlangen, Germany

As deep learning applications continue to deploy increasingly large artificial neural networks, the associated high energy demands are creating a need for alternative neuromorphic approaches. Optics and photonics are particularly compelling as they offer high speeds and energy efficiency. Neuromorphic systems based on non-linear optics promise high expressivity with a minimal number of parameters. However, so far, there is no efficient and generic physics-based training method with gradients for non-linear optical systems with dissipation. In this work, we present “Scattering Backpropagation”, the first efficient physics-inspired method for experimentally measuring approximated gradients for non-linear optical neural networks. Remarkably, our approach does not require a mathematical model of the physical nonlinearity, and only involves two measurements of the system to compute all gradient approximations. In addition, the estimation precision depends on the deviation from reciprocity. We successfully apply our method to well-known benchmarks such as XOR and MNIST. Our method is widely applicable to existing state-of-the-art, scalable platforms, such as optics, microwave, and also extends to other physical platforms such as electrical circuits.

TUE 11.3 Tue 14:45 ZHG104

Hybrid Qubit Encoding: Splitting Fock Space into Fermionic and Bosonic Subspaces — •Francisco Javier del Arco Santos — Institute for Computer Science, University of Augsburg, Augsburg, Germany

The main issue of computational chemistry is solving the Schrodinger Equation. In consequence, many methods have been developed in order to approximate the ground and first excited molecular states. It has already been predicted that the application of quantum computers would be useful for this research area. However, nowadays quantum computers still being reduced in number of qubits (order of a few hundred) and with relatively high noise. Efficient encoding of electronic operators into qubits is essential for quantum chemistry simulations. Most of the methods treat Fermionic degrees of freedom and qubits one a one-to-one fashion, handling their interactions. Alternatively, pairs of electrons can be represented as quasi-particles and encoded into qubits, significantly simplifying calculations. This work presents a Hybrid Encoding that allows splitting the Fock space into Fermionic and Bosonic subspaces. By leveraging the strengths of both approaches, we provide a flexible framework for optimizing quantum simulations based on molecular characteristics and hardware constraints. Afterwards, it has been applied in order to simulate molecular systems, which would be prohibitive without this hybrid schema.

TUE 11.4 Tue 15:00 ZHG104

Thermodynamics of the micromaser — •Anja Seegebrecht and Tanja Schilling — University of Freiburg, Freiburg, Germany

The micromaser is a very simple model to study light-matter interactions and a prototypical example in quantum optics. It can also be used in various ways to discuss quantum thermodynamics. The interaction of thermal atoms with the cavity can be interpreted as a the action of a heat bath since field ends up in a Gibbs state. But the relaxation towards steady state can be non-monotonic. This is a peculiar feature for a thermalization process. Additionally we observe that heating and cooling happen at different rates. The trapping state feature can be used to construct a quantum battery model. With coherent atoms actually useful work (ergortropy) can be stored in the cavity by preparing a pure state. We explore the charging power, extraction protocols and stability of this setup.

TUE 11.5 Tue 15:15 ZHG104

Measuring nuclear resonant phase shifts with a nanoscale double-slit experiment — •Leon Merten Lohse[1,3], Ralf Röhlsberger[4,5,6,3], and Tim Salditt[2] — [1]Universität Hamburg — [2]Georg-August-Universität Göttingen — [3]Deutsches Elektronen-Synchrotron DESY, Hamburg — [4]Friedrich-Schiller-Universität Jena — [5]Helmholtz-Institut Jena — [6]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt

An electromagnetic wave scattering with atoms experiences a phase shift that encodes information about the atoms' quantum states and photon-matter interaction. While interferometers are readily available in the optical regime, measuring phase shifts in the x-ray regime is notoriously challenging, especially at the nanometer scale. To that end, we have devised and implemented a double-waveguide interferometer on the nanometer scale, reminiscent of Thomas Young's celebrated experiment from 1801. The interferometer has enabled us to measure the phase shift that an ultrathin layer of ^{57}Fe Mössbauer nuclei coherently imprints onto x-ray photons propagating through a single-mode x-ray waveguide. Using the extracted phase shift, we were able to accurately quantify the coupling strength between photons and nuclei. Based on this, one can envision to actively control the phase in x-ray nanophotonic devices.

TUE 11.6 Tue 15:30 ZHG104

Observation of Shapiro steps in an ultracold atomic Josephson junction — •Erik Bernhart[1], Marvin Röhrle[1], Florian Binoth[1], Vijay Pal Singh[2], Ludwig Mathey[3], Luigi Amico[2,4], and Herwig Ott[1] — [1]Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [2]Quantum Research Centre, Technology Innovation Institute, Abu Dhabi, UAE — [3]Zentrum für Optische Quantentechnologien and Institut für Quantenphysik, Universität Hamburg — [4]INFN-Sezione di Catania, Via S. Sofia 64, 95127 Catania, Italy

An ultracold atomic Josephson junction is an elementary example of quantum transport and offers a unique platform for quantum simulation of superconducting circuits. The related Josephson effect, where a dissipation-less supercurrent through a tunneling barrier is caused by a phase difference, is well known in superconductors. Is such a junction externally driven, the current-voltage characteristic displays discrete steps, named Shapiro steps, the basis of today's voltage standard. We report on the experimental observation of Shapiro steps in a driven Josephson junction in a gas of ultracold atoms. We demonstrate the universal features of the steps, most noticeable the quantization of the step height. Our experiment provides insights in the microscopic dissipative dynamics, where we observe that the dynamics are caused by phonon emission and collective excitations. The experimental results are underpinned by extensive numerical simulations. Our work expands the understanding of the microscopic dynamics of Shapiro steps and it transfers the voltage standard to ultracold quantum gases.

TUE 11.7 Tue 15:45 ZHG104

Shaping Slow Electron Beam with Plasmonic Near-field — •Fatemeh Chahshouri[1] and Nahid Talebi[1,2] — [1]Institute of Experimental and Applied Physics, Kiel University, 24098 Kiel, Germany — [2]Kiel, Nano, Surface, and Interface Science KiNSIS, Kiel University, 24098 Kiel, Germany

Recent progress in laser-induced near-field electron-photon interactions has opened new possibilities for quantum-coherent manipulation of free-electron wavepackets. In this work, we investigate how polarization, phase control, and field symmetry control inelastic and elastic interactions between slow electrons and plasmonic near-fields near gold nanorods beyond the nonrecoil approximation. First, we explore how the direction of the linear laser pulse controls energy transfer and transverse recoil of the electron beam. Extending this approach, we employ a sequential phase-locked interaction scheme and show that the initial optical phase and the phase offset between localized dipolar zones influence both amplitude and phase modulation of the electron wavepacket. Finally, we study electron shaping under the influence of a rotating plasmonic field, considering plasmonic rotors generated by two orthogonally polarized laser pulses with a controlled phase delay and circularly polarized light with defined handedness. We demonstrate angular momentum transfer and directional dependence of the electron modulation on the handedness of the plasmonic field in both real and reciprocal space. These results highlight the versatility of tailored near-fields for shaping free-electron beams and offer new tools for ultrafast interferometry and quantum-coherent electron microscopy.

TUE 11.8 Tue 16:00 ZHG104

Probing MHz Charge Dynamics in Diamond Using a Tin-Vacancy Color Center — Charlotta Gurr[1], •Cem Güney Torun[1], Gregor Pieplow[1], and Tim Schröder[1,2] — [1]Humboldt-Universität zu Berlin, Germany — [2]Ferdinand-Braun-Institut gGmbH, Leibniz-Institut für Höchstfrequenztechnik, Berlin, Germany

Color centers in diamond are affected by electric noise originating from the diamond host material itself [1]. This noise arises from free charge carriers being intermittently trapped and released by defects (charge traps) in the diamond lattice, generating a fluctuating electric field that shifts the energy levels of the color centers. As a result, the optical transitions become unstable, posing challenges for applications that rely on consistent sources of indistinguishable photons. Despite their significance, the characteristics of these charge traps remain poorly understood. In this work, we present a method to probe the dynamics of individual charge processes in diamond with MHz temporal resolution, utilizing a tin-vacancy color center. Our measurements reveal that charge capture and release rates vary across two orders of magnitude, from Hz to kHz, suggesting the presence of two distinct mechanisms governing these processes. Additionally, we observe that illumination with 520 nm light more strongly affects the charge release rates than higher-energy 445 nm light. These results provide new insights into the nature of charge traps in diamond and the underlying dynamics of single-charge trapping and release.

[1] Pieplow, Torun et al., *Quantum Electrometer for Time-resolved Material Science at the Atomic Lattice Scale*, arXiv:2401.14290, 2024

TUE 12: Quantum Sensing and Decoherence: Contributed Session to Symposium III

Time: Tuesday 14:15–16:00 Location: ZHG105

TUE 12.1 Tue 14:15 ZHG105

Inelastic electron-light interaction probed by holographic scanning transmission electron microscopy — •Nora Bach[1,2], Tim Dauwe[1,2], Murat Sivis[1,2], and Claus Ropers[1,2] — [1]Max Planck Institute for Multidisciplinary Sciences, Göttingen, Germany — [2]4th Physical Institute, University of Göttingen, Germany

In an ultrafast transmission electron microscope (UTEM), inelastic scattering between free electrons and optical near fields allows for coherent manipulations of the electron quantum state [1]. Recently, different techniques have been developed to reveal the near-field phase imprinted onto the electron wave function, but offer only limited variability in tailoring the electron-light interactions and require a highly coherent electron source [2,3]. In this contribution, we introduce scanning transmission electron microscopy with spatially separated coherent electron probes [4] for the full imaging of complex optical near fields at relaxed coherence requirements. In the far field, these electron probes interfere to form a hologram from which we reconstruct phase shifts induced both by elastic scattering processes and by stimulated inelastic interactions. By superimposing multiple parallel interactions, our approach can be extended to tailoring of the electron spectral distribution beyond what is achievable with a single interaction.

[1] Feist et al., Nature 521, (2015)
[2] Gaida et al., Nature Communications 14, (2023)
[3] Gaida et al., Nature Photonics 18 (2024)
[4] Fehmi et al., Journal of Physics D: Applied Physics 51 (2018)

TUE 12.2 Tue 14:30 ZHG105

A nonlinear extension of crystallography - X-ray-optical wavemixing on valence charges — •Dietrich Krebs — Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

As we celebrate 100 years of Quantum Physics, the field of x-ray crystallography simultaneously approaches its 111th anniversary. Both fields are closely intertwined - with innumerable advances in solid-state and quantum physics being propelled by crystallography's outstanding ability to determine the structure of matter microscopically. Yet, crystallography itself never quite progressed into the quantum realm. Instead, it largely remains a method rooted in concepts of classical waves and (spherical) charge densities.

In this talk, we outline how ideas from nonlinear optics and the use of modern x-ray free-electron lasers (XFEL) help to extend crystallography to the next order, namely nonlinear crystallography. Basing this extension on x-ray-optical wavemixing, it offers atomic-scale resolution - similar to regular x-ray crystallography - combined with the spectroscopic sensitivity of optical techniques. We present our results from a recent XFEL-experiment, which demonstrate the feasibility of nonlinear crystallography on laser-excited diamond. In particular, we showcase the 3D-reconstruction of the newly accessible valence-response function, which agrees well with our theoretical predictions from non-relativistic Quantum Electrodynamics.

TUE 12.3 Tue 14:45 ZHG105

Measurement of electron wave phase shifts with Angstrom spatial resolution to analyse electric double layers — Jonas Lindner[1], Ulrich Ross[1,2], Tobias Meyer[1], Sung Sakong[3], Axel Gross[3], Michael Seibt[2], and •Christian Jooss[1] — [1]Institute of Materials Physics, University of Goettingen, Germany. — [2]4th Institute of Physics, Solids and Nanostructures, University of Goettingen, Germany — [3]Institute of Theoretical Chemistry, University Ulm, Germany

Using phase shifting off-axis holography in a transmission electron microscope (TEM), phase shift measurements of electron waves with 1 Angstrom spatial resolution and $2\pi/452$ phase sensitivity was achieved. The detection of phase shifts is then applied to the measurement of atomic scale electric potentials of electric double layers at electrode water interfaces. The effect of inelastic scattering due to gas ambient on electron coherence is studied. The achieved progress in spatial resolution and phase detection allows us to observe ordered water layers at the dynamic state of a platinum (111) surface as well as water reorganization under applied electric potentials. The obtained projected electric potential of water dipole layers is quantitatively compared to ab-initio molecular dynamics simulations. The experimental results reveal an extended ordered water region. The bias-dependent reorientation of molecular dipole network gives new insights into the atomic scale electric field at Helmholtz layers and its impact on proton-coupled electron transfer at interfaces. Finally, we discuss general conclusions on quantum coherence of scattered matter waves.

TUE 12.4 Tue 15:00 ZHG105

Quantum Sensing with a Strongly Driven Spin — •Dhruv Deshmukh and Joachim Ankerhold — Institute for complex quantum systems, Ulm University, Germany

Quantum systems, when exposed to suitably-tuned strong time-periodic fields, may exhibit subharmonic dynamics, the most prominent case being that of period doubling. In this presentation, we introduce conditions required for period k-tupling dynamics to manifest in the simplest paradigmatic quantum system, namely, a single driven two-level system [1]. Experimental observations, with a driven NV centre, verifying period doubling and higher multiplicities up to period quintupling are showcased [2]. Building upon these results, we show how the period k-tupling dynamics can be used for quantum metrology with a few specific examples. First, we explain how the period doubling dynamics of a driven NV centre depends upon its temperature based zero-field splitting, making it a promising tool for thermometry. Next, we also show how the special case of period-1 dynamical freezing may be used for vector magnetometry due to its direction dependent sensitivity on magnetic field [1]. We also briefly discuss the possibilities of detecting neighbouring nuclear spins through their effect on the driven NV centre dynamics.

Research Articles (to be published soon): [1] Period k-tupling in Driven Two-Level Systems (Dhruv Deshmukh and Joachim Ankerhold) [2] Observation of period doubling and higher multiplicity in a driven single-spin system (Dhruv Deshmukh, Raúl B. González, Roberto Sailer, Ressa S. Said, Fedor Jelezko and Joachim Ankerhold)

TUE 12.5 Tue 15:15 ZHG105

Sensing Spins on Surfaces and Following them into Chemical Bonds with Scanning Probe Microscopy — •Dmitriy Borodin — IBS Center for Quantum Nanoscience, Seoul, South Korea

Spins on surfaces have been recently proposed as a promising qubit platform and also for atomic-scale quantum sensing. Control and readout are enabled by single atom electron spin resonance via scanning tunneling microscopes (ESR-STM).

In this work we show that quantum sensing can be enabled by following the electron spin resonance of a single molecule bound to the tip of a scanning probe microscope. We demonstrate that weak electrostatic and magnetic fields of single atomic objects can be quantified with sub-angstrom spatial resolution. The atomic-scale quantum sensor if universally applicable to conductive surfaces.

The spin lifetimes and phase coherence times (T1 and T2) of atomic spins on surfaces were so far limited by electron scattering with the metal - a limitation of STM based spin detection. Therefore, we have implemented sensing of single atom spins using the magnetic exchange force (MxF) between a magnetic tip and an ad-atom on the surface. Surprisingly, studying the spin-spin interaction we observe pattern that reflect the formation of a chemical bond between the surface bound atom and the magnetic atom at the tip.

TUE 12.6 Tue 15:30 ZHG105

Exploring Coherent Manipulation of Spin Systems via the Near-Field of a Modulated Electron Beam — •Thomas Spielauer[1], Matthias Kolb[1], Thomas Weigner[1], Johann Toyfl[1], Giovanni Boero[2], Dennis Rätzel[3], and Philipp Haslinger[1] — [1]VCQ, Technische Universität Wien, Atominstitut, Stadionallee 2, 1020 Vienna, Austria — [2]EPFL, BM 3110 Station 17, CH-1015 Lausanne, Switzerland — [3]ZARM, Universität Bremen, Am Fallturm 2, 28359 Bremen

Electron spin resonance (ESR) is a versatile analytical technique with broad applications in medicine, biology, and material science. While conventional ESR methods rely on magnetic field gradients or sophisticated resonator designs to provide spatial resolution, we explore an alternative approach utilizing the non-radiative near field of a modulated electron beam, implemented within a modified scanning electron microscope.

Our custom-built in-situ ESR platform allows us to investigate the interaction between the modulated electron beam and solid-state spin systems. Using a benchmark sample (Koelsch radical, α,γ-bisdiphenylene-β-phenylallyl) and a conventional ESR detection scheme, we observe signatures compatible with spin interactions driven by the collective non-radiative near field of the beam.

These findings establish a pathway toward coherent spin manipulation using a modulated, free-space electron beam, potentially enabling nanoscale spatial resolution for coherent quantum system control.

TUE 12.7 Tue 15:45 ZHG105

Direct imaging of magnetotransport at graphene-metal interfaces with a single-spin quantum sensor — •Chaoxin Ding, Marius Palm, Kevin Kohli, and Christian Degen — ETH Zurich, Zurich, Switzerland

Magnetotransport underlines many important phenomena in condensed matter physics, such as the Hall effect and magnetoresistance (MR) effect, and forms the basis for applications in magnetic memories and spintronic devices. Thus far, most magnetotransport studies have been based on bulk resistance measurements, without direct access to the nanoscale spatial transport pattern. Here, we discuss nanoscale quantum imaging of magnetotransport in a monolayer graphene with an embedded metal disc using a scanning nitrogen-vacancy magnetometer. By visualizing the current flow under an out-of-plane magnetic field around 0.5 T, we directly observe Lorentz-force-induced current deflection at the graphene-to-metal interface. As the carrier density in graphene increases, the current flowing through the graphene sheet is enhanced. In addition, we observe that the MR is more prominent in the ambipolar regime compared to the electron- or hole- doped regimes, which can be attributed to the intrinsic MR effect. Finally, we show that spatial current imaging uncovers non-uniform contact resistances along the circular graphene-metal interfaces, which cannot be easily identified by optical, electrical or topographic characterization.

Symposium Frustrated Quantum Systems (SYFQ)

Martin Dressel
University of Stuttgart
Pfaffenwaldring 57
70550 Stuttgart, Germany
dressel@pi1.physik.uni-stuttgart.de

The field of quantum magnetism originates in Werner Heisenberg's seminal contribution "Zur Theorie des Ferromagnetismus" in Zeitschrift für Physik 49, 619-636 (1928). Theoretical investigations of frustrated lattice by Phil W. Anderson in the 1970s opened an increasingly active field, that became even more popular after quantum spin liquids could be realized experimentally. Recent advances and novel methods in theory and in experiment lead to totally new aspects in the field of frustrated quantum magnetism. Through the targeted variation of geometry and interactions, the parameter space can be systematically explored, in order to check theoretical predictions. Research on artificial quantum systems and natural solids are mutually beneficial.

Overview of Invited Talks and Sessions

(Lecture hall ZHG008)

Invited Talks

SYFQ 1.1	Wed	10:45–11:25	ZHG008	**Detection of anyon braiding through pump-probe spectroscopy** — •Nandini Trivedi
SYFQ 1.2	Wed	11:25–12:05	ZHG008	**Fate of quantum spin liquid in 2D** — •Alexander A. Tsirlin
SYFQ 1.3	Wed	12:05–12:45	ZHG008	**Quantum disorder and quantum critical states in organic systems with triangular lattices** — •Kazushi Kanoda

Sessions

SYFQ 1.1–1.3	Wed	10:45–12:45	ZHG008	**Frustrated Quantum Systems**

Sessions

– Invited Talks –

SYFQ 1: Frustrated Quantum Systems

Time: Wednesday 10:45–12:45 Location: ZHG008

Invited Talk SYFQ 1.1 Wed 10:45 ZHG008

Detection of anyon braiding through pump-probe spectroscopy — •Nandini Trivedi — The Ohio State University, 191 W. Woodruff Avenue, Columbus, OH 43210, USA

I will discuss how pump-probe non-linear spectroscopy provides a distinctive new probe of quantum spin liquid states, beyond the inconclusive broad features observed in single spin flip inelastic neutron scattering. While the linear response signal oscillates and decays with time, the amplitude of the nonlinear signal for $\chi(3)$XZZ signal features a linear-in-time enhancement at early times. Here XZZ are the directions of pump, probe, and measurement magnetic fields. The comparison between $\chi(3)$XZZ, which involves the non-trivial braiding of electric e and magnetic m anyons, and $\chi(3)$XXX that involves the trivial braiding of the same types of anyons, serves to distinguish the braiding statistics of anyons. We support our analysis by constructing a hard-core anyon model with statistical gauge fields to develop further insights into the time dependence of the pump-probe response.

Invited Talk SYFQ 1.2 Wed 11:25 ZHG008

Fate of quantum spin liquid in 2D — •Alexander A. Tsirlin — Felix Bloch Institute for Solid-State Physics, Leipzig University, Germany

Stabilization of the long-range-entangled state of quantum spin liquid is one of the main allures of frustrated spin systems. In this talk, I will review recent progress in the experimental realization of this exotic state in quasi-2D magnets with the triangular and kagome geometries. I will highlight the role of structural disorder and the delicate competition between quantum spin liquid and random singlet states as two possible scenarios for the frustrated magnet. The microscopic pre-conditions for the spin-liquid formation and its eventual spectral manifestations will be presented.

Invited Talk SYFQ 1.3 Wed 12:05 ZHG008

Quantum disorder and quantum critical states in organic systems with triangular lattices — •Kazushi Kanoda — Max Planck Institute for Solid State Research, Stuttgart, Germany — University of Stuttgart, Germany — University of Tokyo, Japan

The exploration of quantum materials that exhibit macroscopic manifestations of quantum fluctuations and their associated novel properties is currently a focal point in condensed matter physics. Geometrically frustrated lattices, where interparticle interactions conflict with one another, serve as platforms for observing such phenomena. In this symposium, we will review the current status of research on quantum spin liquids (QSLs), with a focus on the triangular-lattice organic system κ-(BEDT-TTF)2Cu2(CN)3. Recent experimental results suggest that this system exhibits (neutral) Fermi-liquid-like behavior, followed by an instability of quantum critical nature at lower temperatures. Next, we will also discuss a metallic and superconducting system, κ-(BEDT-TTF)4Hg2.89Br8, which is a candidate for the doped QSL. In this case, we show both the non-Fermi liquid behavior and the quantum critical characteristics of the normal state, along with its superconducting nature, characterized by a pseudogap and reduced superfluid density. Finally, we will address the interrelationships between the low-temperature phases present in these two systems.

Symposium Quantum Information and the Quest for Fault-Tolerant Quantum Computing (SYQI)

Guido Burkard
University of Konstanz
Universitaetsstrasse 10
78464 Konstanz, Germany
guido.burkard@uni-konstanz.de

Quantum computers have the potential to transform information technology. However, to reach the full potential of quantum computing, errors introduced by external disturbances need to be corrected. Fault-tolerant quantum computing allows for the construction of essentially error-free hardware using error-prone components. In this symposium, three leading experts talk about the beginnings and state of the art of quantum computing hardware and quantum error correction.

Overview of Invited Talks and Sessions

(Lecture hall ZHG010)

Invited Talks

SYQI 1.1	Wed	10:45–11:25	ZHG010	**Quantum Computing and Simulation in the presence of errors** — •Ignacio Cirac
SYQI 1.2	Wed	11:25–12:05	ZHG010	**Scalable quantum computing with trapped ions** — •Ferdinand Schmidt-Kaler
SYQI 1.3	Wed	12:05–12:45	ZHG010	**New opportunities in hybrid atom arrays combining single atoms and ensembles** — •Wenchao Xu

Sessions

SYQI 1.1–1.3	Wed	10:45–12:45	ZHG010	**Quantum Information and the Quest for Fault-Tolerant Quantum Computing**

Sessions

– Invited Talks –

SYQI 1: Quantum Information and the Quest for Fault-Tolerant Quantum Computing

Time: Wednesday 10:45–12:45 Location: ZHG010

Invited Talk SYQI 1.1 Wed 10:45 ZHG010

Quantum Computing and Simulation in the presence of errors — •Ignacio Cirac — Max Planck Institute of Quantum Optics, Garching, Germany

Advancements in quantum computing have enabled the development of small-scale quantum computers and simulators that adhere to the principles of quantum physics. Despite its rapid progress, those devices are not yet flawless and errors accumulate, posing serious challenges to their application to interesting problems. In this talk I will first address how those errors affect the results of both quantum computations and the simulation of quantum many-body systems. In particular, I will present several quantum simulation algorithms, and discuss the potentiality of displaying quantum advantage in the presence of imperfections. Finally, I will describe some new ingredients of such algorithms, like the preparation of highly entangled states, and discuss how they can be sped up with the help of measurements.

Invited Talk SYQI 1.2 Wed 11:25 ZHG010

Scalable quantum computing with trapped ions — •Ferdinand Schmidt-Kaler — QUANTUM, Univ. Mainz

I will describe the challenges on the way to a scalable, eventually a fault tolerant quantum computer [1]. Efforts from physics, informatics [2,3] and mathematics but also engineering [4] are concentrated in BMBF-funded demonstrator setups. The hardware is suited for the implementation of topological quantum error correction with fault-tolerant syndrome readout [1] and feedforward operations. As a first glance into the power of quantum computing, I will describe a couple of usecases: the VQE-simulation of a two-flavor Schwinger quark model executed on a trapped-ion quantum processor [5], and the quantum autoencoder [6], as a simple instance of machine learning error codes of the specific hardware.

References: [1] Hilder et al., Phys. Rev. X.12.011032 (2022), [2] Kreppel et al., Quantum 7, 1176 (2023), [3] Durandeau et al., Quantum 7, 1175 (2023), [4] Kaustal et al., AVS Qu. Sci. 2, 014101 (2020), [5] Melzer et al., arXiv:2504.20824, [6] Locher et al., Quantum 7, 942 (2023).

Invited Talk SYQI 1.3 Wed 12:05 ZHG010

New opportunities in hybrid atom arrays combining single atoms and ensembles — •Wenchao Xu — ETH Zurich

Neutral-atom array platforms have advanced rapidly in recent years and are now among the leading candidates for realizing quantum technologies. However, achieving fault-tolerant quantum computation requires overcoming key challenges, including reconfigurable individual qubit addressability, fast, mid-circuit readout, and scaling beyond 10,000 qubits.

To tackle these limitations, we are developing a novel dual-type, dual-species atom array architecture. In our approach, single ytterbium (Yb) atoms*with their long nuclear spin coherence times*serve as data qubits, while rubidium (Rb) atomic ensembles*with their strong collective optical response*function as ancilla. This combination enables reconfigurable local operations, fast and non-destructive readout of both single- and multi-qubit states and introduces a new scheme for establishing quantum optical links. As part of this effort, we are currently conducting spectroscopic measurements of Yb*Rb Rydberg pair interactions. These studies will benchmark theoretical models of Rydberg states in multi-valence-electron atoms and lay the groundwork for experimental realization of our proposed architecture.

Symposium Quantum Thermalization (SYQT)

Fabian Heidrich-Meisner
University of Göttingen
Friedrich-Hund-Platz 1
37077 Göttingen, Germany
fabian.heidrich-meisner@uni-goettingen.de

Frank Pollmann
Technical University of Munich
James-Franck-Straße 1
85748 Garching, Germany
frank.pollmann@tum.de

Why and how do isolated quantum systems thermalize-or fail to do so? This fundamental question lies at the heart of current research in quantum many-body physics. While the eigenstate thermalization hypothesis (ETH) has provided a framework for understanding quantum chaos and ergodicity, a growing class of systems defies this paradigm. Constrained dynamics can lead to rich and exotic behaviors such as Hilbert-space fragmentation, quantum many-body scars, and anomalous transport.

This symposium covers advances in statistical physics, condensed matter, quantum optics, and lattice gauge theories. The talks will highlight both foundational insights and new experimental platforms, including experiments tailored to realize lattice gauge theories and advanced quantum-gas microscopes, complemented by theoretical talks. The theoretical talks will bridge between quantum thermalization in quantum simulators and high-energy physics.

Overview of Invited Talks and Sessions

(Lecture hall ZHG104)

Invited Talks

SYQT 1.1	Wed	10:45–11:15	ZHG104	**Probing quantum many-body dynamics using subsystem Loschmidt echos** — •Monika Aidelsburger
SYQT 1.2	Wed	11:15–11:45	ZHG104	**Approach to thermalisation in the Schwinger model** — •Adrien Florio
SYQT 1.3	Wed	11:45–12:15	ZHG104	**Timescales for thermalization and many-body quantum chaos** — •Lea Santos
SYQT 1.4	Wed	12:15–12:45	ZHG104	**Observation of Hilbert-space fragmentation and fractonic excitations in tilted Hubbard models** — •Johannes Zeiher

Sessions

SYQT 1.1–1.4	Wed	10:45–12:45	ZHG104	**Quantum Thermalization**

Sessions

– Invited Talks –

SYQT 1: Quantum Thermalization

Time: Wednesday 10:45–12:45 Location: ZHG104

Invited Talk SYQT 1.1 Wed 10:45 ZHG104

Probing quantum many-body dynamics using subsystem Loschmidt echos — •Monika Aidelsburger — MPQ Garching, Germany — LMU Munich, Germany

Neutral atoms in optical lattices offer large system sizes and long coherence times, ideal for investigating out-of-equilibrium dynamics and fundamental questions about the thermalization of isolated quantum many-body systems. The Loschmidt echo - the probability of a quantum many-body system to return to its initial state following a dynamical evolution - generally contains key information about a quantum system, relevant across various scientific fields including quantum chaos, quantum many-body physics, or high-energy physics. However, it is typically exponentially small in system size, posing an outstanding challenge for experiments. Here, I introduce the subsystem Loschmidt echo, a quasi-local observable that captures key features of the Loschmidt echo while being readily accessible experimentally. In the short-time regime, we use it to reveal a dynamical quantum phase transition arising from genuine higher-order correlations. In the long-time regime, it quantitatively determines the effective dimension and structure of the accessible Hilbert space in the thermodynamic limit providing direct experimental evidence for ergodicity breaking due to Hilbert-space fragmentation. These findings establish the subsystem Loschmidt echo as a powerful tool to study out-of-equilibrium dynamics, applicable to a broad range of quantum simulation and computing platforms.

Invited Talk SYQT 1.2 Wed 11:15 ZHG104

Approach to thermalisation in the Schwinger model — •Adrien Florio — Bielefeld

The Schwinger model is a confining theory in one plus one dimensions that has a chiral condensate and a chiral anomaly. I will present tensor network simulations of its real-time dynamics. In particular, I will discuss how the system appears to thermalise when subjected to an inhomogeneous quench reminiscent of the production of hard particles in a QCD jet. I will characterise this approach to equilibrium through the lens of local observables and the rearrangement of entanglement in the system.

Invited Talk SYQT 1.3 Wed 11:45 ZHG104

Timescales for thermalization and many-body quantum chaos — •Lea Santos — University of Connecticut, Storrs, CT, USA

The timescale for isolated many-body quantum systems to reach thermal equilibrium after a dynamical quench remains an important open question.*We examine how the equilibration process depends on the models, observables, energy of the initial state, and system size, revealing distinct dynamical behaviors across different timescales.*Special attention is given to the dynamical manifestations of many-body quantum chaos and methods for detecting them in experimental setups, such as cold atoms, ion traps, and NMR systems. We show that coupling the system to a dephasing environment can reduce dynamical fluctuations that might otherwise obscure these manifestations.

Invited Talk SYQT 1.4 Wed 12:15 ZHG104

Observation of Hilbert-space fragmentation and fractonic excitations in tilted Hubbard models — •Johannes Zeiher — Ludwig-Maximilians-Universität München — Max-Planck-Institut für Quantenoptik

Neutral atoms trapped in optical lattices are a versatile platform to study many-body physics in and out of equilibrium. The relaxation behavior of isolated quantum systems taken out of equilibrium is among the most intriguing problems in many-body physics. Quantum systems out of equilibrium typically relax to thermal equilibrium states by scrambling local information and building up entanglement entropy. In this talk, I will present our recent experiments on probing an exception to this expected thermalization behavior in two-dimensional tilted Hubbard models with strong kinetic constraints. Combining local initial-state control with site-resolved measurements in our quantum-gas microscope, we find a strong dependence of the relaxation dynamics on the specific initial state - a hallmark of the shattering of the underlying Hilbert space in disconnected fragments. Leveraging the control over individual atoms, we furthermore inject mobile excitations into an otherwise immobile state and track their dynamics. We find subdimensional dynamics, which is a feature characteristic of fractonic excitations. Our results pave the way for in-depth studies of microscopic transport phenomena in constrained systems.

Symposium Quantum Physics at the High-Energy Frontier: The Higgs Boson in the Standard Model and Beyond (SYHB)

Johannes Haller
University of Hamburg
Luruper Chaussee 149
22761 Hamburg, Germany
johannes.haller@uni-hamburg.de

Experiments at modern particle colliders probe the fundamental laws of quantum physics at the highest energies. The Standard Model (SM) of particle physics is based on quantum field theory and describes the basic building blocks of matter and the forces acting between them. At its heart is the Higgs boson, an exceptional quantum state that plays a crucial role in generating the masses of bosons, fermions and even itself. This scalar state is closely connected to fundamental open questions in quantum physics and cosmology for which the SM offers no explanation; among them the nature of dark matter, the matter-antimatter asymmetry and the evolution of the universe from the big bang to the present day. For this reason, the Higgs boson could be the key to a new description of the quantum world.

Almost five decades after its postulation, the discovery of the Higgs boson by the ATLAS and CMS experiments at the Large Hadron Collider (LHC) was a triumphant confirmation of quantum physics. The ongoing measurements of the Higgs boson properties constitute an enormous further progress. However, only future experiments at the High-Luminosity LHC (HL-LHC) or at proposed next-generation colliders will provide us with the necessary quantum leap forward in our understanding of nature.

In this symposium, world-class experts will give an overview of the physics of the Higgs boson: its role in the quantum theory of particles and cosmology (Mühlleitner), the experimental path from the establishment of the SM to the Higgs boson discovery (Jakobs), the status of current Higgs boson measurements (Köneke) and an outlook into the future (Klute).

Overview of Invited Talks and Sessions

(Lecture hall ZHG105)

Invited Talks

SYHB 1.1	Wed	10:45–11:15	ZHG105	**The Higgs Boson – Key to our Understanding of the Universe** — •Milada M. Mühlleitner
SYHB 1.2	Wed	11:15–11:45	ZHG105	**The path to the discovery of the Higgs boson** — •Karl Jakobs
SYHB 1.3	Wed	11:45–12:15	ZHG105	**The Higgs boson revealed: What current experiments teach us about this unique quantum state** — •Karsten Köneke
SYHB 1.4	Wed	12:15–12:45	ZHG105	**A Quantum Leap Forward: Unlocking the Higgs Boson at Future Colliders** — •Markus Klute

Sessions

SYHB 1.1–1.4	Wed	10:45–12:45	ZHG105	**Symposium Quantum Physics at the High-Energy Frontier: The Higgs Boson in the Standard Model and Beyond**

Sessions

– Invited Talks –

SYHB 1: Symposium Quantum Physics at the High-Energy Frontier: The Higgs Boson in the Standard Model and Beyond

Time: Wednesday 10:45–12:45 Location: ZHG105

Invited Talk SYHB 1.1 Wed 10:45 ZHG105

The Higgs Boson – Key to our Understanding of the Universe — •Milada M. Mühlleitner — Karlsruhe Institute of Technology, Karlsruhe, Germany

The Higgs boson was discovered 48 years after its postulation based on symmetry principles that are required to hold at the quantum level. It plays a central role in our understanding of the Universe: Through its couplings to all massive particles and as a door opener to dark sectors, it is able to give us answers to our most pressing open questions. These include the nature of Dark Matter and why there is more matter than antimatter in the Universe. Tested to highest precision at the quantum level, it builds a bridge between elementary particle physics, astroparticle physics, and cosmology. In this context, gravitational waves provide us with an exciting tool to investigate its role in the evolution of the Universe by connecting the quantum world with classical physics. The talk will shed light on the central role of the Higgs boson not only for the Standard Model of particle physics but also for our understanding of the Universe as a whole.

Invited Talk SYHB 1.2 Wed 11:15 ZHG105

The path to the discovery of the Higgs boson — •Karl Jakobs — Physikalisches Institut, Universität Freiburg, Freiburg, Germany

The announcement of the discovery of the Higgs boson on July 4, 2012 by the ATLAS and CMS experiments at the European Research Centre for particle physics, CERN in Geneva, marked an important milestone in the research on the fundamental building blocks of matter and the forces acting between them, and on the verification of quantum field theory-based predictions of the Standard Model of particle physics.

The Large Hadron Collider (LHC) was designed back in the 1990s to clarify the question of the existence of the Higgs boson, the last missing building block in the Standard Model. In this talk, the path from the establishment of the Standard Model and its quantum structure to the discovery of the Higgs boson and the first measurement of its properties will be described. In addition, insights into the realisation of the LHC and the associated experiments will be given.

Invited Talk SYHB 1.3 Wed 11:45 ZHG105

The Higgs boson revealed: What current experiments teach us about this unique quantum state — •Karsten Köneke — II. Physikalisches Institut, Georg-August-Universität Göttingen, Göttingen, Germany

At the heart of the Standard Model of particle physics lies the Higgs boson – an exceptional elementary particle distinguished not only by its spin-0 nature. It plays a crucial role within the quantum realm of particle physics in generating the masses of gauge bosons, fermions, and even itself. The Higgs boson is deeply connected to fundamental questions in quantum physics, the early stages of the Universe, and even the underpinnings of everyday chemistry. In this talk, I will present the latest Higgs boson measurement results from the ATLAS and CMS collaborations. I will also discuss ongoing efforts to observe the rare production of Higgs boson pairs – an essential step toward probing the structure of the Higgs potential.

Invited Talk SYHB 1.4 Wed 12:15 ZHG105

A Quantum Leap Forward: Unlocking the Higgs Boson at Future Colliders — •Markus Klute — Karlsruhe Institute of Technology, Karlsruhe, Germany

The Higgs boson stands out as the most intriguing and unique particle in the Standard Model – both a manifestation of the Higgs field and a potential key to new physics. While the Large Hadron Collider has opened the door, the precision frontier –where subtle deviations from the Standard Model may reveal themselves – lies ahead. In this talk, we explore how future experiments, from the High-Luminosity LHC to proposed next-generation colliders like the FCC, aim to transform the Higgs boson from a known particle into a precision tool. By measuring its self-interaction, rare decays, and couplings with unprecedented accuracy, we may uncover clues about the nature of electroweak symmetry breaking, the hierarchy problem, and possible connections to dark matter and the early universe. These future measurements are not just incremental steps – they are a quantum leap forward in our understanding of nature.

Industry Day (WED-ID)

Rishabh Jha
University of Göttingen
Friedrich-Hund-Platz 1
37077 Göttingen, Germany
rishabh.jha@uni-goettingen.de

Wilhelm Kaenders
TOPTICA Photonics AG
Lochhamer Schlag 19
82166 Gräfelfing, Germany
Wilhelm.Kaenders@toptica.com

Overview of Invited Talks and Sessions

(Lecture halls ZHG011, ZHG001, ZHG006, ZHG007, ZHG101, ZHG104, and ZHG105)

Plenary Talk

WED-ID 1.1	Wed	14:05–14:35	ZHG011	**Quantum technologies roadmaps perspective and challenges** — •Olivier Ezratty

Invited Talks

WED-ID 2.1	Wed	14:45–15:05	ZHG001	**Trapped-Ion Quantum Computing at Infineon** — •Clemens Rössler
WED-ID 2.2	Wed	15:10–15:30	ZHG001	**Planck's Reluctant Constant and the Second Semiconductor Revolution** — •Mark Mattingley-Scott
WED-ID 2.3	Wed	15:35–15:55	ZHG001	**Quantencomputing: Von der universitären Forschung zum Startup neQxt** — •Ferdinand Schmidt-Kaler
WED-ID 2.4	Wed	16:00–16:20	ZHG001	**Building quantum computers, atom by atom** — •Alexander Glätzle
WED-ID 2.5	Wed	16:25–16:45	ZHG001	**Progress on superconducting quantum processors at IQM** — •Frank Deppe
WED-ID 3.1	Wed	14:45–15:05	ZHG101	**Quantum Internet: Technologies & Applications** — •Imran Khan
WED-ID 3.2	Wed	15:10–15:30	ZHG101	**From Promise to Practice: The Challenges in Finding Quantum Computing Applications** — •Nicole Holzmann
WED-ID 3.3	Wed	15:35–15:55	ZHG101	**Deterministic Photon-Emitter Interfaces for Quantum Technology** — •Peter Lodahl
WED-ID 3.4	Wed	16:00–16:20	ZHG101	**Entanglement-based Quantum Key Distribution** — •Sebastian Neumann
WED-ID 4.1	Wed	14:45–15:05	ZHG007	**Quantum magnetometers and the aspect of industrialisation** — •Thomas Strohm
WED-ID 4.2	Wed	15:10–15:30	ZHG007	**From Lab to Industry: Fiber Microcavities for Quantum Tech** — •Michael Förg, Jonathan Noé, Manuel Nutz, Thomas Hümmer
WED-ID 4.3	Wed	15:35–15:55	ZHG007	**Advance semiconductor chip analysis with quantum diamond magnetoemters** — •Nimba Oshnik
WED-ID 4.4	Wed	16:00–16:20	ZHG007	**A commercial optical frequency standard based on a single $^{171}Yb^{+}$ ion** — •Stephan Ritter
WED-ID 4.5	Wed	16:25–16:45	ZHG007	**Accelerating semiconductor developments with Quantum Metrology** — •Mathieu Munsch
WED-ID 5.1	Wed	14:45–15:05	ZHG105	**Pathways to Maturity for the Quantum Industry** — •Claudius Riek
WED-ID 5.2	Wed	15:10–15:30	ZHG105	**From Bottlenecks to Breakthroughs: Simplified & Scalable Cryogenics for the Quantum Age** — •Tomek Schulz
WED-ID 5.3	Wed	15:35–15:55	ZHG105	**Quantum technologies enabled by Photonic Integrated Circuits** — •Michael Geiselmann
WED-ID 5.4	Wed	16:00–16:20	ZHG105	**Light Modulators Driving Quantum Innovation** — •Enrico Vogt
WED-ID 5.5	Wed	16:25–16:45	ZHG105	**PicoQuant Insights: Precision and Innovation for Quantum Research and Industry** — •Uwe Ortmann, Andreas Lehr, Michael Wahl, Torsten Krause, Tino Röhlicke, Rainer Erdmann
WED-ID 6.3	Wed	16:00–16:20	ZHG006	**Driven by Quantum, empowered by Quandela** — •Thomas Volz

Sessions

WED-ID 1.1–1.1	Wed	14:00–14:35	ZHG011	**Plenary Talk**
WED-ID 2.1–2.5	Wed	14:45–16:45	ZHG001	**Quantum Computers & Simulators**
WED-ID 3.1–3.4	Wed	14:45–16:20	ZHG101	**Quantum Communication & Internet**
WED-ID 4.1–4.5	Wed	14:45–16:45	ZHG007	**Quantum Sensing & Metrology**
WED-ID 5.1–5.5	Wed	14:45–16:45	ZHG105	**Quantum Enabling I**
WED-ID 6.1–6.4	Wed	15:10–16:45	ZHG006	**Quantum Hardware, Software & Solutions**
WED-ID 7.1–7.4	Wed	15:10–16:45	ZHG104	**Quantum Enabling II**
WED-ID 8.1–8.1	Wed	17:00–17:30	ZHG011	**Panel Discussion**

Sessions

– Plenary, Invited Talks, Discussions, and Contributed Talks –

WED-ID 1: Plenary Talk

Time: Wednesday 14:00–14:35 Location: ZHG011

Welcome Address by Dr. Wilhelm Kaenders

Plenary Talk WED-ID 1.1 Wed 14:05 ZHG011
Quantum technologies roadmaps perspective and challenges — •Olivier Ezratty — EPITA, Quantum Energy Initiative
As quantum technologies are maturing in their respective computing, communications and sensing domains, the challenges ahead to deliver their full potential and promises remain significant. Olivier Ezratty will cast these with showing how science, engineering, economics, and geopolitics are intermingled in this innovation process with both virtuous and side effects. We are parallelizing our validation of the quantum theory at larger scales with scientific experiments, components manufacturing upscaling, stretching the capabilities of enabling technologies and building complex systems integration capabilities. We also start to look at the environmental footprint of these technologies in the making. It gives rise to new scientific disciplines, new interdisciplinarity challenges from physics to software, many interdependencies, a mix of scientific and experimental questions, engineering and technology development. There are still many unknowns and unknown unknowns. More theoretical and fundamental work is also needed at all layers of the stacks on top of engineering and technology developments. All this process may also lead to unexpected side innovation effects. What is the role of the various stakeholders in that ecosystem? How governments influence the landscape? How science and innovation get funded? How can we sustain a virtuous innovation cycle in the long run?

WED-ID 2: Quantum Computers & Simulators

Time: Wednesday 14:45–16:45 Location: ZHG001

Invited Talk WED-ID 2.1 Wed 14:45 ZHG001
Trapped-Ion Quantum Computing at Infineon — •Clemens Rössler — Infineon Technologies Austria AG, Villach, Austria
Quantum computing opens new ways of tackling computational challenges in areas such as healthcare, cybersecurity, finance or logistics. Infineon, a leading semiconductor manufacturer, drives the industrialization of quantum computing from fundamental research into application for industries and partners worldwide. I will introduce trapped-ion quantum computing, its status and challenges and present Infineon's activities in the field.

5 min. break

Invited Talk WED-ID 2.2 Wed 15:10 ZHG001
Planck's Reluctant Constant and the Second Semiconductor Revolution — •Mark Mattingley-Scott — Quantum Brilliance, Stuttgart, Germany
In 1900, Max Planck introduced his quantum hypothesis not as a revolutionary breakthrough, but as a "purely formal assumption" to resolve the ultraviolet catastrophe. Like many contemporaries, Planck himself was skeptical of quantization's physical reality. Yet this reluctant mathematical convenience would fundamentally reshape our understanding of nature and enable technologies that seemed like science fiction to early 20th-century physicists.

Today, we face remarkably similar skepticism about mass deployment of quantum technologies. Critics argue that quantum computing, sensing, and communications will remain confined to specialized laboratories, pointing to decoherence challenges, manufacturing complexities, and infrastructure requirements.

These concerns echo arguments once made against semiconductors, lasers, and the internet, technologies that seemed impractical for widespread adoption until suddenly they weren't.

Mass deployment is not a question of if, but when. The question is whether we - commercially, geopolitically, socially - will lead or follow in its development. I will talk about how we intend to bootstrap the quantum revolution by transforming the engineering challenges into processes - by taking technologies which have the capability for mass deployment and kick start the second Semiconductor Revolution.

5 min. break

Invited Talk WED-ID 2.3 Wed 15:35 ZHG001
Quantencomputing: Von der universitären Forschung zum Startup neQxt — •Ferdinand Schmidt-Kaler — neQxt GmbH — QUANTUM, Johannes Gutenberg Univ. Mainz
Die aktuellen politischen Weichenstellungen führen zu Restriktionen beim internationalen Austausch für Hochtechnologie. Ein moderner Industrie- und Forschungsstandort Deutschland ist aber undenkbar ohne die zukünftigen Anwendungen von Quantencomputern bei chemischer bzw. Materialforschung, bei Optimierungsaufgaben im Logistik- und Finanzbereich, AI-Sektor und für sicherheitsrelevanten Anwendungen. Daher muss Deutschland eigene Anstrengungen zum Bau eines Quantencomputers verfolgen. Auch die Entwicklung von passender Anwendungssoftware benötigt Tests auf eigener Quantenhardware, denn deren Imperfektionen müssen mitberücksichtigt werden. Angestoßen durch den Start des EU-Quantum flagship hat die Bundesregierung die Initiative ergriffen, um Quantencomputing in die Anwendung zu überführen. Ansätze basierend auf Atomen und Ionen profitieren von Traditionen universitärer Forschung und nutzen vor Ort vorhandene Kompetenzen der Technologiefirmen. Neugründungen wie neQxt stehen nun vor der Aufgabe, den Vorsprung großer US Hersteller aufzuholen. Die neQxt GmbH zielt neben dem Verkauf von Quantencomputern darauf darauf Rechenzeit anzubieten, die am deutschen Standort eine hohe Datensicherheit gewährleist - ein besonders wichtiges Gut für industrielle Anwender. Die zukünftigen Herausforderungen liegen bei der Hochskalierung auf tausende von qubits, Quantenfehlerkorrektur und Anbindung an klassische Rechenzentren.

5 min. break

Invited Talk WED-ID 2.4 Wed 16:00 ZHG001
Building quantum computers, atom by atom — •Alexander Glätzle — planqc GmbH, Garching, Germany
This presentation introduces planqc, a quantum computing startup founded out of the Max Planck Institute of Quantum Optics. I will outline the company's origin story and share why we believe Germany provides a uniquely strong foundation - both scientifically and strategically - for building a globally competitive quantum technology venture. The talk will include a brief technical overview of neutral atom quantum computing, highlighting its key principles, current challenges, and opportunities. I will conclude with an outlook on planqc's development roadmap and our vision for advancing scalable quantum computing based on neutral atom platforms.

5 min. break

Invited Talk WED-ID 2.5 Wed 16:25 ZHG001
Progress on superconducting quantum processors at IQM — •Frank Deppe — IQM Quantum Computers, Georg-Brauchle-Ring 23-25, 80992 München, Germany
IQM is a European VC-funded company developing quantum computers based on superconducting circuits. Being part of a highly dynamic and competitive field, one faces significant entrepreneurial and technological challenges. In this context, a suitable balance between innovation and engineering is key. Currently, IQM supports two architectures, both based on transmon qubits and flux-tunable couplers. These are the square lattice with nearest neighbor configuration and the resonator-star with effective all-to-all connectivity. In this presentation, I will give an overview about the latest progress in these two directions.

WED-ID 3: Quantum Communication & Internet

Time: Wednesday 14:45–16:20 Location: ZHG101

Invited Talk WED-ID 3.1 Wed 14:45 ZHG101
Quantum Internet: Technologies & Applications — •Imran Khan — KEEQuant GmbH, Gebhardtstr. 28, 90762 Fürth
We live in an era where the precise control and engineering of quantum states enables new technologies, like quantum computing, quantum communication or quantum sensing. Emerging from the combination of all of these, is the concept of a quantum internet, allowing for unprecedented use cases of such technology. In this talk we will discuss the state of the art and explore what this interplay could look like in the future.

5 min. break

Invited Talk WED-ID 3.2 Wed 15:10 ZHG101
From Promise to Practice: The Challenges in Finding Quantum Computing Applications — •Nicole Holzmann — PsiQuantum, Palo Alto
Quantum computing has long been heralded as a revolutionary force poised to transform numerous industries. Early predictions by consulting firms such as McKinsey and BCG suggested significant impacts across pharma, chemistry, materials science, and related sectors. In pharmaceuticals specifically, quantum computing was expected to revolutionise drug discovery and enhance molecular simulations, substantially reducing R&D timelines and associated costs. Yet, despite considerable investment, these optimistic forecasts have not yet materialised into tangible industrial benefits. Quantum algorithms such as Quantum Phase Estimation (QPE) theoretically offer groundbreaking capabilities, enabling calculations beyond classical limits. However, practical industrial applications remain elusive. Accurate quantum calculations alone do not automatically accelerate drug discovery or improve material designs. Industries require clear, substantial, and cost-effective quantum computing advantages to justify significant investments and organisational changes*a challenge further heightened by continuous improvements in classical computing methods and artificial intelligence. Bridging this gap demands sustained collaboration, realistic expectation setting, and integrated end-to-end methodologies delivering genuinely beneficial outcomes.

5 min. break

Invited Talk WED-ID 3.3 Wed 15:35 ZHG101
Deterministic Photon-Emitter Interfaces for Quantum Technology — •Peter Lodahl — Sparrow Quantum and Niels Bohr Institute, University of Copenhagen, Denmark
Quantum physics is transitioning from an area of fundamental research to the realm of technology. 100 years after Niels Bohr and colleagues unraveled the mind-boggling nature of quantum systems, it is today realized that transformative new technology is possible when exploiting intrinsic quantum phenomena, such as quantum superposition and quantum entanglement. A fundamental challenge has been how to deterministically interface light and matter to create on-demand photon sources. I will discuss how the merger of nanophotonics and atomic physics has bridged that gap, and that we today can construct deterministic photon-emitter interfaces based on solid state quantum emitters (quantum dots). We will discuss the fundamental operational principle, the relevant figures-of-merit, and the routes for implementing these novel foundational building blocks in scalable fault-tolerant quantum computing or a quantum network [1,2].

[1] Uppu et al., Nature Nano. 16, 1308 (2021). [2] Lodahl, Ludwig and Warburton, Phys. Today 75, 3-44 (2022).

5 min. break

Invited Talk WED-ID 3.4 Wed 16:00 ZHG101
Entanglement-based Quantum Key Distribution — •Sebastian Neumann — zerothird/Quantum Industries GmbH, Clemens-Holzmeister-Str. 6/6, 1100 Wien
Online security faces a fundamental threat: With the advent of quantum computing, the main encryption techniques used today will become vulnerable to attacks using Shor's algorithm. Quantum Key Distribution (QKD) is the only technology that can protect internet traffic in a future-proof way. Based on the no-cloning theorem, QKD allows for the creation of physically secure keys for unhackable secret communication. The gold standard of QKD are implementations based on entanglement (eQKD), since monogamy of entanglement intrinsically prevents any information leakage of the quantum state to other degrees of freedom. In my talk, I will introduce the concept of entanglement in a QKD context and present scientific publications whose findings are now being commercialized by zerothird. Special emphasis will be put on the challenges to be overcome for long-distance connections, for creating high key rates over short distances, and for connecting many users in a quantum network. I will also give an outlook regarding future technologies which rely heavily on entanglement, such as quantum repeaters and connections between quantum computers.

WED-ID 4: Quantum Sensing & Metrology

Time: Wednesday 14:45–16:45 Location: ZHG007

Invited Talk WED-ID 4.1 Wed 14:45 ZHG007
Quantum magnetometers and the aspect of industrialisation — •Thomas Strohm — Robert Bosch GmbH, Robert-Bosch-Campus 1, 71272 Renningen
One of the more prominent quantum sensors is the quantum magnetometer based on color centers (NV) in diamond. We present the basic principles of the technology, possible applications and technological as well as industrialisation challenges.

5 min. break

Invited Talk WED-ID 4.2 Wed 15:10 ZHG007
From Lab to Industry: Fiber Microcavities for Quantum Tech — •Michael Förg, Jonathan Noé, Manuel Nutz, and Thomas Hümmer — Qlibri GmbH, Karlsplatz 3, 80335 Munich, Germany
One hundred years after the birth of quantum physics, we are witnessing a new era where quantum technologies are moving from the lab into the real world. At Qlibri, we develop miniature optical devices called fiber-based microcavities that can trap and control light with extreme precision. These tiny structures make it possible to study materials at the nanoscale, detect subtle signals, and even interface with single atoms. Originally used only in fundamental research, our goal is to bring this powerful technology into practical applications - from next-generation sensors to building blocks for quantum devices.

5 min. break

Invited Talk WED-ID 4.3 Wed 15:35 ZHG007
Advance semiconductor chip analysis with quantum diamond magnetoemters — •Nimba Oshnik — QuantumDiamonds GmbH Friedenstraße 18 81671 Munich, Germany
The innovative application of nitrogen-vacancy (NV) centers in diamond-based sensing technology for the analysis of semiconductor chips is explored, focusing on their potential to enhance advanced packaging techniques. NV centers, known for their exceptional sensitivity to magnetic and electric fields, enable precise detection of defects and characterization of materials at wide-field scale. We demonstrate the effectiveness of quantum diamond magnetometers in semiconductor analysis, and highlight the implications for improving packaging processes and failure analysis. This approach promises to lead to more reliable and efficient electronic devices, paving the way for advancements in the semiconductor industry.

5 min. break

Invited Talk WED-ID 4.4 Wed 16:00 ZHG007
A commercial optical frequency standard based on a single $^{171}Yb^{+}$ ion — •Stephan Ritter — TOPTICA Photonics AG, Lochhamer Schlag 19, 82166 Graefelfing / Munich, Germany
Decades of persistent research on frequency standards with optical transitions is paying off. These optical frequency standards (OFS) now surpass current cesium primary frequency standards by two orders of magnitude. Consequently, plans for a redefinition of the second are being pursued. The spectacularly low uncertainties are, however, often achieved at the expense of reliability of these research-type setups, as is manifest in limited uptime and availability. Suitable

OFS with laser-cooled reference atoms have until recently also not been available commercially. Here, we report on tackling both issues with a commercial single-ion optical frequency standard housed in two standard 19-inch racks that are transportable. It features a single $^{171}Yb^{+}$ ion trapped in ultra-high vacuum. Five diode lasers are employed for loading of the ion, laser cooling, state preparation and readout, and interrogation of the clock transition. The system builds on the results of a funded project coordinated by TOPTICA and the National Metrology Institute PTB, in which ten German partners, experts in very different domains, joined forces. The presentation will illustrate how this continued collaboration between a privately held, commercial entity and a federal institute was subsequently turned into a commercial solution, will give an overview over the system design of the OFS, and report on the status of the characterization of its metrological performance.

5 min. break

Invited Talk WED-ID 4.5 Wed 16:25 ZHG007
Accelerating semiconductor developments with Quantum Metrology — •Mathieu Munsch — Qnami, Basel, Switzerland

The rapid advancement of generative AI is driving unprecedented demand for high-performance, energy-efficient semiconductor devices. This shift places enormous pressure on both memory and compute technologies, exacerbating challenges such as the memory wall and pushing the limits of conventional architectures. Emerging solutions including 2D materials, neuromorphic processing units, and quantum processing units are now being explored alongside traditional CPUs and GPUs to meet these requirements.

In this evolving landscape, the need for precise, high-resolution data to guide and accelerate development is more critical than ever. Conventional test tools are reaching their limits in sensitivity and spatial resolution, especially in heterogeneous and quantum-class devices. To address this, we introduce a new class of test solutions based on quantum sensors. These tools offer unprecedented precision and are compatible with a wide range of operating environments, from cryogenic conditions to ambient settings.

Our presentation will demonstrate how quantum metrology enables deeper insights into device behavior at the nanoscale, delivering actionable information that helps our customers explore the cutting edge of science and accelerate R&D cycles. We will highlight case studies where quantum sensing provided a unique advantage, paving the way for the next era of semiconductor innovation

WED-ID 5: Quantum Enabling I

Time: Wednesday 14:45–16:45 Location: ZHG105

Invited Talk WED-ID 5.1 Wed 14:45 ZHG105
Pathways to Maturity for the Quantum Industry — •Claudius Riek — Zurich Instruments Germany, Munich, Germany

Quantum technologies are currently transitioning from lab experiments to systems and components useful for society.

A quantum industry supporting this maturation process relies on both an evolution of enabling technologies and a supportive ecosystem: Technological readiness of quantum technologies can only be enhanced when sufficient funding in research and development is leveraged by cross-disciplinary collaboration.

This talk offers a comprehensive overview of pivotal technologies, such as refrigeration, signal delivery, and quantum control systems for optical and electronic control, highlighting their role in driving quantum advancements. These technologies are vital for addressing core challenges like scalability, coherence preservation, and reliable system integration.

Together, we will explore the technological and strategic pathways necessary for quantum technologies from an emerging field to an mature industry, potentially shaping the future of industrial transformation in the coming decades.

5 min. break

Invited Talk WED-ID 5.2 Wed 15:10 ZHG105
From Bottlenecks to Breakthroughs: Simplified & Scalable Cryogenics for the Quantum Age — •Tomek Schulz — kiutra GmbH, Munich, Germany

As quantum technologies mature, testing at cryogenic temperatures is becoming a crucial bottleneck limiting the speed, scale, and cost-efficiency of innovation. At kiutra, we address this barrier by offering fast characterization solutions, giving quantum scientists and engineers a speed and cost advantage. Our unique, helium-3-free continuous adiabatic demagnetization refrigeration (cADR) technology enables modular, scalable platforms that support the long-term industrialization of quantum technologies sustainably. This talk will reflect on our journey from academic research to building a globally active hardware startup. It will highlight some of the challenges such as IP transfer, acquiring funding, managing investor expectations, securing first customers, and building a first-of-its-kind production facility. These milestones have helped us define our niche and illustrate what it takes to build a tech champion in quantum. The presentation will conclude with a call to action: To unlock the full potential of quantum, it will require not only scientific progress but also a joint effort from various actors to build better funding instruments, support industry knowledge transfer, as well as removing political barriers.

5 min. break

Invited Talk WED-ID 5.3 Wed 15:35 ZHG105
Quantum technologies enabled by Photonic Integrated Circuits — •Michael Geiselmann — LIGENTEC AG, Lausanne, Switzerland

Photonisches Quantencomputing, Quantenkommunikation und Quantensensorik profitieren maßgeblich von photonisch integrierten Schaltkreisen (PICs). Erste Quantencomputer-Prototypen nutzen bereits diese Technologie, die hohe Stabilität, Skalierbarkeit und geringe optische Verluste vereint. In diesem Vortrag gebe ich einen Überblick über aktuelle Fortschritte in der Fertigung photonischer Chips mit besonderem Fokus auf Materialien wie Siliziumnitrid und Lithiumniobat, die sich durch exzellente optische Eigenschaften auszeichnen.

LIGENTEC entwickelt und liefert Siliziumnitrid-basierte PICs für Industrie, Start-ups und akademische Partner weltweit. Gemeinsam mit einem starken europäischen Ökosystem ermöglichen wir nicht nur die Herstellung, sondern auch die Simulation und Integration der Chips zu kompletten Modulen. Auf diese Weise sichern wir eine zuverlässige europäische Lieferkette von Prototypen bis zur Serienfertigung und leisten einen Beitrag zur technologischen Unabhängigkeit Europas in der Quantentechnologie.

5 min. break

Invited Talk WED-ID 5.4 Wed 16:00 ZHG105
Light Modulators Driving Quantum Innovation — •Enrico Vogt — QUBIG GmbH, Grillparzerstr. 6, 81675 Munich, Germany

Quantum technologies are rapidly advancing, with the potential to revolutionize fields such as secure communication, high-precision sensing, and quantum computing. A key enabler of this transformation is the ability to precisely control laser light using electro-optic (EOM) and acousto-optic modulators (AOM), which manipulate the frequency, amplitude, polarisation and phase of laser beams with high speed and accuracy. Traditionally reliant on bulky, alignment-sensitive setups, these modulators have now been redefined by a breakthrough at QUBIG that makes them compatible with surface-mount device (SMD) technology. This innovation dramatically reduces the size, complexity, and cost of advanced laser systems - paving the way for mass-producible, ultra-compact quantum devices. By bridging cutting-edge photonics with modern manufacturing, this innovation unlocks new opportunities for industrial deployment, global competitiveness, and strategic investment in the rapidly growing quantum economy. In this talk, the policy framework conditions that could promote the successful implementation of this technology in Germany are also mentioned.

5 min. break

Invited Talk WED-ID 5.5 Wed 16:25 ZHG105
PicoQuant Insights: Precision and Innovation for Quantum Research and Industry — •Uwe Ortmann, Andreas Lehr, Michael Wahl, Torsten Krause, Tino Röhlicke, and Rainer Erdmann — PicoQuant GmbH, 12157 Berlin, Deutschland

PicoQuant, a Berlin-based company with nearly 30 years of expertise, is a pioneer in precision timing solutions for quantum research. Our latest FPGA-based time taggers achieve 1 ps digital resolution, 2 ps rms timing uncertainty, and ultra-low dead time across multiple input channels. Flexible trigger methods, including constant fraction discriminators, ensure compatibility with detectors like SNSPDs. A high-bandwidth FPGA interface enables pre-processing of time tags, while White Rabbit synchronization guarantees precise timing over long distances. Our intuitive GUI and Python API support real-time data visualization and analysis.

Beyond time taggers, we offer complete, application-driven solutions for setups like Hanbury Brown and Twiss, Hong-Ou-Mandel effect, quantum key distribution, and quantum sensing. PicoQuant drives innovation in photonics, shaping the future of quantum technologies and positioning itself as a leading partner for talent, thought leadership, and investment in the quantum industry.

WED-ID 6: Quantum Hardware, Software & Solutions

Time: Wednesday 15:10–16:45 Location: ZHG006

WED-ID 6.1 Wed 15:10 ZHG006

Evaluating Useful Quantum Advantage in the Calculation of Molecular NMR Spectra — •Keith Fratus, Nicklas Enenkel, Peter Schmitteckert, Andisheh Khedri, Juha Leppäkangas, Michael Marthaler, and Jan Reiner — HQS Quantum Simulations GmbH, Karlsruhe, Germany

An important question facing potential industrial applications of quantum computing is that of use case evaluation in the context of possible quantum advantage, or in other words, the question of whether simulating certain problems using a quantum computer would be worthwhile, or whether it would be sufficient to use traditional classical computers. Key to answering such a question is the ability to estimate the accuracy and performance of competing classical approximation methods when exact classical solutions are not available. In this talk we report on our efforts to develop and understand the behaviour of various classical approximation methods which aim to solve a specific class of chemical simulation problems. In particular, we develop classical simulation methods designed to predict molecular NMR spectra, with the aim of being able to quantify the accuracy and computational requirements of performing these simulations, even for parameter regimes which we do not directly simulate. Using such methods, we work towards a framework for predicting in which parameter regimes, system sizes, and target accuracies one can expect the failure of classical methods for this class of systems, thus allowing for an understanding of when quantum computation would be advantageous.

5 min. break

WED-ID 6.2 Wed 15:35 ZHG006

Security evaluation and certification of QKD devices — •Marc Wehling — TÜV Informationstechnik GmbH

The threat posed by quantum computers requires a new approach to cryptographic security. Although post-quantum cryptography (PQC) offers short- and medium-term security, its underlying mathematical structure could be susceptible to future attacks. Relying on fundamental physical laws, quantum key distribution (QKD) uses photons to encode secret data. Although the security proof provides security at the protocol level, the physical implementation can be targeted in numerous ways by an eavesdropper. Security at the implementation level remains to be evaluated. However, a certification scheme approved by a national certification body is a missing cornerstone. The QuNET+BlueCert initiative aims to fill this crucial gap by developing a blueprint for QKD security evaluation.

TÜV Informationstechnik GmbH (TÜVIT) is collaborating with partners from academia and industry to take a leading role in building a test laboratory for the security evaluation of various QKD components. The aim is to develop a certification scheme that will enable industry partners to protect their products against threats.

This talk covers threats to the implementation of QKD systems, as well as the current state of QKD certification, and provides an analysis of the elements missing on the way to a complete certification scheme.

5 min. break

Invited Talk WED-ID 6.3 Wed 16:00 ZHG006

Driven by Quantum, empowered by Quandela — •Thomas Volz — Quandela GmbH, Munich, Germany

Quandela is a world-leading full-stack photonic quantum computing provider. The company develops hardware, middleware, and software for a range of industrial applications, including energy, cybersecurity, and finance, showcasing the versatility of its unique technology.

The core of Quandela's innovation is its cutting-edge quantum-dot single-photon source technology that effectively eliminates barriers to the scalable manipulation of single-photon qubits. Featuring a modular, scalable, upgradeable, and energy efficient architecture, Quandela's mission is to deliver the first useful quantum computer to drive the quantum transformation to industry and society.

In this talk, I will give a brief intro into Quandela's technology, discuss the current state of development with a focus on real-world applications, and highlight some opportunities for joining Quandela's mission at its German subsidiary.

5 min. break

WED-ID 6.4 Wed 16:25 ZHG006

Provable Exponentially Enhanced QAOA on NISQ Hardware — •Chinonso Onah[1,2] and Kristel Michielsen[2,3] — [1]Volkswagen Group, Germany — [2]Department of Physics, RWTH Aachen, Germany — [3]Forschungszentrum Jülich, Germany

Industrial routing, scheduling and matching problems consume disproportionate compute budgets, yet their feasible solutions typically lie on a low-dimensional algebraic manifold (for example, subspaces with fixed Hamming-weight patterns). Vanilla QAOA must explore the full Hilbert space, diluting amplitude on invalid states and succumbing to barren plateaus. Consequently, we introduce Constraint-Enhanced QAOA (CE-QAOA), which starts and stays inside the exponentially smaller one-hot subspace of size n. A depth-optimal, ancilla-free encoder prepares a uniform superposition of single-excitation states per block, while a block-wise XY mixer preserves feasibility and is native to several hardware platforms. Circuit overhead is minimal: CE-QAOA adds at most the depth of a single XY block beyond vanilla QAOA.

Three exponential advantages compound from:
(i) Feasibility concentration.
(ii) Exponential parameter-transfer amplification.
(iii) Depth-robust exponential separation.

The framework extends to the traveling-salesman problem (TSP), the capacitated vehicle-routing problem (CVRP), graph matching, flow-shop scheduling, graph colouring, and more.

WED-ID 7: Quantum Enabling II

Time: Wednesday 15:10–16:45 Location: ZHG104

WED-ID 7.1 Wed 15:10 ZHG104

Enabling Robust Quantum Technologies - Compact Fiber Optics With Highest Thermal Stability — •Tobias Kroker — Schäfter + Kirchhoff GmbH, Hamburg, Germany

Quantum technologies are on the cusp of moving from laboratory experiments to commercial applications. This poses new requirements on the scalability, thermal stability, and wavelength range of fiber optic systems used to transport, distribute, and modulate laser light.

As an experienced manufacturer in the field, Schäfter + Kirchhoff GmbH develops and produces fiber optic solutions ranging from specialty fiber cables and fiber couplers to complex optomechanical light distribution and modulation units.

Here we report on new developments in compact fiber-coupled optomechanical systems for light distribution and modulation. These systems exhibit such high thermal stability that they can be reliably used in an un-climatized environment, which is tested by harsh thermal cycles in a climatic chamber. This is a crucial step for quantum technologies to leave the optical laboratory.

In addition, active components such as acousto-optic modulators are gradually increasing the functionality of these devices. As a result, they enable the miniaturization and scalability of complex optical systems, making them attractive for quantum computers and technologies being built around the world.

5 min. break

WED-ID 7.2 Wed 15:35 ZHG104

Enabling optical quantum characterization with Photonic Sources — •Ole Peters[1], Hoon Jang[2], Enkeleda Balliu[2], and Korbinian Hens[1] — [1]HÜBNER GmbH & Co. KG, Division HÜBNER Photonics, Kassel, Germany — [2]Cobolt AB, Division HÜBNER Photonics, Solna, Sweden

Within the scope of the second quantum revolution, laboratories and companies around the world focus on the search for the perfect quantum system suitable for applications of 'quantum technology 2.0'. Those applications range from quantum sensing, via quantum communication to quantum simulation and computing using Qubits opening up a vibrant research field to unveil materials with the perfect properties meeting the various requirements has evolved.

In this work, we discuss the optical setup and performance characteristics of commercially available Watt level, narrow linewidth Optical Parametric Oscillators (OPOs), tunable across the visible spectrum. We show several tuning mechanisms based on internal and external frequency stabilization and illustrate their deployment in quantum research applications. We also present a concept for compact laser systems, with narrower tunability, that can be tailored in wavelength to the desired application, as well as an extremely low-noise fiber amplifier platform, dedicated to quantum research. Experimental datasets from a selection of recently published studies on single-photon emitters of various types are presented.

5 min. break

WED-ID 7.3 Wed 16:00 ZHG104

Squeezed Light for Quantum Sensing — •Axel Schönbeck[1], Jan Südbeck[1], Jascha Zander[1], and Roman Schnabel[2] — [1]Noisy Labs GmbH, Luruper Hauptstrasse 1, 22547 Hamburg — [2]Universität Hamburg, Institut für Quantenphysik, Luruper Chaussee 149, 22761 Hamburg

High-precision laser-based measurements are often limited by photon shot noise across various power levels (mW to kW). Conventionally, the signal-to-noise ratio has been enhanced by increasing the optical power.

However, this approach can introduce undesirable side effects. Biological samples may be damaged or exhibit photo-bleaching and delicate mechanical devices may experience thermal effects. Thermal lensing, induced by high power, can misalign measurement devices. Moreover, exceeding eye-safe laser power levels necessitates additional laser safety measures. Economic considerations, including development and energy costs, can also limit the feasibility of power increases.

Squeezed light offers an alternative solution by reducing photon shot noise without significantly increasing the optical power. Noise reductions exceeding a factor of 10 are achievable when detecting most of the light. Gravitational-wave detection is a prominent example for the application of squeezed light.

This presentation will discuss squeezed light technology and its applications in high-precision quantum sensing.

5 min. break

WED-ID 7.4 Wed 16:25 ZHG104

Automated cryogenic test platform for benchmarking superconducting quantum processors — •Thorsten Last, Adam Lawrence, Koushik Kumaran, Gerben Erens, Kelvin Loh, Garrelt Alberts, and Adriaan Rol — Orange Quantum Systems B.V., Elektronicaweg 2, 2628 XG Delft, The Netherlands

Scaling transmon-based quantum processors beyond 100 qubits remains a challenge, especially as traditional R&D methods struggle to keep pace due to scalability limits. Achieving this demands improvements in reproducibility, yield, and low component variability. To support these process aspects, an industry-grade qubit manufacturing cycle must be paired with high-throughput testing and metrology to maintain a high development cadence. Here we introduce an automated cryogenic test system designed for high-throughput characterization of superconducting quantum processors and which can test 150-qubit devices within a 10-day cycle. Its fully integrated cryogenic and quantum control hardware enables advanced diagnostics and feedback. Critical device parameters are automatically extracted across multiple domains such as readout circuits, properties of transmons and tunable couplers, crosstalk, and qubit fidelities, using a graph-based automation protocol that dynamically sequences tests and extracts key metrics. In addition, the system can also provide thermometric analysis of qubits to assess environmental interactions and cryogenic scalability because as system complexity grows, identifying and mitigating thermal decoherence becomes critical.

WED-ID 8: Panel Discussion

Time: Wednesday 17:00–17:30 Location: ZHG011

Discussion WED-ID 8.1 Wed 17:00 ZHG011

Quantum technology at the inflection point? — •Wilhelm Kaenders[1], Olivier Ezratty[2], Emily Meads[3], Peter Soldan[4], Alexander Glätzle[5], and Johannes Otterbach[6] — [1]TOPTICA Photonics AG, Gräfelfing, Germany — [2]Quantum Energy Initiative, Grenoble, France — [3]Quantonation, Paris, France — [4]VDI Technologiezentrum GmbH, Düsseldorf, Germany — [5]planqc GmbH, Garching, Germany — [6]Sprin-D (Bundesagentur für Sprunginnovation), Leipzig, Germany

After multibillion dollars and about a decade of intense research spent by public and private investors, we still have no breakthrough for quantum computing in sight. Quantum sensing for volume markets is struggling, while meteorology pushes boundaries again and again. Where is the future between hype, FOMO and uncharted potential really?

Symposium Quantum 2D-Moiré and Rhombohedral van-der-Waals Systems (SYWS)

Thomas Weitz
University of Göttingen
Friedrich-Hund-Platz 1
37077 Göttingen, Germany
thomas.weitz@uni-goettingen.de

Sirri Batuhan Kalkan
University of Göttingen
Friedrich-Hund-Platz 1
37077 Göttingen, Germany
sbkalkan@uni-goettingen.de

Recent advancements in the field of 2D-Moiré and rhombohedral van-der-Waals systems have significantly enriched the landscape of quantum materials. These versatile platforms allow the creation and control of flat bands and enable tunable quantum phase diagrams – critical for advancing quantum technologies. The tuning of flat bands, either through precise control of the Moiré angle or by introducing an external electric field, has enabled the discovery of various emergent phenomena such as (fractional) Chern insulators, ultrafast exciton dynamics, and superconductivity. The symposium will showcase complementary experimental and theoretical approaches to uncover and control such complex electronic states in novel van-der-Waals heterostructures.

Overview of Invited Talks and Sessions

(Lecture hall ZHG008)

Invited Talks

SYWS 1.1	Thu	10:45–11:15	ZHG008	**Twisted transition metal dichalcogenides for new topological states** — •Jie Shan
SYWS 1.2	Thu	11:15–11:45	ZHG008	**Exciton dynamics in 2D-moiré materials in space and time** — •Stefan Mathias
SYWS 1.3	Thu	11:45–12:15	ZHG008	**Fractional Quantum Anomalous Hall Effect and Chiral Superconductivity in Graphene** — •Long Ju
SYWS 1.4	Thu	12:15–12:45	ZHG008	**Electron Correlations in Moiré vs. Moiréless Quantum Matter** — •Tim Wehling

Sessions

SYWS 1.1–1.4	Thu	10:45–12:45	ZHG008	**Quantum 2D-Moiré and Rhombohedral van-der-Waals Systems**

Sessions

– Invited Talks –

SYWS 1: Quantum 2D-Moiré and Rhombohedral van-der-Waals Systems

Time: Thursday 10:45–12:45 Location: ZHG008

Invited Talk SYWS 1.1 Thu 10:45 ZHG008

Twisted transition metal dichalcogenides for new topological states — •Jie Shan — Max Planck Institute for the Structure and Dynamics of Matter — Cornell University

Moiré materials provide a highly controllable platform to explore electronic correlations and topology. Specifically, flat Chern bands have been predicted in twisted transition metal dichalcogenide bilayers such as MoTe2 and WSe2. In this talk, I will discuss recent experimental observations of the integer and fractional quantum Hall effects in twisted MoTe2 under zero magnetic field. I will also present evidence of a fractional topological insulator with each helical edge contributing 3/2 conductance quantum (e^2/h) in 2.1-degree-twisted MoTe2.

Invited Talk SYWS 1.2 Thu 11:15 ZHG008

Exciton dynamics in 2D-moiré materials in space and time — •Stefan Mathias — I. Physikalisches Institut, Georg-August-Universität Göttingen, 37077 Göttingen, Germany

In 2D semiconducting quantum materials, organic semiconductors and their heterostructures, the energy of absorbed light is stored in Coulomb-bound electron-hole pairs, i.e. excitons. For future technological applications of these classes of materials, for instance in optoelectronics and for energy harvesting, it is crucial to study the initial light-matter interaction and the subsequent relaxation and dissipation processes at the fundamental level [1] and on the relevant length and time scales [2].

I will present the ultrafast formation dynamics of bright and dark excitons in different moiré materials in space and time [3]. In particular, I will report on the identification of a key signature of the moiré superlattice that is imprinted on the momentum-resolved interlayer exciton photoemission signal [4,5]. Furthermore, I will present photoemission exciton tomography [6] that allows us to study ultrafast charge transfer from TMD to organic layers, and to disentangle multiorbital contributions in the exciton formation in the 2D moiré - organic semiconductor heterostructures.

[1] Merboldt et al., Nature Physics (2025).
[2] Schmitt et al., Nature Photonics 19, 187 (2025).
[3] Reutzel et al., Adv. in Phys. X 9,, 2378722 (2024)
[4] Schmitt et al., Nature 608, 499 (2022).
[5] Bange et al., Science Adv. 10, eadi1323 (2024).
[6] Bennecke et al., Nature Comm. 15, 1804 (2024).

Invited Talk SYWS 1.3 Thu 11:45 ZHG008

Fractional Quantum Anomalous Hall Effect and Chiral Superconductivity in Graphene — •Long Ju — MIT, Cambridge, Massachusetts, USA

Condensed matter physics has witnessed emergent quantum phenomena driven by electron correlation and topology. Two prominent examples are Fractional Quantum Hall Effect and Superconductivity. In this talk, I will show how these two disparate phenomena can be unified in the simplest carbon material: a crystalline stacking order of graphene called rhombohedral stacking. Not only it can exhibit both fractional and superconducting electron physics, we observed both with a twist: the FQHE happens at zero magnetic field, therefore Fractional Quantum Anomalous Hall Effect; the superconductor is a magnet by itself, therefore Chiral Superconductor. I will discuss the origin of these states and their implications for fundatmental physics studies and topological quantum computation.

Invited Talk SYWS 1.4 Thu 12:15 ZHG008

Electron Correlations in Moiré vs. Moiréless Quantum Matter — •Tim Wehling — I. Institute of Theoretical Physics, University of Hamburg, 22607 Hamburg, Germany — The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany

Understanding and controlling electron correlations in quantum matter remains a central challenge in materials science. In recent years, a wide range of novel correlated states has been discovered through the precise stacking and twisting of two-dimensional van der Waals materials. These stacked structures uniquely give rise to correlated phases that are not predictable from the properties of the individual layers alone.

In this talk, we compare electron correlations, as well as spin, valley, and superconducting order, in twisted graphene systems [1, 2] and twisted transition metal dichalcogenide multilayers [3] with those in moiréless systems - i.e., non-twisted graphene multilayers [4], doped fullerides [5], and functionalized graphene, where correlations arise at the atomic scale [6]. We discuss how multiorbital physics, flat bands, and quantum geometry govern the emergence of electronic phases in these systems.

[1] G. Rai et al., Phys. Rev. X 14, 031045 (2024).
[2] H. Hu et al., Phys. Rev. Lett. 131, 166501 (2023).
[3] A. Fischer et al., arXiv:2412.14296.
[4] A. Fischer et al., Phys. Rev. Res. 6, L012003 (2024).
[5] N. Witt et al., Npj Quantum Mater. 9, 1 (2024).
[6] N. Witt et al., arXiv:2503.03700.

Symposium Entanglement and Complexity – How "Complex" is Nature? (SYEC)

Julio Magdalena de la Fuente
Freie Universität Berlin
Arnimallee 14
14195 Berlin, Germany
jm@juliomagdalena.de

Entanglement, a key resource in quantum phenomena, was already recognised in the early days of quantum mechanics. In recent decades, the development of quantum information and computing has revealed that carefully engineering quantum dynamics can lead to computational advantages for various classical and quantum problems, as well as secure communication methods. Complexity theory aims to describe and classify different classes of problems based on their "complexity", the resources required to implement the desired task. Surprisingly, these two descriptions reveal a deep connection between how complex and non-classical quantum systems can be. The symposium on entanglement and complexity explores these connections across a wide range of topics. Speakers include M. Heller, who discusses entanglement in quantum field theories; E. Gräfe, exploring entanglement and quantum chaos; N. Callebaut, who delves into entanglement in the AdS/CFT correspondence; and A. Anshu, examining computational complexity and its connection to entanglement. This symposium showcases how these two fields can benefit from mutual exchange.

Overview of Invited Talks and Sessions

(Lecture hall ZHG010)

Invited Talks

SYEC 1.1	Thu	10:45–11:15	ZHG010	**Quantum Information and Spacetime: New Ideas and Results** — •Michal P. Heller
SYEC 1.2	Thu	11:15–11:45	ZHG010	**Entanglement in holography** — •Nele Callebaut
SYEC 1.3	Thu	11:45–12:15	ZHG010	**The theory of learnability of local Hamiltonians from Gibbs states** — •Anurag Anshu
SYEC 1.4	Thu	12:15–12:45	ZHG010	**There's a hole in my quantum bucket – complexified quantum theory and its classical limit** — •Eva-Maria Graefe

Sessions

SYEC 1.1–1.4	Thu	10:45–12:45	ZHG010	**Entanglement and Complexity – How "Complex" is Nature?**

Sessions

– Invited Talks –

SYEC 1: Entanglement and Complexity – How "Complex" is Nature?

Time: Thursday 10:45–12:45 Location: ZHG010

Invited Talk SYEC 1.1 Thu 10:45 ZHG010

Quantum Information and Spacetime: New Ideas and Results — •Michal P. Heller — Department of Physics and Astronomy, Ghent University

In the course of the past two decades, the main driver of progress at the intersection of quantum information and gravity were, first, the notion of entanglement and, later, also complexity. I will discuss new ideas that build on these developments related, on one hand, to the notion of entanglement in time, and, on the other, to the notion of operator growth. Based on 2408.15752, 2412.17785 and work in progress.

Invited Talk SYEC 1.2 Thu 11:15 ZHG010

Entanglement in holography — •Nele Callebaut — University of Cologne, Germany

In this talk I will review how the quantum information theoretic concept of entanglement acquires a geometric interpretation in holographic dualities, and how this insight has led to breakthroughs in both quantum field theory and gravity.

Invited Talk SYEC 1.3 Thu 11:45 ZHG010

The theory of learnability of local Hamiltonians from Gibbs states — •Anurag Anshu — Harvard University, Cambridge, MA

Learning the Hamiltonian underlying a quantum many-body system in thermal equilibrium is a fundamental task in quantum learning theory and experimental sciences. This talk will provide a general overview of the recent learning algorithms for this problem, and highlight how the progress comes hand-in-hand with new insights into the entanglement structure of quantum Gibbs states. We will explore interesting open questions in this direction, in particular the goal of devising algorithms that are easy to implement in experiments.

Invited Talk SYEC 1.4 Thu 12:15 ZHG010

There's a hole in my quantum bucket – complexified quantum theory and its classical limit — •Eva-Maria Graefe — Imperial College London

Traditional quantum mechanics focusses on the description of systems that are closed or well-separated from their environment. Take for example the interior of a bucket. If the bucket is in a good condition its contents will remain inside. However, many physical systems exhibit leakage, such as a loss of a leaking buckets contents to the environment. In quantum mechanics the interior of such an open system can effectively be described by non-Hermitian quantum mechanics, where complex-valued energies encode life-times of states. In this talk, I will provide an overview of non-Hermitian quantum theory, focusing on the aspect of quantum-classical correspondence.

Symposium Precise Quantum Detectors in Space, Time and Energy – Semi- and Superconductors in Particle and Condensed Matter Physics (SYQD)

Axel Lorke
University of Duisburg-Essen
Lotharstraße 1
47057 Duisburg, Germany
axel.lorke@uni-due.de

Norbert Wermes
Rheinische Friedrich-Wilhelms-Universität Bonn
Nußallee 12
53115 Bonn, Germany
wermes@physik.uni-bonn.de

Semiconductor detectors based on quantum effects and quantum generation have revolutionised particle detection in recent decades and are also indispensable for future experiments. Electronic detection and measurement of particles with micrometer spatial and tens of picoseconds time resolution have been made possible. In extreme high-flux and high-rate experiments, such as in pp collisions at the LHC, only semiconductor detectors can be operated as track detectors. New developments in the field of superconducting quantum sensors with the additional potential for precise energy detection of particles further establish the close connection between particle and solid-state physics. The symposium addresses particularly new developments leading into the future of particle and quantum detection with four dedicated presentations, including high precision timing, ultra-thin detectors and the potential of single quantum detection devices.

Overview of Invited Talks and Sessions

(Lecture hall ZHG104)

Invited Talks

SYQD 1.1	Thu	10:45–11:00	ZHG104	**Symposium introduction: semiconductor quantum sensors/detectors in particle physics - a success story** — •Norbert Wermes
SYQD 1.2	Thu	11:00–11:25	ZHG104	**Precision Timing with Silicon Detectors** — •Nicolo Cartiglia
SYQD 1.3	Thu	11:25–11:50	ZHG104	**Quantum sensor systems for enhanced precision particle detection** — •Michael Doser
SYQD 1.4	Thu	11:50–12:15	ZHG104	**High-performance superconducting nanowire single photon detectors** — •Val Zwiller
SYQD 1.5	Thu	12:15–12:40	ZHG104	**ALICE ITS3 – the ultimate paper wrap pixel detector** — •Magnus Mager

Sessions

SYQD 1.1–1.5	Thu	10:45–12:40	ZHG104	**Precise Quantum Detectors in Space, Time and Energy – Semi- and Superconductors in Particle and Condensed Matter Physics**

Sessions

– Invited Talks –

SYQD 1: Precise Quantum Detectors in Space, Time and Energy – Semi- and Superconductors in Particle and Condensed Matter Physics

Time: Thursday 10:45–12:40 Location: ZHG104

Invited Talk SYQD 1.1 Thu 10:45 ZHG104
Symposium introduction: semiconductor quantum sensors/detectors in particle physics - a success story — •Norbert Wermes — Phys. Inst, Bonn University, Bonn, Germany
Introduction to the symposium

Invited Talk SYQD 1.2 Thu 11:00 ZHG104
Precision Timing with Silicon Detectors — •Nicolo Cartiglia — Via Pietro Giuria 1, 10123, Italia
At the core of nearly every current or planned particle detector lies a silicon-based tracking system capable of reconstructing the momenta of particles produced in high-energy collisions.

The continuous advancement of tracking systems, from a few electronic channels three decades ago to the many millions in today's detectors, has been a key enabler of our current understanding of nature. This evolution now faces its greatest challenge, as future high-energy physics experiments impose stringent requirements on spatial and temporal resolution, detector dimensions, and power consumption.

Over the past 15 years, silicon detectors have undergone rapid development, establishing themselves as the technology of choice not only for precision tracking but also for accurate timing measurements. This transformation has been driven by several design innovations, such as Low-Gain Avalanche Diodes (LGADs) and Resistive Silicon Detectors (RSDs), as well as improvements in techniques like Monolithic Active Pixel Sensors (MAPS) and Silicon-Germanium-based readout electronics.

In this contribution, I will review the recent evolution of silicon detector technologies and discuss how the integration of precise timing capabilities is redefining the way experiments are designed.

Invited Talk SYQD 1.3 Thu 11:25 ZHG104
Quantum sensor systems for enhanced precision particle detection — •Michael Doser — CERN EP, 1211 Geneva 23, Switzerland
In the context of the requirements of future particle physics experiments, quantum sensors look likely to play a central role. Among the wide range of possible quantum sensors, five technological axes (Quantum systems in traps and beams; Low-dimensional quantum materials; Superconducting quantum devices; Macroscopic scaled-up quantum systems; Quantum techniques for sensing) look particularly well suited to particle physics. This presentation will give an overview with examples of the range of applications and will highlight their relevance to, and potential impact on, both low and high energy particle physics.

Invited Talk SYQD 1.4 Thu 11:50 ZHG104
High-performance superconducting nanowire single photon detectors — •Val Zwiller — Single Quantum, Delft, Netherlands — Quantum Scopes, Stockholm, Sweden — Royal Institute of Technology, Stockholm, Sweden
The ability to detect single photons is crucial for quantum optics as well as for a wide number of applications. Several technologies have been developed for efficient single photon detection in the visible and near infrared. The invention of the superconducting nanowire single photon detector in 2001 enabled the development of a new class of detectors that can operate close to physical limits. Different aspects will be discussed including wavelength detection range, time resolution, dark counts, saturation rates and photon number resolution along with various applications such as Lidar, quantum communication, deep space communication, microscopy and bio-medical measurements.

Multipixel single photon detectors based on superconducting nanowires will also be discussed, including a quantum spectrometer that is based on an array of high-performance single photon By time stamping single photon detection events at the output of a spectrometer we generate data that can yield spectra as well as photon correlations such as g(2), g(3) to g (n) as well as cross correlations among different spectral lines, under pulsed excitation, transition lifetimes can also be extracted. This instrument therefore replaces a spectrometer, a streak camera, a Hanbury-Brown Twiss interferometer and operates with far higher signal to noise ratio than is possible with existing detectors that are commonly used in the infrared.

Invited Talk SYQD 1.5 Thu 12:15 ZHG104
ALICE ITS3 – the ultimate paper wrap pixel detector — •Magnus Mager — CERN, Geneva, Switzerland
Over the last decade, Monolithic Active Pixel Sensors (MAPS), fabricated in commercial CMOS Imaging technologies, have made their way into several high-energy physics applications, where low material budgets and high resolution are crucial. With its current, record-holding 10 m^2, 12.5 GPixel Inner Tracking System, ITS2, ALICE currently showcases this technology and harvests physics data of unprecedented resolution.

To further improve the experiment, ALICE is upgrading the innermost three tracking layers in the next Long Shutdown of LHC (LS3, 2026–2030) with a novel detector, the ITS3. This detector will be based on truly cylindrical, bent (down to radii of 19 mm), wafer-scale (up to 10×27 cm) MAPS. The sensors are thinned down to 50 μm, and are wrapped around the beam pipe, held in place by carbon foam spacers.

During the R&D phase (2019–2024), a number of novel developments have been demonstrated, notably including the qualification of 65nm MAPS, the demonstration of wafer-scale stitched MAPS, and the demonstration of bent MAPS.

In this talk, the detector concept will be introduced, key R&D results presented, and the path towards detector installation in 2028 given.

Symposium Precise Quantum Molecules (SYQM)

Gereon Niedner-Schatteburg
University of Kaiserslautern-Landau
Erwin-Schrödinger-Straße 52
67663 Kaiserslautern, Germany
gns@chemie.uni-kl.de

Early on, the assignments of molecular spectra have served as benchmarks for fundamental Quantum Hamiltonians, and they continue to do so at an increasing level of sophistication. It is the focus of the Precise Quantum Molecules symposium to shed light onto the soul mate like interconnection of molecular spectroscopy and quantum chemical modelling by the selected contributions elucidating the thread that leads from simple model systems up to industrial applications.

Overview of Invited Talks and Sessions

(Lecture hall ZHG105)

Invited Talks

SYQM 1.1	Thu	10:45–11:15	ZHG105	**The quantum world of molecules revealed with rotational coherence spectroscopy** — •Melanie Schnell
SYQM 1.2	Thu	11:15–11:45	ZHG105	**Accurate calculation of non-covalent interactions using explicitly correlated local correlation methods** — •Hans-Joachim Werner, Andreas Hansen, Peter J. Knowles
SYQM 1.3	Thu	11:45–12:15	ZHG105	**High-resolution spectroscopy of molecular ions** — •Stephan Schlemmer
SYQM 1.4	Thu	12:15–12:45	ZHG105	**Quantum Simulations in the Chemical Industry** — •Ansgar Schäfer

Sessions

SYQM 1.1–1.4	Thu	10:45–12:45	ZHG105	**Precise Quantum Molecules**

Sessions

– Invited Talks –

SYQM 1: Precise Quantum Molecules

Time: Thursday 10:45–12:45 Location: ZHG105

Invited Talk SYQM 1.1 Thu 10:45 ZHG105

The quantum world of molecules revealed with rotational coherence spectroscopy — •Melanie Schnell — Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

Early application of quantum modelling to molecules was limited to diatomics, mostly simple hydrogen. Experimental spectroscopy met such modelling with high precision. The recent developments of various types of experimental spectroscopies at an increasing level of sophistication allowed for their application to larger molecules and at an increasing level of complexity, including highly coherent quantum tunnelling and chirality studies. This lecture will provide some glimpses on the impressive history of spectroscopic experiments using the example of rotational excitations, from the MASER to modern control experiments.

Invited Talk SYQM 1.2 Thu 11:15 ZHG105

Accurate calculation of non-covalent interactions using explicitly correlated local correlation methods — •Hans-Joachim Werner[1], Andreas Hansen[2], and Peter J. Knowles[3] — [1]Institut für Theoretische Chemie, Universität Stuttgart, Germany — [2]Mulliken Center for Theoretical Chemistry, Universität Bonn, Germany — [3]School of Chemistry, Cardiff University, Cardiff CF10 3AT, U.K.

Recent developments of highly accurate electron correlation methods applicable to large molecular systems are reviewed. This includes local correlation approximations, explicit correlation methods, as well as fragmentation or embedding approximations. Using a combination of these approaches it has become possible to predict reaction energies, isomerization energies, conformational energies, and intermolecular interaction energies for systems with over hundred atoms with sub-kcal/mol accuracy. In this talk we present recent benchmark calculations [1] for non-covalent interactions (NCI) in large π-stacked molecular aggregates and host-guest systems using the PNO-LCCSD(T)-F12 method as implemented in Molpro. Key NCI systems previously evaluated using FN-DMC and other LCCSD(T) methods are reexamined with focus on the question whether CCSD(T) overbinds in large π-stacked complexes or other systems with high polarizability.

[1] A. Hansen, P. J. Knowles, and H.-J. Werner, J. Phys. Chem. A (2025), https://doi.org/10.1021/acs.jpca.5c02316

Invited Talk SYQM 1.3 Thu 11:45 ZHG105

High-resolution spectroscopy of molecular ions — •Stephan Schlemmer — I. Physikalisches Institut, Universität zu Köln

Spectroscopy is one of the foundations of quantum mechanics. For molecules the spectra usually break-up into the electronic, vibrational and rotational energy regime based on the Born-Oppenheimer approximation which separates the dynamics of the electrons from those of the nuclei. Vibrational spectra reveal the forces between the atoms constituing the molecule and rotational spectra are related to their mass distribution, i.e., the structure of the molecule and highly precise distances of the atomic nuclei. These findings lead to our today's picture of a molecule as a set of atoms (balls) bound by their electrons (sticks), where, e.g., the methane molecule, CH_4, has a pyramidal structure of the hydrogens with the carbon atom in the center entertaining one bond to each of the hydrogens. As a result of this success story of quantum mechanics complex molecules are found in space based on their fingerprint like spectra. I will present example spectra for molecular ions which have been discovered recently and which play an important role in interstellar chemistry. However, several well bond molecules are very floppy, meaning the nuclei undergo large amplitude motions and the picture of a molecular structure described above is called in question. Finding a proper quantum mechanical description for such systems as well as measuring their spectra is still a challenge today as will be discussed in this work.

Invited Talk SYQM 1.4 Thu 12:15 ZHG105

Quantum Simulations in the Chemical Industry — •Ansgar Schäfer — BASF SE, Carl-Bosch-Straße 38, 67056 Ludwigshafen, Germany

Chemical product and process development can be a challenging endeavor if the chemical and structural search space is huge, the number of tunable parameters is big, knowledge about mechanisms is sparse, and experiments are difficult to perform and/or expensive. Therefore, instead of relying on the conventional approach of trial-and-error empiricism only, an efficient way of predicting and preselecting the most promising candidate materials and experiments is highly desirable. The development of efficient and accurate first-principles simulation methods based on quantum mechanics over the last decades enabled virtual experiments with compounds which have not even been synthesized before. With these techniques, we are able to get insights into the structure, properties and chemical reactivity of substances. We gain knowledge about reaction mechanisms and about the properties determining application performance. Very often, results of the simulations are complementary to the available experimental experience. A clever combination of scientific modeling and experiments is the key to success. In this talk, some examples are given about the application of quantum mechanics to real-world chemical problems in an industrial context.

Thursday Contributed Sessions (THU)

Stefan Kehrein
Fakultät für Physik
Universität Göttingen
Friedrich-Hund-Platz 1
37077 Göttingen, Germany
stefan.kehrein@theorie.physik.uni-goettingen.de

Thomas Weitz
Fakultät für Physik
Universität Göttingen
Friedrich-Hund-Platz 1
37077 Göttingen, Germany
thomas.weitz@uni-goettingen.de

Overview of Sessions

(Lecture halls ZHG001, ZHG002, ZHG003, ZHG004, ZHG006, ZHG007, ZHG008, ZHG009, ZHG101, ZHG103, ZHG104, and ZHG105; Poster ZHG Foyer 1. OG)

Sessions

THU 1.1–1.7	Thu	14:15–16:00	ZHG001	**Fault-Tolerant Quantum Computing: Contributed Session (Quantum Error Correction)**
THU 2.1–2.8	Thu	14:15–16:15	ZHG002	**Quantum Information: Concepts and Methods I**
THU 3.1–3.4	Thu	14:15–16:15	ZHG003	**Arbeitskreis Chancengleichheit (AKC)**
THU 4.1–4.4	Thu	14:15–15:15	ZHG004	**Precise Quantum Molecules: Contributed Session to Symposium**
THU 5.1–5.8	Thu	14:15–16:15	ZHG006	**QIP Implementations: Interfaces**
THU 6.1–6.6	Thu	14:15–15:45	ZHG007	**Quantum Computing and Communication: Contributed Session II (Concepts)**
THU 7.1–7.7	Thu	14:15–16:00	ZHG008	**Entanglement and Complexity: Contributed Session to Symposium II**
THU 8.1–8.7	Thu	14:15–16:00	ZHG009	**Frustrated Quantum Systems: Contributed Session to Symposium**
THU 9.1–9.6	Thu	14:15–15:45	ZHG101	**Correlated Quantum Matter: Contributed Session to Symposium II**
THU 10.1–10.8	Thu	14:15–16:15	ZHG103	**Foundational / Mathematical Aspects – Methods and Approximations**
THU 11.1–11.6	Thu	14:15–15:45	ZHG104	**Quantum Technology and Industry**
THU 12.1–12.8	Thu	14:15–16:15	ZHG105	**Quantum Thermalization: Contributed Session to Symposium**
THU 13.1–13.93	Thu	16:30–18:30	ZHG Foyer 1. OG	**Poster Session: Applications**

Sessions

– Invited Talks, Contributed Talks, and Posters –

THU 1: Fault-Tolerant Quantum Computing: Contributed Session (Quantum Error Correction)

Time: Thursday 14:15–16:00 Location: ZHG001

THU 1.1 Thu 14:15 ZHG001

Myths around quantum computation before full fault tolerance: What no-go theorems rule out and what they don't — •Zoltán Zimborás — University of Helsinki, Finland — Algorithmiq Ltd, Helsinki, Finland

In this talk, following the reasoning of our Perspective article (arXiv:2501.05694), we critically evaluate prevailing viewpoints on the capabilities of near-term quantum computing and the transition toward fully fault-tolerant quantum computing. We examine theoretical no-go results on the practicality of quantum error mitigation techniques and scalability of variational quantum algorithms. By emphasizing the nuances of error scaling, circuit depth, and algorithmic feasibility, we assess the realistic prospects of near-term quantum devices. Our discussion explores strategies for addressing current challenges, such as barren plateaus in variational circuits and the integration of quantum error mitigation and quantum error correction techniques. We conclude with a cautiously optimistic outlook on the possibility for a meaningful quantum advantage in the era of late noisy intermediate scale and early fault-tolerant quantum devices.

THU 1.2 Thu 14:30 ZHG001

Universal fault-tolerant logic with holographic codes — •Alexander Jahn[1], Matthew Steinberg[2,3], Junyu Fan[2], Jens Eisert[1], Sebastian Feld[2], and ChunJun Cao[4] — [1]Department of Physics, Freie Universität Berlin, Germany — [2]QuTech, Delft University of Technology, The Netherlands — [3]Global Technology Applied Research, JPMorganChase, New York, USA — [4]Department of Physics, Virginia Tech, Blacksburg, USA

A core challenge for practical quantum computing lies in the construction of quantum codes with logical gates that are both universal and fault-tolerant. In our work, we introduce a new approach for achieving both features by constructing a class of quantum error-correcting codes - heterogeneous holographic codes - that are derived from models of holographic bulk-boundary dualities, which were previously thought to be unsuitable for applied quantum computing. Overturning earlier work, we show that a universal set of non-Clifford gates can be applied fault-tolerantly on the physical boundary of these codes, while also demonstrating that they allow for high erasure thresholds, another desired feature of quantum codes. Compared to previous concatenated code constructions that our work generalizes, we achieve large overhead savings in physical qubits, e.g. a 21.8% reduction for a two-layer Steane/quantum Reed-Muller combination. Unlike standard concatenated codes, we establish that the new codes can encode more than a single logical qubit per code block by applying “black hole” deformations with tunable rate and distance, while possessing fully addressable, universal fault-tolerant gate sets. [arXiv:2504.10386]

THU 1.3 Thu 14:45 ZHG001

Lattice surgery in near term experimental planar architectures — •Lukas Bödeker[1,2], Áron Márton[1,2], Luis Colmenárez[1,2], Ilya Besedin[3,4,5], Michael Kerschbaum[3,4,5], Jonathan Knoll[3], Ian Hesner[3,4,5], Nathan Lacroix[3,5], Luca Hofele[3,5], Christoph Hellings[3,5], François Swiadek[3,5], Alexander Flasby[3,4,5], Mohsen Bahrami Panah[3,4,5], Dante Colao Zanuz[3,4,5], Andreas Wallraff[3,4,5], and Markus Müller[1,2] — [1]Institute for Theoretical Nanoelectronics (PGI-2), Forschungszentrum Jülich — [2]Institute for Quantum Information, RWTH Aachen University — [3]Department of Physics, ETH Zürich — [4]ETH Zürich - PSI Quantum Computing Hub, Paul Scherrer Institute, Villigen — [5]Quantum Center, ETH Zürich

On the pathway to construct a scalable and fault-tolerantly error-corrected quantum computer, the question of implementing a fault-tolerant gate set must be addressed. For experimental platforms with planar design and limited qubit connectivity, the surface code – complemented with lattice surgery – has emerged as a leading candidate for delivering first proof-of-principle implementations of foundational building blocks. We demonstrate one early building block by creating entanglement between two repetition codes in a superconducting qubit architecture [1]. This is achieved by splitting a distance-three surface code using lattice surgery. Building on this result, we further investigate, through detailed simulations, the realistic performance of teleporting a logical surface-code state [2]. In doing so, we explore optimized lattice surgery protocols that preserve fault tolerance and are compatible with near-term superconducting qubit architectures.

[1] I. Besedin, M. Kerschbaum, J. Knoll, I. Hesner, L. Bödeker et al., "Realizing lattice surgery on two distance-three repetition codes with superconducting qubits", arXiv:2501.04612 (2025).

[2] L.Bödeker et al., "Lattice surgery for near term experimental entanglement creation in planar architectures", In preparation (2025).

THU 1.4 Thu 15:00 ZHG001

Measurement-free quantum error correction optimized for biased noise — •Katharina Brechtelsbauer[1], Friederike Butt[2,3], David F. Locher[2,3], Santiago Higuera Quintero[1], Sebastian Weber[1], Markus Müller[2,3], and Hans Peter Büchler[1] — [1]Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Institute for Quantum Information, RWTH Aachen University, Aachen, Germany — [3]Institute for Theoretical Nanoelectronics (PGI-2), Forschungszentrum Jülich, Jülich, Germany

In this work, we derive optimized measurement-free protocols for quantum error correction and the implemen- tation of a universal gate set optimized for an error model that is noise biased . The noise bias is adapted for neutral atom platforms, where two- and multi-qubit gates are realized with Rydberg interactions and are thus expected to be the dominating source of noise. Careful design of the gates allows to further reduce the noise model to Pauli-Z errors. In addition, the presented circuits are robust to arbitrary single-qubit gate errors, and we demonstrate that the break-even point can be significantly improved compared to fully fault-tolerant measurement-free schemes. The obtained logical qubits with their suppressed error rates on logical gate operations can then be used as building blocks in a first step of error correction in order to push the effective error rates below the threshold of a fully fault-tolerant and scalable quantum error correction scheme.

THU 1.5 Thu 15:15 ZHG001

Benchmarking decoding accuracy — •Kiara Hansenne[1], Pierre Cussenot[1,2], Anthony Benois[1], Grégoire Misguich[1], and Nicolas Sangouard[1] — [1]Université Paris Saclay, CNRS, CEA, Institut de Physique Théorique, 91191 Gif-sur-Yvette, France — [2]Direction Générale de l'Armement, 75015 Paris, France

The development of practical quantum computers is currently a major research topic, with quantum error correction playing a crucial role in achieving fault-tolerant quantum computing. Researchers are working towards qubits with physical noise rate below the error correction code threshold, a critical metric for evaluating an error correction code. This threshold is highly influenced by the noise model and by the decoding techniques used.

In this work, we propose to compare the performances of different decoding strategies (such as belief-propagation or minimum-weight perfect matching) against optimal decoding. Whereas such analysis is usually done by error sampling, our approach follows the quantum state through the circuit, allowing us to reach arbitrarily small error rates. Although this limits the exploration to small code distances, our results will provide essential benchmarks for current decoders and potentially estimate code thresholds with higher accuracy.

THU 1.6 Thu 15:30 ZHG001

Bosonic quantum error correction with neutral atoms in optical dipole traps — •David F. Locher[1,2], Leon H. Bohnmann[1,2], Johannes Zeiher[3,4], and Markus Müller[1,2] — [1]Institut für Quanteninformation, RWTH Aachen University, Germany — [2]Peter Grünberg Institut (PGI-2), Forschungszentrum Jülich, Germany — [3]Ludwig-Maximilians-Universität München, Germany — [4]Max-Planck-Institut für Quantenoptik, Garching, Germany

An atom trapped in an optical tweezer or optical lattice exhibits vibrational modes. In the present work [1] we analyse an experimentally motivated approach to encode quantum information in the vibrational motion of trapped neutral atoms. Specifically, we investigate the realisation of Gottesman-Kitaev-Preskill (GKP) code states [2]. We discuss the feasibility of our idea in realistic setups and we devise protocols for encoding and error correction of GKP states that are compatible with state-of-the-art experimental setups. The key element of our protocols is the controlled coupling of atomic motion to the atom's internal electronic states, which has recently been achieved in arrays of trapped atoms. We lay out that an optical lattice augmented with dynamical optical tweezers is a favourable setup whose experimental feasibility we confirm in numerical simulations. Our work therefore constitutes a significant step towards the first experimental realisation of GKP states in the motion of trapped neutral atoms.

[1] Bohnmann, Locher, Zeiher, Müller, *Phys. Rev. A* **111** 022432 (2025)

[2] Gottesman, Kitaev, Preskill, *Phys. Rev. A* **64** 012310 (2001)

THU 1.7 Thu 15:45 ZHG001

Graph Representations and Circuit-Based Codes from GHZ States — •Zahra Raissi[1], Hrachya Zakaryan[1], Konstantinos-Rafail Revis[1], Yinzi Xiao[1], Stanislaw Soltan[1], Mario Flory[2], and Johannes Blömer[1] — [1]Department of Computer Science and Institute for Photonic Quantum Systems (PhoQS), Paderborn University, Paderborn, Germany — [2]Jagiellonian University, Cracow, Poland

GHZ states are key resources for quantum communication and error correction. While symmetric GHZ states (defined as equal superpositions of basis states) are known to be locally unitary (LU) equivalent to both star-shaped and fully connected graph states, their non-symmetric counterparts lack a comparable framework. Non-symmetric GHZ states, defined as unequal superpositions of basis states, naturally arise in experiments due to decoherence and imperfections in state preparation.

We establish that these non-symmetric GHZ states are LU-equivalent to two graphical formalisms: (i) fully connected weighted hypergraph states, and (ii) controlled-unitary star-shaped graphs. Although weighted hypergraph states typically lack a stabilizer description, we construct a complete stabilizer set using only a single ancilla qubit, independent of system size.

Building on this, we consider a qutrit quantum error-correcting code with parameters $[[n = 3, k = 1, d = 2]]_3$, whose codewords take the form of GHZ states. We inject these codewords into quantum circuits arranged in brickwall architectures and construct new quantum codes. Using this method, we obtain both optimal and good codes.

THU 2: Quantum Information: Concepts and Methods I

Time: Thursday 14:15–16:15 Location: ZHG002

THU 2.1 Thu 14:15 ZHG002

Concentration of ergotropy in many-body systems — •Karen Hovhannisyan[1], Rick P. A. Simon[2,1], and Janet Anders[1,2] — [1]University of Potsdam, Institute of Physics and Astronomy, Karl-Liebknecht-Str. 24-25, 14476 Potsdam, Germany — [2]Department of Physics and Astronomy, University of Exeter, Stocker Road, Exeter EX4 4QL, UK

Ergotropy—the maximal amount of unitarily extractable work—measures the “charge level” of quantum batteries. We prove that in large many-body batteries ergotropy exhibits a concentration of measure phenomenon. Namely, the ergotropy of such systems is almost constant for almost all states sampled from the Hilbert–Schmidt measure. We establish this by first proving that ergotropy, as a function of the state, is Lipschitz-continuous with respect to the Bures distance, and then applying Levy’s measure concentration lemma. In parallel, we showcase the analogous properties of von Neumann entropy, compiling and adapting known results about its continuity and concentration properties. Furthermore, we consider the situation with the least amount of prior information about the state. This corresponds to the quantum version of the Jeffreys prior distribution—the Bures measure. In this case, there exist no analytical bounds guaranteeing exponential concentration of measure. Nonetheless, we provide numerical evidence that ergotropy, as well as von Neumann entropy, concentrate also in this case.

THU 2.2 Thu 14:30 ZHG002

Learning in Continuously-Monitored and Repeatedly-Interacting Quantum Systems — •Felix Binder — Trinity College Dublin, Dublin, Ireland

To characterise a quantum system, we must observe it. The observation record the allows us to estimate the parameters governing its behaviour. While conventional approaches to parameter estimation and tomography rely on repeated measurements under reset conditions, we ask what can be learned in a single shot when memory persists between sequential measurements. We consider two separate scenarios: a continuously monitored open quantum system and a system coupled to a finite-sized environment probed at discrete time steps.

In the first case, we focus on quantum trajectories in the jump unravelling and develop analytic and computational tools to compute the Fisher Information in both renewal and non-renewal processes. Our methods account for data compression and post-selection, and are illustrated with physically relevant examples.

In the second case, we introduce a learning framework where only the system is probed and the environment acts as a hidden quantum memory. We characterise the gauge freedoms arising in this scenario, define a suitable gauge-invariant distance between quantum processes, and show how the Fisher Information matrix reveals the dimensionality of the accessible model space.

THU 2.3 Thu 14:45 ZHG002

An infinite hierarchy of quantum-enhanced learning tasks — •Jan Nöller[1], Viet Tran[2], and Richard Kueng[2] — [1]Technische Universität Darmstadt — [2]Johannes-Kepler-Universität Linz

Learning properties of quantum states from empirical data is arguably the most fundamental quantum learning challenge. Seminal work over the past years has shown that the sample complexity associated with such tasks strongly depends on the underlying measurement primitive. As an example, determining all Pauli-observables on an n-qubit becomes sample-efficient if we allow entangling measurements on pairs of state copies, where an exponential number of samples is required if only single-copy measurements are performed. Similar separations also apply to purity testing. However, so far it has been unclear whether such exponential separation results also hold for 3 or more state copies: are there learning tasks that must be exponentially hard for (k -1)-copy measurements, but become very efficient if we allow k-copy measurements? Here, we answer this question affirmatively for every k that is a prime number. The underlying learning challenges arise from carefully extending n-qubit Pauli tomography to Weyl-Heisenberg tomography on n qudits. Up to our knowledge, our findings describe the first infinite family of rigorous separation results for multi-copy state learning.

THU 2.4 Thu 15:00 ZHG002

Relative entropy of magic — •Carolin Deckers, Justus Neumann, Hermann Kampermann, and Dagmar Bruss — Heinrich-Heine Universität Düsseldorf, Germany

We investigate the relative entropy of magic for a single qubit and for two qubits. Although the relative entropy of resource has favorable properties, it is difficult to compute in general. We apply the partial results derived for the relative entropy of entanglement [Friedland, Gour, J. Math. Phys. 52, 052201 (2011)] to the resource theory of magic. In the single-qubit case, we analyze the geometric behavior and derive an approximate analytic expression for identifying the closest stabilizer state to a pure magic state. We further investigate the two-qubit case by explicitly treating a minimal set of facets.

THU 2.5 Thu 15:15 ZHG002

Efficient distributed inner product estimation via Pauli sampling and its applications: a matter of magic and entanglement — Marcel Hinsche[1], Marios Ioannou[1], Sofiene Jerbi[1], Lorenzo Leone[1], Janek Denzler[1], Santiago Varona[2], Tommaso Guaita[1], Jens Eisert[1], and •Jose Carrasco[1] — [1]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany — [2]Instituto de Física Teórica, UAM-CSIC, Universidad Autónoma de Madrid, Cantoblanco, 28049 Madrid, Spain

Cross-device verification (a.k.a. distributed inner product estimation) allows two remote parties to estimate inner products $\mathrm{tr}(\rho\sigma)$, with each having black-box access to copies of ρ and σ, respectively. When the states ρ and σ exhibit low entanglement or can be prepared with few non-Clifford gates, this task can be reduced to independently learning efficient classical descriptions of each state using established techniques, and sharing this description in order to compute the overlap. In this talk, we will argue that efficient cross-device verification is also possible via Pauli sampling without the need to explicitly learn classical descriptions of the states (arXiv: 2405.06544). This allows us to do efficient cross-device verification in more complex scenarios where tensor network and stabilizer-based methods are insufficient (arXiv: 2501.11688). We discuss possible applications of the results in secure quantum communication, cryptography and verification.

THU 2.6 Thu 15:30 ZHG002

Optimal randomized measurements for a family of non-linear quantum properties — Zhenyu Du[1], •Yifan Tang[2], Andreas Elben[3], Ingo Roth[4], Jens Eisert[2], and Zhenhuan Liu[1] — [1]Tsinghua University, Beijing, China — [2]Freie Universität Berlin, Berlin, Germany — [3]Paul Scherrer Institute, Villigen, Switzerland — [4]Technology Innovation Institute, Abu Dhabi, United Arab Emirates

Quantum learning encounters fundamental challenges when estimating non-linear properties, owing to the inherent linearity of quantum mechanics. Although recent advances in single-copy randomized measurement protocols have achieved optimal sample complexity for specific tasks, generalizing these protocols to estimate broader classes of non-linear properties without sacrificing optimality remains an open problem. In this work, we introduce the observable-driven randomized measurement (ORM) protocol enabling the estimation of $\mathrm{Tr}(O\rho^2)$ for an arbitrary observable O—an essential quantity in quantum computing and many-body physics. We establish an upper bound for ORM’s sample complexity and prove its optimality for all Pauli observables, closing a gap in the literature. Furthermore, we develop simplified variants of ORM for local Pauli observables and introduce a braiding randomized measurement protocol for fidelity estimation, both of which significantly reduce circuit complexities in practical applications. Numerical experiments validate that ORM requires substantially fewer state samples to achieve the same precision compared to classical shadows.

THU 2.7 Thu 15:45 ZHG002

Sparse semidefinite programming in quantum information theory — •Lucas Vieira[1,2] and Costantino Budroni[3] — [1]Dept. of Computer Science, TU Darmstadt, Darmstadt, 64289 Germany — [2]IQOQI-Vienna, Austrian Academy of Sciences, Boltzmanngasse 3, 1090 Vienna, Austria — [3]Dept. of Physics "E. Fermi", Univ. of Pisa, Largo B. Pontecorvo 3, 56127 Pisa, Italy

Large-scale semidefinite programs (SDPs) are ubiquitous in quantum information, typically arising from relaxations of harder underlying problems. These relaxations usually incur significant computational costs, requiring efficient representations before numerical tractability. Since relaxations may not yield feasible solutions to the original problem (e.g., the solution only satisfies a relaxed constraint), one typically prioritizes obtaining an optimal value for the objective function over its corresponding optimizer in the relaxation. Inspired by this, we introduce a heuristic method for constructing sparse representations of general SDPs, specifically targeting the sparse structure arising from their sparse objective: a typical scenario in quantum information. Unlike existing approaches, our heuristic method discards irrelevant variables and constraints by finding the effective sparsity implicit in an instance of a problem, not directly apparent from its full definition, but which emerges naturally from its structure. Our method works by iteratively assembling a self-sufficient subset of variables and constraints which, directly or indirectly, affect the objective function. This talk will outline our method and demonstrate its significant advantages in typical SDP relaxations encountered in quantum information.

THU 2.8 Thu 16:00 ZHG002

Quantum signal processing as time evolution — •Shawn Skelton — Leibniz Universität Hannover

The quantum circuit model has become a standard tool in quantum algorithm development. However, it can be preferable to formulate quantum algorithms as the time evolution generated by a Hamiltonian, for example as is done in quantum adiabatic computing. While adiabatic quantum computation can be polynomially mapped to the circuit model, algorithms developed in the circuit model and adiabatic quantum computation remain conceptually and practically separate.

In this talk, I consider a template for quantum algorithm development in the circuit model, known as quantum signal processing (QP). I derive the generator and time-evolved operator corresponding to a given QSP circuit. I then show how, for a restricted class of Hamiltonians, any QSP circuit can be implemented with a quantum adiabatic evolution. Algorithms have been developed for every major quantum computation problem with QSP, and it is known that QSP can solve BQP-complete problems. Thus, my work provides a pathway for many quantum algorithms to be reformulated in terms of well-understood physical time evolution.

THU 3: Arbeitskreis Chancengleichheit (AKC)

Time: Thursday 14:15–16:15 Location: ZHG003

Invited Talk THU 3.1 Thu 14:15 ZHG003

Reshaping the History of Quantum Physics: Paths to Gender Equality — •Andrea Reichenberger — TU Munich, Germany

We are all familiar with gender dynamics, biases, and stereotypes on the online platforms we visit, use, and co-create every day. They are ubiquitous in large language models (LLMs) and other generative AI technologies trained on large amounts of data. Their spillover effects are now well studied in scientific research. There is comparatively little research on how the history of physics is represented and practiced in today's online spaces. This talk will take you on a journey through the history of quantum physics, exploring new avenues for a gender-sensitive future of the history of physics. And it offers a critical insight into how expertise in the history of physics, science communication and public opinion influence and reinforce each other in the practice of digital history. Drawing on a series of case studies on women in the history of quantum physics, we examine the Matilda effect on online platforms and offer perspectives on how to successfully counteract this effect, which gives a name to the systematic misrecognition of women's contributions to science and technology.

Invited Talk THU 3.2 Thu 14:45 ZHG003

Women in the History of Quantum Physics — •Margriet van der Heijden — Eindhoven University of Technology (TU/e), The Netherlands

The narratives of the development of quantum mechanics are as "male-dominated" as this subfield of science itself, science historian Massimiliano Badino noted some nine years ago. The book Women in the History of Quantum Physics: Beyond Knabenphysik aims to challenge these conventional "all-male" narratives. In sixteen chapters, the authors – all members of the international and interdisciplinary working group Women in the History of Quantum Physics – analyse the work and lives of women who contributed to quantum developments in the twentieth century. Not the handful of famous women like Marie Skłodowska Curie, Maria Goeppert Mayer and Lise Meitner, but the women who remained in the shadows, had to interrupt their careers or whose work was overlooked. By analysing and comparing their lives and work, themes can be distilled that are relevant to understanding why women's participation in physics research remains low even today. I will explore some of these themes and illustrate them with the lives and experiences of some of the protagonists of the book chapters.

Invited Talk THU 3.3 Thu 15:15 ZHG003

Visibility, invisibility and hypervisibility of women in quantum technologies — Martina Erlemann, •Andrea Bossmann, and Tamar Grosz — Fachbereich Physik, Freie Universität Berlin, Deutschland

Quantum technologies are widely recognized as key technologies of the future. With their broad range of applications, they have the potential to address major societal challenges and contribute to the sustainable, future-oriented development of society. However, equal participation of highly qualified women in quantum technologies has not yet been achieved. Women remain significantly underrepresented in STEM fields that lead to careers in research and development within quantum technologies, such as physics, computer science, and certain branches of engineering. Additionally, high-achieving women in quantum technologies often receive less visibility than their male counterparts. This lack of visibility is evident both within the scientific community, in the form of fewer awards, recognitions, or leadership appointments, and externally, in public discourse, industry, politics, and the media. At the same time, women in these fields are hypervisible because of being part of a minority, which however doesn't lead to recognition, but rather to a higher level of being exposed and scrutinized. Here we will discuss the effects of these competing types of visibility and preliminary findings of our BMBF-funded research project WomenInQuantumTech: In/visibility of Women in Quantum Technologies - Development of effective strategies for better participation.

Invited Talk THU 3.4 Thu 15:45 ZHG003

Leadership, Cooperation and Conflicts in Physics: Research Leaders' Perspectives — •Maike Reimer — Bayerisches Staatsinstitut für Hochschulforschung und Hochschulplanung (IHF), Arnulfstraße 56, 80335 München

"Can Germany rein in its academic bullying problem?" This question was recently raised prominently in a nature article. Anecdotal evidence as well as systematic surveys among researchers indeed paint a bleak picture of research leadership and institutional structures for conflict prevention and management in research settings in Germany and its German-speaking neighbouring states. However, the perspectives and voices of senior researchers are conspicuously absent from this discourse. Therefore, in collaboration with the DPG, we conducted 11 interviews and a survey among all members with leadership experience, about one crucial aspect and challenge of leadership: dealing with conflicts in their research teams. Here, we will present results from the full report on the frequency, kind, antecedents and consequences of conflicts and the ways they were resolved with or without institutional support. In addition, we investigate gender specific patterns in conflict experience. We hope to contribute to a more nuanced discussion and ultimately an improvement in research institutions conflict management structures.

THU 4: Precise Quantum Molecules: Contributed Session to Symposium

Time: Thursday 14:15–15:15 Location: ZHG004

THU 4.1 Thu 14:15 ZHG004

Floquet-Engineering of Bound States in the Continuum — •Alexander Guthmann, Louisa Marie Kienesberger, Felix Lang, and Artur Widera — Physics Department and Research Center OPTIMAS, University of Kaiserslautern-Landau

Scattering resonances play a pivotal role in quantum phenomena, from nuclear reactions to ultracold atomic collisions. Our recent work has demonstrated that periodic modulation of the magnetic field can be used to induce Floquet-Feshbach resonances in a two-component gas of fermionic lithium-6 [1], enabling precise control over resonance positions and suppression of inelastic losses.

This talk will focus on a new application of this technique: the realization of Bound States in the Continuum (BICs) through interference at an avoided crossing between two Floquet-engineered resonances. BICs are exotic quantum states that remain localized despite existing within the energy continuum of scattering states. As first predicted by Friedrich and Wintgen [2], such states can emerge through destructive interference at an avoided crossing of two resonances. While BICs have been realized in photonic and acoustic platforms, their observation in a true molecular dimer system has remained a longstanding challenge.

[1] A. Guthmann, F. Lang, L. M. Kienesberger, S. Barbosa, A. Widera, arXiv 2503.05454 (2025).
[2] H. Friedrich and D. Wintgen, Phys. Rev. A 32, 3231 (1985).

THU 4.2 Thu 14:30 ZHG004

Near-complete chiral selection in rotational quantum states — •Elahe Abdiha, JuHyeon Lee, Shilpa Yadav, Sejun An, Boris G Sartakov, Gerard Meijer, and Sandra Eibenberger-Arias — Fritz-Haber-Institut der Max-Planck-Gesellschaft; Berlin, 14195, Germany

In our work, we accomplish near-complete chiral selection in rotational quantum states [1]. Beyond mere chiral analysis, enantiomer-specific state transfer (ESST) enables the control and manipulation of chiral molecules at the quantum level. We overcome previous limitations of ESST by applying UV laser and microwave radiation to a triad of rotational states connected to the absolute ground state. Our experimental results show that 96% state-specific enantiomeric purity can be obtained from a racemic mixture, in an approach that is universally applicable to all chiral molecules of C1 symmetry. Our work has the potential to significantly advance the experimental methods to measure parity-violation effects in chiral molecules [4].

We will also present our ongoing efforts to address the intrinsic limitation of ESST due to orientational degeneracy of rotational states by incorporating theoretically tailored microwave pulse schemes [5].

[1] Lee et al. Nat. Commun. 15, 7441 (2024)
[2] Eibenberger et al. Phys. Rev. Lett. 118, 123002 (2017)
[3] Pérez et al. Angew. Chem. Int. Ed. 56, 12512 (2017)
[4] Erez et al. Phys. Rev. X, 13, 041025, (2023)
[5] M. Leibscher et al. Commun. Phys. 5, 110 (2022).

THU 4.3 Thu 14:45 ZHG004

Observation of rovibrational state interference in molecule-surface collisions — •Christopher Reilly[1], Daniel J. Auerbach[2], and Rainer D. Beck[1] — [1]EPFL, Lausanne, Switzerland — [2]MPINAT, Göttingen, Germany

While for all but the lightest molecular species the collisional generation and absorption of surface phonons typically obscures the ultimately quantum mechanical nature of molecule-surface collisions, a special continuous reflection symmetry in the interaction between methane and a gold surface permits observation of striking interference effects in the distribution of quantum states populated in the scattering event. Moreover, this interference effect is unique to molecules with some minimum amount of internal structure and is thus absent for the simpler molecular species typically studied.

Using laser-based quantum state preparation and detection, we are able to observe a novel form of high-contrast destructive interference between rovibrational states in molecule-surface scattering[1]. By exciting molecules to or from a rovibrational state of zero angular momentum, we prepare a state of pure reflection parity, and when probing the scattered molecules we find an almost total absence of population in states of the opposite parity. Reflection parity conservation is observed in both the ground and excited vibrational states, with constrast ratios approaching 100:1. High-contrast interference is also observed for rare vibrational relaxation events, shedding light on their microscopic mechanism.

[1] Reilly et al., Science 387, 962 (2025)

THU 4.4 Thu 15:00 ZHG004

Quantum-mechanical calculations for million-atom biological systems — •Luc Wieners and Martin E. Garcia — Institut für Physik, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany

Quantum-mechanical first-principles calculations are commonly only used for systems containing a few hundred atoms which leaves biological systems with thousands or millions of atoms inaccessible. In this study we show a new algorithm for the Hartree-Fock method combined with a divide-and-conquer approach which enables calculations of million-atom biological systems, including a whole bacteriophage in a solution which in total contains 45 million atoms.

The high computational speed also allows the calculation of spectra for systems with hundreds to a few thousand atoms. This is used to compute absorption spectra for proteins, DNA and medications. Additionally, Hartree-Fock atomic energies are found to coincide with AlphaFold's pLDDT confidence score for protein structure predictions, showing a connection between first-principle calculations and protein structure assessment.

We anticipate that the presented methods open a pathway to fully quantum-mechanical investigations including more accurate molecular dynamics simulations and theoretical predictions of spectral properties for systems in biology and medicine.

THU 5: QIP Implementations: Interfaces

Time: Thursday 14:15–16:15 Location: ZHG006

THU 5.1 Thu 14:15 ZHG006

Quantum repeater applications with single trapped ions and single photons — •Pascal Baumgart, Max Bergerhoff, Jonas Meiers, Stephan Kucera, Christian Haen, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken

For the realization of large-distance quantum networks, quantum repeaters (QR) are needed to overcome the exponential loss of direct transmission by dividing a transmission link into asynchronously driven cells [1] and segments [2]. We report on the implementation of these QR building blocks with free-space-coupled photons from two $^{40}Ca^{+}$ ions in the same Paul trap as quantum memories. Atom-photon entanglement is generated by controlled emission of single, separately fiber-coupled photons from the individually addressed ions. In the QR cell, entanglement is swapped from the ions to two asynchronously generated photons by a Mølmer-Sørensen gate and subsequent state detection [3], while in the QR segment, atom-atom entanglement is generated by a photonic Bell-state measurement.

In preparation for real-world QR applications, quantum communication protocols using a parametric down-conversion source of entangled photon pairs and a trapped-ion quantum memory, together with quantum frequency conversion, have been demonstrated over the 14.4 km Saarbrücken urban fiber link [4].

[1] D. Luong et al., Appl. Phys. B 122, 96 (2016)
[2] P. van Loock et al., Adv. Quantum Technol., 3: 1900141 (2020)
[3] M. Bergerhoff et al., Phys. Rev. A 110, 032603 (2024)
[4] S. Kucera et al., npj Quant. Inf. 10, 88 (2024)

THU 5.2 Thu 14:30 ZHG006

An Efficient Spin-Photon Interface for Tin-Vacancy Centers in Diamond — •Kerim Köster[1], Andras Lauko[1], Philipp Grasshoff[2], Dominic Reinhardt[3], Thomas Hümmer[4], Cyril Popov[2], Jan Meijer[3], and David Hunger[1] — [1]Karlsruher Institut für Technologie — [2]Uni Kassel — [3]Uni Leipzig — [4]Qlibri GmbH

The realization of long-distance quantum networks requires efficient interfaces of photons and stationary memories. The Tin-Vacancy (SnV) center in diamond emerged as a promising solid-state based spin photon interface, featuring spin-selective optical transitions, long memory times and efficient spin control. However, scaling to multi-node networks remains challenging, as they rely on the efficient coupling between these defect centers and optical cavities. Here, we present the integration of single addressable SnV centers in a micrometer-thin membrane into an open, fully tuneable and cryogenic microcavity to attain emission enhancement in a single optical mode. The cavity platform operates within a dilution cryostat at temperatures around 1K, featuring a passive mechanical stability below 10 pm. We observe a significant Purcell-induced lifetime shortening, indicating strong light-matter interaction. The system operates in the high-cooperativity regime, which allows us to probe the coherent coupling evidenced by emitter-induced extinction in the transmission profile of the cavity. Our platform further supports the integration of a superconducting magnet and a microwave antenna, enabling spin readout and coherent control. This represents a significant step towards realizing an efficient spin-photon interface for group IV color centers in diamond.

THU 5.3 Thu 14:45 ZHG006

Single erbium dopants in silicon resonators — •Benedikt Braumandl, Andreas Gritsch, Jakob Pforr, Alexander Ulanowski, Arantza Pineda Gonzalez, and Andreas Reiserer — Technical University of Munich, TUM School of Natural Sciences and Munich Center for Quantum Science and Technology (MCQST), 85748 Garching, Germany

Establishing long-distance quantum networks requires not only low-loss photon transmission, but also efficient, scalable interfaces between stationary and flying qubits. One promising approach leverages rare-earth ions, whose optical transitions lie directly in the telecom band, ensuring compatibility with existing fiber infrastructure [1]. In particular, erbium dopants in silicon offer a robust route to integrating quantum emitters with photonic circuitry, combining telecom-wavelength emission with the scalability of silicon nanotechnology [2].

We investigate the optical coherence of single erbium dopants embedded in high-Q silicon nanophotonic resonators, where Purcell enhancement enables efficient coupling between the emitter and photonic modes [3]. We further evaluate photon indistinguishability via Hong–Ou–Mandel-type interferometry, observing high visibility at short time delays. This demonstrates the emitter's suitability for photon-mediated entanglement protocols between distant qubits.

[1] Reiserer, A. Rev. Mod. Phys. 94, 041003 (2022)
[2] Gritsch, A. et. al. Phys. Rev. X 12 (4): 041009 (2022)
[3] Gritsch, A. et. al. Nat Commun 16, 64 (2025)

THU 5.4 Thu 15:00 ZHG006

Large-scale Localization of Diamond Color Centers for Deterministic Fabrication of Nanophotonic Spin-Photon Interfaces — •Maarten H. van der Hoeven[1], Julian M. Bopp[1,2], Marco E. Stucki[1,2], Tommaso Pregnolato[1,2], and Tim Schröder[1,2] — [1]Department of Physics, Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Germany — [2]Ferdinand-Braun-Institut (FBH), Gustav-Kirchhoff-Straße 4, 12489 Berlin, Germany

Quantum photonic circuits are fundamental building blocks for quantum information applications. Over the past decades, it has been demonstrated that color centers in diamond have excellent properties to serve as qubits in such systems [1]. To create an efficient spin-photon interface, the color centers have to be coupled to nanostructures. Achieving scalable fabrication of such devices with high yield and optimal performance requires deterministic fabrication techniques [2]. In this work, we use a widefield fluorescence microscope to localize tens of color centers per image frame and thousands across a diamond chip with uncertainties of just a few tens of nanometers. We then characterize all emitters and deterministically fabricate nanostructures at their positions. Our results show a device placement with high accuracy and precision. This makes it a powerful tool for the scalable and efficient integration of photonic spin qubits into quantum circuits.

[1] M. Ruf et al., Journal of Applied Physics 130, 070901 (2021)
[2] S. Rodt et al., J. Phys: Condensed Matter 32, 153003 (2020)

THU 5.5 Thu 15:15 ZHG006

The Sawfish spin-photon interface: fabrication and characterization — •Marco E. Stucki[1,2], Alok Gokhale[2], Julian M. Bopp[1,2], Maarten H. v. d. Hoeven[2], Tommaso Pregnolato[1,2], and Tim Schröder[1,2] — [1]Ferdinand-Braun-Institut (FBH), Berlin, Germany — [2]Humboldt-Universität, Berlin, Germany

Color centers in diamond are promising qubit candidates. They offer individually addressable spin states with long coherence times. By coupling color centers to optical cavities, their emission into the zero-phonon line can be enhanced via the Purcell effect. Solid-state cavities with a small mode volume are typically realized as photonic crystal cavities (PhCCs). The most common design for PhCCs consists of a periodic pattern of holes in a dielectric material. These features are difficult to fabricate in diamond due to its hardness and chemical stability. We recently proposed a new 1D PhCC geometry, the "Sawfish" cavity, that uses a cosine-based corrugation pattern to avoid creating these high aspect-ratio holes. Here, we fabricate Sawfish cavities in diamond. We investigate the structural and spectroscopic properties of the devices by a scanning electron microscope and a confocal optical setup, respectively. From our investigation we find that, despite roughness and erosion, quality factors exceeding 3800 were achieved. To increase the quality of the fabricated devices and make the fabrication more reliable, improvements in the etching processes are currently investigated. Using image analysis software developed in-house, we examine the erosion in our structures and compensate for it in our lithography mask.

THU 5.6 Thu 15:30 ZHG006

Near Lifetime-limited NV Centers Integrated into Diamond Photonic Crystal Cavities — •Alok Gokhale[1], Julian M. Bopp[1,2], Laura Orphal-Kobin[1], Kilian Unterguggenberger[1], Marco E. Stucki[1,2], Tommaso Pregnolato[1,2], and Tim Schröder[1,2] — [1]Department of Physics, Humboldt Universität zu Berlin, Berlin, Germany — [2]Ferdinand Braun Institute (FBH), Berlin, Germany

Candidate quantum network node platforms need to satisfy a variety of properties. These include: interfacing between stationary and flying qubits, long storage times, indistinguishable photons and a large photon flux. Nitrogen-vacancy centers in diamond (NV) weakly coupled to cavities fulfil most of these criteria. Nanofabrication leads to a large number of unstable charge traps on the material surface, close to the emitter. The unstable fields cause a Stark-shift in the NV energies, leading to inhomogeneous broadening of the NV zero-phonon-line (ZPL) and loss of indistinguishability. It was recently demonstrated that narrow (150 MHz) NVs can exist in nanopillars [1]. Here, we adapt and extend the developed methods and show NV centers with linewidths as low as 21 MHz, in a Sawfish photonic crystal cavity [2,3]. We also demonstrate the tuning of the cavity resonance, through N2 gas deposition, over 20 nm. We show initial indications of Purcell enhancement of the NV ZPL as the cavity is tuned through it.

[1] L. Orphal-Kobin et al., Phys. Rev. X 13, 011042 (2023).
[2] J. M. Bopp et al., Adv. Optical Mater. 12, 2301286 (2024).
[3] T. Pregnolato et al., APL Photonics 9(3), 036105 (2024).

THU 5.7 Thu 15:45 ZHG006

Color centers for the secure processing of quantum tokens — •Gregor Pieplow[1], Yannick Strocka[1], Mohamed Belhassen[1], and Tim Schröder[1,2] — [1]Humboldt-Universität zu Berlin, Berlin, Germany — [2]Ferdinand-Braun-Institut, Berlin, Germany

We present a quantum token scheme [1] for secure authentication or payment. Building on Wiesner's quantum money concept, tokens are encoded as multi-qubit states generated by a single-photon source, then transmitted and securely stored in a quantum-memory register. To manipulate and verify the token, we employ a sawfish nanophotonic-crystal cavity as a spin-photon interface, enabling the required spin-photon entangling gates. High-fidelity fractional quantum gates are realized via trains of optical $\pi/8$ pulses, achieving fidelities above 99% under realistic conditions. Although all-optical methods yield superior rates, limited storage times may constrain some applications. Incorporating microwave control, and leveraging long-lived nuclear spins extends token viability but lowers operational rates, highlighting a key trade-off for practical deployment.

[1] Strocka et al., arXiv:2503.04985 (2025)

THU 5.8 Thu 16:00 ZHG006

Towards laser cooling of erbium crystals — Daniele Amato[1,2], Florian Burger[1,2], Justus Edelmann[1,2], •Nilesh Goel[1,2], Andreas Gritsch[1,2], Till Nemolclev[1,2], Andrew Propper[1,2], Stephan Rinner[1,2], Stefano Romboni[1,2], Kilian Sandholzer[1,2], and Andreas Reiserer[1,2] — [1]Technical University of Munich, TUM School of Natural Sciences, 85748 Garching, Germany — [2]Zentrum für QuantumEngineering, ZQE, 85748 Garching, Germany

Thermal management in nanophotonic devices is vital in various research and technology fields, including quantum photonics. This necessitates a consistent measurement and control of temperature within nanophotonic devices. Established methods employ sensors attached to the components, which provide poor spatial resolution and hence hamper the assessment of local heating effects. To address such limitations, we investigate an alternate temperature sensing approach that measures the luminescence of erbium emitters directly incorporated into nanophotonic silicon waveguides. To span the temperature range from 295 K to 2 K, we look at two approaches: thermal activation of non-radiative decay channels above 200 K and thermal depopulation of spin- and crystal-field levels at lower temperatures [1]. To further analyse the applicability of this method, we look at the properties of erbium crystals and laser cooling of solids with erbium dopants. We investigate the efficacy of such a technique for cooling a solid system to enable quantum and optomechanical applications.

[1] Sandholzer, K., et al. Nanophotonics 14, 20250067 (2025).

THU 6: Quantum Computing and Communication: Contributed Session II (Concepts)

Time: Thursday 14:15–15:45 Location: ZHG007

THU 6.1 Thu 14:15 ZHG007

Quantum resource in quantum optimization — •Gopal Chandra Santra[1,2,3], Daniel J. Egger[4], and Philipp Hauke[1,2] — [1]Pitaevskii BEC Center, INO-CNR and Department of Physics, University of Trento, Via Sommarive 14, I-38123 Trento, Italy — [2]INFN-TIFPA, Trento Institute for Fundamental Physics and Applications, Via Sommarive 14, I-38123 Trento, Italy — [3]Kirchhoff- Institut fur Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany — [4]IBM Quantum, IBM Research Europe - Zurich, Säumerstrasse 4, CH-8803 Rüschlikon, Switzerland

Variational quantum algorithms are promising for solving combinatorial optimization problems on near-term, pre-fault-tolerant quantum hardware. However, to what extent these algorithms harness quantum correlations and whether current quantum devices can provide them remains unclear. This work investigates this open question by examining the roles of entanglement and nonstabilizerness within the Quantum Approximate Optimization Algorithm (QAOA). To begin, we leverage a strong connection between QAOA and quantum metrology, using quantum squeezing to analyze entanglement through numerical simulations and experiments on IBM quantum hardware. While increasing bipartite entanglement with system size is known to be insufficient for fully unlocking quantum computational advantages, we address this limitation by focusing on genuine multipartite entanglement. Finally, we examine the role of nonstabilizerness in QAOA and investigate how it relates to output fidelity. Our results provide deeper insights into how quantum resources influence quantum optimization.

THU 6.2 Thu 14:30 ZHG007

Regular parameterizations of the special unitary group and convergence of variational algorithms — •Marco Wiedmann[1], Daniel Burgarth[1], and Christian Arenz[2] — [1]Friedrich-Alexander Universität Erlangen-Nürnberg, Staudtstraße 7 91058 Erlangen, Germany — [2]Arizona State University, 650 E Tyler Mall, Tempe, AZ 85281, USA

Variational algorithms have gained a lot of attention in the recent years as a potential application of quantum computers. In broad terms, a parameterized unitary is implemented on a quantum computer, which is then used to measure some objective function that should be minimized by a classical optimization routine.

Gradient based optimizers can however get stuck at singular points of the parameterization, which resembles a gimbal lock like effect. We show that some popular parameterizations do indeed admit these singular points and propose alternatives which are globally regular. Finally, we use these parameterizations to prove that if the Variational Quantum Eigensolver does not run off to infinity, it almost always converges to a true ground state of the problem Hamiltonian.

THU 6.3 Thu 14:45 ZHG007

Accuracy of Quantum Simulation under Random Errors and Noise — •Jayant Rao, Jens Eisert, and Tommaso Guaita — Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany

Quantum simulation emerges as a highly promising application of quantum computing. At present, a critical question revolves around the robustness of digital and analog approaches to simulating quantum systems in the presence of errors and noise.

We consider the task of simulating local observables in a d dimensional lattice. Each local Hamiltonian carries an error bounded by a small parameter δ in spectral norm to the correct Hamiltonian. We compute the deviation from the ideal evolution in a worst case, where we find that the error scales with $O(\delta t^{d+1})$ in both the analog and digital method. We consider as a more realistic model randomly distributed Hamiltonian error terms, where we can show that the Trotter circuits error concentrates at $O(\delta)$ with high probability. We also show similar concentration effects which emerge considering random input states.

It is widely believed that analog quantum simulators are more resilient to noise because they allow for more error interference to happen. Our considerations show that strong error cancellation is present in Trotter based simulation as well. This leads us to motivate rethinking some beliefs about which strategies for quantum simulation are indeed more resilient to errors and noise.

THU 6.4 Thu 15:00 ZHG007

Local Complementation Orbit Scaling and Universal Resources for MBQC — •Frederik Hahn — Electrical Engineering and Computer Science Department, Technische Universität Berlin, 10587 Berlin, Germany

In Measurement-Based Quantum Computing (MBQC), quantum computation is performed through adaptive measurements on entangled resource states, with graph states serving as the canonical example. The computational power and efficiency of MBQC is fundamentally connected to the properties of these underlying graph states. Here, we focus on how classes of quantum graph states transform under local Clifford operations and how these transformations scale in the number of qubits. It is well known that local Clifford transformations can be represented by local complementations of the underlying graphs. All graphs that can be reached via local complementation from a given starting graph form that graph's local complementation orbit. We can now investigate how the size of these local complementation orbits scales with the number of qubits n of the underlying graph states. For simple classes, such as GHZ states, this scaling is known to be linear in n and an upper bound is given by 3^n. However, for general graph states, counting the orbit sizes is a problem that is known to be #P-complete. Can we still calculate the orbit scaling for classes of graph states that are known to be universal quantum computing resources?

THU 6.5 Thu 15:15 ZHG007

Expressivity Limits of Quantum Reservoir Computing — •Nils-Erik Schütte[1,2], Niclas Götting[2], Hauke Müntinga[1], Meike List[1,3], Daniel Brunner[4], and Christopher Gies[2] — [1]German Aerospace Center, Institute for Satellite Geodesy and Inertial Sensing, Bremen, Germany — [2]Institut für Physik, Fakultät V, Carl von Ossietzky Universität Oldenburg — [3]University of Bremen — [4]Institut FEMTO-ST, Université Franche-Comté CNRS UMR, Besançon, France

Quantum machine learning (QML) merges quantum computing and artificial intelligence, two transformative technologies for data processing. While gate-based quantum computing employs precise unitary operations on qubits via parameterized quantum circuits (PQCs), quantum reservoir computing (QRC) leverages physical systems as quantum neural networks, relying on Hamiltonian dynamics rather than controlled gate operations, with learning performed at the output layer. Despite their differing foundations, these approaches share connections and can be formally mapped onto each other.

We formulate the QRC approach in the language of gate-based circuits and apply recently developed methods for PQCs to QRC. Contrary to expectations, we find that the effective computational dimensionality of quantum reservoirs does not scale with the reservoir dimension but is mainly determined by the input encoding [1]. For commonly used single-qubit rotations, we show that exponential scaling, one of the main promises of QRC over classical RC, cannot be reached.

[1] Schütte et al., arXiv: 2501.15528

THU 6.6 Thu 15:30 ZHG007

Connection between memory performance and optical absorption in quantum reservoir computing — •Niclas Götting, Steffen Wilksen, Alexander Steinhoff, and Christopher Gies — Institute for Physics, Faculty V, Carl von Ossietzky University Oldenburg, 26129 Oldenburg, Germany

Quantum reservoir computing (QRC) leverages dynamical quantum systems to perform machine learning tasks. Due to the complex quantum dynamics, it exhibits the capability to store information over a period of time determined by the system properties. This short-term memory capacity (STMC) has become an abundant benchmark for QRC architectures, but relies on the processing of large amounts of data, thus posing a challenge for real-world application.

In our work, we lay new grounds for the memory analysis in QRC by connecting the fields of information theory (i.e. the STMC) and optics. We demonstrate how the STMC of a QRC setup based on open quantum systems can be assessed solely via optical absorption measurements. By establishing a link between absorption and STMC via the dissipation strength of the open quantum reservoir, we unravel the particular "sweet-spot" behavior the STMC has shown in several studies with respect to the dissipation [1-3]. This physical view on information-theoretical properties in QML opens up a new avenue for problem-specific hardware design.

[1] N. Götting et al., Physical Review A 108, 052427 (2023)
[2] F. Monzani et al., arXiv:2409.07886 (2024)
[3] Y. Kurokawa et al., arXiv:2408.09577 (2024)

THU 7: Entanglement and Complexity: Contributed Session to Symposium II

Time: Thursday 14:15–16:00 Location: ZHG008

THU 7.1 Thu 14:15 ZHG008

Complexity-driven ground state estimation in the Agassi model — •Sönke Momme Hengstenberg[1] and Caroline Robin[1,2] — [1]Fakultät für Physik, Universität Bielefeld, D-33615, Bielefeld, Germany — [2]GSI Helmholtzzenturm für Schwerionenforschung, Planckstraße 1, 64291 Darmstadt, Germany

I will discuss entanglement and non-stabilizerness (also referred to as magic) in ground states of the Agassi model. This model describes a non-trivial quantum many-body system exhibiting both superfluid pairing and collective deformation phases. We present multi-partite entanglement measures and stabilizer Rényi entropies to characterize the quantum complexity of the system. Based on this knowledge, we provide techniques to accelerate the estimation of ground states of this model in different regimes. I conclude with a short outlook on how to generalize this method to more complex quantum many-body systems.

THU 7.2 Thu 14:30 ZHG008

Complexity transitions in chaotic quantum systems — Gopal Chandra Santra[1,2,3], •Alex Windey[1,2], Soumik Bandyopadhyay[1,2], Andrea Legramandi[1,2], and Philipp Hauke[1,2] — [1]Pitaevskii BEC Center, INO-CNR and Department of Physics, University of Trento, Via Sommarive 14, I-38123 Trento, Italy — [2]INFN-TIFPA, Trento Institute for Fundamental Physics and Applications, Via Sommarive 14, I-38123 Trento, Italy — [3]Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

Complex quantum systems—composed of many interacting particles—are intrinsically hard to model. In the presence of disorder, such systems transition into non-ergodic and localized regimes, reducing relevant basis states. Whether these transitions also reflect abrupt complexity changes remains open. We study such transition in the power-law random banded matrix, Rosenzweig-Porter, and hybrid SYK+Ising models, comparing three complexity markers: fractal dimension, entanglement entropy, and stabilizer Rényi entropy. All markers show sharp transitions between high- and low-complexity phases, though at distinct critical points. Thus, while markers align in ergodic and localized regimes, they diverge in an intermediate fractal phase. The stabilizer Rényi entropy is sensitive to many-body symmetries such as fermion parity and time reversal. Our findings show different markers capture complementary facets of complexity, requiring their combination for a comprehensive diagnosis of phase transitions and revealing implications for classical simulability of chaotic systems.

THU 7.3 Thu 14:45 ZHG008

Communication Complexity Bounds using Information Causality — •Prabhav Jain[1], Nikolai Miklin[2], and Mariami Gachechiladze[1] — [1]Technische Universität Darmstadt — [2]Technische Universität Hamburg

In a distributed computing scenario, two parties (say Alice and Bob) aim to compute a given function with as minimum communication as possible. The communication cost or the complexity depends not only on the function itself but the shared resources to which both parties have access to such as public randomness or entangled Bell pairs. In this work, we aim to study communication complexity in theories satisfying the information causality principle. The principle essentially states that the information potentially available to Bob about Alice's data cannot be higher than the amount of information Alice sends to Bob. We formulate an extension of the information causality principle which is valid for any distributed computation scenario and apply it to several well known functions. We show a reduction for some of these problems to known functions and hence derive one-way communication complexity bounds in a theory independent manner. Finally, we prove that the information causality principle is at least as strong as the principle of non-trivial communication complexity.

THU 7.4 Thu 15:00 ZHG008

Splitting and interconnecting atomic singlets in dynamical superlattices — •Yann Kiefer, Zijie Zhu, Lars Fischer, Konrad Viebahn, and Tilman Esslinger — ETH Zürich, Zürich, Switzerland

The transport of atoms, electrons or entanglement in general in large many-body systems is becoming an increasingly important task for quantum applications. Often, long-distance qubit connectivity relies on the transport of particles, which leads to unwanted excitations and heating and ultimately the loss of information. To circumvent this, we present a ground-state preserving transportation scheme based on periodic modulation of an optical lattice potential.

In detail, we leverage topological pumping in a periodically modulated one-dimensional optical superlattice to realise the transport of coherent fermionic two-particle states over large distances. Furthermore, we use the access of the optical lattice potential to implement gate operations by engineering the local superexchange coupling J. More specifically, when two particles meet in a double well of the optical lattice, we can control J using two different methods, such that two-particle (SWAP)^n gates are implemented while preserving the motional many-body ground state of the system. We reveal the successful implementation of such gates by observing multi frequency singlet-triplet oscillations (STOs) as a direct signature of entanglement between fermions distributed over tens of lattice sites.

THU 7.5 Thu 15:15 ZHG008

Measurable Krylov spaces and eigenenergy count in quantum state dynamics — •Saud Čindrak, Lina Jaurigue, and Kathy Lüdge — Technische Universität Ilmenau, Ilmenau, Germany

Krylov complexity is defined on the Krylov space, which consists of the powers of the Hamiltonian acting on the initial state. We prove that an equivalent space can be constructed by taking time-evolved states as a basis, which is also quantum-mechanically measurable. The Krylov complexities computed with respect to both spaces exhibit almost identical behavior, thus enabling the use of Krylov complexity for systems where the Hamiltonian is unknown or in experimental settings. This is particularly relevant for quantum machine learning, where the system is described by unitaries and the Hamiltonian is not explicitly known. We then use this newly defined Krylov space to introduce the effective dimension, which captures the extent to which the state has evolved in the Krylov basis. This measure is upper-bounded by the number of pairwise distinct eigenvalues of the Hamiltonian, thereby providing a method to experimentally determine the number of eigenenergies.

[1] S. Čindrak, L. Jaurigue, K.Lüdge, J. High Energ. Phys 2024, 83

THU 7.6 Thu 15:30 ZHG008

Hamiltonian many-body model for strong vibrational coupling — •Mathis Noell, Jakob Kullmann, and Carsten Henkel — Universität Potsdam, Institut für Physik und Astronomie, Germany

Molecular vibrations may be strongly coupled to infrared micro cavities, and controversial results have been reported regarding changes in chemical reactions in and out of resonance. We study a simple many-body Hamiltonian that permits to retrieve strong-coupling conditions without recourse to damping. The cavity modes are represented as a dense continuum in an obvious extension of the Tavis-Cummings model. Depending on the scaling of the coupling constants (molecular oscillator strength) with the number of cavity modes and molecules, we find different regimes: the spectrum changes from a collective polariton mode to a photonic band with an anti-crossing. In between these limits, multiple scattering seems to generate spatially complex field patterns. We also consider an interaction including anti-rotating terms and estimate the energy shift of the collective ground state. This bridges polariton and Casimir physics.

THU 7.7 Thu 15:45 ZHG008

Impact of boundary conditions on a topological quantum kicked rotor — •Victoria Motsch[1], Nikolai Bolik[1], and Sandro Wimberger[2,3] — [1]Institut für Theoretische Physik, Universität Heidelberg — [2]Department of Mathematical, Physical and Computer Sciences, Parma University — [3]INFN, Sezione Milano-Bicocca, Parma group

We investigate the on-resonance Spin-1/2 Double Kicked Rotor under the influence of open (hard wall) and periodic boundary conditions. This system shows topological phases which could be observed in Bose-Einstein condensate experiments [1]. The Mean Chiral Displacement (MCD) as the proposed observable displays a strong dependence on the chosen boundary conditions. The spectrum under open boundary conditions displays edge states that can be shown to localize at the edge of the momentum basis. While the bulk observable MCD is sensitive to the boundary conditions as soon as the evolution touches the boundaries, the edge states could still act as indicators for topological transitions.

[1] N. Bolik *et. al.*, Phys. Rev. A 106, 043318 (2022)

THU 8: Frustrated Quantum Systems: Contributed Session to Symposium

Time: Thursday 14:15–16:00 Location: ZHG009

THU 8.1 Thu 14:15 ZHG009

Stretched Drude response in doped Mott insulators: Peculiar charge dynamics in molecular quantum spin liquids — Savita Priya[1], •Martin Dressel[1], and Simone Fratini[2] — [1]1. Physikalisches Institut, Universität Stuttgart, Germany — [2]Néel Institute - CNRS and Université Grenoble Alpes, Grenoble, France

Among the extensively studied class of low-dimensional molecular quantum-spin-liquid compounds κ-(BEDT-TTF)$_4$Hg$_{2.89}$Br$_8$ is of particular interest because the incommensurate anion layer results in a extraordinary charge transfer: the strongly correlated system remains metallic down to the superconducting transition. Our comprehensive investigations of its optical properties reveal a peculiar charge dynamics and show that the strange-metal behavior in the resistivity is tightly related to a stretched Drude response in the optical conductivity, i.e. a generalized form of the Drude absorption representing a stretched exponential relaxation. Our study may help to solve the longstanding puzzle of unusual metallic properties frequently observed in high-T_c cuprate and other transition metal oxides.

We thank our collaborators: J. Liebman, N. Drichko, K. Kanoda, H. Taniguchi, T. Kobayashi, J. Ovčar, I. Lončarić

THU 8.2 Thu 14:30 ZHG009

Majorana Fermi Surface and Transient Localization from Coherent Disorder — •Shi Feng[1], Penghao Zhu[2], Kang Wang[3], Tao Xiang[3], Nandini Trivedi[2], Michael Knap[1], and Johannes Knolle[1] — [1]Technical University of Munich, Garching, Germany — [2]The Ohio State University, Columbus, USA — [3]Institute of Physics, Chinese Academy of Sciences, Beijing, China

We propose a mechanism to explain the emergence of the intermediate gapless spin liquid phase in the Kitaev material under an external magnetic field. In moderate fields, flux-trapped localized Majorana resonances are nucleated in the ground state. As the density of these fluxes increases with field strength, the Majorana modes begin to overlap, leading to the formation of an emergent Z2 quantum Majorana metallic state with a Fermi surface at zero energy. Our analysis shows that the Majorana spectral function obtained by our mean-field approach captures the dynamical spin and dimer correlations computed via infinite projected entangled pair states and density matrix renormalization group methods. The identification of the intermediate gapless phase as a quantum Majorana metal at zero temperature suggests a new class of gapless quantum spin liquids that is complementary to the conventional Dirac spin liquids and U(1) spinon Fermi surface states found in prevailing theories. Based on the picture of a Majorana metal induced by zero-temperature coherent disorders in the emergent gauge field, we further discuss the possibility of transient localization and unconventional transport properties, and comment on potential realization in Rydberg atom array experiments.

THU 8.3 Thu 14:45 ZHG009

Optical investigations of incommensurate κ-BEDT-TTF based molecular quantum materials — •Savita Priya[1], Juraj Ovčar[2], Maxim Wenzel[1], Jesse Liebman[3], Takuya Kobayashi[4], Hiromi Taniguchi[4], Dita Puspita Sari[5], Yasuyuki Ishii[5], Kazushi Kanoda[1,6,7], Ivor Lončarić[2], Natalia Drichko[3], and Martin Dressel[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Germany — [2]Ruder Bošković Institute, Zagreb — [3]Department of Physics and Astronomy, Johns Hopkins University — [4]Department of Physics, Saitama University — [5]Global Course of Engineering and Science, SIT, Tokyo — [6]Department of Advanced Materials Science, University of Tokyo — [7]MPI-FKF, Stuttgart

κ-BEDT-TTF based charge transfer salts are correlated electron system. Their distinct triangular lattice arrangement is highly susceptible to geometric and magnetic frustration, leading to exotic phases like quantum-spin liquids, antiferromagnetism, charge ordering, Mott-insulator and superconductivity at low temperatures. In our study, we focus on κ-(BEDT-TTF)$_4$Hg$_{2.89}$Br$_8$ and κ-(BEDT-TTF)$_4$Hg$_{2.78}$Cl$_8$ by broadband infrared spectroscopy and Raman scattering spectroscopy to examine the effects of the non-stoichiometric anion layer as a crucial parameter on geometric frustration and their unusual response. Optical spectroscopy methods allow us to study these compounds by probing the electronic and structural responses (by molecular and lattice vibrations) with temperature. The well-resolved electronic response enables us to employ theories of correlated physics, strengthening our understanding of these unusual κ-phase salts.

THU 8.4 Thu 15:00 ZHG009

Control of the carrier distribution in a quasi-2D Mott-Hubbard solid via ultrafast photodoping and pressure-tuning revealed by terahertz-infrared spectroscopy — Konstantin Warawa[1], Yassine Agarmani[1], Sheng Qu[1], Harald Schubert[1], Martin Dressel[2], Michael Lang[1], Hartmut G. Roskos[1], and •Mark D. Thomson[1] — [1]Physikalisches Institut, J. W. Goethe-Universität, 60438 Frankfurt am Main, Germany — [2]1. Physikalisches Institut, Universität Stuttgart, 70550 Stuttgart, Germany

Electronic correlations in solids can yield a rich phase diagram including a Mott metal-insulator transition (MIT), superconductivity and magnetic order, not only due to the interplay between bandwidth (W) and Coulomb repulsion (U), but also the concerted response of the band structure to charge-carrier excitation. This can lead to drastic effects in Mott-Hubbard insulators with small energy gaps (Δ of some 10 meV), such as the organic charge-transfer salt presented here, κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$]Cl. We present two experimental approaches using terahertz-infrared (THz-IR) pulses to probe the carrier distribution/conductivity: 1. Ultrafast photodoping, where the quasi-equilibrium is a hot electronic state with a non-thermal phonon distribution and significant deformation of the Hubbard bands (even for low excited carrier densities ~1%). 2. Pressure-tuning across the MIT (below 30 MPa), where the THz dynamic conductivity senses metallic domains within the MI coexistence regime, complementary to DC transport where the MIT is dominated by a macroscopic percolation threshold.

THU 8.5 Thu 15:15 ZHG009

Pressure control of magnetic frustration — •Björn Wehinger — European Synchrotron Radiation Facility, 71, avenue des Martyrs, CS 40220, 38043 Grenoble Cedex 9, France.

Low-dimensional materials with strong magnetic frustration and enhanced quantum fluctuations embody the characteristics of the long-sought spin liquid where magnetic order is suppressed and fractional excitations and entanglement are expected. Significant progress in materials science has been made in realizing copper-based quantum magnets where localized spin-1/2 moments are arranged in low dimensions allowing for geometrical frustration.

In this contribution I will show how external pressure can be used to control magnetic frustration. Using single crystal x-ray diffraction at high-pressure and low temperature together with density functional theory calculations we investigate how pressure-induced modifications in the structure influences the strength of the magnetic exchange [1]. In presence of anisotropy in the system the various super-exchange paths are affected differently by hydrostatic pressure which allows direct control of magnetic frustration [2]. Stabilizing new quantum phases at high pressure opens the possibility to drive systems close to quantum critical points which in-turn enables to investigate the development of spin and lattice correlations as the system approaches criticality.

Finally, I will give a broader overview of research possibilities on quantum materials at the European Synchrotron.

[1] B. Wehinger et al., Phys. Rev. Lett. 121, 117201 (2018).
[2] D. Chatterjee et al., arXiv:2502.09733 (2025).

THU 8.6 Thu 15:30 ZHG009

Diamond-decorated quantum antiferromagnets in two dimensions — •Andreas Honecker[1], Katarína Karl'ová[1], Malo Rouxel[1], Jozef Strečka[2], Taras Verkholyak[3], Stefan Wessel[4], and Nils Çaçi[5] — [1]Laboratoire de Physique Théorique et Modélisation, CNRS, CY Cergy Paris Université, France — [2]Department of Theoretical Physics and Astrophysics, P.J. Šafárik University, Košice, Slovakia — [3]Institute for Condensed Matter Physics, National Academy of Sciences of Ukraine, L'viv — [4]Institute for Theoretical Solid State Physics, RWTH Aachen University, Germany — [5]Laboratoire Kastler Brossel, Collège de France, France

The spin-$\frac{1}{2}$ Heisenberg antiferromagnet on the diamond-decorated square and honeycomb lattices is a highly frustrated quantum spin system that in the presence of a magnetic field displays a rich phase diagram, including the Lieb-Mattis ferrimagnetic, dimer-tetramer, monomer-dimer, and spin-canted phases, in addition to the fully saturated state. We investigate the thermodynamic properties of this model using exact diagonalization, an effective monomer-dimer description, and sign-problem-free quantum Monte Carlo simulations. In the parameter region favoring the dimer-tetramer phase, the ground-state problem can be represented by a classical hard-dimer model and retains a macroscopic degeneracy even under a magnetic field. We detect an enhanced magnetocaloric effect on the square lattice. The ground-state degeneracy in the zero-field dimer-tetramer phase can be lifted by a small distortion. In a particular case on the honeycomb lattice, this gives rise to a Kastelyn-type phase transition.

THU 8.7 Thu 15:45 ZHG009

Quantifying entanglement in frustrated transverse-field Ising model — •Leonardo dos Santos Lima — lslima@cefetmg.br

In this paper, we analyzed the effect of quantum phase transition (QPT) on quantum correlation and entanglement in the frustrated antiferromagnetic transverse-field Ising model on ruby lattice. We get the reduced density matrix entropy as a function of exchange interactions J_i ($i = 1, 2, 3$) and external transverse-field h which induces phases transitions in the system, with the aim to verify its influence on quantum correlation and entanglement. We get that the effect of opening of the gap in the spectrum generates a small variation in the behavior of the von Neumann entropy (VN) due to the fact that analyzing the influence of QPT on entanglement in quantum spin systems is a complex field and an intriguing task in recent years. We focus on how these frustrating competing interactions and the different phases affect the quantum correlation and entanglement.

THU 9: Correlated Quantum Matter: Contributed Session to Symposium II

Time: Thursday 14:15–15:45 Location: ZHG101

THU 9.1 Thu 14:15 ZHG101

Intertwined superconductivity and orbital selectivity in a three-orbital Hubbard model for the iron pnictides — Vito Marino[1,2], Alberto Scazzola[3], Federico Becca[4], Massimo Capone[1], and •Luca F. Tocchio[2] — [1]International School for Advanced Studies (SISSA) and CNR-IOM, Trieste, Italy — [2]Institute for Condensed Matter Physics and Complex Systems, DISAT, Politecnico di Torino, Italy — [3]Department of Electronics and Telecommunications, Politecnico di Torino, Italy — [4]Dipartimento di Fisica, University of Trieste, Italy

We study a three-orbital Hubbard-Kanamori model relevant for iron-based superconductors using variational wave functions explicitly including spatial correlations and electron pairing. We span the nonmagnetic sector from filling $n = 4$, which is representative of undoped iron-based superconductors, to $n = 3$, where a Mott insulating state with each orbital at half filling is found. In the strong-coupling regime, when the electron density is increased, we find a spontaneous differentiation between the occupation of d_{xz} and d_{yz} orbitals, leading to an orbital-selective state with a nematic character that becomes stronger at increasing density. One of these orbitals stays half filled for all densities while the other one hosts (together with the d_{xy} orbital) the excess of electron density. Most importantly, in this regime long-range pairing correlations appear in the orbital with the largest occupation. Our results highlight a strong link between orbital-selective correlations, nematicity, and superconductivity, which requires the presence of a significant Hund's coupling.

THU 9.2 Thu 14:30 ZHG101

Collective advantages in finite-time thermodynamics — •Alberto Rolandi[1,2], Paolo Abiuso[3], and Martí Perarnau-Llobet[2,4] — [1]Atominstitut, TU Wien, Vienna, Austria — [2]Département de Physique Appliquée, Université de Genève, Genève, Switzerland — [3]Institute for Quantum Optics and Quantum Information - IQOQI, Vienna, Austria — [4]Física Teòrica: Informació i Fenòmens Quàntics, Universitat Autònoma de Barcelona, Bellaterra (Barcelona), Spain

A central task in finite-time thermodynamics is to minimize the excess or dissipated work W_{diss} when manipulating the state of a system in contact with a thermal bath. We consider this task for an N-body system whose constituents are identical and uncorrelated at the beginning and end of the process. In the regime of slow but finite-time processes, we show that W_{diss} can be dramatically reduced by considering collective protocols in which interactions are suitably created along the protocol. This can even lead to a sub-linear growth of W_{diss} with N: $W_{\mathrm{diss}} \propto N^x$ with $x < 1$; to be contrasted to the expected $W_{\mathrm{diss}} \propto N$ satisfied in any non-interacting protocol. We derive the fundamental limits to such collective advantages and show that $x = 0$ is in principle possible, however it requires long-range interactions. We further explore collective processes with spin models featuring two-body interactions and achieve noticeable gains (sub-linear scaling of the dissipation) under realistic levels of control in simple interaction architectures. As an application of these results, we focus on the erasure of information in finite time and prove a faster convergence to Landauer's bound.

THU 9.3 Thu 14:45 ZHG101

Phase diagram of the extended anyon Hubbard model in one dimension — •Imke Schneider[1], Martin Bonkhoff[2], Shijie Hu[3], Kevin Jägering[1], Axel Pelster[1], and Sebastian Eggert[1] — [1]University of Kaiserslautern-Landau, Landesforschungszentrum OPTIMAS — [2]Universität Hamburg — [3]Beijing Computational Science Research Center

We study one-dimensional lattice anyons with extended Hubbard interactions. At unit filling a repulsive next-nearest neighbor interaction generally leads to gapped phases, but it is far from trivial which correlations are the dominant ones as a function of topological exchange angle and on-site interaction U. We find that a careful derivation of all terms in the Luttinger liquid theory predicts an intermediate phase between a Mott insulator for large repulsive U and a charge density wave at negative U. As a function of exchange angle the intermediate phase changes from Haldane insulator for pseudo bosons to a dimerized phase for pseudo fermions at an interesting multicritical point. Our results are confirmed by extensive numerical simulations.

THU 9.4 Thu 15:00 ZHG101

The Impact of Tree Tensor Networks for Open Quantum System Simulations — Richard Maximilian Milbradt[1], •Pouriya Haji Ghadimi[2], and Christian Mendl[1,3] — [1]Technische Universität München, School of Computation, Information and Technology, Munich, Germany — [2]University of Bologna, Department of Physics and Astronomy, Bologna, Italy — [3]Technische Universität München, Institute of Advanced Studies, Munich, Germany

In recent years tensor network methods have seen increasing use in the classical simulation of quantum systems that interact with an environment. We explore the use of more general tree tensor networks compared to the more common matrix product/tensor train structure for these kinds of simulations. We explore the impact of the tree structure for a direct solution of the Lindblad master equation by time evolving a density matrix represented as a tree structure in the Liouville space. Additionally, we consider tree tensor network representations of pure states in the quantum jump method. We compare this impact for spin chain models, such as the Ising and Heisenberg models, as well as for the Bose-Hubbard model for dozens of sites.

THU 9.5 Thu 15:15 ZHG101

Parafermions Ex Machina — •Steffen Bollmann[1], Andreas Haller[2], Jukka I. Väyrynen[3], Thomas Schmidt[2] und Elio J. Köng[4] — [1]Max Planck Institut for Solid State Research, Stuttgart, Germany — [2]University of Luxembourg, Limpertsberg Luxembourg, Luxembourg — [3]Purdue University, West Lafayette, Indiana, USA — [4]University of Wisconsin-Madison, Madison, Wisconsin, USA

Fractional quantum anomalous Hall states in materials such as transition metal dichalcogenides and penta-layer graphene suggest that heterostructures of fractional Hall edge states and superconductors will be experimentally much more realistic. It has been theorized that such heterostructures could host parafermions of interest for topological quantum computing.

Building on these developments, we explore a Z_3 parafermion chain that can be realized using FQH states, subject to fluctuations in the superconducting order parameter. By employing a combination of analytical techniques and numerical methods, including density matrix renormalization group (DMRG), we construct the phase diagram and examine critical behaviour as a function of system parameters. We find various Mott insulating phases and two gapless phases - one with excitations of charge 2e/3 and one with excitations of minimal charge 2e. We compare our results for the transition between these states with the conjecture that the $U(1) \times Z_3$ model flows to an emergent $SU(2)_3$ theory and discuss the appearance of parafermionic domain wall states beyond mean field superconductivity.

THU 9.6 Thu 15:30 ZHG101

Few-electron states in molecular networks bonded to metals — •Max Best and Carsten Henkel — Universität Potsdam, Institut für Physik und Astronomie, Germany

A simple tight-binding model for electrons in an organic molecule ("network") is studied to provide some understanding on electron transport beyond the single-particle picture. Many-fermion states are properly anti-symmetrised without using Slater determinants explicitly. The geometric symmetry group of the network (e.g., hexagonal ring) is implemented carefully on the N-electron subspaces. We discuss the influence of the Coulomb interaction on the electron-hole symmetry, the assignment of degeneracies to irreducible representations of the symmetry group, and the splitting of these under a magnetic field. Hydrodynamic models for a metallic surface including exchange and von-Weizsäcker kinetic energy are developed as a tribute to 100 years of quantum physics and applied to current problems in plasmonic catalysis.

THU 10: Foundational / Mathematical Aspects – Methods and Approximations

Time: Thursday 14:15–16:15 Location: ZHG103

THU 10.1 Thu 14:15 ZHG103

Shadow tomography for relativistic scattering experiments — Chau Nguyen, •Matthias Kleinmann, Otfried Gühne, Carmen Diez Pardos, and Gilberto Tetlalmatzi-Xolocotzi — University of Siegen, Germany

Scattering experiments produce relativistic particles that carry besides momentum information also spin, where the spin information of a decaying particle is accessible via the momenta of the decay particles. However, associating a consistent spin state to the particle proves to be difficult: In particular in the relativistic setting the spin state strongly depends on the reference frame, and with it, for example, change its purity and entanglement properties. This is further aggravated by the fact that each decaying particle has different momentum. We show that techniques from shadow tomography are best suited to handle this situation and that this can be used to infer a meaningful notion of entanglement, test the validity of the underlying physical model, and to extract information that can be otherwise difficult to access, like the ratio between different production channels.

THU 10.2 Thu 14:30 ZHG103

Absolute and relational many-body Green's function theories — •Ville Härkönen — Tampere University, Tampere, Finland

Quantum mechanics, now a century old, has relied heavily on the Coulomb problem and the Born-Oppenheimer (BO) approximation [1] for describing atoms, molecules, and solids. While the BO approximation is widely used, its limitations are evident in materials like superconducting hydrides.

Wave function methods are impractical for solids due to poor scaling, leading to alternatives like BO-based density functional theory and many-body Green's function theory. A beyond-BO Green's function approach was proposed in the 1960s [2], but it contains foundational issues [3].

We have developed an exact many-body Green's function theory to address these problems [4], revealing that quantum theory may need to be relational rather than absolute [5].

In this talk, we summarize recent developments in beyond-BO Green's function theory [4,5,6] and explore the implications of relational versus absolute frameworks in quantum mechanics [7].

[1] M. Born and R. Oppenheimer, Ann. Phys. (Leipzig) 389, 457 (1927).
[2] G. Baym, Ann. Phys. 14, 1 (1961).
[3] B. Sutcliffe, Adv. Chem. Phys. 114, 1 (2000).
[4] V. J. Härkönen, R. van Leeuwen, and E. K. U. Gross, Phys. Rev. B 101, 235153 (2020).
[5] V. J. Härkönen, arXiv:2503.01417 .
[6] V. J. Härkönen, Phys. Rev. B 106, 205137 (2022).
[7] J. B. Barbour, Br. J. Philos. Sci. 33, 251 (1982); L. Smolin, arXiv:1805.12.

THU 10.3 Thu 14:45 ZHG103

Geometry of quantum correlations — •Konrad Szymanski — Research Center for Quantum Information, Slovenská Akadémia Vied, Bratislava, Slovakia

Quantum mechanics gives rise to nonclassical correlations between observables, with rich mathematical theory behind and experimental importance: these correlations between observables affect metrological performance, entanglement detection, and phase transitions at zero temperature.

In this talk, numerical and analytical methods for the study of quantum correlations will be presented, focusing on the sets of admissible joint expectation values of observables and their covariance matrices. This framework will be illustrated through its application to entanglement characterization in photonic quantum states.

THU 10.4 Thu 15:00 ZHG103

Quantum into the mesoscopic: progress in matter-wave interference of massive sodium nanoclusters. — •Bruno E. Ramírez-Galindo[1,2], Sebastian Pedalino[1,2], Richard Ferstl[1,2], Klaus Hornberger[3], Stefan Gerlich[1], and Markus Arndt[1] — [1]University of Vienna, Faculty of Physics, Vienna, Austria — [2]University of Vienna, Vienna Doctoral School in Physics, Vienna, Austria — [3]University of Duisburg-Essen, Faculty of Physics, Duisburg, Germany

The wave-particle duality has been a cornerstone in quantum theory since Louis de Broglie's foundational insight in the early 20th century. Yet, some fundamental questions remain unresolved: Is there a limit in mass, size, or complexity beyond which quantum behavior gives way to classical physics? And, is it possible to realize quantum superpositions of mesoscopic matter states that are classically considered mutually exclusive - analogous to Schrödinger's cat being both dead and alive? In this work, we discuss experimental advances addressing these questions through matter-wave interference of sodium nanoclusters with physical sizes approaching the mesoscopic scale. We report on the use of a near-field Talbot-Lau interferometer equipped with three UV photo-depletion gratings, where recent measurements suggest its potential for testing the linearity of quantum mechanics and for enabling quantum-assisted precision measurements in nanocluster science.

THU 10.5 Thu 15:15 ZHG103

Tunneling Modeled via First-Passage Times — •Philipp Tesch, Kai-Hendrik Henk, and Wolfgang Paul — MLU Halle-Wittenberg

Since quantum mechanics lacks a self-adjoint time operator, time is not an observable in the standard formalism. As a result, time measurements such as tunneling durations are not directly accessible within the conventional framework. In 1966, Edward Nelson introduced a stochastic mechanics approach to describe quantum systems [1]. In this framework, quantum systems are treated as open systems undergoing conservative, time-reversible diffusion processes. This is modeled by Brownian motion guided by velocity fields. This framework is applied for quantum tunneling in symmetric double-well potentials. Instead of tunneling, particles overcome the finite potential barrier due to energy fluctuations. Ground states are obtained numerically via the stationary Schrödinger equation, from which probability densities and osmotic velocities are calculated. Solving the stochastic differential equations to simulate sample paths of particles allows us to compute first-passage times across the potential barrier under two different threshold criteria. An inverse relation between mean first-passage times τ and the energy splitting ΔE in double-well potentials emerges. Furthermore, this framework allows for a detailed study of the probability distribution of tunneling times (modelled as first passage times), which can be addressed by attosecond spectroscopy [2].

[1] E. Nelson, *Phys. Rev.* 150 (1966) [2] A. S. Landsmann et al., *Optica* 1 (2014)

THU 10.6 Thu 15:30 ZHG103

Approximations in light-matter interaction — •Leonhard Richter, Daniel Burgarth, and Davide Lonigro — Department Physik FAU Erlangen-Nürnberg, Staudtstr. 7, 91058 Erlangen

I will present recent advances in quantifying the quality of approximations such as the rotating-wave approximation. Specifically, I present bounds on the norm difference between the unitary evolutions generated by the full Hamiltonian and the approximation applied to the same initial state. As full-quantum models of light-matter interaction are unbounded in energy, the derived error bounds depend on the particular initial state of the system and convergence is only given in the strong and not in the uniform sense. The central method enabling such derivation in these settings is based on repeated integration-by-parts of the difference of two unitary evolutions.

THU 10.7 Thu 15:45 ZHG103

The perils of finite dimensional approximations — •Felix Fischer — FAU Erlangen, Staudtstr. 7 91058 Erlangen

When numerically simulating the unitary time evolution of an infinite-dimensional quantum system, one is usually led to treat the Hamiltonian H as an "infinite-dimensional matrix" by expressing it in some orthonormal basis of the Hilbert space, and then truncate it to some finite dimensions. However, the solutions of the Schrödinger equations generated by the truncated Hamiltonians need not converge, in general, to the solution of the Schrödinger equation corresponding to the actual Hamiltonian. In some cases, the approximate solutions do not converge to any valid state at all, whilst in others they converge to the dynamics generated by a "wrong" Hamiltonian different from the initial one. In this talk, I present multiple necessary and sufficient conditions for the convergence of finite dimensional approximations to the correct dynamics. Multiple examples from quantum chemistry and quantum optics illustrate the convergence issues which can appear in practice. Using our abstract results, I discuss why these issues arise and showcase how to ensure convergence to the correct dynamics we aim to simulate.

THU 10.8 Thu 16:00 ZHG103

Improved Gerchberg-Saxton Approach to the One-Dimensional Pauli Phase Retrieval Problem — Felipe de Andrade Ferreira da Silva, Karen Fernanda Pagnoni, and •Alexys Bruno-Alfonso — Department of Mathematics, School of Sciences, UNESP - São Paulo State University, Bauru, 17033-360, Brazil

The iterative Gerchberg-Saxton algorithm retrieves the phases of a Fourier pair from the corresponding intensities. It can deal with the one-dimensional phase-retrieval Pauli problem: the calculation of the state representations $\psi(x)$ and $\phi(k)$ from the probability densities $\rho(x)=|\psi(x)|^2$ and $\mu(k) = |\phi(k)|^2$. We improve the algorithm in several ways. First, we find compatibility tests between two given densities $\rho(x)$ and $\mu(k)$. Second, we enhance the algorithm stability by adding two stages after each Fourier transformation: (i) we replace the exact absolute value of the transform by its weighted harmonic mean with the approximate one, (ii) we multiply the transform by a factor that reproduces the expected values and variances of x and k as given by $\rho(x)$ and $\mu(k)$.

THU 11: Quantum Technology and Industry

Time: Thursday 14:15–15:45 Location: ZHG104

THU 11.1 Thu 14:15 ZHG104

Quantum Valley Lower Saxony - An ecosystem for quantum technologies — •Lena Bittermann — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Quantum Valley Lower Saxony (QVLS) is a growing ecosystem for quantum technologies based in Braunschweig and Hanover. QVLS connects research institutions, startups, and industry partners to drive innovation and accelerate the development of enabling technologies.

In our Cluster4future QVLS-iLabs we promote technology transfer through close cooperation between science and industry. With strong regional infrastructure, collaborative projects, and strategic partnerships, QVLS supports the path from fundamental research to real-world applications in the emerging quantum economy.

THU 11.2 Thu 14:30 ZHG104

Patentierung von Quantentechnologie — •Matthias Grob — Pavant Patentanwälte PartGmbB, Hamburg, Germany

Im Bereich der Quantentechnologie, insbesondere des Quantencomputings und der Quantensimulation, werden in zunehmender Zahl Patente angemeldet. Der Beitrag gibt Einblicke in das Patentwesen mit starkem Bezug zur Quantentechnologie und illustriert dabei auch die Motivation für Patentanmelder:innen und -inhaber:innen. Zudem geht der Beitrag auf die Patentierbarkeit von Quantentechnologie ein.

THU 11.3 Thu 14:45 ZHG104

Ultra Broadband Lens for Quantum Computing Applications — •Thomas Fricke-Begemann[1], Gregor Matz[1], Christoph Charton[1], Thomas Thoeniss[1], Astrid Bingel[2], and Friedrich Rickelt[2] — [1]Excelitas Technologies, Göttingen, Germany — [2]Fraunhofer IOF, Jena, Germany

Quantum computing platforms using trapped ions or neutral atoms require optical control of an array of single qubits for a wide range of functionality including e.g. MOTs, optical tweezers, laser cooling, single and two qubit gates and detection. Ideally, the optical access involving multiple laser beam arrays over a large spectral bandwidth can be provided via a single optical system.

Here, we report on the development of an objective lens that allows the control of Rydberg atom qubits over a wavelength range from approximately 310 to 820 nm, thus enabling the use of a multitude of atomic transitions. It provides an ultra-long working distance and is designed to operate through the window of a UHV glass cell. The high NA allows addressing single qubits within a large field. To ensure high transparency over the large spectral bandwidth and to meet polarization preserving requirements, special AR-coatings including nanostructured layers with very low effective refractive index are used inside the lens.

THU 11.4 Thu 15:00 ZHG104

Streamlining Quantum Measurements: Simplifying Complexity — •Avishek Chowdhury — Zurich Instruments GmbH

Quantum sensing and metrology applications frequently depend on transferring quantum information between different physical systems across a wide range of frequencies. This process is often linked with the need for continuous or pulsed measurements and sophisticated feedback mechanisms. In this talk I connect the insights from my own research on optomechanics and quantum sensing with how the current product offerings from Zurich Instruments are facilitating a more streamlined approach for efficient implementations.

THU 11.5 Thu 15:15 ZHG104

Advanced Quantum Technologies - expert peer review and quality quantum science publishing in QUTE — •Stefan Hildebrandt, Christiana Varnava, and Huan Wang — Advanced Quantum Technologies, Wiley-VCH GmbH, Berlin, Germany

Since 2018, Wiley-VCH with Editorial Offices in Berlin and Beijing has been publishing Advanced Quantum Technologies (QUTE, http://www.advquantumtech.com), which is now one of the leading peer-reviewed quantum journals, ranked Q1/Q2 in quantum science, technology and optics. The editors provide a first-class editorial service, offering expert peer review and rapid publication (with a typical turnaround time of <10 days for the first editorial decision, about 90 days to acceptance, and 19 days from acceptance to online publication). Core areas will be presented that cover a broad spectrum of regular papers, including Reviews, Perspectives and Research Articles, with highlights and special issues focusing on quantum networks, quantum communication and key distribution, quantum photonics, quantum materials and many other topics, ranging from theory to experimental applications. We will describe submission requirements, the editorial process and the role of artificial intelligence in today's science publishing, as well as opportunities for open access publication with CC-BY licenses under the Wiley-DEAL agreement and other transformational agreements worldwide.

THU 11.6 Thu 15:30 ZHG104

From Bits to Qubits: d-fine's Role in Pioneering Quantum Technology Innovations — •Sabine Matysik, Daniel Ohl de Mello, and Daniel Herr — d-fine GmbH

d-fine is a European consulting firm specialised in analytical, quantitative and technological challenges. Since 2018, we have been continuously expanding our team in the field of quantum technologies and quantum computing, and are conducting an increasing number of projects in collaboration with research institutes and industry partners.

During the presentation, we will provide an overview of our approach to projects and initiatives to date. These include projects on the development of algorithms for use cases in climate modelling, material science and mobility, as well as software development for managing access to quantum hardware, analysing security aspects of quantum machine learning, and the development of efficient hardware decoders for quantum error correction.

THU 12: Quantum Thermalization: Contributed Session to Symposium

Time: Thursday 14:15–16:15 Location: ZHG105

THU 12.1 Thu 14:15 ZHG105

A minimal model of relaxation in isolated quantum systems — •Uwe Holm, Morgan Berkane, Anja Kuhnhold, and Andreas Buchleitner — Physikalisches Institut, Universität Freiburg, Germany

In classical thermodynamics, heat flow is commonly introduced by a thought experiment that employs two gas-filled boxes separated by a fixed wall and initially prepared with different internal energies. Subsequently, the subsystems exchange energy irreversibly, and the internal energies of both boxes equilibrate.

We introduce an analogue microscopic model consisting of two quantum particles contained in two 2D-boxes separated by a fixed wall, and isolated against the outside world. Thermal contact is realized via long-range interactions between the particles in the adjacent boxes. We numerically simulate the resulting, non-integrable two-body dynamics, with specific focus on the questions of whether and how relaxation can be witnessed already in this very minimalist setting, and whether heat, entropy and temperature can be defined consistently.

THU 12.2 Thu 14:30 ZHG105

Eigenstate Thermalization Hypothesis correlations via non-linear Hydrodynamics — •Jiaozi Wang[1], Ruchira Mishra[2], Tian-Hua Yang[3], Luca V. Delacrétaz[2], and Silvia Pappalardi[4] — [1]U Osnabrück, Germany — [2]U Chicago, USA — [3]U Princeton, USA — [4]U Köln,, Germany

The thermalizing dynamics of many-body systems is often described through the lens of the Eigenstate Thermalization Hypothesis (ETH). ETH postulates that the statistical properties of observables, when expressed in the energy eigenbasis, are described by smooth functions, that also describe correlations among the matrix elements. However, the form of these functions is usually left undetermined. In this work, we investigate the structure of such smooth functions by focusing on their Fourier transform, recently identified as free cumulants. Using non-linear hydrodynamics, we provide a prediction for the late-time behavior of time-ordered free cumulants in the thermodynamic limit. The prediction is further corroborated by large-scale numerical simulations of a non-integrable spin-1 Ising model, which exhibits diffusive transport behavior. Good agreement is observed in both infinite and finite-temperature regimes and for a collection of local observables. Our results indicate that the smooth multi-point correlation functions within the ETH framework admit a universal hydrodynamic description at low frequencies.

THU 12.3 Thu 14:45 ZHG105

Generating constraints and Hilbert space fragmentation by periodic driving — •Somsubhra Ghosh[1], Indranil Paul[2], Krishnendu Sengupta[3], and Lev Vidmar[1,4] — [1]Dept of Theoretical Physics, J. Stefan Institute, Ljubljana, Slovenia — [2]Laboratoire Materiaux et Phenomenes Quantiques, Paris, France — [3]School of Physical Sciences, Indian Association for the Cultivation of Science, Kolkata, India — [4]Dept of Physics, University of Ljubljana, Ljubljana, Slovenia

Hilbert space fragmentation (HSF) has long been proposed as a route to evade thermalization in isolated quantum systems by restricting its dynamics through the imposition of constraints. However, in equilibrium, such constraints are inserted *a priori* in the Hamiltonian of the system. In one of our earlier works, we had considered one such system and showed that such constraints can be realized through periodic driving. In this work, we generalize this idea and propose a general framework to generate such emergent constraints for a given system. We show that special drive frequencies exist where destructive interference suppresses processes which violate the constraints and thereby reinforces these constraints as emergent phenomena. Led by this insight, we suggest what kind of drive protocol might be suitable to generate a particular constraint for a given system. This result, in fact, goes beyond the purview of HSF and applies to the more general context of emergent symmetries in driven systems. As an application, we use this protocol to spatially localize quantum information in a spin-1/2 chain through HSF.

THU 12.4 Thu 15:00 ZHG105

Investigation of semiclassical simulations for Heisenberg-Langevin equations at low temperatures — •Scott Daniel Linz and Jochen Gemmer — Department of Mathematics/Computer Science/Physics, University of Osnabrück, D-49076 Osnabrück, Germany

A system of spins coupled to a bath is a traditional set-up in open quantum systems. Through Heisenberg's equation the spin dynamics can be modeled by a dynamical system. Interpreting terms as noise and non-Markovian damping one can arrive at a Heisenberg-Langevin equation. These are notoriously difficult to solve due to the dimensionality of the Hilbert space. Classical generalized Langevin equations, involving non-Markovian damping and colored noise are well understood and can be treated numerically with comparative ease. Thus, a semiclassical ansatz can be made by substituting quantum expectation values with classical functions. This allows the application of standard methods developed for classical stochastic dynamical systems to tackle spin dynamics. However, this approach is uncontrolled and should be benchmarked against known quantum dynamics. In this investigation a Hamiltonian for spin dynamics is manipulated in order to receive a set-up similar to the Weisskopf-Wigner theory of spontaneous emission in order to compare the results.

THU 12.5 Thu 15:15 ZHG105

Comprehensive analysis of electronic relaxation in one dimension Kondo lattice model — •Arturo Perez Romero, Mica Schwarm, and Fabian Heidrich-Meisner — Institut for Theoretical Physics, Georg-August-Universität Göttingen, D-37077 Göttingen, Germany

Recent advancements in laser technology have made it possible to create non-equilibrium conditions on timescales that outpace energy exchange across a wide range of degrees of freedom. The above represents a challenge not only for condensed matter experimental physicists but also for theoretical physicists who are motivated to describe a great variety of far-from-equilibrium systems. In this paper, we study the real-time dynamics of two paradigmatic models: the Kondo lattice model (KLM) and the Kondo-Heisenberg model (KHM) in one dimension. We analyze the role of exchange couplings for the relaxation of a single charge carrier via the time-dependent Lanczos method. We conduct a comprehensive study of the time evolution by evaluating the z-spin component of the conduction electron, the local spin-spin correlation between localized and conduction electrons, the spin-spin correlation between localized spins, and the electronic momentum distribution. The study includes a comparison with statistical mechanics predictions for steady state and a study of the effect of diagonal disorder. This work was funded by the Deutsche Forschungsgemeinschaft (DPG, German Research Foundation) via CRC 1073

THU 12.6 Thu 15:30 ZHG105

Graph theory and tunable slow dynamics in quantum East Hamiltonians — •Heiko Georg Menzler[1], Mari Carmen Bañuls[2,3], and Fabian Heidrich-Meisner[1] — [1]Institut für Theoretische Physik, Georg-August-Universität Göttingen, D-37077 Göttingen, Germany — [2]Max-Planck-Institut für Quantenoptik, D-85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Schellingstrasse 4, D-80799 München

We show how graph theory concepts can provide an insight into the origin of slow dynamics in systems with kinetic constraints. In particular, we observe that slow dynamics is related to the presence of strong hierarchies between nodes on the Fock-space graph in the particle occupation basis, which encodes configurations connected by a given Hamiltonian. To quantify hierarchical structures, we develop a measure of centrality of the nodes, which is applicable to generic Hamiltonian matrices and inspired by established centrality measures from graph theory. We illustrate these ideas in the quantum East (QE) model. We introduce several ways of detuning nodes in the corresponding graph that alter the hierarchical structure, defining a family of QE models. We numerically demonstrate how these detunings affect the degree of non-ergodicity on finite systems, as evidenced by both the time dependence of density autocorrelations and eigenstate properties in the detuned QE models.

(Funded by: DFG 436382789, 493420525, 499180199 via FOR 5522 and GOE-Grid cluster; Germany's Excellence Strategy EXC - 2111 - 390814868)

THU 12.7 Thu 15:45 ZHG105

Hierarchy of the relaxation timescales in a disordered spin-1/2 XX ladder — •Kadir Çeven, Lukas Peinemann, and Fabian Heidrich-Meisner — Institut für Theoretische Physik, Georg- August-Universität Göttingen, Göttingen, Germany

Understanding the timescales associated with relaxation to equilibrium in closed quantum many-body systems is one of the central focuses in the study of their non-equilibrium dynamics. At late times, these relaxation processes are believed to exhibit universal behavior, emerging from the inherent randomness of chaotic Hamiltonians. In this work, we investigate a disordered spin-1/2 XX ladder—an experimentally realizable model known for its diffusive dynamics—to explore the connection between transport properties and spectral measures derived solely from the system's energy levels via these relaxation timescales.

We begin by analyzing the spectral form factor, which reveals the timescale at which the system begins to exhibit random matrix theory (RMT) statistics, known as the RMT time. We then determine the Thouless time—the time for particle to diffuse across the entire finite system—through transport analysis of the disordered model. Our numerical results confirm that, during relaxation, the RMT time occurs significantly later than the Thouless time, signalling distinct temporal regimes in the system's approach to equilibrium.

We acknowledge funding from the Deutsche Forschungsgemeinschaft (German Research Foundation) within the Research Unit FOR5522 (Project No. 499180199).

THU 12.8 Thu 16:00 ZHG105

Observing dynamical localization on a trapped-ion qudit quantum processor — •Gonzalo Camacho — Deutsches Zentrum für Luft- und Raumfahrt (DLR), Köln, Germany

Recent impressive advances in quantum processors have opened up the possibility to witness emergent dynamical behavior in quantum many-body systems. An outstanding example is the observation of time-crystalline behavior in periodically driven systems breaking the discrete symmetry of the drive. Going beyond qubit-based architectures, in this work we use a trapped-ion qudit quantum processor to study a disorder-free, spin-1 interacting Floquet model that displays time-crystalline behavior protected by symmetry of an effective prethermal Floquet Hamiltonian. We also address the role played by multipartite entanglement in the system dynamics through the Quantum Fisher Information, which can be employed as a proxy to characterize the crossover from dynamically localized to ergodic regimes. These results pave the way for the exploration of emergent non-equilibrium phenomena in higher-dimensional quantum systems.

THU 13: Poster Session: Applications

Time: Thursday 16:30–18:30 Location: ZHG Foyer 1. OG

THU 13.1 Thu 16:30 ZHG Foyer 1. OG

Understanding Loss Channels in Fluxonium Qubits through High-Impedance LC Resonators — •Matthias Zetzl[1,2,3], Johannes Schirk[1,2,3], Florian Wallner[1,2,3], Ivan Tsitsilin[1,2,3], Niklas Bruckmoser[1,2,3], Christian Schneider[1,2,3], and Stefan Filipp[1,2,3] — [1]Walther-Meißner-Institut, Garching, Germany — [2]Technische Universität München, Munich, Germany — [3]Munich Center for Quantum Science and Technology, Munich, Germany

Superconducting qubits are currently limited by decoherence, making the identification of loss mechanisms critical for improving system performance. We investigate dissipation in Josephson junction arrays, a key component of protected qubits such as fluxonium and zero-pi qubits. To probe these loss channels, we study high-impedance lumped-element LC resonators composed of two charge islands connected by a Josephson junction array. This architecture closely resembles that of fluxonium qubits but enables more direct characterization through transmission measurements. We focus on power dependence spectroscopy and time traces of the resonator transmission. With this we achieve a fast and efficient characterization of the junction parameters and quality, providing a robust method to improve Josephson junction performance for fluxoniums and protected circuits.

THU 13.2 Thu 16:30 ZHG Foyer 1. OG

Error Rate of Quantum Circuits Involving Coded Computational Operations — •Yunos EL KADERI[1,2], Andreas HONECKER[1], and Iryna

ANDRIYANOVA[2] — [1]LPTM, CNRS UMR 8089 CY Cergy Paris University, France — [2]ETIS, CNRS UMR 8051 CY Cergy Paris University, France

Our work is motivated by the coded computation framework, where useful data is first encoded before being processed, and most elementary operations are faulty, including the encoding part. The output error rate of such coded quantum circuits can be simulated by means of existing quantum simulators, but typically at a cost that increases exponentially with the number of qubits. With the aim to reduce the simulation complexity, we suggest a less complex method to approximate the output error rate of quantum circuits, and we apply these methods in the framework of coded computation. This is benchmarked against numerical simulations.

THU 13.3 Thu 16:30 ZHG Foyer 1. OG

Stochastic Emulation of Quantum Algorithms — •Anagha Shriharsha and Daniel Braun — Institute for Theoretical Physics, Eberhard Karls University of Tübingen, Auf der Morgenstelle 14 D - 72076 Tübingen

We introduce a fully classical stochastic emulation of pure-state quantum circuits by treating higher-order partial derivatives of an N-particle position distribution as analogue quantum states and discretizing them into 2(n + 1) classical stochastic bits. Each single- and two-qubit unitary gate is realised as a convex stochastic map on these grabit bins, reproducing the exact realified evolution up to a global prefactor and enabling an automated translation of any pure-state quantum algorithm into a classical stochastic algorithm. We demonstrate the approach on the Deutsch Jozsa and Bernstein Vazirani algorithms, as well as on the Quantum Fourier Transform and the Quantum Approximate Optimization Algorithm, validating that gate-by-gate stochastic propagation faithfully tracks the intended quantum evolution. By analysing how the number of samples must grow with qubit count for fixed accuracy, we uncover how genuine many-particle interference emerges within classical probabilities and at what sampling cost.

THU 13.4 Thu 16:30 ZHG Foyer 1. OG

Error correction on IBM's quantum computers — •Simona Grigorova — Center for quantum tehcnologies, Sofia, Bulgaria

I present implementations of the repetition and bit flip codes on IBM's superconducting qubit platforms. This work demonstrates effective error detection and correction, significantly mitigating bit-flip errors. The study outlines the experimental setup, key challenges, and results, emphasizing the potential for scalable, fault-tolerant quantum computation on current hardware.

THU 13.5 Thu 16:30 ZHG Foyer 1. OG

A Near-Constant-Depth Quantum Algorithm for Quantum Chemistry — •Yu Wang[1], Martina Nibbi[1], Maxine Luo[3,4], and Christian Mendl[1,2] — [1]Technical University of Munich, CIT, Department of Computer Science, Boltzmannstrasse 3, 85748 Garching, Germany — [2]Technical University of Munich, Institute for Advanced Study, Lichtenbergstrasse 2a, 85748 Garching, Germany — [3]Max Planck Institute of Quantum Optics, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany — [4]Munich Center for Quantum Science and Technology, Schellingstrasse 4, 80799 Munich, Germany

In this work, we present an efficient quantum algorithm for simulating time evolution in quantum chemistry. Its circuit depth scales logarithmically with the system size, which can be viewed as effectively constant for large molecules. The approach is inspired by the fast multipole method, in which we aggregate the one-to-one interactions between grids in two regions into region-to-region interactions. Following this strategy and assuming a two-dimensional structured quantum computer, we estimate the number of electrons in each area and then compute the corresponding time evolution when working with the discretized form of the electronic Hamiltonian. Moreover, the estimation of electron numbers can be implemented in constant depth if the fan-out gate is available, which is realized in recent experiments on various hardware platforms. Consequently, the circuit depth for a single-step time evolution simulation is determined by the number of levels that scale logarithmically in the fast multipole method.

THU 13.6 Thu 16:30 ZHG Foyer 1. OG

Towards fast ion separation for trapped ion quantum computing — •Lino Savaş[1], Rodrigo Munoz[1], Lars Krieger[1], Florian Ungerechts[1], Masum Billah[1], Janina Bätge[1], Phil Nuschke[1], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

A promising approach for a trapped-ion-based quantum computer is the quantum charge-coupled device architecture, as it enables scalability through the use of microfabrication methods and using junctions allows natural all-to-all connectivity of the qubit array.

Based on a surface electrode Paul trap, we disscuss current simulation results for separating Coulomb crystals while maintaining a constant trap frequency. This decreases the sensitivity to heating due to uncontrolled acceleration during the merging and splitting processes, which is a critical step for high fidelity quantum computing for trapped-ion based systems.

THU 13.7 Thu 16:30 ZHG Foyer 1. OG

Building trapped-ion quantum processors using MAGIC technology — •Mathew Chan — eleQtron GmbH

In recent years, trapped ions have emerged as a prime candidate for the establishment of noisy intermediate-scale quantum (NISQ) computers. eleQtron is a quantum startup which was established as a spin-off from the group of Prof. Christof Wunderlich, where quantum computing with trapped 171Yb+ ions interacting via MAGIC (MAgnetic Gradient Induced Coupling) has been pioneered. MAGIC[1] refers to the deployment of a static magnetic field gradient along the ion chain. This gradient results in a differentiation between the qubit transition energy at each ion position, facilitating the use of microwave frequencies to achieve coherent control of individual ions whilst minimizing undesirable crosstalk. This also induces a coupling between ions which can be exploited for the implementation of multi-qubit gates. Additionally, mature microwave technology in the commercial space is leveraged to overcome the scalability challenge. For the next generation of MAGIC-based quantum computers, we are now focused on scaling up our ion trap platform. To this end, we first need to miniaturize the trap into a modular planar design, which is then housed within an ultra-high vacuum and cryogenic conditions, which serve to reduce the ion motional heating rates. Here, we present a summary of the technical building blocks of our platform and a future path to scalability for digital quantum computing with trapped ions in the NISQ era.

[1] F. Mintert & C. Wunderlich, Phys. Rev. Lett. 87, 257904 (2001)

THU 13.8 Thu 16:30 ZHG Foyer 1. OG

Rymax one: A neutral atom quantum processor to solve optimization problems — •Hendrik Koser[1], Benjamin Abeln[1], Tobias Ebert[1], Silvia Ferrante[1], Kapil Goswami[1], Jonas Witzenrath[2], Hauke Biss[1], Jonas Gutsche[2], Giovanni de Vecchi[1], Nader Mostaan[1], Suthep Pomjaksilp[1], Tobias Pätkau[2], José Vargas[1], Rick Mukherjee[3], Niclas Luick[1], Thomas Niederprüm[2], Dieter Jaksch[1], Henning Moritz[1], Herwig Ott[2], Peter Schmelcher[1], Klaus Sengstock[1], and Artur Widera[2] — [1]University of Hamburg, 22761 Hamburg, Germany — [2]RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [3]University of Tennessee, TN 37996 Knoxville, USA

Computationally hard problems are deeply embedded into modern society. Finding solutions to these problems via classical means still requires substantial computational effort. Quantum processors, on the contrary, promise a significant advantage in solving them. To explore the potential of quantum computing for real-world applications, we set up Rymax One, a quantum processor designed to solve hard optimisation problems. We trap ultracold neutral Ytterbium atoms in arbitrary arrays of optical tweezers, ideally suited to solve optimisation problems and perform quantum operations in a hardware-efficient manner. The level structure of Yb provides the possibility of attaining qubits with long coherence times as well as Rydberg-mediated interactions and high-fidelity gate operations. These features allow us to realise a scalable platform for quantum processing to test the performance of novel quantum algorithms tailored to tackle real-world problems.

THU 13.9 Thu 16:30 ZHG Foyer 1. OG

Thin film diamond nano-photonics — •sunil kumar mahato[1,2], donika imeri[1,2], konstantin beck[1,2], nick brinkmann[1,2], leonie eggers[1,2], caius niemann[1], rikhav shah[1], and ralf riedinger[1] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg — [2]The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany

Silicon-vacancy (SiV) color centers in diamonds have emerged as one of the most promising platforms for quantum communication, quantum information processing, and quantum networks because of their special optical and spin characteristics. Inversion symmetry, which distinguishes the SiV* center from other color centers, results in extremely stable optical transitions with little spectral diffusion. Their ability to produce indistinguishable single photons, a crucial prerequisite for scalable quantum networks, makes them perfect candidates. Additionally, it is possible to represent the SiV* core as a two-level quantum system, which allows for coherent single-photon control and manipulation. SiV* centers can be coupled to optical cavities and waveguides.

Thanks to recent developments in nanofabrication and photonic integration, which are greatly improving spin-photon coupling efficiency.

THU 13.10 Thu 16:30 ZHG Foyer 1. OG

PTB Testbed for Quantum Key Distribution Metrology — •Ali Hreibi[1], Mohsen Esmaeilzadeh[2], Tara Liebisch[3], and Stefan Kück[4] — [1]Ali.hreibi@ptb.de — [2]mohsen .esmaeilzadeh@ptb.de — [3]Tara .Liebisch@ptb.de — [4]Stefan.Kueck@ptb.de

Various QKD systems, based on different protocols, have been developed for both free-space and optical fiber communication. However, despite significant progress over the past decades, achieving long-distance communication using single photons remains challenging. To mitigate rapid signal decay during transmission, technical compromises are often employed, which come at the expense of single-photon purity and overall communication fidelity, ultimately weakening the security provided by the laws of quantum mechanics. As a result, technical solutions are continuously being developed and implemented to prevent emerging attacks. We are developing various metrology techniques for calibrating and characterizing key components of QKD systems both in the laboratory and in field-deployed optical fibers. For example, to support QKD in daylight conditions, we are developing calibration methods for single-photon detectors operating with higher detection efficiencies at the Fraunhofer sodium D1 line, allowing for precise performance characterization under realistic environmental conditions. As well, we are developing techniques to characterize entangled photon sources using quantum state tomography and to multiplex different QKD signals in optical fiber.

THU 13.11 Thu 16:30 ZHG Foyer 1. OG

Characterization and mitigation of optical side-channels in QKD — •Evelyn Edel[1], Moritz Birkhold[1,2], Sebastian Mahlik[4], Harald Weinfurter[1,2,3], and Lukas Knips[1,2,3] — [1]Ludwig Maximilian University, Munich, Germany — [2]Munich Center for Quantum Science and Technology, Munich, Germany — [3]Max Planck Institute of Quantum Optics, Garching, Germany — [4]University of Gdańsk, Gdańsk, Poland

Unlike classical key distribution methods reliant on computationally hard problems, quantum key distribution (QKD) achieves information-theoretic security by the principles of quantum physics. The decoy-state BB84 protocol offers a practical scheme for realizing free-space QKD sender modules, allowing the use of highly attenuated laser pulses as a photon source. However, imperfections in devices could enable side-channel attacks by an eavesdropper.

This work presents a characterization of spectral side-channels in our sender module. To prepare the different polarization states, four vertical-cavity surface-emitting lasers (VCSELs) in a monolithic array are used, which results in imperfect spectral overlap opening up a side-channel. The spectral behavior of over 100 VCSELs was characterized under varying bias and modulation currents. Together with the time-resolved pulse analysis enabled by a streak camera, this allows identification of arrays with optimal spectral overlap and facilitates future module optimization. First steps were taken to quantify the information leakage via mutual information, which will be used to appropriately adjust privacy amplification in the protocol.

THU 13.12 Thu 16:30 ZHG Foyer 1. OG

QSOC - The DLR Quantum Space Operations Center — Andreas Spörl, Nikolas Pomplun, Santana Lujan, •Catharina Broocks, Francisca Maria Marques Reis Warden Gois, Sven Prüfer, Clemens Schefels, and Jan Pitann — German Aerospace Center, Münchener Str. 20, 82234 Weßling, Germany

The Quantum Space Operations Center (QSOC) is a platform for integration of cutting-edge quantum technologies in traditional space mission operations. Our interdisciplinary research group collaborates extensively with leading academic institutions and industry partners to address complex challenges in spacecraft scheduling, satellite control, data analysis, and secure communication.

We present novel quantum algorithms for combinatorial optimization problems, specifically tailored for spacecraft mission planning challenges. The exploration of rarely utilized quantum algorithms allows to uncover a vast potential to improve a broad spectrum of day-to-day spacecraft operation tasks. Additionally, we delve into quantum optimal control theory for robust satellite attitude management. Quantum Machine Learning methods are employed for anomaly detection in satellite telemetry data, showcasing their potential in improving the reliability and efficiency of space missions. Our initiatives in quantum error correction address the reliability challenges of state-of-the-art quantum computing devices.

Further, we discuss the integration of Quantum Key Distribution systems into satellite ground segments, ensuring secure data transfer and enhancing the overall cybersecurity posture of space operations.

THU 13.13 Thu 16:30 ZHG Foyer 1. OG

Towards entanglement distribution in a metropolitan dark-fibre network in Berlin — •William Staunton[1] and Harald Herrmann[2] — [1]Humboldt University, Berlin,Germany — [2]Paderborn University, Germany

Efficient distribution of entanglement along quantum channels is essential in the potential realization of a quantum internet. Alongside an infrastructure of SM dark fibers, with quantum repeater functionalities we could move towards distributed quantum computation and quantum communication on a global scale. We present the work towards entanglement distribution in a metropolitan, field-installed dark-fibre network in Berlin. With focus on results of the active polarization stabilization employed. We also introduce the novel, resonant, type II periodically poled Lithium Niobate (PPLN) spontaneous parametric down-conversion (SPDC) waveguide source engineered to produce entangled photon pairs with high brightness and narrow linewidth. Crucially, such sources emit photons with pure spectral states. Use of the clustering effect reduces the effect spectral filtering has on overall brightness mode. With an emission bandwidth optimized for interacting with quantum memories, we show how the source is optimized for quantum repeater demonstrations.

THU 13.14 Thu 16:30 ZHG Foyer 1. OG

High Frequency Ion-Photon Interfaces for Distributed Quantum Computing — •Lasse Jens Irrgang[1], Luca Graf[1], Tuncay Ulaş[1], Rikhav Shah[1,2], and Ralf Riedinger[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany

Decades of excessive research have proven the key towards a quantum advantage of quantum computing compared to classical computers is the scalability of the quantum processor. In analogy to classical super computing clusters we propose a network of small interconnected trapped-ion-based quantum processors to achieve flexibly scalable quantum computing.

In detail, a fibre-based Fabry-Pérot cavity integrated in an ion-trap provides an efficient ion-photon interface. This enables entanglement of ion-qubits in spatially separated traps at a high frequency, and therefore distributed computing in a network of ion-based quantum processors.

Being per se platform-independent, the concept is firstly demonstrated connecting a room-temperature blade trap and a cryogenic blade trap. A novel blade-integrated design of the fibre-cavity ensures plenty of free-space access for cooling and operation lasers. To cope with accumulating charges in the dielectric glass-fibres, disturbing the trapping field, an in-house designed conductive coating applied to the fibres circumvents these effects.

THU 13.15 Thu 16:30 ZHG Foyer 1. OG

Towards time-bin entangled photon cluster states — •Siavash Qodratipour, Thomas Häffner, and Oliver Benson — Nano-Optik, Humboldt-Universität zu Berlin, Berlin, Germany

Single photons are ideal carriers of quantum information due to the lack of interaction with each other. However, manipulating and controlling them for quantum computing becomes a difficult task. One-way quantum computation [1] overcomes this challenge by avoiding non-linear two-qubit interaction and instead uses highly entangled states called *cluster states*. Together with single qubit measurements and feed-forward a scalable universal quantum computer can be implemented [2].

The aim of our research is to realize a cluster state by fusion of few photon qubits which are time-bin encoded (early and late time-bins) in optical fibres. In this presentation, we will report on the generation of time-bin entangled photon pairs at 1560 nm and the subsequent characterization of the energy-time and time-bin entanglement by two photon interference [3]. We will also outline how we implement interferometric phase stability and arbitrary phase point control which are necessary to achieve a reproducible and deterministic interference. Scalability of our approach will be discussed as well.

[1] R. Raussendorf et al. Phys. Rev. Lett. 86, 5188 (2001).
[2] CY. Lu et al. Nature Phys. 3, 915 (2007).
[3] S. Tanzilli et al. Eur.Phys. J. D 18, 155 (2002).

THU 13.16 Thu 16:30 ZHG Foyer 1. OG

Entanglement distribution in hybrid discrete- and continuous-variable microwave networks — •Simon Gandorfer[1,2], Joan Agustí[1,2], Maria-Teresa Handschuh[1,2], Kedar E. Honasoge[1,2], Achim Marx[1], Peter Rabl[1,2,3], Rudolf Gross[1,2,3], and Kirill G. Fedorov[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]School of Natural Sciences, Technische Universität München, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology, 80799 Munich, Germany

Distributing entanglement between spatially separated nodes of a large-scale quantum network is a fundamentally important milestone for quantum information processing tasks. In particular, quantum entanglement is needed for quantum teleportation or logical quantum gates with remote qubits. In our experiment, we employ a superconducting transmon qubit in a 3D cavity driven by a microwave two-mode squeezed (TMS) bath. We investigate a build-up of entanglement between the remote superconducting nodes due to their interaction with the common, quantum-correlated, reservoir. The corresponding entanglement conversion between continuous- and discrete-variables allows for promising and robust quantum microwave network architectures. Finally, we discuss possible extensions and applications for distributed quantum computing.

THU 13.17 Thu 16:30 ZHG Foyer 1. OG

Semi-device-independently characterizing quantum temporal correlations — •Shin-Liang Chen[1] and Jens Eisert[2] — [1]National Chung Hsing University, Taichung, Taiwan — [2]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, Berlin, Germany

We propose a general framework for analyzing quantum temporal correlations in scenarios where an initial quantum state undergoes a first measurement, evolves through a quantum channel, and is subsequently measured again. This approach is fully device-independent, meaning it does not rely on any assumptions about the internal workings of the systems or measurements involved. Nonetheless, it is flexible enough to accommodate additional constraints under semi-device-independent assumptions. Our framework provides a natural method for quantum certification in temporal settings involving uncharacterized or partially characterized devices. It also supports the analysis of quantum temporal correlations under specific assumptions, such as time no-signalling, system dimension bounds, rank restrictions - under which we demonstrate genuine quantum advantages over local hidden variable models - or other linear constraints. We illustrate the utility of the framework through various applications, including establishing bounds on the maximal violation of temporal Bell inequalities, measuring temporal steerability, and evaluating the highest success probabilities in quantum randomness access codes.

THU 13.18 Thu 16:30 ZHG Foyer 1. OG

Gradient Based Optimization of a Hybrid Quantum System for Fock State Preparation — •Benjamin Stodd[1], Martin Gärttner[1], and Sina Saravi[2] — [1]Institute of Condensed Matter Theory and Solid State Optics, Friedrich-Schiller University Jena, Germany — [2]Department of Electrical Engineering and Information Technology, Paderborn University, Germany

The development of efficient and tailorable sources of quantum light, such as Fock states, is of major interest for the realization of optical quantum technologies. We investigate a hybrid quantum system composed of a quantum dot and a nonlinear crystal embedded in an optical cavity, driven by controlled pump pulses. This setup enables quantum state generation in one of the cavity modes, which can be tailored to be at an arbitrary frequency. Within this framework, we present a gradient-based numerical optimization of the system dynamics to identify pulse parameters that maximize the fidelity of the output state with a target Fock state. We demonstrate that very high fidelities can be achieved, particularly for low-photon-number states ($F > 0.99$ for $N = 1, 2, 3$). To account for realistic conditions, we further aim to develop a scheme that enables optimization of the system dynamics in the presence of loss, described by the Lindblad master equation. Our results highlight the potential of such hybrid platforms for reliable and tunable quantum state generation.

THU 13.19 Thu 16:30 ZHG Foyer 1. OG

Faithful certification of steerability-breaking channels — •Po-Ting Hsu and Shin-Liang Chen — Department of Physics, National Chung Hsing University, Taichung 40227 , Taiwan

We consider a scenario where Alice prepares a pair of particles and sends one to Bob through a quantum channel, and she convinces him that the pair is entangled. Namely, it is a steering scenario. Bob will never be convinced as long as the channel is steerability-breaking, i.e., the channel destroys steerability for any input state. To verify that the state undergoing channel is not useful for demonstrating steering, one has to consider all possible measurements performed by Alice and check if the conditional states Bob receives admit local-hidden-state (LHS) models. Intuitively, it is a hard problem since one has to consider an infinite combination of measurements. Here, we show a method that can be used to tackle this problem. We also explicitly consider several common quantum channels and derive conditions that the channels destroy steerability but still preserve entanglement.

THU 13.20 Thu 16:30 ZHG Foyer 1. OG

Activation of Genuine Multipartite Entanglement and Genuine Multipartite Nonlocality — •Markus Miethlinger, Bora Ulu, Alejandro Pozas-Kerstjens, Sadra Boreiri, Pavel Sekatski, and Nicolas Brunner — Department of Applied Physics, University of Geneva, 1211 Geneva 4, Switzerland

Entanglement and nonlocality have long been central to the study of quantum foundations. It is known that bipartite nonlocality can be activated–i.e., preparing multiple copies of a local state can result in a nonlocal one–in stark contrast to bipartite entanglement, which cannot be activated. However, recent results show that genuine multipartite entanglement (GME) can be activated from fully inseparable biseparable states, and that genuine multipartite nonlocality (GMNL) can be activated using bilocal states. Furthermore, GME is recognized as a necessary condition for GMNL in the single-copy regime. Yet, the simultaneous activation of GME and GMNL–i.e., activating GMNL using biseparable states–has not been studied. Here, we show that GMNL can be activated using multiple copies of a fully local, $N-1$ separable state in a star network. We consider a family of states and identify a threshold number of copies for which the global state remains biseparable, as well as a sufficient condition for it to be GME above this threshold. Using a multipartite nonlocal game featuring unbounded Bell inequality violations, we derive a sufficient condition for the states to be GMNL-activatable. This result shows that single-copy GME is not a necessary condition for GMNL activation, and may indicate that GME and GMNL coincide in the asymptotic limit.

THU 13.21 Thu 16:30 ZHG Foyer 1. OG

Scalable quantum firmware via Atomiq and HEROS — •Suthep Pomjaksilp[1], Christian Hölzl[2], Thomas Niederprüm[3], Florian Meinert[2], and Henning Moritz[1] — [1]University of Hamburg, 22761 Hamburg, Germany — [2]5th Institute of Physics, Universität Stuttgart, Germany — [3]Department of Physics and research center OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Germany

The increasing complexity and fast cycle times of quantum technology experiments demand control systems that are not only high-performance but also accessible and adaptable. To orchestrate these intricate experimental platforms, we introduce a quantum firmware layer consisting of Atomiq and HEROS.

Atomiq is a modular framework designed to bridge the gap between ARTIQ hardware primitives and the high-level abstractions familiar to experimental physicists. It combines control devices into intuitive lab objects and uses a block-based experiment structure to encapsulate common procedures into reusable and extensible components. This approach enables clear, concise, and maintainable experiment code while preserving access to performance-critical features. Targeting the full experimental infrastructure, the HEROS object sharing service makes any software or hardware entity network transparent. It facilitates seamless interactions between real-time control and non-real-time instruments, environmental sensors and data handling workflows.

Combining the open-source tools ATOMIQ and HEROS empowers researchers to build, adapt, and scale their experiments with ease.

THU 13.22 Thu 16:30 ZHG Foyer 1. OG

Towards Scalable Swap-Based Self-Testing under Multiple Bell Constraints in High-Dimensional Quantum Networks — •Lingxuan Tang — TU Darmstadt Darmstadt, Germany

This thesis proposes a modular swap-based self-testing method for quantum state fidelity authentication in high-dimensional quantum networks in device-independent scenarios where multiple Bell inequalities act simultaneously. The authors conceive a structure that decomposes the global fidelity problem into multiple local SDP subproblems, thereby reducing the computational complexity from exponential to linear. The method achieves independent optimisation of each subsystem by constructing local swap mappings and independent moment matrices, and introduces edge consistency constraints to ensure physical reasonableness in the presence of device sharing. Through numerical simulation comparisons, the paper verifies the performance of the framework under different numbers of subsystems and NPA tiers, showing a significant increase in computational efficiency (up to 35 times) while maintaining fidelity accuracy, which is particularly applicable to large-scale quantum networks. The work provides an effective tool for practical scalable device-independent authentication and lays the foundation for future adaptive hybrid optimisation methods.

THU 13.23 Thu 16:30 ZHG Foyer 1. OG

Optimal Parameters for Quantum Approximate Optimization via Weak Measurements — •Lena Wagner[1,2] and Tobias Stollenwerk[1] — [1]Forschungszentrum Jülich — [2]Universität des Saarlandes

Quantum imaginary time evolution (QITE) has emerged as a potentially promising method for ground state preparation in quantum computing, leveraging its inherent ability to amplify ground state amplitudes and exponentially suppress those of excited states. In this work, we focus on an QITE inspired approach based on weak measurements. Conditional unitary operations ("scrambling") are used to correct for the non-unitary evolution and undesired measurement outcomes. These scrambling operations are implemented via rotations introducing optimizable angles and activate only when measurement outcomes exceed a certain threshold. Further tunable parameters include a scaling factor for energy spectrum normalization and the choice of an initial state with non-zero overlap with the ground state. By generalizing this algorithm from exact to approximate optimization, we enable applications to combinatorial optimization problems such as MaxCut. We investigate performance of the algorithm with respect to these parameters and present parameter studies on MaxCut instances, revealing how scrambling angles, threshold, scaling factors, and the randomness of the weak measurement impact convergence and solution quality.

THU 13.24 Thu 16:30 ZHG Foyer 1. OG

Integrated Photonic Quantum Walks for Universal Computation — •Lasse Wendland[1], Florian Huber[2,3,4], and Jasmin D. A. Meinecke[1,2] — [1]Institute of Physics and Astronomy , Technische Universität Berlin, 10623 Berlin, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany — [3]Department für Physik, Ludwig-Maximilians-Universität, München, Germany — [4]Munich Center for Quantum Science and Technology (MCQST), München, Germany

As the quantum mechanical analog of a classical random walk, quantum walks offer a powerful framework for advancing various modern quantum technologies. Beyond their foundational significance, quantum walks can also serve as a model for universal quantum computation. However, scaling such models requires the interaction of multiple quantum walkers, a task that poses significant experimental challenges. In our research, we explore the feasibility of quantum walk computation using photonic waveguide arrays, a platform that offers inherent stability, compactness, and versatility.

THU 13.25 Thu 16:30 ZHG Foyer 1. OG

First Hitting Times through Indirect Measurements — •Tim Heine[1], Eli Barkai[2], Klaus Ziegler[3], and Sabine Tornow[4] — [1]Institute of Quantum Technologies, German Aerospace Center (DLR), Ulm, Germany) — [2]Institute of Nanotechnology and Advanced Materials, Bar-Ilan University, Ramat-Gan, Israel — [3]Institut für Physik, Universität Augsburg, Augsburg, Germany — [4]Research Institute CODE, Universität der Bundeswehr München, Munich, Germany

We study the first detected return time problem of continuous-time quantum walks on graphs. While previous works have employed projective measurements to determine the first return time, we implement a protocol based on weak, indirect measurements on a dilated system, enabling minimally invasive monitoring throughout the evolution. To achieve this, we extend the theoretical framework and complement it with both numerical simulations and experimental investigations on an IBM quantum computer. Despite the implementation of a generalized measurement, our modified formalism of indirect recurrence provides a description purely within the Hilbert space of the quantum system. Our results reveal that the first hitting time scales inversely with the coupling parameter between the ancilla and the quantum system.

THU 13.26 Thu 16:30 ZHG Foyer 1. OG

Active Stabilization of Laser Diode Injection Using a Polarization-Spectroscopy Technique — •Luka Milanovic[1,2], Greg Ferrero[1,2], Robin Oswald[1,3], Thomas Kinder[3], Julian Schmidt[1], and Cornelius Hempel[1,2] — [1]ETH Zürich - PSI Quantum Computing Hub, 5232 Villigen PSI, Switzerland — [2]Institute of Quantum Electronics, ETH Zürich, Otto-Stern-Weg 1, 8093 Zurich, Switzerland — [3]TEM Messtechnik GmbH, 30559 Hanover, Germany

Injection-locking is a powerful technique to amplify laser light while retaining its spectral properties. However, it can be sensitive to fluctuations in seed power, frequency, and diode temperature. Here we present an active stabilization method [1] inspired by the Hänsch-Couillaud technique that continuously monitors the injection-locking condition using only a few standard optical components. The scheme runs in the background, requires no modulation, and significantly improves robustness against environmental changes. We demonstrate reliable locking even under large perturbations to the seed frequency, power, and diode temperature.

[1] Milanovic et al., Rev. Sci. Instrum. 1 May 2025; 96 (5): 053003. https://doi.org/10.1063/5.0249681

THU 13.27 Thu 16:30 ZHG Foyer 1. OG

A compact nonlinear interferometer for spectroscopy with undetected photons in the mid-infrared — •Theresa Kloss[1], Helen M. Chrzanowski[2], and Sven Ramelow[3] — [1]Humboldt-Universität zu Berlin — [2]Humboldt-Universität zu Berlin — [3]Humboldt-Universität zu Berlin

Infrared spectroscopy is a powerful workhorse of science and industry. Over the past decade, quantum optics has offered a new approach to infrared sensing with quantum nonlinear interferometry allowing us to decouple the sensing and detection wavelengths. However, the practical implementation of this technique is often limited by strong absorption from components of the ambient air, such as H_2O(g) or CO_2(g). Here, we demonstrate a compact implementation of a nonlinear interferometer for mid-IR spectroscopy, successfully mitigating the impact of gaseous H_2O(g) and allowing the successful characterization of a chrysotile asbestos sample in the wavelength range from 2.68 μm to 2.77 μm.

THU 13.28 Thu 16:30 ZHG Foyer 1. OG

Mid-infrared quantum spectroscopy in a dispersion-engineered integrated SU(1,1) interferometer — •Abira Gnanavel, Franz Roeder, René Pollmann, Olga Brecht, Laura Padberg, Christof Eigner, Benjamin Brecht, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Straße 100, 33098 Paderborn, Germany

Mid-infrared (MIR) spectroscopy is an important tool for sample characterization and environmental monitoring. For example, greenhouse gases exhibit distinct transition lines, which provide fingerprint-like absorption features. However, classical MIR spectroscopy is limited by costly, inadequate detectors. Nonlinear quantum interferometry with undetected photons offers a solution, where the long-wavelength photon of a photon-pair interacts with a sample under test in a nonlinear interferometer, while information is then read out by detecting only the short-wavelength photon at the output of the interferometer.

Here, we present an ultra-broadband SU(1,1) interferometer based on a dispersion-engineered integrated photon-pair source that generates bi-photons in the near-infrared (NIR) and MIR. We demonstrate quantum spectroscopy with undetected photons by measuring the transmission of UV fused silica in the MIR while only detecting the NIR photons with off-the-shelf single photon detection. This result paves the way towards miniaturized and cost effective MIR sensors for future industrial applications.

THU 13.29 Thu 16:30 ZHG Foyer 1. OG

Setup and calibration of a single-photon spectrometer — •Jannis Sode, David Lindler, Marlon Schäfer, Tobias Bauer, Akriti Raj, and Christoph Becher — Universität des Saarlandes, Fachrichtung Physik, Campus E2 6, 66123 Saarbrücken

Fiber-based quantum networks consist of spin-photon interfaced quantum memory nodes utilizing flying qubits with wavelengths in the low-loss telecom bands. These photons are either directly generated via optical transitions or transducted using quantum frequency conversion. This enables communication and transfer of quantum states via preexisting optical fiber infrastructure. Due to the small signal level of the transmitted quantum states of light, it is mandatory to explore and control the noise sources in the transmission channels.

To this end, an exact spectral analysis of signals on the single-photon level is necessary to determine the spectral noise distribution. However, commercially available spectrometers typically have a small detection efficiency at infrared wavelengths.

In this contribution, we present the setup of a spectrometer able to measure single-photon signals in the telecom wavelength range (1500-1600 nm) using superconducting nanowire single photon detectors with high detection efficiency. We discuss the overall efficiency as well as the accuracy of the spectrometer. To demonstrate its performance we resolve the spectral distribution of non-linear optical processes at the single-photon level, in particular spontaneous parametric down conversion and pump-induced noise in quantum frequency conversion.

THU 13.30 Thu 16:30 ZHG Foyer 1. OG

Comparing on-off detector and single photon detector in photon subtraction based continuous variable quantum teleportation — Chandan Kumar[1,2], •Karunesh Mishra[3], and Sibasish Ghosh[1,2] — [1]Optics and Quantum Information Group, The Institute of Mathematical Sciences, Chennai, India — [2]Homi Bhabha National Institute, Mumbai, India — [3]Extreme Light Infrastructure - Nuclear Physics, Bucharest, Romania

We consider two distinct photon detectors namely, single photon detector and on-off detector, to implement photon subtraction on a two-mode squeezed vacuum state. The two distinct photon subtracted two-mode squeezed vacuum states generated are utilized individually as resource states in continuous variable quantum teleportation. Owing to the fact that the two generated states have different success probabilities (of photon subtraction) and fidelities (of quantum teleportation), we consider the product of the success probability and fidelity enhancement as a figure of merit for the comparison of the two detectors. The results show that the single photon detector should be preferred over the on-off detector for the maximization of the considered figure of merit.

Ref.: arXiv:2409.16072 [quant-ph]

THU 13.31 Thu 16:30 ZHG Foyer 1. OG

Deterministic generation of highly indistinguishable single photons in the telecom C-band — •Nico Hauser[1], Matthias Bayerbach[1], Jochen Kaupp[2], Yorick Reum[2], Giora Peniakov[2], Johannes Michl[2], Martin Kamp[2], Tobias Huber-Loyola[2], Andreas T. Pfenning[2], Sven Höfling[2], and Stefanie Barz[1] — [1]Universität Stuttgart, Institut für funktionelle Materie und Quantentechnologien — [2]Julius-Maximilians-Universität Würzburg, Physikalisches Institut, Lehrstuhl für Technische Physik

The deterministic generation of highly indistinguishable single photons in the telecom C-band is a critical requirement for many quantum communication and distributed quantum computation protocols. While quantum dot-based single-photon sources have demonstrated excellent performance in the 780 nm to 960 nm range, extending this performance to the telecom C-band remains an active area of research. Here, we present a single-photon source operating in the telecom C-band based on an InAs quantum dot in a circular bragg grating resonator, achieving raw two-photon interference visibilities exceeding 90%. We explore different optical excitation schemes to optimize the performance of the source in terms of multi-photon emission probability and two-photon interference visibility.

THU 13.32 Thu 16:30 ZHG Foyer 1. OG

Reducing losses in time multiplexed multi-loop heralded single photon sources — •Zora Kutz, Xavier Barcons Planas, Lasse Wendland, Jasmin Meinecke, and Janik Wolters — Technical University Berlin

In order to achieve quasi-deterministic heralded single photon sources, the probabilistic nature of spontaneous parametric down conversion can be mitigated with time multiplexing. Depending on the time of pulsed pump induced photon-pair generation, measured by the herald, the signal photon can be stored in a switchable fibre delay line until the end of the clock cycle, with single [1] or multiple loops [2]. The advantage of using several fibre storage loops of different lengths, lies in the reduction of necessary round trips. Overall losses scale with the number of round trips and losses at the out- and in-coupling. Increasing the fibre coupling efficiency as well as implementing the multi-loop model will result in a more efficient source. To increase the coupling efficiency, the tip/tilt degree of freedom of the collimator lens was investigated.

[1] T. B. Pittman, B. C. Jacobs, und J. D. Franson, Phys. Rev. A, Bd. 66, Nr. 4, S. 042303, Okt. 2002
[2] E. Lee, S. M. Lee, und H. S. Park, Opt. Express, Bd. 27, Nr. 17, S. 24545, Aug. 2019

THU 13.33 Thu 16:30 ZHG Foyer 1. OG

InP-based photonic structures at telecom wavelengths for quantum communication — •Mohamed Benyoucef[1], Ranbir Kaur[1], Johann Peter Reithmaier[1], Ryota Katsumi[2], Yasutomo Ota[3], and Yuming He[4] — [1]Institute of Nanostructure Technologies and Analytics (INA), CINSaT, University of Kassel, Heinrich-Plett-Street 40, 34132 Kassel, Germany — [2]Department of Electrical and Electronic Information Engineering, Toyohashi University of Technology, Toyohashi, Aichi 441-8580, Japan — [3]Department of Applied Physics, Keio University, Yokohama 223-8522, Japan — [4]Hefei National Laboratory, University of Science and Technology of China, Hefei 230088, China

Single-photon sources operating at fiber-optic communication wavelengths are essential for transmitting quantum information over long distances. Self-assembled semiconductor quantum dots (QDs) in microcavities that emit in the telecom C-band, where silica fiber losses are minimal, are particularly promising. In this study, we present our recent progress in InP-based photonic structures operating at telecom wavelengths. The fabrication of low-density symmetric QDs is achieved by carefully controlling the QD growth using a special growth technique. Low-temperature single-dot spectroscopy reveals sharp excitonic emission lines with negligible fine structure splitting. These QDs exhibit bright and pure single-photon emission over a wide range of the third telecom window. Furthermore, the hybrid integration of InP-based single-photon sources on a CMOS processed silicon photonic chip is discussed.

THU 13.34 Thu 16:30 ZHG Foyer 1. OG

Toward Strong Coupling of Rare-Earth Ions in High-Q Photonic Crystal Cavities on a Hybrid LNOI-TiO_2 Platform — •Tobias Feuerbach, Georgii Grechko, Christopher Ng, Roman Kolesov, and Jörg Wrachtrup — University of Stuttgart, 3rd Institute of Physics, Pfaffenwaldring 57, 70569 Stuttgart

We report progress toward integrating rare-earth ions (REIs) into high-Q photonic crystal cavities (PCCs) for achieving strong light-matter coupling. Our approach leverages a hybrid material system combining lithium niobate on insulator (LNOI), offering electro-optical tunability, with TiO_2, a spin-free host for REIs. High-Q PCCs in LNOI have been achieved, and development is underway to incorporate REI-doped TiO_2 films into the platform. This hybrid architecture offers a promising path toward scalable, tunable quantum interfaces. Recent milestones in fabrication and characterization will be presented.

THU 13.35 Thu 16:30 ZHG Foyer 1. OG

Quantum interference in a Ti:LiNbO3 waveguide device as a tool for spectral and temporal shaping — •Jonas Babai-Hemati, Kai Hong Luo, Patrick Folge, Sebastian Lengeling, Harald Herrmann, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Str. 100, 33098 Paderborn, Germany

Quantum technologies represent a promising advancement in fields such as metrology, computing, and secure data transmission. Among the various platforms available, waveguide-integrated photonic systems have emerged as a particularly promising approach for implementing these quantum operations. In these systems, two-photon quantum states form the simplest building blocks that can exhibit quantum effects like entanglement. These states can be efficiently generated through a quantum process known as parametric down-conversion (PDC) implemented in waveguide devices. However, the use of only a single PDC process offers limited flexibility in tailoring quantum properties. A new approach to extend the frame of tailorable quantum properties lies in the interference of multiple generation processes like the PDC in a so-called SU(1,1) interferometer. In this work, we present a two-PDC integrated Ti:LiNbO3 waveguide interferometer featuring a cascade of nine electro-optic polarization converters and two phase shifters. Simulations were performed to analyze the spectral and temporal correlations of the quantum states generated by such a device. These simulations were validated using both classical and quantum measurement methods.

THU 13.36 Thu 16:30 ZHG Foyer 1. OG

Deterministic Generation of Linear Photonic Cluster States with Semiconductor Quantum Dots: A Detailed Comparison of Different Schemes — •Nikolas Köcher[1], David Bauch[1], Nils Heinisch[1], and Stefan Schumacher[1,2] — [1]Department of Physics, Center for Optoelectronics and Photonics Paderborn (CeOPP) and Institute for Photonic Quantum Systems (PhoQS), Paderborn University, D-33098 Paderborn, Germany — [2]Wyant College of Optical Sciences, University of Arizona, Tucson, AZ 85721, USA

Graph and cluster states are types of multipartite entangled states with applications in quantum communication and measurement-based quantum computation. We theoretically investigate and compare different schemes for the deterministic generation of linear photonic cluster states using spins in charged semiconductor quantum dots with strong Purcell enhancement. The schemes differ in the method used for spin control and whether the emitted photonic qubits are polarization or time-bin encoded. We efficiently track the fidelity and the useable length of the cluster states by calculating the expectation values of their stabilizer generators based on photonic multi-time correlation functions $G^{(n)}(t_1, t_2, ...)$, assessing their actual state fidelity beyond the calculation of gate fidelities [1]. We find that the performance of the schemes and which scheme is optimal strongly depend on the cavity environment and the coherence time of the spin qubit.

[1] D. Bauch, N. Köcher, N. Heinisch, S. Schumacher, APL Quantum **1**, 036110 (2024).

THU 13.37 Thu 16:30 ZHG Foyer 1. OG

Stabilization of Quantum Dot to Atomic Transitions — •Hala Said[1], Esteban Gómez-López[1], Karol Winkler[2], Jonathan Jurkat[2], Moritz Meinecke[2], Tobias Huber-Loyola[2], Sven Höfling[2], and Oliver Benson[1] — [1]Institut für Physik, Humboldt-Universität zu Berlin, 12489, Berlin, Germany — [2]Technische Physik, University of Würzburg, 97074, Würzburg, Germany

Quantum dot-based single-photon sources (SPS) are promising candidates for scalable quantum networks due to their ability to generate bright, on-demand single photons with high purity [1]. Embedding quantum dots in micropillar cavities significantly enhances light extraction and improves collection efficiency, which is critical for practical quantum communication systems [2]. To enable long-distance quantum communication, interfacing these solid-state emitters with atomic systems such as cesium vapor cells is highly desirable, as atomic transitions provide stable and well-defined references for quantum memories and quantum repeater protocols [3]. In this work, we focus on tuning the emission of quantum dots to achieve resonance with the Cs D1 transition line. Our goal is to stabilize the quantum dot emission, enabling coherent interaction between single photons and atomic ensembles.

THU 13.38 Thu 16:30 ZHG Foyer 1. OG

Fabrication of shape optimized, adiabtic fiber tapers for highly efficient cavity to fiber coupling — •Pascal Frehle and Max Heimann — Humboldt-Universität zu Berlin, Institut für Physik

Fiber coupling in quantum networking is essential for establishing world wide communication links. Therefore an efficient, stable and scalable solution for coupling of light from nanostructures within integrated photonic circuit to optical fibers is needed. One of the most efficient ways to realize this chip to fiber interface is the adiabatic mode transfer from nanostructures to optical-fiber nanotapers. We present an automated setup to fabricate shape and surface roughness optimized optical-fiber nanotapers via an etching process in hydrofluoric-acid (HF), which produces tapers with high transmission efficiency and short taper lengths. We also show improved diamond sawfish cavity resonance measurement capabilites via evanescent coupling of the produced nanotapers to cavities in comparison to confocal measurements and our progress towards a permanent and stable fiber cavity interface for cryogenic temperatures.

THU 13.39 Thu 16:30 ZHG Foyer 1. OG

Towards an integrated sensor for optimized OCT with undetected photons — •Franz Roeder, René Pollmann, Viktor Quiring, Christof Eigner, Benjamin Brecht, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Straße 100, 33098 Paderborn, Germany

Quantum nonlinear interferometers, which can be constructed from cascaded parametric down-conversion (PDC) sources, are used for the realization of so-called measurements with undetected photons. These employ photons generated at non-degenerate wavelengths and allow to probe an object under test at a long wavelength, e.g., in the mid-IR, while detecting in a technically more accessible wavelength regime such as the near-IR. While many such systems rely on bulk nonlinear optics, integration is necessary for the development of practical quantum sensors.

Here, we realize a quantum nonlinear interferometer with a broadband, non-degenerate type-II PDC source based on a dispersion engineered periodically poled lithium niobate waveguide. We identify both the best interferometer configuration as well as the best operation mode for optimum performance in optical coherence tomography (OCT) with undetected photons. Our measurements show that practical OCT sensors are best realized in the so-called induced coherence configuration while employing temporal interferometry and photon counting, allowing for measurements at pump powers as low as 50 μW, orders of magnitude less than in other realizations.

THU 13.40 Thu 16:30 ZHG Foyer 1. OG

Towards fiber-integrated quantum frequency conversion for quantum networks — •Felix Rohe, Marlon Schäfer, Tobias Bauer, David Lindler, and Christoph Becher — Universität des Saarlandes, Fachrichtung Physik, Campus E2 6, 66123 Saarbrücken

Quantum frequency conversion to the low-loss telecom bands is a key enabling technology for long-range fiber-based quantum networks. While many state-of-

the-art conversion setups use free-space coupling to nonlinear waveguides, for applications outside of a controlled lab environment, devices would greatly benefit from the substitution of free-space optics in favor of fiber-based components. Here, we present the coupling of a solid-core photonic crystal fiber (PCF) to a periodically-poled lithium niobate (PPLN) waveguide. PCF are promising candidates for a fiber-integrated design because of their ability to simultaneously guide waves with a large difference in wavelength in the fundamental mode.
To evaluate the performance of this approach we down-convert photons at 619 nm to 885 nm by mixing with a strong pump field at 2062 nm in a difference frequency generation process. This provides the first stage of a two-stage, low-noise conversion scheme for photons emitted from the tin-vacancy center in diamond [1]. We show the efficiencies for simultaneous coupling of both input fields to the PPLN waveguide, as well as first results on the conversion efficiency and conversion-induced noise rates.
[1] Lindler, D. et al., Optica Quantum 2.0, paper QW4A.1

THU 13.41 Thu 16:30 ZHG Foyer 1. OG

Mode-selective low-noise up-conversion of light with an all-telecom quantum pulse gate — •Ankita Khanda, Laura Serino, Cristof Eigner, Michael Stefszky, Benjamin Brecht, and Christine Silberhorn — Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Paderborn University, Warburger Straße 100, Paderborn 33098, Germany

The quantum pulse gate (QPG) is a highly selective coherent temporal mode filter operating at a single-photon level via sum frequency generation (SFG) and group-velocity phasematching in a periodically poled lithium niobate waveguide. Coherent time-frequency filtering is the most efficient noise elimination method in the spectral-temporal domain, making the QPG an ideal candidate for detection in free-space applications, such as deep space communications, where few-photon detection and noise rejection from background light are essential. There is a strong advantage in moving operation to all-telecom wavelengths, thus allowing utilization of a higher-efficiency type 0 phasematching process, easy integration into fiber-optic networks, and reduced system complexity. However, other linear and non-linear processes impact the type 0 SFG and become sources of noise in the output signal, necessitating further feasibility studies. In this work, we implement the telecom QPG (tQPG) and study the efficiency of the SFG process, as well as investigate the associated noise effects impacting the SNR of the detectable signal. We achieved 83.4% efficiency at 1.08 mW average pump power with 4×10^{-3} noise photons/pulse, paving the way for efficient low-noise long-range detection in free space.

THU 13.42 Thu 16:30 ZHG Foyer 1. OG

Multistep Two-Copy Distillation of Squeezed States via Two-Photon Subtraction — •Stephan Grebien[1], Julian Göttsch[1], Boris Hage[2], Jaromír Fiurášek[3], and Roman Schnabel[1] — [1]Institut für Quantenphysik & Zentrum für Optische Quantentechnologien (ZOQ), , Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Institut für Physik, Universität Rostock, 18051 Rostock, Germany — [3]Department of Optics, Faculty of Science, Palacký University, 17. listopadu 12, 77900 Olomouc, Czech Republic

Squeezed states of light are a vital resource in quantum computing and quantum cryptography. The higher the amount of squeezing available the greater the quantum advantage.

The squeeze factor is mainly limited by the effective nonlinearity of the medium and optical loss. In our experiment we analyzed the multi-step distillation of weakly squeezed states of light increasing the squeeze factor from 2.4 dB to 2.8 dB and finally 3.4 dB. The first step was purely experimental and achieved by conditioning the measurement on a 2-photon subtraction event.

For the second step we simultaneously measured the squeezed and the anti-squeezed quadratures of the already distilled state and probabilistically emulated a second two-copy distillation step. This provided data as it would be measured on a 3.4-dB squeezed state. We theoretically found out that multi-step two-copy distillation allows the increase of the squeeze factor beyond the limits set by the effective nonlinearity and in the ideal case even an infinite squeeze factor.

THU 13.43 Thu 16:30 ZHG Foyer 1. OG

Characterization of squeezing using higher order correlation functions — •Vladyslav Dyachuk[1], Fabian Schlue[1], Kai Hong Luo[1], Timon Schapeler[2], Michael Stefszky[1], Tim Bartley[2], and Christine Silberhorn[1] — [1]Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS),Paderborn University, Paderborn, Germany — [2]Institute for Photonic Quantum Systems (PhoQS), Paderborn University, Paderborn, Germany

With the rise of photonic quantum computing systems, for example Gaussian Boson Samplers (GBS), the precise characterization of the input of a multimode field consisting of multiple unknown light sources becomes critical. In GBS, knowing the modal structure and the amount of squeezing are critical for determining system performance.

We will present a method to determine the modal structure of input light sources without the need for mode-resolved detectors such as homodyne detectors, by using photon number resolving detectors to measure higher order photon number correlation functions. We present recent state reconstruction results, from both simulations and experiment, and discuss the reliability of the results and the next steps towards realising a reliable squeezed state characterisation scheme using only photon number resolved measurements.

THU 13.44 Thu 16:30 ZHG Foyer 1. OG

Development of a photon-pair source for quantum repeaters — •Henning Mollenhauer[1,2], Helen Chrzanowski[3], Leon Messner[2], and Janik Wolters[1,2] — [1]DLR Berlin-Adlershof, Berlin — [2]TU Berlin — [3]HU Berlin

We are reporting on the development of a photon-pair source for signal and idler photons at 894nm and 1550nm. The underlying process is spontaneous parametric down-conversion (SPDC) inside a periodically poled KTP crystal. To achieve spectrally pure and narrow-band characteristics for signal and idler photons our ppKTP crystal is designed as a monolithic cavity [1]. Pulsed pump light at 567nm for the SPDC process is produced in sum frequency generation from the target wavelengths. For the future we plan to interface our photon source with a single-photon quantum memory [2], to build a demonstrator of a quantum repeater. [1] Mottola et al. (2020) [2] Jutisz et al. (2024)

THU 13.45 Thu 16:30 ZHG Foyer 1. OG

Towards realizing a single mode fiber wavelength division multiplexer for quantum frequency conversion — •Zoë Matti, Marlon Schäfer, Felix Rohe, David Lindler, Tobias Bauer, and Christoph Becher — Universität des Saarlandes, Fachrichtung Physik, Campus E2 6, 66123 Saarbrücken

Quantum networks using preexisting optical fiber infrastructure require photons with wavelengths in the low-loss telecom bands. As most quantum memories show optical transitions in the visible to near-infrared, quantum frequency conversion, i.e. a nonlinear difference frequency mixing process, of single photons to telecom wavelengths is regarded as a key enabling technology. Achieving near-unity internal conversion efficiencies requires a high spatial overlap of the single photon signal and the mixing wave. While devices based on free-space optics have been demonstrated, a large scale deployment would benefit greatly from a robust and compact fiber-based design. However, overlapping the single photons with the mixing wave in the fundamental mode of a nonlinear waveguide becomes particularly challenging when the interacting wavelengths differ significantly.
Here we investigate an approach for a single-mode fiber wavelength division multiplexer (WDM), combining the visible single photon and mid-infrared mixing beam into an endlessly single-mode photonic crystal fiber (PCF). We show initial results using a commercially available WDM spliced to a PCF and present simulations of the spatial mode profiles of the guided modes in the SMF28 fiber and the PCF to estimate the lowest attainable insertion loss.

THU 13.46 Thu 16:30 ZHG Foyer 1. OG

Integrated Photonic Information Processing for Quantum Networks — •Louis L. Hohmann[1,2], Jeldrik Huster[1,2], Jonas C. J. Zatsch[1,2], Tim Engling[1,2], and Stefanie Barz[1,2] — [1]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, 70569 Stuttgart, Germany — [2]Center for Integrated Quantum Science and Technology (IQST)

We present our progress in generating multipartite entangled states, a key component for photonic quantum computing. The states are generated on a silicon-on-insulator photonic quantum circuit powered by spontaneous parametric down-conversion single-photon sources. The circuit comprises tunable beam splitters and phase shifters, enabling the generation of various entangled states. The fiber-to-chip interface is realized using 3D-printed photonic wirebonds, a low-loss and high-stability interconnect between single-mode fibers and on-chip edge couplers. These novel interconnects, in combination with integrated photonic circuits, pave the way towards fully packaged photonic quantum computing devices.

THU 13.47 Thu 16:30 ZHG Foyer 1. OG

Impact of electrode noise on the qubit coherence time in a 2D ion trap — •Daniel Busch, Benjamin Bürger, Patrick Huber, Dorna Niroomand, and Christof Wunderlich — Department of Physics, School of Science and Technology, University of Siegen, 57068 Siegen, Germany

An obstacle to achieve long qubit coherence times for quantum computing are uncontrolled parameter fluctuations (noise). Its elimination and mitigation to the point that fault-tolerance can be achieved constitutes one of the main challenges on the path to scalability. In the specific case of trapped-ion quantum computers, ion traps with segmented electrode are one approach to scale up the number of qubits. However, electric field fluctuations at DC electrodes introduce yet another source of noise. We set up a cryogenic quantum demonstrator that includes a cryogenic digital-to-analog converter (DAC) combined with a switching matrix to handle this issue. Here, we present first results of evaluating proof-of-principle optical switches in a room temperature experiment using a 2D segmented ion trap that includes built-in micromagnets. We report on coherence times measured in Ramsey experiments and discuss potential remaining electric noise originating from the electrodes.

THU 13.48 Thu 16:30 ZHG Foyer 1. OG

Towards Surface-Electrode Ion Traps with Chip-Integrated Near-Field Microwave Control and Integrated Photonics — •Mohammad Masum Billah[1,2], Florian Ungerechts[1], Rodrigo Munoz[1], Janina Bätge[1], Axel Hoffmann[1,4], Giorgio Zarantonello[1,3], and Christian Ospelkaus[1,2,5] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Laboratorium für Nano- und Quantenengineering, Leibniz Universität Hannover — [3]QUDORA Technologies GmbH — [4]Institut für Hochfrequenztechnik und Funksysteme, Leibniz Universität Hannover — [5]Physikalisch-Technische Bundesanstalt

Microfabricated surface-electrode ion traps provide a scalable platform for trapped-ion quantum processors. However, as chip size increases, edge clipping of free-space lasers addressing ions closely above the chip surface becomes a concern. To address this, optical waveguides and grating couplers can be embedded within the chip structure. Further, laser-free gates with chip-integrated microwave conductors have been demonstrated. The combination of both techniques significantly increases the complexity of the trap design and microfabrication. We present an overview of our recently developed single- and multilayer trap architectures with integrated microwave conductors and outline the possible integration of optical elements into these or future devices. In particular, we investigate routing strategies for electrical and optical signal paths for high interconnect density, signal integrity, and fabrication feasibility.

THU 13.49 Thu 16:30 ZHG Foyer 1. OG

Spin-selective coherent light scattering from ion crystals — •Zyad Shehata[1], Benjamin Zenz[2], Ansgar Schaefer[2], Maurizio Verde[2], Stefan Richter[1], Joachim von Zanthier[1], and Ferdinand Schmidt-Kaler[2] — [1]Department Physik, FAU Erlangen Nürnberg — [2]QUANTUM, Institut für Physik, JGU mainz

We study spin-selective coherent light scattering from linear crystals with up to twelve 40Ca+ ions [1]. The Ca+ ions are excited on a two-photon quadrupole and dipole transition at 729 and 854 nm, respectively; in this way emission of coherent photons at 393 nm is induced such that in the far field an interference pattern of a background-free signal is recorded on a high spatiotemporal resolution camera (LINCAM). We realize spin-selective excitation from the Zeeman-split ground states S1/2, m= *1/2, of Ca+ and thus observe spin-dependent interference patterns displaying the spin textures of the ion crystals. We investigate their dynamics by measuring the temporal evolution of the spatial Fourier frequencies of the observed patterns.

[1] M. Verde et al., arXiv:2404.12513

THU 13.50 Thu 16:30 ZHG Foyer 1. OG

Two-dimensional ion trap array with integrated photnics — •Dominique Zehnder — Paul Scherrer Institute, Villigen, Switzerland

One step toward scaling ion traps for quantum technologies is to deliver the laser light from within the trap chip. Photonic integration of infrared laser light was previously demonstrated in surface electrode ion traps [Mehta2019]. Our ion trapping group at PSI, in collaboration with ETHZ, is deploying the next generation of integrated photonics ion traps combining waveguides fabricated from Al_2O_3 for ultraviolet and Si_3N_4 for infrared light. In our setup we employ a 2D array of 20 trapping zones to implement key elements of the QCCD architecture [Kielpinski]. Besides applications in quantum information processing with parallel coherent control, we envision to demonstrate clock operation using multiple atomic ensembles [Borregard, Hume / Leibrandt].

THU 13.51 Thu 16:30 ZHG Foyer 1. OG

Rack-mounted ion trap with integrated optical cavity — •Franz Krieger[1], Lara Becker[1], Jolan Costard[1], Stephan Kucera[1,2], and Jürgen Eschner[1] — [1]Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken, Germany — [2]Luxembourg Institute of Science and Technology, 4362 Belveaux, Luxembourg

Single trapped ions as quantum memories and single photons as quantum information carriers are promising building blocks of quantum networks, providing high-fidelity entanglement in controlled single-photon absorption and emission [1]. Ion-photon interfaces are thus well-suited for implementing a quantum repeater [2] that mitigates the propagation loss in direct transmission, and also for connecting quantum processors into a quantum computing network.

We are setting up a multi-segment linear Paul trap for $^{40}Ca^+$ ions with an integrated fiber cavity that realizes an interface with high photon collection and generation efficiency. We are working on two different designs, a ferrule trap and a glass trap. Both trap types are micro-structured and metal-coated to create a segmented electrode structure and are equipped with a borehole perpendicular to the trap axis to introduce the sub-mm optical cavity. In a first prototype we integrated a cavity with 220 μm length and 11 000 finesse with a trap of 190 μm electrode separation. With its compact design, the trap-cavity system including the vacuum chamber, control electronics, ablation and photo-ionization laser will be stored in a single transportable rack.

[1] E. Arenskötter, et al., npj Quantum Inf. 9, 34 (2023)
[2] M. Bergerhoff, et al., Phys. Rev. A 110, 032603 (2024)

THU 13.52 Thu 16:30 ZHG Foyer 1. OG

Combining Ion shuttling and individual Ion addressing in a segmented linear Trap — •Robin Strohmaier, Daniel Wessel, Janis Wagner, Paula Bañuls, Benjamin Zenz, Janine Hilder, Björn Lekitsch, Jonas Vogel, Ulrich Poschinger, and Ferdinand Schmidt-Kaler — Johannes-Gutenberg Universität Mainz

Quantum information platforms have seen significant progress in recent years, with trapped ions emerging as a promising candidate due to their high gate fidelities for laser-driven operations. Here, we present our latest results from a trapped $^{40}Ca^+$ experiment utilizing medium-sized ion crystals trapped in a segmented linear Paul trap. Our trap features 40 segments enabling reliable ion shuttling and a versatile reconfiguration of ion crystals, transport of single ions and crystals, split and merge and ion swap. Additionally, our setup has a single-ion addressing unit based on two crossed acousto-optical deflectors, where we encode qubits on the two Zeeman states of the $S_{1/2}$ ground state. We have demonstrated site-selective operations in linear ion chains, with a low crosstalk of less than 10^{-4} using laser-driven gates via a stimulated Raman process at 400 nm. Now, we combine qubit register configuration operations with single-ion addressing. We demonstrate arbitrary, individual single-qubit gate operations on ions in separate crystals and that entanglement between two ions in a crystal is preserved through the shuttling process. These results mark a step toward reconfigurable architectures for quantum computing eventually with 50 to 100 trapped ions.

THU 13.53 Thu 16:30 ZHG Foyer 1. OG

Towards a spin-exchange collision-based optical quantum memory in noble-gas spins — •Alexander Erl[1,2], Norman Vincenz Ewald[1,2], Andrés Medina Herrera[2], Denis Uhland[3], Wolfgang Kilian[2], Jens Voigt[2], Ilja Gerhardt[3], and Janik Wolters[1,4] — [1]DLR, Institute of Space Research, Berlin — [2]PTB, 8.2 Biosignals, Berlin — [3]LUH, Institute of Solid State Physics, Hannover — [4]TUB, Institute of Optics and Atomic Physics, Berlin

A critical limitation on current room-temperature quantum memory systems [1] is the maximum achievable storage time on the order of a few μs, which must be extended for various quantum communication applications, such as unforgeable quantum tokens for authentication. We report on our first steps towards a long-lived quantum memory with an all-optical interface based on a mixture of ^{129}Xe noble gas and ^{133}Cs alkali metal vapor, both confined in a glass cell at near room temperature. The interface relies on EIT, implemented through a Λ-scheme in the Zeeman sublevels of the long-lived hyperfine ground states of ^{133}Cs, coupled to an excited state via the D_1 line at 895 nm [2]. Spin-exchange collisions in the strong coupling regime are envisioned to transfer the stored information from the alkali vapor to the noble gas [3]. The coherence time of ^{129}Xe, which can extend up to several hours [4], offers the potential for long-term storage of quantum information in collective atomic excitations.

[1] M. Jutisz et al., Phys. Rev. Applied 23, 024045 (2025)
[2] G. Buser et al., PRX, 020349 (2022)
[3] O. Katz et al., PRA 105, 042606 (2022)
[4] C. Gemmel et al., EPJ D 57, 303-320 (2010)

THU 13.54 Thu 16:30 ZHG Foyer 1. OG

Rotational state preparation of CaOH$^+$ — •Miriam Kautzky, Brandon Furey, Zhenlin Wu, Mariano Monsalve, Andrea Turci, René Nardi, Tim Duka, and Philipp Schindler — Institut für Experimentalphysik, Universität Innsbruck, Austria

Molecules provide complex degrees of freedom not available in atoms. In particular, the quantum mechanical rotation of molecules is a promising resource for quantum technologies, and enables efficient quantum error correction (QEC) codes [1]. Preparing molecules in pure rotational states is a necessary step toward implementing such codes. For this, we aim to cool molecules into low rotational states and control them precisely with Raman interactions. We are developing an experimental setup capable of achieving rotational-state cooling and state preparation of $CaOH^+$ ions with broadband laser pulses, even outside cryogenic environments. The approach is based on driving rovibrational transitions using spectrally shaped broadband laser pulses. Shaping allows selective population transfer between rotational levels, enabling rotational cooling. It requires high spectral resolution and precise control of the laser spectrum to target only specific transitions. While rotational cooling to the ground state has been demonstrated before [2], precise control over rotational states, particularly in polyatomic molecules, remains much less explored. Successful implementation of rotational state control could enable exploration of quantum information processing and QEC with trapped molecular ions.

[1] B. Furey et al., Quantum 8, 1578 (2024)
[2] T. Schneider et al., Nature Phys 6, 275 (2010)

THU 13.55 Thu 16:30 ZHG Foyer 1. OG

Widefield fluorescence microscopy of color centers in diamond — •Caius Niemann[1], Leonie Eggers[1,2], Konstantin Beck[1], Nick Brinkmann[1,2], Sunil Kumar Mahato[1,2], Donika Imeri[1,2], Elaheh Bakhshaei Ghoroghaghaei[1,2], Rikhav Shah[1], and Ralf Riedinger[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany

Color centers in diamond combined, with nanophotonic structures, are a promising platform for quantum communication applications. Various elements are being studied as building blocks of these quantum memories, but Silicon and Nickel are especially promising due to their insensitivity to noise.

We demonstrate a custom widefield microscope for imaging, and possibly spectral analysis, of silicon-vacancy (SiV) and nickel-vacancy (NiV) centers in diamond using photoluminescent excitation. The device is composed of readily available parts only and uses a cooled camera to achieve comparable results to high-end confocal microscopes. This is a simpler and low-cost solution compared to pre-built confocal solutions and enables in-house characterisation of implanted diamond samples.

THU 13.56 Thu 16:30 ZHG Foyer 1. OG

Coherent Control of a Coupled Three-Electron Spin Quantum Register in Diamond — •Fabian Müller[1], Samuele Brambilla[1], Timo Joas[1], Philipp J. Vetter[1], Tobias Spohn[1], Matthias M. Müller[2], and Fedor Jelezko[1] — [1]Institute for Quantum Optics, Ulm University, 89081 Ulm, Germany — [2]Peter Grünberg Institute-Quantum Control (PGI-8), Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany

High-fidelity gates between coupled electron spins at room temperature were recently demonstrated using molecularly implanted nitrogen-vacancy (NV) centers in diamond [1]. In addition to NV centers, the implantation can also create P1 defects, offering further scalability for the system.

In this work, we demonstrate the initialization, control and readout of a single P1 defect and its nuclear spin via a coupled NV-NV pair. DEER spectroscopy allows us to selectively address the P1 center's eigenstates through the nearby NV center. Polarization and readout of the P1 center's electron and nuclear spin are achieved using the PulsePol sequence. Our work expands the scalability of room-temperature electron spin registers in diamond.

[1] T. Joas et al. Physical Review X 15.2 (2025) 021069.

THU 13.57 Thu 16:30 ZHG Foyer 1. OG

Addressing Fabrication Challenges in Photonic Crystal Cavities for Diamond Color Centers — •Lucca Valerius[1,2], Marco E. Stucki[1,2], Tommaso Pregnolato[1,2], and Tim Schröder[1,2] — [1]Ferdinand-Braun-Institut (FBH), Gustav-Kirchhoff Str. 4, Berlin, Germany — [2]Humboldt-Universität zu Berlin, Newtonstr. 15, Berlin, Germany

Color centers in diamond are a promising platform for quantum communication, providing a spin-photon interface suitable for quantum networks. Embedding these centers in photonic crystal cavities (PhCCs) enhances emission into the zero-phonon line via the Purcell effect, enabling the efficient generation of photon entanglement. However, fabricating diamond-based PhCCs using reactive ion etching remains a major challenge. With feature sizes often below 100 nm, imperfections such as rough sidewalls, micromasking, and etch variability can significantly alter performance and yield. A critical factor is the hard mask material used during oxygen plasma etching, which strongly influences pattern transfer fidelity. In this work, we present an overview of our fabrication approach and development of new methods, including a systematic analysis of common sources of uncertainty and loss in diamond nanofabrication. Our aim is to identify and mitigate key challenges in order to advance reliable, high-performance spin-photon interfaces. By refining fabrication techniques, we contribute to improving the scalability and robustness of diamond-based quantum photonic devices.

THU 13.58 Thu 16:30 ZHG Foyer 1. OG

Generation of Highly Indistinguishable Single Photons from Tin-Vacancy Centers in Diamond — •Dennis Herrmann, Robert Morsch, and Christoph Becher — Fachrichtung 7.2, Universität des Saarlandes, Campus E2.6, 66123 Saarbrücken, Germany

The tin-vacancy (SnV) center in diamond is a promising platform for photonic quantum technologies, combining bright, spectrally stable single-photon emission with optically accessible spin states exhibiting coherence times of up to 10 ms under dynamical decoupling [1,2,3]. Here, we demonstrate two photon quantum interference of highly indistinguishable single photons consecutively emitted into a fine structure transition of the SnV center. Using 180 ps optical π-pulses with high extinction ratio and a cross-polarization excitation/detection scheme, we achieve polarization-based suppression of resonant laser light by more than 5×10^6. We observe raw Hong-Ou-Mandel visibilities exceeding 95 % at photon rates of up to 3000 Hz and single-photon purities of $g^2(0) < 0.02$. These results represent a significant step towards the realization of a spin-photon interface, a crucial component for quantum repeaters, scalable quantum networks and the generation of cluster states.

[1] New J. Phys. 22, 013048 (2020)
[2] npj Quantum Inf 8, 45(2022)
[3] Phys. Rev. X 14, 031036 (2024)

THU 13.59 Thu 16:30 ZHG Foyer 1. OG

Generation of Coherent Laser Fields for Coherent Population Trapping on Spin-Levels of the Tin-Vacancy Center in Diamond — •Linus Ehre, Robert Morsch, Dennis Herrmann, and Christoph Becher — Fachrichtung Physik, Universität des Saarlandes, Campus E2.6, D-66123, Germany

The negatively charged Tin-Vacancy color center in diamond (SnV^-) is a promising candidate for solid-state quantum network nodes since it possesses optically accessible spin transitions and exhibits coherence times of up to T_2 = 10ms [1] under dynamical decoupling.

All optical coherent control of the SnV^- center's spin state requires the use of two laser fields with sufficient phase coherence. Here, we show the generation of coherent sidebands from a single laser source by means of a free-space electro-optic phase modulator (EOPM). With our approach we demonstrate a coherent population trapping (CPT) scheme on the Zeeman-split spin states of a single SnV^- center at temperatures of T = 1.7K.

Successful observation of a characteristic dark resonance confirms sufficient phase correlation between the two laser fields and yields a lower bound on the spin dephasing time of $T_2^* \geq 1.1(7)\mu$s. Furthermore we develop simulations of the coherent population dynamics as well as of the photon emission process, hence, supporting the development of SnV^- centers as reliable quantum network nodes.

[1] Karapatzkis, I. et. al.; Phys. Rev. X 14, 031036 (2024)

THU 13.60 Thu 16:30 ZHG Foyer 1. OG

Interfacing Tin-Vacancy Centers in diamond and $^{40}Ca^+$ Ions via Quantum Frequency Conversion — •David Lindler, Tobias Bauer, Pascal Baumgart, Max Bergerhoff, Marlon Schäfer, Jürgen Eschner, and Christoph Becher — Universität des Saarlandes, FR Physik, Campus E2.6, 66123 Saarbrücken

Quantum frequency conversion is an essential technique for integrating different quantum memories into a heterogeneous quantum network. It addresses the issue of high loss in optical fibers at visible and near-infrared wavelengths by converting the emitted photons from the various memories to a central wavelength within the low-loss telecom band. This process also serves to eliminate the frequency distinguishability between photons, enabling the distribution of entanglement via a Bell state measurement on photons originating from different quantum memories.

We present a combination of two quantum frequency converters based on difference frequency generation in PPLN waveguides, which convert photons from two quantum memories, such as Tin-Vacancy centers in diamond at 619 nm and $^{40}Ca^+$ ions at 854 nm, to the telecom C-band. To minimize frequency mismatch, we employ a locking scheme that distributes a common frequency reference, generated by a frequency comb, to all lasers involved in the conversion process. We will present initial results on the conversion efficiency, conversion-induced noise count rates and the frequency stabilization of the lasers.

THU 13.61 Thu 16:30 ZHG Foyer 1. OG

Magnetic Field Dependent Spectroscopic Investigation of a ^{13}C Nuclear Spin Strongly Coupled to a SnV Center — •Mohamed Elshorbagy[1], Jeremias Resch[1], Ioannis Karapatzakis[1], Philipp Fuchs[2], Marcel Schrodin[1], Michael Kieschnick[3], Julia Heupel[4], Luis Kussi[1], Christoph Sürgers[1], Cyril Popov[4], Jan Meijer[3], Christoph Becher[2], Wolfgang Wernsdorfer[1], and David Hunger[1] — [1]Karlsruher Institut für Technologie — [2]Universität des Saarlands — [3]Universität Leipzig — [4]Universität Kassel

The implementation of quantum network protocols relies on entanglement swapping, where a communication qubit acquires a quantum state via a photonic link and subsequently transfers it to a memory qubit. This enables sequential state reception and two-qubit gate operations. Group-IV color centers in diamond, such as tin-vacancy (SnV) centers, coupled to nearby ^{13}C nuclear spins, are promising candidates for such applications. Their strong hyperfine interaction allows for efficient microwave control of the nuclear spin state. However, the trade-off between electron spin lifetime, Rabi frequency, and electro-nuclear gate fidelity requires a careful choice of magnetic fields for initialization and readout protocols. In this work, we investigate the variation of the magnetic field orientation to optimize the electron and nuclear spin Rabi frequencies and branching ratios, thereby improving the single-shot readout fidelity of a low-strain SnV and enhancing the robustness of quantum memory operations.

THU 13.62 Thu 16:30 ZHG Foyer 1. OG

Towards Efficient Spin Control of Tin-Vacancy Color Centers in Diamond for Quantum Networks — •Jonas Wollenberg[1], Keisuke Oshimi[1], Charlotta Gurr[1], Alok Gokhale[1], Cem Güney Torun[1], Mohamed Belhassen[1], Natalia Kemf[2], Matthias Matalla[2], Ralph-Stefan Unger[2], Ina Ostermay[2], Alexander Külberg[2], Andreas Thies[2], Tommaso Pregnolato[1,2], Gregor Pieplow[1], and Tim Schröder[1,2] — [1]Department of Physics, Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Germany — [2]Ferdinand-Braun-Institut (FBH), Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany

Tin-vacancy (SnV) color centers in diamond are a promising platform for realizing quantum information networks. Crucial to their performance as photonic quantum memories are gate fidelities that can be realized with the spin qubits embedded in their electronic structure. Direct microwave driving of the spin transitions can be used to achieve fidelities over 99%. This requires external magnetic DC fields as well as sufficient crystal strain which imposes additional constraints. However, a recent model has shown that there should exist optimal orientations of the magnetic AC and DC field independent of the strain environment. In this work, we investigate experimentally how the alignment of the magnetic AC and DC field can enable efficient spin control in low strain environments. For this, we optically address single SnVs confined in nanostructures using a confocal fluorescence microscope. Using a vector magnet and a variable MW antenna design, we realize different AC and DC field configurations.

THU 13.63 Thu 16:30 ZHG Foyer 1. OG

Deep Learning Strategies for Stabilizing NV Center Emission Spectra — •Clara Zoé Baenz[1], Gregor Pieplow[1], Kilian Unterguggenberger[1], Laura Orphal-Kobin[1], and Tim Schröder[1,2] — [1]Humboldt-Universität zu Berlin, Berlin, Germany — [2]Ferdinand-Braun-Institut, Berlin, Germany

Understanding and predicting spectral diffusion is essential for stabilizing quantum emitters in photonic networks. We explore the use of machine learning, specifically recurrent neural networks with Long Short-Term Memory (LSTM) architecture, to model and forecast spectral fluctuations in nitrogen vacancies in diamond. By training LSTM networks on time-series data of the optical transition frequency, we aim to perform corrections that can be predicted to stabilize the zero-phonon line of a quantum emitter. We present a preliminary test of our model with negatively charged nitrogen vacancies in nano pillars.

THU 13.64 Thu 16:30 ZHG Foyer 1. OG

SiV color center in diamond as Quantum Network Nodes — •Leonie Eggers[1,2], Donika Imeri[1,2], Konstantin Beck[1], Nick Brinkmann[1,2], Sunil Kumar Mahato[1,2], Caius Niemann[1], Rikhav Shah[1], and Ralf Riedinger[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg — [2]The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany

Silicon vacancy color center (SiV) in diamond combined with nanophotonic cavities are a promising platform for network-based quantum solid-state processors, due to their optically addressable spin transition and high noise tolerance. Paired with a fiber network this can enable efficient long-distance quantum communication and a modular approach to building larger quantum processors. We present our experimental platform and first results.

THU 13.65 Thu 16:30 ZHG Foyer 1. OG

Development of spin-impurity controlled nanodiamonds for quantum sensing — •Keisuke Oshimi[1,2], Hitoshi Ishiwata[3], Hiromu Nakashima[1], Sara Mandić[1], Hina Kobayashi[1], Minori Teramoto[4], Hirokazu Tsuji[4], Yoshiki Nishibayashi[4], Yutaka Shikano[5,6], Toshu An[7], and Masazumi Fujiwara[1] — [1]Okayama University, Okayama, Japan — [2]Humboldt-Univeritätt zu Berlin, Berlin, Germany — [3]The National Institutes for Quantum Science and Technology, Chiba, Japan — [4]Sumitomo Electric Industries, Ltd., Hyogo, Japan — [5]University of Tsukuba, Ibaraki, Japan — [6]Chapman University, California, United States — [7]Japan Advanced Institute of Science and Technology, Ishikawa, Japan

The nitrogen vacancy (NV) center in fluorescent nanodiamonds (FNDs) is a promising quantum sensor for detecting physical parameters at the nanoscale via spin-based measurements. In quantum sensing, achieving long spin relaxation times in FNDs is essential to improve measurement sensitivity. Here, we present bright FNDs containing 0.6-1.3-ppm negatively charged NV centers by enriching spin-less ^{12}C-carbon isotopes and reducing substitutional nitrogen spin impurities. They show average spin-relaxation times of $T_1 = 0.68$ ms ($T_1^{max} = 1.6$ ms) and $T_2 = 3.2\,\mu$s ($T_2^{max} = 5.4\,\mu$s), which are 5- and 11-fold longer than conventional FNDs, respectively. These enhanced spin properties enable shot-noise-limited temperature measurements with a sensitivity of approximately 0.28 K/$\sqrt{\text{Hz}}$. As a demonstration of biological application, we performed T_1 and T_2 measurements in live cells.

THU 13.66 Thu 16:30 ZHG Foyer 1. OG

Coherent optical spectroscopy on ensembles of tin-vacancy color centers in diamond — •Fabian Voltz, Anna Fuchs, Dennis Herrmann, and Christoph Becher — Universität des Saarlandes, Saarbrücken 66123, Germany

Single negatively charged group IV-vacancy (G4V) color centers in diamond are among the leading candidates for qubit systems in quantum communication due to their long spin coherence times and narrow optical emission lines. Whereas mostly single G4V centers are investigated as qubit systems, also dense ensembles show promising properties, e.g. ensembles of silicon-vacancy (SiV^-) centers revealing strong light-matter interaction [1] and enabling applications such as Raman-based quantum memories, single-photon nonlinearities, and quantum sensing. As the tin-vacancy (SnV^-) center exhibits longer spin coherence times at elevated temperatures (~ 2 K) [2], we here strive to combine strong light-matter interaction in ensembles with longer spin coherence times. As a first step we investigate the spin coherence times of ensembles of SnV^- centers by coherent optical spectroscopy such as spectral hole burning (SHB) and coherent population trapping (CPT).

We will highlight our recent results on SnV^- ensembles and evaluate their suitability for quantum applications based on these findings.

[1] Weinzetl et al., Phys. Rev. Lett. 122, 063601 (2019)
[2] Görlitz et al., npj Quantum Inf 8, 45 (2022)

THU 13.67 Thu 16:30 ZHG Foyer 1. OG

Towards wide-field vector magnetometry — •Tofianme Sorgwe[1], Florian Sledz[1], Mario Agio[1,2], and Assegid Flatae[1] — [1]Laboratory of Nano-Optics, University of Siegen, 57072 Siegen, Germany — [2]National Institute of Optics (INO), National Research Council (CNR), 50019 Sesto Fiorentino, Italy

In recent time, a development of polarimetric vector magnetometry based on nitrogen-vacancy color centers in diamond without the need for an external bias field has been demonstrated [1]. However, this approach has so far been conducted on a localized area of the sample. By employing a camera-based detection system in conjunction with broad-field illumination, this method is currently extended to generate spatially resolved maps of magnetic field across a wider sample area with a sensitivity down to μT.

[1] P. Reuschel et al., Adv. Quantum Technol., 5, 2200077 (2022).

THU 13.68 Thu 16:30 ZHG Foyer 1. OG

Towards an all-optical magnetic field quantum sensor based on an ensemble of Silicon-vacancy color centers — •Anna Fuchs and Christoph Becher — Universität des Saarlandes, Saarbrücken 66123, Germany

Ensembles of SiV^- centers in diamond exhibit strong coherent light-matter interactions [1], enabling applications such as Raman-based optical quantum memories, the realization of single-photon nonlinearities and quantum sensors. In this work, we focus on a narrow spectral feature observed in spectral hole burning (SHB) measurements on an ensemble of SiV^- centers – a dip with a linewidth of only a few MHz. This sharp resonance is attributed to coherent population oscillations (CPO) and holds significant promise for the development of magnetic field quantum sensors based on SiV^- ensembles.

We experimentally investigate the response of this narrow CPO resonance to variations of the external magnetic field. In parallel, we perform simulations to quantify its magnetic field sensitivity theoretically. Based on our combined study, we evaluate the suitability of the CPO resonance as a sensitive, all-optical probe in diamond-based magnetic field quantum sensors.

[1] Weinzetl et al., Phys. Rev. Lett. 122, 063601 (2019)

THU 13.69 Thu 16:30 ZHG Foyer 1. OG

Defect Centers in Hexagonal Boron Nitride for Single-Photon Emitters — •Marcel Buch[1], Jan Böhmer[2], Annkathrin Köhler[2], Carsten Ronning[2], and Claudia Rödl[1] — [1]Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Institut für Festkörperphysik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Single photons constitute an indispensable resource for emerging quantum technologies: They serve as qubits in quantum computing architectures, enable secure communication via quantum key distribution, and facilitate unprecedented sensitivity in quantum sensing. A central challenge in deploying these applications is the realization of stable, room-temperature single-photon sources with narrow emission linewidths and high photostability. Defects in hexagonal boron nitride (h-BN), a van-der-Waals-bonded layered semiconductor, have recently attracted significant attention in this respect due to their demonstrated single-photon emission at ambient conditions.

We use *ab-initio* simulations in the framework of density-functional theory and many-body perturbation theory to characterize and predict structural, electronic, and optical properties of intrinsic point defects in h-BN, such as vacancies and antisites, as well as extrinsic defects, that are, for instance, due to Ga irradition. We compare our calculations to luminescence data obtained for h-BN flakes whose emission properties are modified by irradiation with focused electron and ion beams.

THU 13.70 Thu 16:30 ZHG Foyer 1. OG

Towards Controlling Nuclear Spin Ensembles in Diamond using a 3D-Printed Modular Experiment Platform — Glen Neiteler[1], •Jonas Homrighausen[1], Dennis Stiegekötter[2], David Ahlmer[2], Marina Peters[1,3], Peter Glösekötter[2], and Markus Gregor[1] — [1]Department of Engineering Physics, FH Münster, 48565 Steinfurt, Germany — [2]Department of Electrical Engineering and Computer Science, FH Münster, 48565 Steinfurt, Germany — [3]Experimentalphysik, Universität des Saarlandes, 66123 Saarbrücken, Germany

With quantum physics being more and more a part of our daily lives, there is a high demand of bringing its concepts and fundamentals to the public. We are using a open source and 3D-printed experiment platform [1] to enable hands-on quantum experiment kits like BB84 [2], quantum eraser [2], interferometers [3] and quantum sensing [4].

Here, we present our current progress towards a new kit controlling nitrogen-14 spin ensembles in bulk diamond, mediated by the NV electron spin. By tuning the system into the excited state level anticrossing (ESLAC) regime, the nuclear spin can be optically polarized. Coherent nuclear spin control is enabled by RF signals. This experiment builds on our existing kit of coherent control of the NVs electron spin and demonstrates both the electron-nuclear spin interaction and the distinct spin dynamics of nuclear spins compared to electron spins.

[1] Diederich, B. *et al. Nat. Commun.* **11**, 5979 (2020)
[2] www.o3q.de
[3] N. Haverkamp *et al. Phys. Educ.* **57**, 25019 (2022)
[4] J.Stegemann, *et al. Eur. J. Phys.* **44**, 35402 (2023)

THU 13.71 Thu 16:30 ZHG Foyer 1. OG

High resolution event time tagger with outstanding timing precision, user selectable trigger methods, and flexible interfacing — Florian Weigert, Tino Röhlicke, Hans-Jürgen Rahn, Nicolai Adelhöfer, Torsten Krause, •Torsten Langer, and Michael Wahl — PicoQuant GmbH, Berlin, Germany

The presented FPGA-based device Time-Correlated Single Photon Counting (TCSPC) and time tagging offers a digital time resolution of 1 ps, a timing uncertainty of 2 ps rms and a sub-nanosecond dead time, with multiple input channels. Flexible trigger methods, including a constant fraction discriminator (CFD), enable adaptation to different detector types such as SNSPDs. A high-bandwidth external FPGA interface allows pre-processing of time tags, while white rabbit synchronization provides precise synchronization over long distances. Control is via a user-friendly GUI or a Python API that supports real-time visualization and data analysis. With low jitter, high channel count rates and precise synchronization, the device is an ideal building block for applications in optical quantum research like characterization of non-classical light emitters or long-distance quantum key distribution.

THU 13.72 Thu 16:30 ZHG Foyer 1. OG

Quantum telescopes: imaging beyond classical limits — •Elaheh Bakhshaei ghoroghaghaei[1,2], Rikhav Shah[1], Donika Imeri[1,2], Nick Brinkmann[1,2], Leonie Eggers[1,2], Sunil Kumar mahato[1,2], Konstantin Beck[1,2], Caius Niemann[1], Lasse Irrgang[1], and Ralf Riedinger[1] — [1]University of Hamburg,Department of Physics Luruper Chaussee 149 22671 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging

A novel Distributed Quantum Telescope Array (DQTA)is designed to revolutionize atmospheric sensing and quantum network performance. By harnessing advanced quantum optical techniques such as quantum interferometry, and entangled photon detection the DQTA aims to achieve real-time, high-resolution monitoring of atmospheric fluctuations. These measurements are critical for enhancing the fidelity and stability of quantum communication links established via Silicon Vacancy (SiV) centers in diamond, which serve as robust quantum memory and processing nodes. Through the synchronized operation of multiple quantum telescopes, the system will generate volumetric atmospheric data to enable adaptive feedback control for quantum channels. This integration of quantum sensing with quantum communication marks a significant step toward scalable, resilient quantum networks, supporting future applications in secure communications, astronomical imaging, and the global quantum internet.

THU 13.73 Thu 16:30 ZHG Foyer 1. OG

A Quantum Telescope: Quantum memory assisted optical-interferometric astronomy — •Rikhav Shah[1], Donika Imeri[1,2], Elaheh Bakhshaei Ghoroghaghaei[1], and Ralf Riedinger[1,2] — [1]Universität Hamburg — [2]Hamburg Centre for Ultrafast Imaging (CUI)

High-resolution astronomical imaging with radio frequency and microwave interferometry has been well established, with resolutions of $\mathcal{O}(100)$ μas. Extending this intricate methodology to the optical and near-infrared regimes offers the potential for enhanced resolution, enabling deeper surveys of exoplanets and galaxy disks. This transition, introduces considerable experimental challenges, notably the delay line compensation between telescopes, which constrains classical interferometry. However, this can be subverted by employing a long-lived quantum memory state. This novel quantum-assisted boost to interferometry describes a new paradigm for astronomical imaging, helping realize unparalleled resolutions. Such a quantum memory state and testbed telescope scheme, employing Silicon Vacancy defects in diamond (SiVs), is discussed here. These are optically active point like defects which show strong photon coupling and long coherence times $\mathcal{O}(100)$ μs in cryogenic environments. The promising utility of SiVs for optical telescopes, and the experimental setup being built to operate the SiVs is described.

THU 13.74 Thu 16:30 ZHG Foyer 1. OG

Resonator enhanced NIR-MIR correlations for cancer cell detection — Roman Schnabel, Axel Schönbeck, Jan Südbeck, and •Rene Reichow — University of Hamburg, Hamburg, Germany

Using quantum correlations between pairs of photons allows to measure systems with a higher precision than non-correlated light would allow.

This work implements a ring resonator to produce entangled near-infrared (NIR) and mid-infrared (MIR) photons in a SU(1,1) interferometer for the QUANCER collaboration. The MIR photons are then used to interrogate biological samples for cancer cells inside the interferometer. Through the entanglement, however, the attained signal is measured in the NIR spectrum. This allows the use of more efficient detectors, increasing the SNR of the attained result.

Beyond the detection of cancer cells the setup provides a platform for other spectroscopic analyses using undetected photons.

THU 13.75 Thu 16:30 ZHG Foyer 1. OG

Fast Mid-IR Spectroscopy with Cavity Enhanced SPDC source — •Atta ur Rehman Sherwani[1], Helen Chrzanowski[1], Felix Mann[1], Emma Pearce[4], Fabian Wendt[3], and Sven Ramelow[1,2] — [1]Faculty of Mathematics and Natural Sciences, Humböldt-Universität zu Berlin, Germany — [2]Ferdinand-Braun-Institut GmbH, Leibniz-Institut für Höchstfrequenztechnik, Berlin, Germany — [3]Fraunhofer-Institut für Lasertechnik ILT, Aachen, Germany — [4]School of Physics and Astronomy, University of Glasgow, Scotland

Microplastics, typically between 1 and 10 um in size, are persistent pollutants that pose significant environmental and health risks due to their resistance to degradation and biological accumulation. Conventional detection techniques, such as Fourier-Transform Infrared (FTIR) and Raman spectroscopy, analyse vibrational absorption spectra but face limitations when identifying micro-scale particles, including high costs, slow acquisition, and complex sample preparation. This work explores an alternative way to mid-infrared spectroscopy by using undetected photons generated via spontaneous parametric down-conversion (SPDC) in a monolithic cavity of ppKTP. One photon probes the sample in the mid-infrared, while its entangled partner is detected in the visible range using silicon detectors, eliminating the need for expensive mid-infrared sensors. The system is designed to target specific absorption bands characteristic of plastics. This technique holds strong potential as a compact, cost-effective, and rapid alternative for microplastic detection in environmental and biological monitoring applications.

THU 13.76 Thu 16:30 ZHG Foyer 1. OG

Cavity enhanced characterisation of perovskite quantum dots — •Svenja Müller[1], David Hunger[1], Maksym Kovalenko[2], Gabriele Raino[2], and Amrutha Rajan[2] — [1]Karlsruher Institut für Technologie, Physikalisches Institut, Karlsruhe, Germany — [2]ETH Zurich, Department of Chemistry and Applied Biosciences, Zurich, Switzerland

Characterizing and controlling nanoobjects optically is challenging due to their weak interaction with light. The interaction between matter and light can be amplified, by placing a particle in an optical micro-resonator, due to the Purcell effect. Interfacing a bright material like Perovskite Quantum Dots with an optical cavity gives the possibility to study a highly coherent emitter of single photons. Perovskites exhibit interesting characteristics like a narrow emission line with and high quantum yield. A possible future application is the generation of indistinguishable photons at room temperature, which can later be used in experiments on quantum networks.

THU 13.77 Thu 16:30 ZHG Foyer 1. OG

Coherent scattering optomechanics - probing interaction strength — •Erik Bus — Institute of Scientific Instruments

Technological advances have made it possible to link quantum optics to atomic physics, while also enabling the study of macroscopic objects (such as nanoparticles) on a larger scale. One platform for realising macroscopic quantum states or non-classical dynamics is levitated optomechanics. In this parametric study, we analyse our current experimental setup to enhance interaction strength. We also discuss potentially feasible experiments and possible modifications to the setup.

THU 13.78 Thu 16:30 ZHG Foyer 1. OG

Calibrating Photodiodes using Quantum Metrology — •Leif Albers, Jan-Malte Michaelsen, and Roman Schnabel — Institut für Quantenphysik und Zentrum für Optische Quantentechnologien Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Quantum sensing and optical quantum computing require highly efficient and well-calibrated photodiodes and balanced homodyne detectors. We further develop our quantum metrology technique for calibrating photodiodes using squeezed light [1]. It fundamentally relies on the Heisenberg uncertainty relation, eliminating the need for calibrated spectral references or cryogenic radiometers. Using squeezed states with a moderately high squeeze factor of 10 (10 dB), we significantly reduce experimental requirements compared to previous work with 15 dB of squeezing [1], while enabling direct, in situ measurements of quantum efficiency. We demonstrate our method by calibrating commercial photodiodes for 1550 nm with an uncertainty of ± 0.4 %.

[1] H. Vahlbruch et al., Phys. Rev. Lett. 117, 110801 (2016)

THU 13.79 Thu 16:30 ZHG Foyer 1. OG

Observation of squeezed light in the 2-um range in the signal band of future gravitational wave observatories — Julian Gurs, •Nils Sültmann, and Roman Schnabel — University of Hamburg, Hamburg, Germany

Next generation of squeezed-light-enhanced gravitational wave (GW) observatories could achieve higher sensitivities by reducing the thermal noise of the suspended mirrors, which involves shifting the wavelength into the 2-um range [1,2]. Photodiodes made of extended InGaAs are available for this wavelength regime, but their quantum efficiencies in the low frequency signal band of GW observatories is strongly limited by photo diode dark noise [3,4]. Here we present the successful extension of 2128-nm-squeezed-light measurements [4] into the signal band of a few ten hertz of typical GWs.

The squeeze factor achieved is limited by the photodiode*s quantum efficiency. Our results show that photodiodes with higher quantum efficiency must be developed for wavelengths in the 2*m range so that squeeze factors of *10dB become possible.

[1] A cryogenic silicon interferometer for gravitational-wave detection by R. X. Adhikari (10.1088/1361-6382/ab9143)
[2] Silicon-Based Optical Mirror Coatings for Ultrahigh Precision Metrology and Sensing by J. Steinlechner (10.1103/PhysRevLett.120.263602)
[3] Squeezed vacuum phase control at 2 μm by M. J. Yap (10.1364/OL.44.005386)

THU 13.80 Thu 16:30 ZHG Foyer 1. OG

Gauging the ground-state photon content of the Quantum Rabi model — •Arka Dutta, Daniel Braak, and Marcus Kollar — Theoretische Physik III, University of Augsburg

The quantum Rabi model (QRM) features the simplest type of coupling between a single cavity light mode and an atomic electron. It is integrable if the electronic degree of freedom is truncated to just two states [1]. The derivation of the effective Hamiltonian leads to different forms depending on the chosen gauge [2]. In the dipole gauge, the ground state of the QRM exhibits non-zero photon number in contrast to its weak coupling approximation, the Jaynes-Cummings model. We compute the exact photon content for all eigenstates in an arbitrary gauge and obtain a gauge for which the ground state contains a minimal number of photons. Conversely the ground state photon content determines the corresponding gauge of the Rabi model.

[1] D. Braak, Phys. Rev. Lett. 107, 100401 (2011).
[2] O. Di Stefano et al., Nat. Phys. 15, 803 (2019).

THU 13.81 Thu 16:30 ZHG Foyer 1. OG

Equivalence between the second order steady state for the spin-boson model and its quantum mean force Gibbs state — Prem Kumar, •Athulya K.P., and Sibasish Ghosh — Optics and Quantum Information Group, The Institute of Mathematical Sciences, C.I.T. Campus, Taramani, Chennai 600113, India

When the coupling of a quantum system to its environment is nonnegligible, its steady state is known to deviate from the textbook Gibbs state. The Bloch-Redfield quantum master equation, one of the most widely adopted equations for solving the open quantum dynamics, cannot predict all the deviations of the steady state of a quantum system from the Gibbs state. In this paper, for a generic spin-boson model, we use a higher-order quantum master equation (in system-environment coupling strength) to analytically calculate all the deviations of the steady state of the quantum system up to second order in coupling strength. We also show that this steady state is exactly identical to the corresponding generalized Gibbs state, the so-called quantum mean force Gibbs state, at arbitrary temperature. All these calculations are highly general, making them immediately applicable to a wide class of systems well modeled by the spin-Boson model, spanning a diverse range of topics, from nanomaterials to various condensed-phase processes, and quantum computing (e.g., environment-induced corrections to the steady state of a superconducting qubit). As an example, we use our results to study the dynamics and the steady state of a solid-state double-quantum-dot system under physically relevant choices of parameters.

THU 13.82 Thu 16:30 ZHG Foyer 1. OG

Design and optimization of bimodal cavities coupled to multi-level quantum systems — •Oscar Camacho Ibarra, Jan Gabriel Hartel, and Klaus D. Jöns — Paderborn University, Paderborn, Germany

Photonic integrated cavities are essential building blocks for qubit-controlled switches, routers, and gates in quantum networks and quantum information processing. These devices rely on the integration of multi-level quantum systems coupled to multiple photonic modes inside a cavity. Our present work introduces a systematic workflow for the design of bimodal cavities by employing one-dimensional crossed photonic crystal nanobeam cavities with non-zero cavity lengths enabling quantum emitter integration. By optimizing three key parameters*the periodicity, a single feature size of the hole shape, and the central cavity length*we establish a robust methodology for designing crossed nanobeam cavities with quality factors up to the order of 105. Our approach supports configurations with either matching or mismatched resonance frequencies, offering flexibility for diverse on-chip photonic quantum applications.

THU 13.83 Thu 16:30 ZHG Foyer 1. OG

Two-color resonant excitation to study the Auger effect in a single photon emitter — •Nico Schwarz[1], Fabio Rimek[1], Hendrik Mannel[1], Marcel Zöllner[1], Britta Maib[1], Arne Ludwig[2], Andreas D. Wieck[2], Axel Lorke[1], and Martin Geller[1] — [1]Faculty of Physics and CENIDE, University Duisburg-Essen, Germany — [2]Chair of Applied Solid State Physics, Ruhr-University Bochum, Germany

In solid state physics, the quantum dot (QD) as a single photon emitter is an ideal system to study quantum phenomena like the Auger effect in a confined nanostructure. We used two-color, time resolved resonance fluorescence spectroscopy with a high spectral resolution to record the charge carrier dynamics in a single quantum dot and differentiate between the different recombination paths: Auger, spin-flip and spin-flip Raman recombination [1]. In high-photon-yield, low-dephasing single-photon emitters, the Auger effect should be supressed, because it is an electron-electron scattering effect leading to a non-radiative recombination of, e.g., the charged exciton [2]. We observe an unexpected behaviour of the Auger recombination rate, which shows an oscillatory behaviour up to 4 Tesla, before decreasing by a factor of approx. 3 in fields up to 8 Tesla. For the spin-flip and spin-flip-Raman recombination rates we observe a power dependency for lower magnetic fields around 1 Tesla. These new findings may be the starting point for further theoretical and experimental studies to unterstand or even supress this scattering effect.

[1] H. Mannel et al., JAP **134**, 154304 (2023).
[2] P. Lochner et al., Nano Lett. **20**, 1631-1636 (2020).

THU 13.84 Thu 16:30 ZHG Foyer 1. OG

Optimization of etching processes for quantum well structures to enhance IR emission — •Daniel Janzen[1], Peter Zajac[1], Sascha R. Valentin[2], Arne Ludwig[1], and Andreas D. Wieck[1] — [1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstr. 150, 44801 Bochum — [2]Gesellschaft für Gerätebau mbH, Klönnestr. 99, 44143 Dortmund

The precise control of etching processes is crucial for the properties of quantum well structures, especially in terms of IR emitter efficiency. This study examines how different etching techniques affect surface quality, defect formation, and electrical properties of the epitaxially grown GaSb layers. A critical aspect is the formation of oxides and metallic antimony, which can lead to leakage currents and short circuits. Through Atomic Force Microscopy (AFM) and Fourier Transform Infrared Spectroscopy (FTIR), the influence of etching parameters on optical properties are investigated. Reducing defect states and optimizing material passivation could contribute to the long-term improvement of emission efficiency. This research bridges materials science and semiconductor physics by discussing strategies to optimize surface states for IR emitters. The findings are relevant not only for quantum optics but also for sensor applications and industrial semiconductor fabrication.

THU 13.85 Thu 16:30 ZHG Foyer 1. OG

Miniaturizing optical resonators - Fiber-based Fabry-Perot cavities — •Usman Adil[1], Franziska Haslinger[2], Michael Förg[2], Sambit Mitra[2], Manuel Nutz[2], Jonathan Noé[2], and Thomas Hümmer[2] — [1]LMU Munich — [2]Qlibri GmBH

Microscopic optical resonators have proven to be a versatile tool through their ability to enhance light-matter interaction. Constructing the mirrors on the endfacets of optical fibers offers a compact and tunable solution with intrinsic fiber coupling: Fiber Fabry-Perot Cavities (FFPCs). Successful experimental examples/applications range from non-destructive qubit readout in quantum information processing over sensing applications of gases or liquids to the usage as frequency filter for optical signals. Here, we present the prototype of a readily available FFPC and provide first insights on fiber alignment and positioning. Core parameters like finesse, length stability and mode matching are analyzed as a function of fiber type, mirror shape and coating properties.

THU 13.86 Thu 16:30 ZHG Foyer 1. OG

Hardware-efficient GHZ state generation using measurements — S. Siddardha Chelluri[1], •Stephan Schuster[2], Sumeet Sumeet[3], and Riccardo Roma[4] — [1]Institute of Physics, Johannes-Gutenberg University of Mainz, Staudingerweg 7, 55128 Mainz, Germany — [2]Quantum Optics and Quantum Information Group, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstr. 1, 91058 Erlangen, Germany — [3]Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen, Germany — [4]Theoretical Physics, Saarland University, 66123 Saarbrücken, Germany

The application of mid-circuit measurements as non-unitary operations in quantum circuits is a promising approach for more efficient state preparation and long-range entangling gates. Combined with conditional feedforward operations, such dynamic circuits can, for example, overcome the efficiency constraints on the generation of entangled states that are imposed by unitary operations alone. In this work, we propose a new algorithm incorporating mid-circuit measurements for the preparation of Greenberger-Horne-Zeilinger (GHZ) states on quantum devices with limited qubit connectivity. Our algorithm leverages the two-dimensional qubit layout of the device to generate low-depth circuits for preparing the desired GHZ states. We additionally benchmark our algorithm on different connectivity layouts, including the latest IBM Heron R2 architecture, and compare it to a purely unitary method based on a breadth-first search of the layout graph.

THU 13.87 Thu 16:30 ZHG Foyer 1. OG

Magneto-levitating Systems: Theory of Feedback Cooling and Intrinsic Dissipation — •Pietro Oreglia[1,2], Gianluigi Catelani[3,4], Daniele Contessi[1,5], Alessio Recati[1], Andrea Vinante[6], and Gianluca Rastelli[1,2] — [1]Pitaevskii BEC Center, CNR-INO and Dipartimento di Fisica, Università di Trento, I-38123 Trento, Italy — [2]INFN-TIFPA, Trento Institute for Fundamental Physics and Applications, Trento, Italy — [3]JARA Institute for Quantum Information (PGI-11), Forschungszentrum Jülich — [4]Quantum Research Center, Technology Innovation Institute, Abu Dhabi — [5]Traverlbrain srl, Trento, Italy — [6]6Istituto di Fotonica e Nanotecnologie-CNR and Fondazione Bruno Kessler, Trento, Italy

I study theoretically the fluctuation dynamics in the presence of feedback and the intrinsic mechanism of dissipation of a magneto-levitated system formed by a spherical micromagnet suspended in a superconducting trap. For the study of the feedback, I analyzed the cold damping method and applied it to describe a first experiment realized here in Trento, in which the microsphere, initially at the temperatures of a few kelvins, is cooled down up to tens of mK.

Moreover, I am also exploring the use of a machine learning approach, in which an agent learns the optimal way to induce the feedback in the loop, to improve the lowest achievable temperature.

In parallel, I investigate the dissipative effect due to the quasi-particle excitations hosted in the superconductor to set an upper bound to the intrinsic dissipation in this kind of system.

THU 13.88 Thu 16:30 ZHG Foyer 1. OG

A practical graphene quantum Hall resistance standard for realizing the unit ohm — •Yefei Yin[1], Mattias Kruskopf[1], Stephan Bauer[1], Teresa Tschirner[1], Klaus Pierz[1], Frank Hohls[1], Hansjörg Scherer[1], Rolf J. Haug[2], and Hans W. Schumacher[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Institut für Festkörperphysik, Leibniz Universität Hannover, 30167 Hannover, Germany

Quantum Hall resistance (QHR) standards play an essential role for the realization of the units ohm, farad, ampere, and kilogram in the revised International System of Units. The primary realization of the unit ohm is still mainly based on GaAs-based QHR standards with the quantized resistance $R_H = h/2e^2$ operating at high magnetic flux densities B > 10 T, limited currents I < 50 μA, and low temperatures T < 1.5 K. These operating conditions significantly hinder a wide application of these standards other than at highly specialized national metrology institutes. In this work, we developed practical primary QHR standards based on n- and p-type epitaxial graphene devices operating at relaxed conditions. The presented study systematically demonstrates that p-type epitaxial graphene can be used for primary resistance standards and is as accurate (10^{-9} accuracy) as GaAs and n-type graphene counterparts for realizing the unit ohm.[1] The n-type graphene QHR standards achieved world-class performance with 10^{-9} accuracy under relaxed conditions (B = 4.5 T, I = 232.5 μA, and T = 4.2 K).[2–3] [1] Appl. Phys. Lett., 125, 064001 (2024); [2] Adv. Phys. Res. 1, 2200015 (2022). [3] Phys. Rev. Applied, 23, 014025 (2025)

THU 13.89 Thu 16:30 ZHG Foyer 1. OG

Optimizing thermal management of equipment via FEM-simualtions — •Tristan Stiller — CreaTec, Erligheim, Deutschland

Keeping track of temperatures for any given process is extremely important. Whether it is to accurately estimate evaporation rates of thermal effusion cells, or to gain a better understanding of spatial temperature gradients along a sample, which in turn affects growth conditions. Using COMSOL's simulation capabilities we can simulate Joule heating of filaments, heat transfer in solids, and thermal radiation, which is the main heat transfer mechanism in UHV applications. Two use cases of these simulation results were both the optimization of effusion cell design, as well as improvement in substrate heating; both of which play a crucial role in quantum dot growth or the investigation of the behavior of single atoms in magneto-optical traps, for example.

THU 13.90 Thu 16:30 ZHG Foyer 1. OG

Integrating Adiabatic Demagnetization Refrigeration with PPMS for Sub-50 mK Studies — •Marvin Klinger, Anna Klinger, Jorginho Villar Guerrero, Tim Treu, Anton Jesche, and Philipp Gegenwart — Experimental Physics VI, Center for Electronic Correlations and Magnetism, University of Augsburg

Accessing temperatures in the millikelvin regime is crucial for exploring fundamental quantum phenomena and advancing fields like quantum computing, superconductivity, and low-temperature physics. While 3He/4He dilution refrigeration has been the traditional approach, adiabatic demagnetization refrigeration (ADR) is gaining renewed attention as a cost-effective alternative [1]. Conventional ADR systems using hydrated salts face challenges regarding chemical instability and thermal contact degradation. To address these limitations, we have developed novel materials, enabling reliable measurements below 50 mK [2]. Our custom ADR insert for the Quantum Design PPMS achieves temperatures below 30 mK for several hours without any modification to the host cryostat. The system offers multiple experimental capabilities, including electrical transport, stress/strain and heat capacity measurements.

[1] T. Treu, M. Klinger, N. Oefele, P. Telang, A. Jesche and P. Gegenwart, J. Phys. Condens. Matter 37, 013001 (2025)

[2] Y. Tokiwa, S. Bachus, K. Kavita, A. Jesche, A. Tsirlin, and P. Gegenwart, Commun. Mater. 2 (2021) 42.

THU 13.91 Thu 16:30 ZHG Foyer 1. OG

Millikelvin Microwave Photonic Probestation — Matthias Weiss and •Hubert Krenner — Physikalisches Institut, Universität Münster, Münster, Germany

Many practical implementations demand such flexible hybrid architectures which combine the unique strengths of individual components and at the same time avoid individual shortcomings.

Here, we present this innovative platform for the validation of hybrid quantum devices and its capabilities. At the Physikalische Institut at Universität Münster we set up a standardized test and development system for source and detection devices to validate the performance of hybrid quantum devices and their individual components. The central apparatus is a photonic probestation equipped with optical fiber ports and microwave connections designed and specified for operation at millikelvin temperatures. This unique combination of functionalities opens applications in testing and benchmarking of e.g. quantum transduction of quantum information between photonic, electronic, or phononic domains. This apparatus is part of a DFG-Major Instrumentation Initiative and open for joint research projects outside of Universität Münster.

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THU 13.92 Thu 16:30 ZHG Foyer 1. OG

Accurate modeling of polarization in large-scale molecular dynamics simulations — •Hikaru Azuma[1], Shuji Ogata[1], Ryo Kobayashi[1], Masayuki Uranagase[2], Yuta Takahashi[1], and Takahiro Tsuzuki[1] — [1]Nagoya Institute of Technology, Japan — [2]Riken, Japan

First-principles calculations yield the polarization, dielectric, and piezoelectric responses, which serve as indicators of the ferroelectric material's performance. However, these properties depend strongly on temperature in experiments. For instance, in BaTiO3, the polarization direction changes through successive phase transitions as temperature increases. Classical molecular dynamics simulations that assign point charges to atoms provides only a rough estimate of polarization based on atomic displacements. First-principles calculations reveal that each atom's contribution is anisotropic and varies dynamically with its environment. This variation is quantified by the Born effective charge, which is a feature that a fixed point-charge model cannot capture. The shell model includes these effects using multiple point charges to an atom but underestimate polarization-related properties.

Here, we perform MD simulations using a novel hybrid interatomic potential that combines a shell model with a machine-learning potential. Our model accurately reproduces BaTiO3's phase transitions and improves polarization predictions. We examine how precise modeling of polarization and Born effective charges affects predictions of the temperature dependence of the dielectric and piezoelectric responses.

THU 13.93 Thu 16:30 ZHG Foyer 1. OG

Hyperspectral Imaging and Optical Characterisation of Localized and Delocalized Exciton Complexes in Transition Metal Dichalcogenides — •Shachi Machchhar, Bhabani Sankar Sahoo, Yuhui Yang, Imad Limame, Johannes Schall, Sven Rodt, Chirag Chandrakant Palekar, and Stephan Reitzenstein — 1Institut für Physik und Astronomie, Technische Universität Berlin, Berlin, Germany

The development of on-demand sources of single photons with high indistinguishability represents a crucial step in the creation of photonic quantum systems, such as those required for the construction of large-scale quantum networks for the secure transfer of data. One potential avenue for the realization of such sources in a scalable and cost-effective manner is the exploitation of defect centres in transition metal dichalcogenides (TMDCs). The fabrication of these defect centres in TMDC monolayers (MLs) can be achieved through the introduction of strain, ion implantation, and the structuring or patterning of the substrate. In this study, we pattern hBN with the help of electron beam lithography and deposit a WSe2 ML on the top to induce strain, which facilitates the generation of single-photon sources with distinct quantum optical properties. We then perform hyperspectral cathodoluminescence imaging on the fabricated structure to determine the localised and delocalised excitonic states in the ML. We optically characterise the said states and furthermore, demonstrate the single-photon nature of these single-photon emitters through second-order correlation measurements.

Friday Contributed Sessions (FRI)

Stefan Kehrein
Fakultät für Physik
Universität Göttingen
Friedrich-Hund-Platz 1
37077 Göttingen, Germany
stefan.kehrein@theorie.physik.uni-goettingen.de

Thomas Weitz
Fakultät für Physik
Universität Göttingen
Friedrich-Hund-Platz 1
37077 Göttingen, Germany
thomas.weitz@uni-goettingen.de

Overview of Sessions

(Lecture halls ZHG001, ZHG002, ZHG003, ZHG004, ZHG006, ZHG007, ZHG008, ZHG009, ZHG101, ZHG103, ZHG104, and ZHG105)

Sessions

FRI 1.1–1.7	Fri	10:45–12:30	ZHG001	**Quantum Information: Concepts and Methods II**
FRI 2.1–2.6	Fri	10:45–12:15	ZHG002	**Many-Body Quantum Dynamics III**
FRI 3.1–3.5	Fri	10:45–12:00	ZHG003	**Quantum Chaos**
FRI 4.1–4.7	Fri	10:45–12:30	ZHG004	**Foundational / Mathematical Aspects – Alternative Views**
FRI 5.1–5.8	Fri	10:45–12:45	ZHG006	**QIP Implementations: Solid-State Devices II**
FRI 6.1–6.5	Fri	10:45–12:00	ZHG007	**Quantum Error Mitigation**
FRI 7.1–7.6	Fri	10:45–12:15	ZHG008	**Entanglement and Complexity: Contributed Session to Symposium III**
FRI 8.1–8.6	Fri	10:45–12:15	ZHG009	**Quantum Detectors in Optics and Particle Physics**
FRI 9.1–9.3	Fri	10:45–11:30	ZHG101	**Fundamental Quantum Tests**
FRI 10.1–10.8	Fri	10:45–12:45	ZHG103	**Foundational / Mathematical Aspects – Unconventional Approaches**
FRI 11.1–11.7	Fri	10:45–12:30	ZHG104	**Quantum 2D-Moiré and Rhombohedral van-der-Waals Systems: Contributed Session to Symposium**
FRI 12.1–12.7	Fri	10:45–12:30	ZHG105	**Quantum Phenomena in Solid-State Devices**

Sessions

– Talks –

FRI 1: Quantum Information: Concepts and Methods II

Time: Friday 10:45–12:30 Location: ZHG001

FRI 1.1 Fri 10:45 ZHG001

Metainformation in quantum guessing games — •Teiko Heinosaari and Hanwool Lee — Faculty of Information Technology, University of Jyväskylä, Finland

Quantum guessing games form a framework for analyzing quantum information processing tasks, where information is encoded into quantum states and retrieved through measurements. Classical side information is partial knowledge about the input. It can significantly influence the guessing strategy and earlier work has shown that the timing of such side information, whether revealed before or after the measurement, can affect the structure of optimal strategies and success probabilities. We go beyond this established distinction by introducing the concept of metainformation. Metainformation is information about information, and in our context it is knowledge that additional side information of certain type will become later available, even if it is not yet provided. We show that this seemingly subtle difference between having no expectation of further information versus knowing it will arrive can have operational consequences for the guessing task. Our results demonstrate that metainformation can, in certain scenarios, enhance the achievable success probability up to the point that post-measurement side information becomes as useful as prior-measurement side information, while in others it offers no benefit. By distinguishing metainformation from actual side information, we uncover a finer structure in the interplay between timing, information, and strategy, offering new insights into the capabilities of quantum systems in information processing tasks.

FRI 1.2 Fri 11:00 ZHG001

From bosons and fermions to spins: A multi-mode extension of the Jordan-Schwinger map — Benoît Dubus[1], •Tobias Haas[1,2], and Nicolas J. Cerf[1] — [1]Centre for Quantum Information and Communication, Université libre de Bruxelles — [2]Institut für Theoretische Physik, Universität Ulm

The Jordan-Schwinger map is widely employed to switch between bosonic or fermionic mode operators and spin observables, with numerous applications ranging from quantum simulation and ultracold quantum gases to quantum optics. While the construction of observables obeying the algebra of spin operators across multiple modes is straightforward, a mapping between bosonic or fermionic Fock states and spin states has remained elusive beyond the two-mode case. Here, we generalize the Jordan-Schwinger map by algorithmically constructing complete sets of spin states over several bosonic or fermionic modes, allowing one to describe arbitrary multi-mode systems faithfully in terms of spins. We discuss our method's potential for efficiently simulating complex many-body dynamics with spin systems.

FRI 1.3 Fri 11:15 ZHG001

Optimising measurement of correlators for fermionic quantum simulators — •Ahana Ghoshal[1], Carlos de Gois[1], Kiara Hansenne[1,2], Otfried Guehne[1], and Hai-Chau Nguyen[1] — [1]Naturwissenschaftlich-Technische Fakultat, Universitat Siegen, Walter-Flex-Straße 3, 57068 Siegen, Germany — [2]Université Paris-Saclay, CEA, CNRS, Institut de Physique Théorique, 91191 Gif-sur-Yvette, France

Simulating many-body fermionic systems on conventional quantum computers poses significant challenges due to the overheads associated with the encoding of fermionic statistics in qubits, leading to the proposal of native fermionic simulators as an alternative. This raises the question of characterising the state of a fermionic simulator, which often boils down to measuring certain overlapping sets of few-point correlators from the output of the quantum simulation. We present a systematic framework for optimising the measurement of two- and four-point correlators in fermionic simulators based on their native fermionic gates.This is obtained by developing a graph representation for the set of correlators to be measured, which is then overlaid by a graph describing the constraints from the fermionic gates. Optimising measurement settings is then mapped to graph theoretical problems, for which various algorithms can be applied. We illustrate our methods for the recently proposed fermionic simulators with various sets of two- and four-point correlators as examples.

FRI 1.4 Fri 11:30 ZHG001

Lindblad engineering for quantum Gibbs state preparation under the eigenstate thermalization hypothesis — •Eric Brunner[1], Luuk Coopmans[1], Gabriel Matos[1,2], Matthias Rosenkranz[1], Frederic Sauvage[1], and Yuta Kikuchi[3,4] — [1]Quantinuum, London SW1P 1BX, United Kingdom — [2]Quantinuum, Oxford OX1 2NA, United Kingdom — [3]Quantinuum K.K., Tokyo, Japan — [4]iTHEMS, RIKEN, Wako, Saitama 351-0198, Japan

Building upon recent progress in Lindblad engineering for quantum Gibbs state preparation algorithms, we propose a simplified protocol that is shown to be efficient under the eigenstate thermalization hypothesis (ETH). The ETH reduces circuit overheads of the Lindblad simulation algorithm and ensures a fast convergence toward the target Gibbs state. Moreover, we show that the realized Lindblad dynamics exhibits an inherent resilience against stochastic noise, opening up the path to a first demonstration on quantum computers. We complement our claims with numerical studies of the algorithm's convergence in various regimes of the mixed-field Ising model. In line with our predictions, we observe a mixing time scaling polynomially with system size when the ETH is satisfied. In addition, we assess the impact of algorithmic and hardware-induced errors on the algorithm's performance by carrying out quantum circuit simulations of our Lindblad simulation protocol with a local depolarizing noise model. This work bridges the gap between recent theoretical advances in dissipative Gibbs state preparation algorithms and their eventual quantum hardware implementation.

FRI 1.5 Fri 11:45 ZHG001

Discrete Quantum Walks with Near-Term Neutral Atom Hardware Error Modelling — •Stephanie Foulds and Vivien Kendon — University of Strathclyde, Glasgow, UK

Quantum walks, the quantum analogue to the classical random walk, have been shown to be able to model fluid dynamics [1,2]. Neutral atom hardware is a promising choice of platform for implementing quantum walks due to its ability to implement native multiqubit gates and to dynamically re-arrange qubits [3]. Using error modelling for multiqubit Rydberg gates via two-photon adiabatic rapid passage [4], we present the gate sequences and final state fidelities for some toy quantum walks, including 'lazy' quantum walks.

[1] S.Succi et al., EPJ Quantum Technol. 2, 12 (2015).
[2] S. Hatifi et al., arXiv:2503.05393v2.
[3] K. McInroy et al., arXiv:2402.02127v1.
[4] G. Pelegrí et al., Quantum Sci. Technol. 7 (2022) 045020.

FRI 1.6 Fri 12:00 ZHG001

Universal dissipators for driven open quantum systems and the correction to linear response — •Lorenzo Bernazzani, Balázs Gulácsi, and Guido Burkard — University of Konstanz, D-78457 Konstanz, Germany

We investigate in parallel two common pictures used to describe quantum systems interacting with their surrounding environment, i.e., the stochastic Hamiltonian description, where the environment is implicitly included in the fluctuating internal parameters of the system, and the explicit inclusion of the environment via the time-convolutionless projection operator method. Utilizing these two different frameworks, we show that the dissipator characterizing the dynamics of the reduced system, determined up to second order in the noise strength or bath-system coupling, is universal. That is, it keeps the same form regardless of the drive term, as long as the drive is weak. We thoroughly discuss the assumptions on which this treatment is based and its limitations. By considering the first non-vanishing higher-order term in our expansion, we also derive the linear response correction due to memory-mediated environmental effects in driven-dissipative systems. We demonstrate this technique to be highly accurate for the problems of dephasing in a driven qubit and for the theory of pseudomodes for quantum environments [1].

[1] L. Bernazzani, B. Gulácsi, G. Burkard. arXiv:2505.19262 (2025).

FRI 1.7 Fri 12:15 ZHG001

Turning qubit noise into a blessing: automatic state preparation and long-time dynamics for impurity models on quantum computers — •Corentin Bertrand[1], Pauline Besserve[1,2,3], Michel Ferrero[2,3], and Thomas Ayral[1] — [1]Eviden Quantum Lab, 78340 Les Clayes-sous-Bois, France — [2]Collège de France, Université PSL, 11 place Marcelin Berthelot, 75005 Paris, France — [3]CPHT, CNRS, Ecole Polytechnique, Institut Polytechnique de Paris, 91128 Palaiseau, France

Noise is often regarded as a limitation of quantum computers. In this work, we show that in the dynamical mean field theory (DMFT) approach to strongly-correlated systems, it can actually be harnessed to our advantage. Indeed, DMFT maps a lattice model onto an impurity model, namely a finite system coupled to a dissipative bath. While standard approaches require a large number of high-quality qubits in a unitary context, we propose a circuit that harvests amplitude damping to reproduce the dynamics of this model with a blend of noisy and noiseless qubits. We find compelling advantages with this approach: a substantial reduction in the number of qubits, the ability to reach longer time dynamics, and no need for ground state search and preparation. This method would naturally fit in a partial quantum error correction framework.

FRI 2: Many-Body Quantum Dynamics III

Time: Friday 10:45–12:15 Location: ZHG002

FRI 2.1 Fri 10:45 ZHG002

Geometric speed limit of state preparation and curved control spaces — Maximilian Goll[1,2] and •Robert H. Jonsson[2] — [1]Freie Universität Berlin, Germany — [2]Nordic Institute for Theoretical Physics, Stockholm University, Sweden

The preparation of quantum many-body systems faces the difficulty that in a realistic scenario only few control parameters of the system may be accessible. In this context, an interesting conjecture was put forward by Bukov et al. in 2019, that the minimal length of any accessible state preparation protocol, as measured by the Fubini-Study metric, may lower bound the integrated energy fluctuation during any state preparation protocol.

We show that the conjecture holds if the accessible parameter space has no extrinsic curvature, when embedded into the space of all dynamically accessible states. However, we construct counter examples to the general form of the conjecture for qubits and harmonic oscillators.

[1] arXiv:2504.15175

FRI 2.2 Fri 11:00 ZHG002

Quantum phase transitions and collective excitations in long-range interacting spin XX models with superconducting qubits — •Benedikt J.P. Pernack, Mikhail V. Fistul, and Ilya M. Eremin — Theoretische Physik III, Ruhr-Universität Bochum, Bochum 44801, Germany

We investigate the emergence of collective quantum phases in coherent networks of superconducting qubits described effectively by interacting spin XX models with both short- and long-range couplings, subject to tunable local longitudinal and transverse magnetic fields. The spin interactions are engineered via the direct embedding of π-Josephson junctions in dissipationless transmission lines, enabling precise control over the interaction range and local field strengths [1]. Using advanced numerical techniques, including density matrix renormalization group (DMRG) analysis, we map out the phase diagram and identify quantum phase transitions between distinct ground states. Analytically, we employ a hard-core boson approach to characterize the ground state properties, order parameters, and the spectrum of Bogoliubov collective modes. Our results reveal a rich landscape of quantum phases, including paramagnetic, compressible superfluid, and weakly compressible superfluid states, and provide insight into the interplay between interaction range, local fields, and collective excitations in engineered quantum systems.

[1] B.J.P. Pernack, M.V. Fistul, I.M.Eremin, Phys. Rev. B 110, 184502 (2024)

FRI 2.3 Fri 11:15 ZHG002

Computational fluid dynamics simulation of dipolar gases in the hydrodynamic regime — •Michael Mayle[1], Reuben R. W. Wang[2,3], and John L. Bohn[4] — [1]Fakultät Angewandte Mathematik, Physik und Allgemeinwissenschaften, Technische Hochschule Nürnberg Georg Simon Ohm, Nürnberg, Germany — [2]ITAMP, Center for Astrophysics | Harvard & Smithsonian, Cambridge, Massachusetts 02138, USA — [3]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA — [4]JILA, NIST, and Department of Physics, University of Colorado, Boulder, Colorado 80309, USA

In a recent theoretical effort, a hydrodynamic model of ultracold, but not yet quantum condensed, dipolar gases has been derived. Within this model, the dipolar scattering results in an anisotropic viscosity tensor. Effects of the anisotropy have been predicted to be observable in the weltering motion, i.e., the collective oscillations of a dipolar Fermi gas, as well as in its acoustic behavior.

In this contribution, we approach dipolar fluids from a computational fluid dynamics (CFD) perspective. To this end, previously derived analytic expressions of the anisotropic viscosity tensor are implemented in the finite-element software COMSOL Multiphysics. This allows us to investigate a whole spectrum of fluid flow situations but now including the inherent anisotropy of dipolar scattering. We present first results of such CFD simulations with an emphasis on effects attributable to the special characteristics of the anisotropic viscosity tensor.

FRI 2.4 Fri 11:30 ZHG002

Fully numerical Hartree-Fock calculations for atoms and small molecules with quantics tensor trains — •Paul Haubenwallner and Matthias Heller — Fraunhofer Institut für Graphische Datenverarbeitung IGD, Darmstadt, Deutschland

We present a fully numerical framework for the optimization of molecule-specific quantum chemical basis functions within the quantics tensor train format using a finite-difference scheme. The optimization is driven by solving the Hartree*Fock equations (HF) with the density-matrix renormalization group algorithm on Cartesian grids that are iteratively refined. In contrast to the standard way of tackling the mean-field problem by expressing the molecular orbitals as linear combinations of atomic orbitals (LCAO) our method only requires as much basis functions as there are electrons within the system. Benchmark calculations for atoms and molecules with up to ten electrons show excellent agreement with LCAO calculations with large basis sets supporting the validity of the tensor network approach. Our work therefore offers a promising alternative to well-established HF-solvers and could pave the way to define highly accurate, fully numerical, molecule-adaptive basis sets, which, in the future, could lead to benefits for post-HF calculations.

FRI 2.5 Fri 11:45 ZHG002

Long-range polarization models for reactive molecular systems. — •Shuran Xu and Stefan Ringe — Department of chemistry, Korea University, Seoul, Republic of Korea.

The combination of the molecule-based many-body expansion (MBE) with machine learning interatomic potentials (MLIP) has proven highly potent in generating surrogate potential energy surfaces for fast computational sampling of condensed phases. Key to accurate MBE-MLIP potentials is an accurate description of long-range electrostatics which requires the definition of element-specific fixed atomic parameters such as atomic charges and polarizabilities. In the case of reactive systems, such a treatment falls short due to significant charge transfer generating atomic environment-dependent atomic charges and polarizabilities. In this work, we systematically investigate this problem at the example of protonated water clusters and discuss possible solution strategies from Thole-type polarization models up to MBE-corrected models.

FRI 2.6 Fri 12:00 ZHG002

Role of many-body electronic structure effects on carbon monoxide surface distribution and dynamics on copper — •Seungchang Han and Stefan Ringe — Korea University, Seoul, Republic of Korea

Electrochemical CO2 reduction offers a promising and sustainable approach to producing valuable chemicals and fuels. Copper (Cu) stands out as the sole catalyst capable of yielding substantial quantities of higher reduced products such as ethylene, ethanol, and methane. The complex nature of the active site environment, including facet, site, and coverage dependencies of the central carbon monoxide (CO) intermediate, is known to influence product selectivity significantly. To investigate these adsorption phenomena and their energetic profiles, studies often use the Perdew-Burke-Ernzerhof (PBE) functional based on the generalized gradient approximation (GGA). Although widely used, this approach relies on error compensation, which can limit its applicability to systems for which the error is unknown. It also leads to an inconsistent prediction of adsorption trends across different surface facets and adsorption sites. Applying many-body corrections based on the random phase approximation (RPA) has been shown to improve the prediction of facet- and site-dependent stability significantly. In this study, we investigate the initial relationships between facet and site dependencies that affect adsorption energies, incorporating results derived from the RPA. Additionally, we elucidate coverage-dependent adsorption energy trends to deepen understanding of surface interactions.

FRI 3: Quantum Chaos

Time: Friday 10:45–12:00 Location: ZHG003

FRI 3.1 Fri 10:45 ZHG003

Chaos and integrability in partially distinguishable fermions on a lattice — •Caroline Stier, Edoardo Carnio, Gabriel Dufour, and Andreas Buchleitner — Albert-Ludwigs-Universität Freiburg

We study the fermionic many-body quantum dynamics generated by a Hubbard-like Hamiltonian with nearest neighbour interaction and a continuously tunable level of distinguishability of the particles. For not strictly indistinguishable fermions, distinct invariant symmetry sectors of the many-body Hilbert space are populated, with tangible impact on the many-body dynamics. For indistinguishable fermions, the dynamics is integrable; for partially distinguishable fermions, however, numerical results show the emergence of chaotic dynamics. We explain the breakdown of integrability with analytical arguments, in tandem with simulations of the dynamics within specific symmetry sectors.

FRI 3.2 Fri 11:00 ZHG003

High dimensional hyperbolic motion is maximally quantum chaotic — •Gerrit Caspari, Fabian Haneder, Juan Diego Urbina, and Klaus Richter — University of Regensburg

The Maldacena-Shenker-Stanford (MSS) bound is a condition on a system's quantum Lyanpunov exponent, defined as the growth rate of the regularized out-of-time-order correlator (OTOC) with respect to a thermal state. It states that the exponent is bounded by the system's temperature T, with maximally chaotic quantum systems, e.g. black holes, being defined by its saturation. Thus, it is expected that non-gravitational, maximally chaotic systems should have a gravitational dual.

In this contribution, we study the OTOC of a particle on a hyperbolic surface in arbitrary dimensions. Using the Wigner-Moyal formalism and a saddle-point approximation based on exact results for the mean level density given by the Selberg trace formula we show compliance to the MSS bound for low temperatures and finite dimensions and the asymptotic approach to a saturation formally obtained for infinite dimensions. To this end, a controlled asymptotic analysis of the interplay between dimensionality, temperature and quantum corrections is mandatory and nicely displays a transition from a sqrt(T) behavior into a T behavior of the quantum Lyapunov exponent. Together with the previous analysis of previous works, our results strongly indicate that high-dimensional hyperbolic motion admits an effective description in terms of emergent gravitational degrees of freedom.

FRI 3.3 Fri 11:15 ZHG003

Controlling Many-Body Quantum Chaos — •Lukas Beringer[1], Mathias Steinhuber[1], Juan Diego Urbina[1], Klaus Richter[1], and Steven Tomsovic[1,2] — [1]Institut für Theoretische Physik, Universität Regensburg, Regensburg, Germany — [2]Department of Physics and Astronomy, Washington State University, Pullman, WA USA

Controlling chaos is a well-established technique that leverages the exponential sensitivity of classical chaotic systems for efficient control. This concept has been generalized to single-particle quantum systems [1] and, more recently, extended to bosonic many-body quantum systems described by the Bose-Hubbard model [2]. In direct analogy to the classical paradigm, a localized quantum state can be transported along a specific trajectory to a desired target state. In the bosonic many-body case, this approach reduces to time-dependent control of the chemical potentials, making it suitable for rapid and customizable state preparation in optical lattice experiments. We discuss how this protocol can serve as a toolbox for studying many-body interference and present recent progress on preparation protocols for entangled states.

[1] S. Tomsovic, J. D. Urbina, and Klaus Richter, Controlling Quantum Chaos: Optimal Coherent Targeting, PRL 130.2 (2023): 020201.

[2] L. Beringer, M. Steinhuber, J. D. Urbina, K. Richter, S. Tomsovic, Controlling many-body quantum chaos: Bose-Hubbard systems, New J. Phys (2024): 26 073002.

FRI 3.4 Fri 11:30 ZHG003

Non-Markovianity in Chaotic Subsystem Evolution — •Zhuo-Yu Xian[1], Shao-Kai Jian[2], and Greg White[3,4,5] — [1]Department of Physics, Freie Universität Berlin, Arnimallee 14, DE-14195 Berlin, Germany — [2]Department of Physics and Engineering Physics, Tulane University, New Orleans, Louisiana, 70118, USA — [3]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany — [4]School of Physics and Astronomy, Monash University, Clayton, VIC 3800, Australia — [5]School of Physics, University of Melbourne, Parkville, VIC 3010, Australia

The process tensor captures how an environment influences a system across multiple time intervals, and its multi-time mutual information furnishes a measure of non-Markovianity. We examine the non-Markovianity of a subsystem's dynamics embedded in various unitary evolutions of the global system, described by random matrices, various Sachdev-Ye-Kitaev models, and holographic conformal field theories. This non-Markovianity arises from two distinct mechanisms: (i) interaction-induced temporal correlations, which appear already at early times, and (ii) entanglement phase transition, which appears at the Page time of a finite environment. We further show that the process-tensor mutual information coincides with the timeline pseudo-entropy when the subsystem is depolarized and establishes its holographic correspondence in the dual black hole spacetime. Our results on non-Markovianity connect the fields of quantum chaos, many-body dynamics, and the black hole information problem.

FRI 3.5 Fri 11:45 ZHG003

Statistical Hadronization of Loosely Bound Nuclei — •Hjalmar Brunssen — Physikalisches Institut, Universität Heidelberg

It has been shown that the statistical hadronization model (SHM) yields an excellent description of hadron and light-nucleus yields in heavy-ion collisions at the LHC. While the yields of hadrons are in general well understood, the hadronization of nuclei is a very active research topic. In particular, the hypertriton, whose wavefunction is similar in size to the entire fireball, represents an ideal probe to test the production mechanism of nuclei.

This talk presents an approach for incorporating the size of loosely bound nuclei into the SHM calculation of production yields, focusing on hypertriton, deuteron and helium-3 nuclei. For this, the finite spatial extent of the wavefunction is considered, which leads to a significant correction relative to a point-like treatment, especially in small collision systems. We test the approach by comparing its predictions with data from ALICE and STAR.

FRI 4: Foundational / Mathematical Aspects – Alternative Views

Time: Friday 10:45–12:30 Location: ZHG004

FRI 4.1 Fri 10:45 ZHG004

Three Steps Turn Euclidean Relativity Into a Pillar of Physics — •Markolf H. Niemz — Heidelberg University, Germany

In special relativity (SR), there is coordinate time t and proper time τ. Two facts deserve reflection: (1) Clocks measure τ, but the construct t is more common in the equations of physics than natural τ. (2) Cosmology is aware of the Hubble parameter H_θ, but the parameter τ is preferred to $\theta = 1/H_\theta$ in both SR and general relativity (GR). **We show:** Euclidean relativity (ER) describes nature exclusively in natural concepts. Three steps make ER work: (1) The new time coordinate is τ. (2) The new parameter is θ. (3) An observer's reality is a projection from 4D Euclidean space (ES). Because of the different concepts, ER neither conflicts with nor requires SR/GR! All energy moves through ES at the speed c. Absolute ES is experienced as a relative Euclidean spacetime: Each object experiences its 4D motion as its proper time and the other three axes as its proper space. Both the Lorentz factor and gravitational time dilation are recovered in ER. Thus, ER predicts the same relativistic effects as SR/GR. In ER, τ is the length of a 4D Euclidean vector "flow of proper time" $\boldsymbol{\tau}$. Gravity makes its comeback as a force. Any acceleration rotates an object's $\boldsymbol{\tau}$ and curves its worldline in ES. $\boldsymbol{\tau}$ is crucial for objects that are very far away or entangled. Information hidden in θ and in $\boldsymbol{\tau}$ is not available in SR/GR. ER solves the wave–particle duality and explains entanglement without postulating non-locality. Entangled objects have never been spatially separated in their view, but their proper time flows in opposite 4D directions. https://www.preprints.org/manuscript/202207.0399

FRI 4.2 Fri 11:00 ZHG004

On Schrödinger's requirements for space functions — •Dieter Suisky — Berlin (suisky5@aol.com)

It will be demonstrated that the wave function and the energy of the ground state of a quantum mechanical system can be derived from the requirements which had been posed by Schrödinger in the First Communication in 1926: In order to substitute the traditional quantum conditions Schrödinger looked for real, single-valued in the whole configuration space, finite and twice continuously differentiable functions. From these requirements alone and the theorem of Rolle it follows that there is such function which (1) is symmetric and zero in the end points, (2) has one maximum and two turning points, (3) the position of the maximum is at x =0. Furthermore, a differential equation of 1st order can be established from which the wave function of the ground state can be calculated. The coordinates of the turning points can be obtained by the differential equation of 2nd order which follows straightforwardly from the previously derived differential equation of 1st order if the condition for all turning points of the twice differentiable space function f(x) is taken into account. Moreover, the energy value of the lowest state can be calculated too and is different from zero, E > 0, which is typical for the quantum mechanical systems. The procedure fits for the quantum mechanical harmonic oscillator. The differential equation of 2nd order is nothing else the well-known Schrödinger equation, which is now already obtained from a differential equation of 1st order. The analysis of the relations between differential equations of different orders can be traced back to Euler.

FRI 4.3 Fri 11:15 ZHG004

How come the quantum? Testing a proposal for the origin of Planck's quantum of action — •Christoph Schiller — Motion Moutain

The answer to Wheeler's question "How come the quantum?" given by Kauffman is presented and explored. The answer, going back to an approach by Dirac, proposes a topological origin of Planck's quantum of action. The proposal is checked against all quantum effects, including non-commutativity, spinor wave functions, entanglement, Heisenberg's indeterminacy relation, and the Schrödinger and Dirac equations. The principle of least action is deduced. The spectra of elementary particles, the gauge interactions, and general relativity are derived. Estimates for elementary particle masses and for coupling constants, as well as numerous experimental predictions are deduced. Complete agreement with observations is found. The derivations also appear to eliminate alternatives and thus provide arguments for the uniqueness of the proposal.

Details, publications and preprints at https://motionmountain.net/strands

FRI 4.4 Fri 11:30 ZHG004

A Fresh Geometric Perspective of an Electron and its Waves — •Fong Yang — Minnesota, United States

Matter consists of particles and waves. Every day we interact with particles while essentially disregarding waves. Quantum mechanics mathematically describe matter from the waves perspective while disregarding particles. This description does not reflect our everyday experience with matter.

The double slit experiment shows that electrons inherently have wave properties. Quantum mechanics can predict time-elapsed double slit experiment results using wave mechanics. But it is unable to explain how electrons interact with the macroscopic environment within this experiment.

My theoretical research illustrates how electrons interact with its macroscopic environment using basic geometry and algebra, and the conservation of energy concept.

Theoretical research begins with a suggested first-person perspective of a traveling electron and its waves. The physical restrictions of the double slit experiment setup, the mathematical geometrics of the electron's waves, and the conservation of energy concept, together constrains the electron to certain locations in space until its interaction with the macroscopic environment. Basic algebra is then used to translate the geometric perspective into two distinctive wave properties. These properties are at a minimum a 99% match compared to double slit experiment calculations derived from conventional trigonometric perspective of the electrons' waves.

FRI 4.5 Fri 11:45 ZHG004

Superposition and Entanglement of Polarized Photons without Hidden Variables — •Eugen Muchowski — Primelstraße 10, 85591 Vaterstetten

Superposition and mixtures of indistinguishable photon beams are equivalent under certain conditions. This idea explains the correlations of entangled photons as well as entanglement swapping and teleportation without using hidden variables. This sheds new light on the Einstein-Bohr debate. The superposition of indistinguishable photon beams can be experimentally demonstrated with a Mach-Zehnder interferometer.

FRI 4.6 Fri 12:00 ZHG004

Particle masses generated by mass quanta and elementary charges circulating in individual eigenspaces of particles, not embedded in space-time. — •Herrmann Hans-Dieter — Berlin

Intrinsic properties of particles such as invariant mass, spin, magnetic dipole moment and Compton wave length are modelled assuming an extra space fixed to the structure of an individual particle. The particle appears as composited and extended in its eigenspace. The eigenspace resembles the space spanned by body-fixed coordinates of a spinning top, a satellite or a drone. The structural building stones of particle models are so called rotons with D=3+1 dimensions. The biroton with D=5+1 dimensions represents the minimum structure of a lepton model or a quark-equivalent. The meson model consists of a biroton and an anti-biroton with D=9+1 dimensions. A baryon model needs D=25+1 dimensions, it consists of six birotons with quarter-valued spins. This model structure provides mass values, spin and magnetic momenta in reasonable agreement with the experiment.

The mass quantum mQ approx.= 1/32 of the muon mass is calculated using muon data as input and serves as a universal constant. It may have both signs in the eigenspace, such that the small electron mass and the vanishing neutrino masses can be modelled as differences between positive and negative partial masses. The partial masses of a particle may be located at different positions in space-time, this could explain quantum nonlocality as well as nonlocal gravity.

FRI 4.7 Fri 12:15 ZHG004

The alleged necessity of quantum mechanics — •Albrecht Giese — Taxusweg 15, 22605 Hamburg

To what extent is quantum mechanics unavoidable for describing elementary particles? Historically the existence of quantization occurred in the investigations of the energy levels of atoms. Atoms are oscillators and these oscillators are subject to specific constraints. It is a physical fact that certain constraints permit only specific oscillation energies. However, the development of QM has since led to the assumption that most physical quantities are subject to quantization. Is this a reasonable or necessary development?

We have examples of specific facts about elementary particles that can be better, or even only, explained classically. A striking example is the development of inertia, where the classical derivation yields precise results, whereas the accepted Higgs model does not give us any. There are other examples where known rules have been successfully postulated in quantum mechanics but can instead be *derived using classical methods. A prominent example is the Planck relation E = h*ny.

We will recommend a discussion on the conclusions that can be drawn from this fact.

FRI 5: QIP Implementations: Solid-State Devices II

Time: Friday 10:45–12:45 Location: ZHG006

FRI 5.1 Fri 10:45 ZHG006

The challenges of developing electronic design automation tools for quantum technology — Karen Bayros[1], Martin Cyster[1], Jackson Smith[1], Jesse Vaitkus[1,2], Nicolas Vogt[1,2], Salvy Russo[1], and •Jared Cole[1] — [1]Theoretical, Computational and Quantum Physics group, School of Science, RMIT University, Melbourne, Australia — [2]HQS Quantum Simulations GmbH, Karlsruhe, Germany

Large-scale quantum computing requires extremely high precision qubits, with long coherence times, accurately calibrated control and free from unpredictable parameter drift.

Equivalent constraints have been addressed in conventional semiconductor electronics and other branches of engineering, often with the help of advanced computer simulation tools - referred to as Electronic Design Automation (EDA). For quantum technology, we are facing entirely new difficulties in terms of the scale and precision required for creating quantum EDA tools.

I will discuss the fundamental challenges in developing EDA tools for quantum technology, specifically those relevant to superconducting and semiconducting qubits. These challenges ultimately stem from the fundamental structure of quantum physics, which is ironic given that we need to solve quantum physics problems to build a quantum computer, in order to efficiently solve those quantum physics problems!

In discussing these issues, I will present our recent efforts to develop proof-of-principle multi-scale quantum EDA tools.

FRI 5.2 Fri 11:00 ZHG006

Semiconductor quantum dots in fiber-based microcavities — •Jonas Grammel[1], Nam Tran[2], Simone Luca Portalupi[2], Peter Michler[2], and David Hunger[1] — [1]Physikalisches Institut, Karlsruher Institut für Technologie — [2]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart

Semiconductor single photon sources are fundamental building blocks for quantum information applications. The current limitations of such quantum dot sources are the emitting wavelength and insufficient collection efficiency in fiber-based implementations. In the project *Telecom Single Photon Sources* we aim to realize high brightness, fiber coupled sources of single and indistinguishable photons at the telecom wavelength for the upcoming realization of fiber-based quantum networks. We employ open cavities realized with fiber-based mirrors, in combination with InGaAs quantum dots emitting in the telecom O-band and C-band. To achieve Fourier-limited photons we utilize the lifetime reduction of the emitters via the Purcell effect. We optimize the mode matching between the cavity mode and the guided fiber mode by introducing a fiber-integrated mode-matching optics that can basically reach near-unity collection efficiency. Fundamentally new is also the combination of Fabry-Perot micro-cavity modes with lateral micro- and nanostructures to reduce the cavity mode volume and thereby boost the emission enhancement and efficiency of the single photon emitters.

FRI 5.3 Fri 11:15 ZHG006

Two-photon spectrum and dynamics of a quantum dot under phonon-assisted excitation — •Lennart Jehle[1], Lena Maria Hansen[1], Thomas Sando[1], Patrik Isene Sund[1], Raphael Joos[2], Simone Luca Portalupi[2], Mathieu Bozzio[1], Peter Michler[2], and Philip Walther[1] — [1]University of Vienna, Faculty of Physics, Vienna Center for Quantum Science and Technology (VCQ), 1090 Vienna, Austria — [2]Institut für Halbleiteroptik und Funktionelle Grenzflächen, University of Stuttgart, 70569 Stuttgart, Germany

Quantum dots promise to emit with high probability exactly one photon when pumped by a short laser pulse. However, there exists a finite chance of exciting the quantum dot twice within the duration of a single laser pulse, leading to the consecutive emission of two photons and imposing a fundamental limit on the multiphoton probability. Here, we resolve the distinct temporal shape of each of the photons' wavepackets using fast coincidence detection and report an asymmetric two-photon spectrum unique to phonon-assisted excitation. We demonstrate how this two-photon process provides insights into the emission dynamics and enables a direct measurement of the effective Rabi frequency, thus allowing us for the first time to extract the Rabi frequency of a non-resonantly driven quantum dot. By extending the temporal and spectral analysis further, we uncover correlations between the emission time and wavelength. Finally, we use this new understanding of the re-excitation process to maintain a low multiphoton probability regardless of the laser pulse length and thus improve the performance for quantum cryptography and quantum computing.

FRI 5.4 Fri 11:30 ZHG006

Deterministic single-step fabrication of quantum dot-circular Bragg grating resonators with high process yield — •Avijit Barua[1], Kartik Gaur[1], Léo J. Roche[1], Suk In Park[2], Priyabrata Mudi[1], Sven Rodt[1], Jin-Dong Song[2], and Stephan Reitzenstein[1] — [1]Institut für Physik und Astronomie, Technische Universität Berlin (TUB), Berlin, Germany — [2]Korea Institute of Science and Technology (KIST), Seoul, Republic of Korea

The integration of quantum dot (QD) single-photon emitters into photonic structures is pivotal for the establishment of hybrid quantum networks. Here, we use the deterministic, single-step in-situ electron-beam lithography (i-EBL) for integrating QDs into circular Bragg grating (CBG) resonators with high accuracy and scalability. Notably, devices with two/three rings deliver photon extraction efficiencies comparable to structures with more rings, enabling faster fabrication, reduced device footprint, and compatibility with electrical contacting. To demonstrate scalability, we report on the fabrication of several hundred QD-CBG devices across multiple sessions and samples. The devices exhibit bright, narrow-linewidth single-photon emission with excellent optical quality. To evaluate QD placement accuracy, we perform cathodoluminescence mapping along with scanning electron microscopy, and the statistical analysis of these devices shows that our i-EBL concept allows for sub-40 nm alignment accuracy and >80% process yield across various CBG geometries. Our findings highlight a reliable route toward scalable, high-performance QD-based single-photon sources for future integration in hybrid quantum photonic networks.

FRI 5.5 Fri 11:45 ZHG006

Spectroscopy and coherent nuclear spin manipulation of Eu-based molecular systems — •Evgenij Vasilenko[1], Vishnu Unni C.[1], Barbora Brachnakova[1], Weizhe Li[2], Nicholas Jobbitt[1], Senthil Kuppusamy[1], Mario Ruben[1], and David Hunger[1] — [1]Karlsruhe Institute of Technology — [2]FAU Erlangen

Rare-earth ions in solid-state hosts are promising spin qubit candidates due to their excellent optical and spin coherence properties. Recent work on Eu^{3+}-based molecular materials has demonstrated exceptional optical coherence [1], showing that ligand fields can be chemically engineered to improve both optical and spin properties for quantum applications. We investigate Eu^{3+}-doped molecular crystals and powders that exhibit long spin lifetimes and narrow homogeneous linewidths at 4.2 K [1,2]. In a single macroscopic crystal of $[Eu(Ba)_4(pip)]$, we observe inhomogeneous linewidths of 1.95 GHz, homogeneous linewidths of 120 kHz, spin $T_{1,sp}$ on the order of hours, and photon echo decays around 3 μs at 4.2 K, representing an improvement over previous results [1]. A complete spin characterization was performed on the same molecular complex, including both hyperfine transitions. Spin echo experiments revealed a coherence time of 613 μs, extended to 2 ms via CPMG dynamical decoupling. We also demonstrate the integration of these molecular crystals into open-access Fabry-Pérot fiber cavities to enhance emission via the Purcell effect [3].

[1] Serrano et al., Nature, 603, 241-246 (2022)
[2] Kuppusamy et al., J. Phys. Chem. C 127, 22 (2023)
[3] Hunger et al., New J. Phys 12, 065038 (2010)

FRI 5.6 Fri 12:00 ZHG006

Superconducting parallel-plate resonators for the detection of single electron spins — •André Pscherer, Jannes Liersch, Patrick Abgrall, Hélène Le Sueur, Emmanuel Flurin, and Patrice Bertet — Quantronics Group, Université Paris-Saclay, CNRS, SPEC, 91191 Gif-sur-Yvette Cedex, France

Solid-state spins have been explored as a resource for quantum sensing, computation and communication using mostly optical transitions to control and read out single spins [1]. Even though detecting spins via their spin-flip transition in the microwave frequency range would extend the palette of usable spins to those without optical transitions, this path seems impractical for single spins due to their vanishingly low radiative decay rates. Only recently, our group demonstrated the microwave-only detection of a single spin [2], enabled by a superconducting resonator with a Purcell factor of 10^{14} and a single-microwave-photon detector [3]. In this talk, I will explain the design of the currently used resonator and our progress towards a significantly improved resonator, which will shorten the spin lifetime to ~ 10 μs.

[1] D. Awschalom *et al.*, Nature Photonics, 12(9), 516-527 (2018)
[2] Z. Wang, L. Balembois *et al.*, Nature, 619, 276-281 (2023)
[3] R. Lescanne *et al.*, PRX 10, 021038 (2020)

FRI 5.7 Fri 12:15 ZHG006

Influence of dephasing on the indistinguishability of 2D and bulk-embedded semiconductor quantum emitters — •Steffen Wilksen, Alexander Steinhoff, and Christopher Gies — Institute for Physics, Faculty V, Carl von Ossietzky University Oldenburg, 26129 Oldenburg, Germany

The generation of high-quality single photons is an important prerequisite for a multitude of quantum applications, including linear (photonic) quantum computing and quantum communication. While antibunching has been demonstrated in many cases, limitations of the Hong-Ou-Mandel (HOM) indistinguishability, quantifying the ability of emitted photons to interfere with each other, remain an open research question especially in single-photon sources based on 2D van der Waals materials.

In this talk, we analyze the influence of the coupling to acoustic phonon modes on the photon indistinguishability in two types of semiconductor-based single-photon sources, i.e. quantum dots in transition-metal dichalcogenides (TMDs), and III-V quantum-dot molecules. We simulate the HOM experiment and determine the indistinguishability by numerically computing two-time correlation functions. Results are obtained using an exact diagonalization approach, taking into account both markovian and non-markovian contributions. An optical cavity is considered for altering the recombination rate via the Purcell effect. Our results reveal fundamental limitations of HOM indistinguishability in TMD-based single-photon sources, rooted in the two-dimensional nature of the phonons.

FRI 5.8 Fri 12:30 ZHG006

Two-photon polymerization of strip-loaded thin-film lithium niobate waveguides for high-efficient photon pair sources and quantum circuits — •Alexandra Rittmeier[1,2], Muhamed A. Sewidan[2,3], Elisavet Chatzizyrli[1,2], Philipp Gehrke[1,2], Laura Bollmers[4], Silia Babel[4], Laura Padberg[4], Christof Eigner[4], Christine Silberhorn[4], Douglas Bremner[5], Anna Karoline Rüsseler[1,2], Andreas Wienke[1,2], Dietmar Kracht[1,2,3], Moritz Hinkelmann[1,2], and Michael Kues[1,2,3] — [1]Laser Zentrum Hannover e.V., Germany — [2]PhoenixD, LUH, Germany — [3]Institute of Photonics, LUH, Germany — [4]Paderborn University, Germany — [5]Alter Technology, Livingston, UK

Advancements in integrated photonics are essential for future chip-scale photonic systems and depend on new materials and fabrication methods. Lithium niobate (LN) is highly attractive due to its strong nonlinearity and excellent electro-optical properties. We introduce an etchless fabrication method for strip-loaded thin-film LN waveguides using two-photon polymerization (2PP), achieving low propagation losses of 0.15 dB/cm and rapid production cycles. The approach enables LN substrate reuse, promoting sustainable manufacturing. Using this fabrication approach, we realized a photon pair source with a 201 MHz pair generation rate and a coincidence-to-accidental ratio of 379, outperforming platforms fabricated via etching methods. In addition, we realized key components such as grating and directional couplers, demonstrating the potential of 2PP-fabricated optical components on LN for scalable, high-performance quantum photonic circuits.

FRI 6: Quantum Error Mitigation

Time: Friday 10:45–12:00 Location: ZHG007

FRI 6.1 Fri 10:45 ZHG007

Error Mitigation for Time-Evolution Approach for Greens Functions on Quantum Computers — •Jannis Ehrlich[1] and Daniel F. Urban[1,2] — [1]Fraunhofer-Institut für Werkstoffmechanik IWM, Freiburg, Germany — [2]Freiburger Materialforschungszentrum, Universität Freiburg, Germany

The computation of Greens functions plays a central role in many-particle physics, as they are directly connected to the energy of the system and the spectral function. Their calculation with classical computers is challenging due to the explicit treatment of electron interactions, especially in the case of strong correlation effects. We present a time-evolution approach for extracting the Greens function by simulating the quantum system on a quantum computer. We explicitly investigate the influence of errors on the results and proper error mitigation strategies as well as the effect of symmetry protection for simulations on current quantum devices.

FRI 6.2 Fri 11:00 ZHG007

Coherently mitigating boson samplers with stochastic errors — Deepesh Singh[1], Ryan J Marshman[1], •Nathan Walk[2], Jens Eisert[2,3], Timothy C Ralph[1], and Austin P Lund[1,2] — [1]University of Queensland — [2]Freie Universität Berlin — [3]Helmholtz-Zentrum Berlin

Sampling experiments provide a viable route to show quantum advantages of quantum devices over classical computers in well-defined computational tasks. However, devices such as boson samplers are susceptible to various errors, including stochastic errors due to fabrication imperfections causing the implemented unitary operations to deviate randomly from their intended targets. Whilst full-scale quantum error correction remains challenging, quantum error mitigation schemes have been devised to estimate expectation values, but it is unclear how these would work for sampling experiments. Here, we adopt the unitary averaging protocol which employs multiple stochastic boson samplers to generate a distribution that better approximate the ideal distribution as the number of samplers increases. We derive rigorous upper bounds on the trace distance between the output probability distributions induced by invertible vacuum-heralded networks based on the Schur-Weyl duality. More broadly, these results suggests a path towards understanding error mitigation for sampling experiments and developing analysis tools for photonic circuits incorporating measurements and feed-forward. Other applications include the implementation of linear combination of unitaries and fabrication benchmarking.

FRI 6.3 Fri 11:15 ZHG007

Quantum error mitigation combining subspace and probabilistic techniques — Prachi Sharma[1], João C. Getelina[2], Thomas Iadecola[2,3], Yong-Xin Yao[2,3], and •Peter P. Orth[1] — [1]Department of Physics, Saarland University, 66123 Saarbrücken, Germany — [2]Ames National Laboratory, Ames, Iowa 50011, USA — [3]Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011, USA

As quantum computing advances toward real-world applications, mitigating errors remains a critical challenge, particularly when determining ground state energies of many-body models on noisy quantum hardware. To address this, synergistic approaches to quantum error mitigation are necessary, combining the strengths of multiple techniques to ensure more reliable quantum operations. In this work, we integrate quantum subspace expansion methods with probabilistic error reduction techniques to address these challenges. We apply this framework to ground state energy calculations of a 16-site mixed field Ising model on IBM quantum hardware and noisy simulators using the Variational Quantum Eigensolver (VQE) [1]. Our results demonstrate a two order-of-magnitude improvement in the accuracy of the ground state energy on IBM's noisy backend simulators, highlighting the effectiveness of this approach in systematically enhancing the reliability of quantum computations.

[1] J. Getelina et al., APL Quantum 1, 036127 (2024).

FRI 6.4 Fri 11:30 ZHG007

Mitigation of correlated readout errors without randomized measurements — •Adrian Aasen[1,2], Andras Di Giovanni[3], Hannes Rotzinger[3], Alexey Ustinov[3], and Martin Gärttner[2] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Heidelberg, Germany — [2]Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Jena, Germany — [3]Physikalisches Institut, Karlsruher Institut für Technologie, Karlsruhe, Germany

Quantum simulation, the study of strongly correlated quantum matter using synthetic quantum systems, has been the most successful application of quantum computers to date. It often requires determining observables with high precision, for example when studying critical phenomena near quantum phase transitions. Thus, readout errors must be carefully characterized and mitigated in data post-processing, using scalable and noise-model agnostic protocols. We present a readout error mitigation protocol that uses only single-qubit Pauli measurements and avoids experimentally challenging randomized measurements. The proposed approach captures a very broad class of correlated noise models and is scalable to large qubit systems. It is based on a complete and efficient characterization of few-qubit correlated positive operator-valued measures (POVMs), using overlapping detector tomography. To assess the effectiveness of the protocol, observables are extracted from simulations involving up to 100 qubits employing readout errors obtained from experiments with superconducting qubits.

FRI 6.5 Fri 11:45 ZHG007

Revealing correlated noise with single-qubit operations — •Balázs Gulácsi, Joris Kattemölle, and Guido Burkard — University of Konstanz

Spatially correlated noise poses a significant challenge to fault-tolerant quantum computation by breaking the assumption of independent errors. Existing methods such as cycle benchmarking and quantum process tomography can characterize noise correlations but require substantial resources. We propose straightforward and efficient techniques to detect and quantify these correlations by leveraging collective phenomena arising from environmental correlations in a qubit register. In these techniques, single-qubit state preparations, single-qubit gates, and single-qubit measurements, combined with classical post-processing, suffice to uncover correlated relaxation and dephasing. Specifically, we use that correlated relaxation is connected to the superradiance effect which we show to be accessible by single-qubit measurements. Analogously, the established parity oscillation protocol can be refined to reveal correlated dephasing through characteristic changes in the oscillation line shape, without requiring the preparation of complex and entangled states.

FRI 7: Entanglement and Complexity: Contributed Session to Symposium III

Time: Friday 10:45–12:15 Location: ZHG008

FRI 7.1 Fri 10:45 ZHG008

Entanglement theory with limited computational resources — Lorenzo Leone, Jacopo Rizzo, Jens Eisert, and •Sofiene Jerbi — Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, Germany

The precise quantification of the ultimate efficiency in manipulating quantum resources lies at the core of quantum information theory. However, purely information-theoretic measures fail to capture the actual computational complexity involved in performing certain tasks. In this work, we rigorously address this issue within the realm of entanglement theory. We consider two key figures of merit: the computational distillable entanglement and the computational entanglement cost, quantifying the optimal rate of entangled bits (ebits) that can be extracted from or used to dilute many identical copies of n-qubit bipartite pure states, using computationally efficient LOCC. We demonstrate that computational entanglement measures diverge significantly from their information-theoretic counterparts. While the von Neumann entropy captures information-theoretic rates for pure-state transformations, we show that under computational constraints, the min-entropy instead governs optimal entanglement distillation. Meanwhile, efficient entanglement dilution requires maximal ($\tilde{\Omega}(n)$) ebits even for nearly unentangled states. Our results establish a stark, maximal separation of $\tilde{\Omega}(n)$ vs $o(1)$ between computational and information-theoretic entanglement measures. Finally, we find new sample-complexity bounds for measuring and testing the von Neumann entropy, efficient state compression, and efficient LOCC tomography protocols.

FRI 7.2 Fri 11:00 ZHG008

Quantum Magic and Entanglement in Nuclear Many-Body Systems — •Federico Rocco[1], James W. T. Keeble[1], and Caroline Robin[1,2] — [1]Fakultät für Physik, Universität Bielefeld, D-33615 Bielefeld, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, D-64291 Darmstadt, Germany

Concepts of quantum information science shed light on the complexity of quantum many-body systems, providing new insights into the structure of matter and emergence of degrees of freedom. Non-stabilizerness, or magic, is related to the amount of non-Clifford resources required to perform a quantum simulation and has emerged as a central quantity in the study of quantum complexity. Beyond that, estimates of non-local magic between different partitions of the nuclear system can uncover many-body correlations not captured by entanglement. In this talk, I will discuss investigations of magic and non-local magic based on stabilizer Rényi entropies in atomic nuclei, as well as the connection between quantum complexity, emergent collective behavior and shape deformation.

FRI 7.3 Fri 11:15 ZHG008

Revealing continuous-variable entanglement through derivatives of phase-space distributions — •Elena Callus[1], Martin Gärttner[1], and Tobias Haas[2] — [1]Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena — [2]Institute of Theoretical Physics, Universität Ulm

The Peres–Horodecki, or positive partial transpose, criterion is a necessary condition for bipartite separability, and its violation is sufficient to certify the presence of entanglement. In this work, we explore the implication of this criterion on phase-space distributions of separable states. More specifically, we show that one can formulate separability criteria in terms correlations of phase-space distributions, together with their spatial derivatives, at arbitrary points in phase space. This approach complements work on certification of nonclassicality by means of such distributions [1]. We demonstrate the versatility of this approach by considering the relevance of low-ordered criteria in certifying entanglement in important classes of states. Finally, we also discuss possible experimental approaches in order to access these entanglement witnesses.

[1] M. Bohmann, E. Agudelo, and J. Sperling, "Probing nonclassicality with matrices of phase-space distributions", Quantum 4, 343 (2020).

FRI 7.4 Fri 11:30 ZHG008

Demonstration of verified BosonSampling — •Naomi Spier[1], Redlef B G Braamhaar[1], Riko Schadow[2], Sara Marzban[1], Jens Eisert[2], Nathan Walk[2], and Jelmer J Renema[1] — [1]University of Twente — [2]Freie Universität Berlin

Sampling from random quantum circuits has been proposed as a first demonstration of a concrete computational advantage for special purpose, non-universal quantum processors. Whilst ideal sampling implementations have extremely strong complexity theoretic arguments for their classical intractability, real sampling devices are vulnerable to the potential existence of efficient, classical simulation algorithms and the status of many claimed advantage demonstrations remains contested. The original sampling proposal, BosonSampling, involves the propagation of single photon states through a random linear optical interferometer and has received significant attention, especially due to the rapid increase in the size, quality and configurability of integrated photonic waveguides. Whilst photon loss errors are immediately apparent from the data, errors due interferometer imperfections and photon distinguishability can also destroy quantum advantage but are more challenging to quantify. In this work, utilising recently developed photonic fidelity witnesses, we carry out a proof-of-principle, efficient verification of a BosonSampler using an integrated, reconfigurable interferometer. The verification is shown to detect errors due to interferometer noise, distinguishability and Poissonian photon sources.

FRI 7.5 Fri 11:45 ZHG008

Purification of Noisy Measurements and Faithful Distillation of Entanglement — •Jaemin Kim, Jiyoung Yun, and Joonwoo Bae — School of Electrical Engineering, Korea Advanced Institute of Science and Technology (KAIST), 291 Daehak-ro, Yuseong-gu, Daejeon 34141, Republic of Korea

We consider entanglement distillation with noisy operations in which quantum measurements that constitute a general quantum operation are particularly noisy. We present a protocol for purifying noisy measurements and show that imperfect local operations can distill entanglement. The protocol works for arbitrary noisy measurements in general and is cost-effective and resource-efficient with single additional qubit per party to resolve the distillation of entanglement. The purification protocol is feasible with currently available quantum technologies and readily applied to entanglement applications.

FRI 7.6 Fri 12:00 ZHG008

Entangled subspaces through algebraic geometry — •Masoud Gharahi[1] and Stefano Mancini[2] — [1]University of Trieste, Trieste, Italy — [2]University of Camerino, Camerino, Italy

We propose an algebraic geometry-inspired approach for constructing entangled subspaces within the Hilbert space of a multipartite quantum system. Specifically, our method employs a modified Veronese embedding, restricted to the conic, to define subspaces within the symmetric part of the Hilbert space. By utilizing this technique, we construct the minimal-dimensional, non-orthogonal yet Unextendible Product Basis (nUPB), enabling the decomposition of the multipartite Hilbert space into a two-dimensional subspace, complemented by a Genuinely Entangled Subspace (GES) and a maximal-dimensional Completely Entangled Subspace (CES). In multiqudit systems, we determine the maximum achievable dimension of a symmetric GES and demonstrate its realization through this construction. Furthermore, we systematically investigate the transition from the conventional Veronese embedding to the modified one by imposing various constraints on the affine coordinates, which, in turn, increases the CES dimension while reducing that of the GES.

FRI 8: Quantum Detectors in Optics and Particle Physics

Time: Friday 10:45–12:15 Location: ZHG009

FRI 8.1 Fri 10:45 ZHG009

Laser-Doppler-Vibrometer mit quetschlichtverbesserter Auflösung — •Mengwei Yu[1], Pascal Gewecke[2], Roman Schnabel[2] und Christian Rembe[1] — [1]Institut für Elektrische Informationstechnik, TU Clausthal, 38678 Clausthal-Zellerfeld — [2]Institut für Quantenphysik, Universität Hamburg, 22761 Hamburg

Das heterodyne Laser-Doppler-Vibrometer (LDV) detektiert kleinste Schwingungsamplituden bei mechanischen Strukturen mit einer Auflösung im Sub-Picometerbereich und ist typischerweise durch Photonenschrotrauschen beschränkt. Kennzeichnend für das heterodyne LDV ist, dass das Fotodetektorsignal einen Träger bei der Differenzfrequenz zwischen Mess- und Referenzlicht hat. Korrelierte Photonen überwinden als sogenanntes Quetschlicht die Schrotrauschgrenze von optischem Messverfahren. Durch das Einkoppeln von vakuumquetschtem Licht in den Messstrahl eines LDVs kann entweder das Amplituden- oder das Phasenrauschen des Lichts effektiv unterdrückt werden. Die Reduzierung des Phasenrauschens führt zu einer Verbesserung des Träger-Rausch-Verhältnisses und folglich zu einer verbesserten Amplitudenauflösung bei der Schwingungsmessung. In dieser Studie wird ein heterodynes LDV vorgestellt, das die Einspeisung von Quetschlicht mit synchroner Abtastung und Demodulation kombiniert. Die digitale Vibrationsamplitudenauflösung wird in diesem Beitrag von einem durch Schrotrauschen limitierten Wert von 6 $\mathrm{fm}/\sqrt{\mathrm{Hz}}$ auf ein sub-Schrotrauschen-Niveau von 4 $\mathrm{fm}/\sqrt{\mathrm{Hz}}$ verbessert, was das Potenzial quantenbasierter Technologien in hochpräzisen optischen Messsystemen aufzeigt.

FRI 8.2 Fri 11:00 ZHG009

Dynamics of quantum mixtures in microgravity — •Lakshmi Priyanka Guggilam, Jonas Böhm, and Dorthe Leopoldt — Institut für Quantenoptik, Leibniz Universität Hannover

The MAIUS (Matter wave interferometry under microgravity) project aims to demonstrate atom interferometry in weightlessness as a promising tool for precision measurements, e.g., of Einstein*s equivalence principle (EEP), with accuracies that couldn*t be achieved with classical tests. With the launch of MAIUS-1, it was possible to create the first BECs in space using Rb-87 atoms and performing interference experiments with these macroscopic quantum objects. In MAIUS-2, we focus on understanding the dynamics of K-41 and Rb-87 quantum mixtures in microgravity to pave the wave for long-time dual species atom interferometry. This talk is focused on the preparation of K-41 and Rb-87 quantum mixtures in the Einstein Elevator, an active drop tower providing 4 s of microgravity time every 4 minutes. In addition, the simultaneous transport of both species to weaker traps using Shortcut To Adiabaticity (STA) protocols and their resulting dynamics will be discussed. These techniques are important prerequisites to perform EEP tests with BECs created on an atom chip under microgravity. The MAIUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number: 50WP1431.

FRI 8.3 Fri 11:15 ZHG009

Gravitational wave-induced photon superradiance in atoms — •Navdeep Arya and Magdalena Zych — Stockholm University, Stockholm, Sweden

The effects of spacetime curvature on atoms are typically very small. However, we argue that spontaneous buildup of quantum coherence enables atoms in an array to cooperate and amplify their response to gravitational waves. This cooperation manifests as gravitational wave-induced photon superradiance—delayed, intense, and directional emission of photons at frequencies shifted by the gravitational wave frequency. This effect arises in a regime distinct from flat-spacetime superradiance, which allows gravitational effects to dominate the collective atomic response. The effect persists despite common experimental challenges like position disorder and partial filling, highlighting coherent atom arrays as potential candidates for broadband gravitational wave detection. Our findings demonstrate a coupling interface between general relativistic gravity and quantum matter under laboratory settings in a many-body system, with implications for both fundamental science and practical applications.

FRI 8.4 Fri 11:30 ZHG009

Label-free mid-IR imaging with undetected photons — •Marlon Placke[1], Chiara Lindner[2], Felix Mann[1], Inna Kviatkovsky[1], Helen Chrzanowski[1], Frank Kühnemann[2], and Sven Ramelow[1] — [1]Institute for Physics, Humboldt-Universität zu Berlin, Germany — [2]Fraunhofer Institute for Physical Measurement Techniques IPM, Freiburg, Germany

Sensing with undetected photons has become a distinct research field with numerous demonstrated applications, often dedicated to mid-infrared wavelength regions. Since these spectral bands entail molecule specific absorbance signatures also referred to as their fingerprints, sample compositions may be probed spectroscopically. To sidestep the challenges associated with camera sensors and low noise and broadband illumination sources for low-energy mid-infrared photons, we utilise a nonlinear interferometer in a widefield imaging arrangement with around 3500 resolved spatial modes and broadband signal and idler emission around 800 and 3800 nm, respectively. To importantly combine this with high-resolution spectral information, we employ Fourier transform infrared spectroscopy by scanning the interferometric delay and analysing the resulting interferogram for each illuminated camera pixel. Finally, we demonstrate the practicality of our novel hyperspectral technique for applications such as microplastics detection and bio-imaging tasks. Accordingly, this quantum imaging method holds good potential for applications relying on compact, cost-effective, and label-free analysis near the intrinsic performance limit of the probe light itself.

FRI 8.5 Fri 11:45 ZHG009

Optimisation of TES design for the CRESST experiment — •Colin Moore — Max-Planck-Institut für Physik

The Cryogenic Rare Event Search with Superconducting Thermometers (CRESST) experiment aims at the direct detection of sub-GeV dark matter particles via elastic scattering off nuclei in a variety of target crystals at cryogenic temperatures. Located at the underground Laboratori Nazionali del Gran Sasso (LNGS) in Italy, CRESST operates cryogenic calorimeters consisting of an absorber crystal equipped with a tungsten Transition Edge Sensor (W-TES).

The W-TES developed in CRESST are composed of a tungsten thin film serving as the sensitive part of the thermometer, a gold thermal link connecting the sensor to the heat bath, and aluminum phonon collectors which increase the collection area of the sensors. Additionally, each W-TES is equipped with a heater which stabilises the sensors within their superconducting transition.

The technology utilised by CRESST allows for a leading energy threshold. Nevertheless, continuous R&D efforts are underway to further improve signal to noise ratio and overall sensitivity. Optimising the TES design is a non-trivial task, owing to the complex interdependence of the properties of the absorber and sensor. To address these challenges, we have conducted detailed studies targeting specific aspects of the TES design and carried out comparative evaluations of various sensors configurations.

In this contribution, we present the outcomes of these optimisation studies and their impact on the performance of CRESST detectors.

FRI 8.6 Fri 12:00 ZHG009

COMPASSO mission and its quantum optical clock — •Johanna Popp[1], Frederik Kuschweski[1], Jan Wüst[1], Markus Oswald[1], Tim Blomberg[1], Jonas Pollex[2], André Bussmeier[1], Niklas Röder[1], Issaree Khattiwiriyapinyo[1], Thilo Schuldt[1], and Claus Braxmaier[1,3] — [1]DLR Institute of Quantum Technologies — [2]DLR Institute of Space Systems — [3]Institute of Microelectronics, University of Ulm

Quantum optical clocks are high-performance devices in terms of frequency stability and accuracy and are therefore important instruments in research of fundamental and applied physics, such as in geodesy and navigation with the Global Navigation Satellite System (GNSS). The established microwave clock technologies on GNSS satellites are one limititation for geolocation with cm precision. Hence national and international space agencies are aiming to replace these systems with next-generation technologies. In the DLR COMPASSO mission, a quantum optical clock based on modulation transfer spectroscopy of iodine will be deployed to the ISS as a technology demonstrator [1]. In this contribution, we present the mission architecture and highlight the key part of the optical clock: the iodine-based optical frequency reference reaching a fractional instability down to 10^{-15}.

[1] Kuschewski, F. et al. GPS Solut 28, 10 (2024).

FRI 9: Fundamental Quantum Tests

Time: Friday 10:45–11:30 Location: ZHG101

FRI 9.1 Fri 10:45 ZHG101

Optically Hyperpolarized Materials for Levitated Optomechanics - Testing the Nuclear Einstein de-Haas and Barnett Effect — •Marit O. E. Steiner, Julen S. Pedernales, and Martin B. Plenio — Institute of Theoretical Physics, Ulm University, Germany

Levitated solids with controllable spins offer a new platform for exploring spin-mechanical interactions in the solid state. Nuclear spin hyperpolarization enables investigation of the weak couplings between nuclear spins and rotational degrees of freedom, which have so far eluded experimental observation.

I will explore the potential of levitating solids embedded with optically controllable electron spins, which can hyperpolarize their nuclear spin environment. Pentacene-doped naphthalene serves as a leading example. Leveraging photoexcited triplet states in pentacene, this system achieves nuclear spin hyperpolarization in naphthalene with demonstrated polarization rates up to 80%, significantly enhancing spin-dependent forces and sensitivity to spin-rotational couplings.

I then investigate the use of hyperpolarized naphthalene to probe the nuclear Einstein-de Haas and Barnett effect. These theoretically predicted effects have not yet been observed in solids due to weak spin-mechanical coupling. By combining polarized hydrogen nuclear spins with controllable particle rotation, we propose a protocol to enable their first detection in the solid state.

FRI 9.2 Fri 11:00 ZHG101

99 years old and going stronger than ever: the molecular hydrogen ion — Stephan Schiller[1], •Soroosh Alighanbari[1], Magnus Schenkel[1], Vladimir Korobov[2], and Jean-Philippe Karr[3] — [1]Heinrich-Heine-Universität Düsseldorf — [2]Joint Institute for Nuclear Research, Dubna — [3]LKB, Sorbonne Université; Université d' Evry-Val d' Essonne

At the end of 1926, the same year that Schrödinger presented his wave equation, it was applied for the first time to a molecule, the molecular hydrogen ion (MHI) by Burrau. Even famous physicists (Pauli, Teller, Herzberg, Dehmelt, Lamb) worked on the topic at some time. Nevertheless, for the first 70 years, it did not appear that this family of three-body systems would become of much relevance to fundamental physics - it was too difficult to handle, experimentally and computationally. However, thanks to the efforts of a few reserach teams, today the precision physics of the MHI is entering center stage. MHIs are beginning to contribute to the determination of fundamental constants, tests of quantum physics, and the search for new interparticle forces. Furthermore, the perspective of comparing vibrational transitions in H_2^+ and its antimatter counterpart could lead to novel and ultra-accurate tests of CPT invariance.

MHIs are today studied with some of the most advanced techniques, such as sympathetic laser cooling, rotational laser cooling, quantum logic spectroscopy, Penning-Malmberg traps, frequency-comb-based optical metrology, cw-optical parametric oscillators. A bright future of high-accuracy results still lies ahead.

FRI 9.3 Fri 11:15 ZHG101

Multi-Path and Multi-Particle Tests of Complex versus Hyper-Complex Quantum Theory — Ece Ipek Saruhan, Joachim von Zanthier, and •Marc-Oliver Pleinert — Quantum Optics and Quantum Information Group, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 1, 91058 Erlangen, Germany

The axioms of quantum mechanics provide limited information regarding the structure of the Hilbert space, such as the underlying number system. The latter is generally regarded as complex, but generalizations of complex numbers, so-called hyper-complex numbers, cannot be ruled out in theory. Therefore, specialized experiments to test for hyper-complex quantum mechanics are needed. To date, experimental tests are limited to single-particle interference exploiting a closed phase relation in a three-path interferometer called the Peres test. The latter distinguishes complex quantum mechanics from quaternionic quantum mechanics. Here, we propose a general matrix formalism putting the Peres test on a solid mathematical ground. On this basis, we introduce multi-path and multi-particle interference tests, which provide a direct probe for any dimension of the number system of quantum mechanics.

[Phys. Rev. Lett. 134, 060201 (2025)]

FRI 10: Foundational / Mathematical Aspects – Unconventional Approaches

Time: Friday 10:45–12:45 Location: ZHG103

FRI 10.1 Fri 10:45 ZHG103

Particle-wave duality and quantization: Self-organisation of particle movement in zero-point field — •Christian Jooss — Institute of Materials Physics, University of Goettingen, Friedrich-Hund-Platz 1, 37077 Goettingen, Germany

The Göttingen physicist Friedrich Hund gave a fitting definition of quantum theory, namely as 'The theory of the role that h plays in nature'.[1] In this contribution, I discuss the Planck constant h as being an emergent quantity, reflecting the threshold between energy and momentum conserving random motions of particles in the Lorentz-invariant zero-point field and the lasting energy / momentum changes of quantum states. The analysis builts up on the analysis of the stochastic effects of a real zero-point field on particle motion[2], distinguishing reversible fluctuations which underly detailed energy balance and abrupt lasting changes in quantum state determined by h. Based on simple models of these processes, the emergence of particle-wave duality can be understood in terms of a self-organization effect, where the effect of the zero-point field on particle motion and its back reaction on zero-point fluctuations gives rice to the emergence of matter waves. Thus, existence of the quantum of action is interpreted as an expression of an organizational law[3]. The impact of this analysis on the realistic interpretation of quantum mechanics is discussed.

[1] F. Hund, Geschichte der Quantentheorie, BI Wissenschaftsverlag 1975.

[2] L. de la Pena and A. M. Cetto, The quantum dice: An introduction to stochastic electrodynamics, Kluwer Academic Publishers, 1996.

[3] Ch. Jooss, Self-organization of Matter, de Gruyter 2020.

FRI 10.2 Fri 11:00 ZHG103

Quantum randomness revisited: simulating quantum measurement as a unitary time evolution — •Thomas Dittrich, Oscar Rodríguez, and Carlos Viviescas — Departamento de Física, Universidad Nacional de Colombia, Bogotá D.C., Colombia

Quantum measurement is usually regarded as incompatible with unitary time evolution, since the collapse of the wave packet breaks time reversal invariance. We challenge this view, studying quantum measurement as a unitary time evolution of the measurement object coupled to an environment that represents the meter and the apparatus. Modelled as a heat bath comprising only a finite, if large, number of boson modes, it is fully included in the time evolution of the entire system. We perform unitary numerical simulations of projective measurements of σz in spin-1/2 particles. They are prepared in a neutral pure state, the environment in a product of coherent states with centroids chosen at random from a thermal distribution. Initially, the spin gets entangled with the heat bath and loses coherence, reproducing the collapse. For large times and most of the initial states of the environment, the spin returns to a pure state, either spin up or spin down with equal probability, as definite outcome of the measurement. Unitarity allows us to run the simulations backwards from final state to preparation, undoing the measurement and tracing its result back to those initial conditions of the heat bath that entailed this result. That reveals the observed randomness as amplified quantum and thermal noise of the macroscopic environment. Extending our approach to an EPR setup is sketched as work in progress.

FRI 10.3 Fri 11:15 ZHG103

A heuristic solution to the time of arrival problem via mathematical probability theory — •Maik Reddiger — Anhalt University of Applied Sciences

There does currently not exist any scientific consensus on how to predict the probability that a single quantum particle impinges on an ideal detector in a given interval of time. The apparent simplicity of the problem is overshadowed by the deep conceptual discrepancies, which are exposed by the multitude of solutions proposed so far. Ab initio approaches need to model the ideal detector in such a manner, that it is compatible with quantum dynamics. A corresponding boundary condition for the Schrödinger equation was suggested by Werner in the 1980s, yet there is reason to question the physical validity of this detector model. In this talk I present an approach via mathematical probability theory and a physically natural adaption of the Madelung equations, which assures that the detector is perfectly absorbing. The presented solution is heuristic in the sense that a full solution would require a well-posedness result for the Cauchy problem of the corresponding system of PDEs for sufficiently regular initial data.

This solution of the time of arrival problem is obtained within the more general framework of geometric quantum theory. Geometric quantum theory is a novel adaption of quantum mechanics, which makes the latter consistent with mathematical probability theory.

FRI 10.4 Fri 11:30 ZHG103

Simultaneous processes in mechanics and quantum physics — •Grit Kalies[1] and Duong D. Do[2] — [1]HTW University of Applied Sciences, Dresden, Germany — [2]The University of Queensland, Brisbane, Australia

Processes change the properties of objects. Using examples such as the lifting, acceleration or displacement of a body as well as of a quantum object, we substantiate the plausibility and advantages of replacing 'force is action' with 'process is action'. Since each process with energy transfer describes the change in one property of a macroscopic or microscopic object, simultaneous processes allow for a more detailed energetic analysis than forces. The notion of acting forces and the current general definition of work are interpreted as helpful geometric substitute concepts, which conceal the actual dynamic processes such as the momentum work that takes place at the macroscopic and quantum levels.

FRI 10.5 Fri 11:45 ZHG103

Plasma-like description for quantum particles — •Andrey Akhmeteli — LTASolid Inc., Houston, Texas, USA

A scalar complex wave function can be made real by a gauge transformation (Schrödinger, Nature, 1952). Similarly, one real function is also enough to describe matter in more realistic theories, such as the Dirac equation in an arbitrary electromagnetic (Akhmeteli, J. Math. Phys., 2011, Eur. Phys. J. C, 2024) or Yang-Mills (A., Quantum Rep., 2022) field. As these results suggest some "symmetry" between positive and negative frequencies and, therefore, particles and antiparticles, one-particle wave functions can be described as plasma-like collections of a large number of particles and antiparticles (A., Eur. Phys. J. C, 2013, Entropy, 2022). The similarity of the dispersion relations for the Klein-Gordon equation and a simple plasma model provides another motivation for the plasma-like description of quantum particles.

The criterion for approximation of continuous charge density distributions by discrete ones with quantized charge is based on Gaussian smoothing (A., arXiv:2503.10667). A discrete distribution satisfying this criterion can be found for any smooth distribution. An example mathematical model of the interpretation is proposed.

The plasma-like description can offer an intuitive picture of the uncertainty principle, the double-slit experiment, and negative probabilities. Wave function spreading is not problematic for the model. Any experimental results that can be described using one-particle wave functions can be emulated using the plasma-like description.

FRI 10.6 Fri 12:00 ZHG103

Pinning quantum particles to surfaces and curves: a momentum operator-based approach — •Mohammad Shikakhwa — Department of Basic Sciences, TED University, Ziya Gökalp Caddesi No.48, Kolej - Çankaya, Ankara, Turkey

A physical, intuitive approach is proposed to confine a spin zero particle in 3D to arbitrary surfaces and curves embedded in the 3D space through the introduction of strong confining potential(s). The idea is to start from the onset with the Hamiltonian expressed in terms of the Hermitian *components* of the momentum operator and achieve confinement to the lower dimensional manifolds by dropping these Hermitian components that are normal to these manifolds along with setting the corresponding normal coordinates to zero. The resulting Hamiltonian, expressed now in terms of the manifold momenta along with a geometrical potential is a Hermitian operator. The resulting manifold momenta are at the kinematical ones proportional to the velocity of the particle on these manifolds.

FRI 10.7 Fri 12:15 ZHG103

Two quantum analogies — •Ryszard Wojnar — Institute of Fundamental Technological Research PAS

In the first analogy, the diffusion equation with an imaginary diffusion coefficient D=ih/2m is considered. The solutions are harmonic functions decaying in time. The disappearance time of a wave packet is proportional to m/h: for an electron of the order of seconds, for a mass of 1 g of the order of 10^10 years.

The second analogy refers to the hexatic transformation. The change in the contact of the particles participating in the transformation leads to either the creation or annihilation of dislocations 5-7, formations distinguished against the background of the hexagonal lattice.

FRI 10.8 Fri 12:30 ZHG103

Volume Portions Provide the Quantum Postulates and Exact Quantum Frames For Space Navigation — •Hans-Otto Carmesin — Universität Bremen, Fachbereich 1, Postfach 330440, Bremen — Studienseminar Stade, Bahnhofstr. 5, Stade — Gymnasium Athenaeum, Harsefelder Straße 40, Stade

A space paradox shows that space is an average of microscopic volume portions. These imply the quantum postulates, as well as gravity and curvature in spacetime. It is very valuable and insightful that the volume portions show how the quantum postulates are derived from spacetime and how they are applied to spacetime: In this manner, exact quantum frames of spacetime are derived and exact space navigation is enabled for the first time (Carmesin 2025). Predictions are derived, have been tested empirically, and can additionally be tested by space flights in various manners.

[1] Carmesin, H.-O. (2025): On the Dynamics of Time, Space and Quanta - Essential Results for Space Flight and Navigation. Berlin: Verlag Dr. Köster.

FRI 11: Quantum 2D-Moiré and Rhombohedral van-der-Waals Systems: Contributed Session to Symposium

Time: Friday 10:45–12:30 Location: ZHG104

FRI 11.1 Fri 10:45 ZHG104

Observation of Floquet states in graphene — •Marco Merboldt[1], Michael Schüler[2], David Schmitt[1], Jan Philipp Bange[1], Wiebke Bennecke[1], Karun Gadge[3], Klaus Pierz[4], Hans Werner Schumacher[4], Davood Momeni[4], Daniel Steil[1], Salvatore R. Manmana[3], Michael Sentef[5], Marcel Reutzel[1], and Stefan Mathias[1] — [1]Georg-August-Universität Göttingen, I. Physikalisches Institut, Germany — [2]Department of Physics, University of Fribourg, Fribourg, Switzerland — [3]Georg-August-Universität Göttingen, Institut für Theoretische Physik, Germany — [4]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [5]Institute for Theoretical Physics, University of Bremen, Bremen, Germany

Floquet engineering – the coherent dressing of matter via time-periodic perturbations – is a mechanism to realize and control emergent phases in materials out of equilibrium. However, the broad applicability of Floquet engineering to quantum materials is in question, especially with respect to (semi-)metals and graphene in particular.

Here, we resolve this long-standing debate by using electronic structure measurements to provide direct spectroscopic evidence of Floquet effects in graphene [1]. We report light-matter-dressed Dirac bands by measuring the contribution of Floquet sidebands, Volkov sidebands, and their quantum path interference to graphene's photoemission spectrum. Fully supported by experiment and theory, we demonstrate that Floquet engineering in graphene is possible.

[1] Merboldt *et al.*, Nature Physics (2025)

FRI 11.2 Fri 11:00 ZHG104

Giant chiral current in gapped graphene at room temperature — •Fanrong Lin[1], Weilong Guo[2], Qingjun Tong[2], and Yanpeng Liu[3] — [1]Georg-August-University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]Hunan University — [3]Nanjing university of aeronautics and astronautics

Nonlinear electrical signals serve as a complementary probe for investigating intrinsic quantum geometric properties while also revealing unconventional charge transport phenomena in systems with specific band topologies. A paradigmatic example is the chiral charge transport observed in gapped monolayer graphene, where the chiral Bloch electrons undergo unidirectional skew scattering. However, these nonlinear signals are typically exceedingly weak, necessitating either intrinsic topological band structures or extrinsic circuit enhancements to achieve detectable magnitudes. Here, we introduce a linear projection method that amplifies nonlinear physical, yielding a dramatically enhanced signal even at room temperature. Using this approach, we observe a robust unidirectional skew-scattered current, exhibiting a signal of several microvolt at room temperature. Furthermore, this chiral current exhibits dual tunability via external gate and DC bias voltages, enabling control over both the majority carrier type and the skew conductivity. Finally, we demonstrate nonlocal transport mediated by this tunable chiral current, generating a substantial nonlocal signal in remotely gated Hall bar pairs with a geometric factor of 4. This unconventional charge transport mechanism opens a pathway for long-range control in next-generation electronic devices.

FRI 11.3 Fri 11:15 ZHG104

Thermoelectric Transport Measurements in Dual-Gated Bernal Bilayer Graphene — •Moritz Knaak[1], Martin Statz[1], Kenji Watanabe[2], Takashi Taniguchi[3], and Thomas Weitz[1] — [1]1. Institute of Physics, Faculty of Physics, University of Göttingen, Göttingen, Germany — [2]Research Center for Functional Materials, National Institute for Materials Science, Tsukuba, Japan — [3]International Center for Materials Nanoarchitectonics, National Institute for Materials Science, Tsukuba, Japan

In dual-gated, hexagonal boron-nitride(hBN) encapsulated Bernal bilayer graphene(BLG) devices a cascade of correlated phases have been identified by magnetoconductance measurements. The correlated phases emerge close to Lifshitz-transitions. There, the density of states(DOS) is high and the kinetic energy gets quenched. While conductance measurements alone can be used to study correlated phases, it is difficult to precisely connect the DOS with said phases. The Seebeck coefficient, extracted from thermoelectric transport measurements provides a more direct probe of the DOS. It is defined as the ratio of the thermal voltage to its inducing temperature difference. We demonstrate measurements of the Seebeck coefficient at 4 K up to a calibration factor. For the measurements we employed an on-chip heater next to an hBN-encapsulated BLG device with graphite contacts and dual graphite gates to simultaneously tune the Fermi-level and an out-of-plane electric field. The source-drain contacts were simultaneously used as quasi-4-point-probe on-chip resistance thermometers to determine the local temperature differences between them.

FRI 11.4 Fri 11:30 ZHG104

Two-particle spin and valley blockade in graphene double quantum dots — •Christian Volk[1,2], Samuel Möller[1,2], Luca Banszerus[1,2], Katrin Hecker[1,2], Hubert Dulisch[1,2], Kenji Watanabe[3], Takashi Taniguchi[4], and Christoph Stampfer[1,2] — [1]JARA-FIT and 2nd Institute of Physics, RWTH Aachen University — [2]Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich — [3]Research Center for Functional Materials, NIMS, Tsukuba, Japan — [4]International Center for Materials Nanoarchitectonics, NIMS, Tsukuba, Japan

Double quantum dots (DQDs) are promising building blocks for spin or valley qubits. The weak hyperfine interaction and the weak spin-orbit interaction in bilayer graphene (BLG) promise long spin coherence times. Additionally, the well tunable valley degree of freedom offers the possibility to create valley-based qubits in BLG DQDs. Efficient readout requires a spin- or valley-to-charge conversion, often provided by Pauli blockade. Thus, a comprehensive understanding of the limits and the tunablility of spin and valley blockade in BLG DQDs is necessary for evaluating their potential for hosting qubits.

Here, we show spin and valley blockade in two-electron BLG DQDs. Magnetotransport measurements reveal a rich level spectrum and we observe a magnetic field tunable spin and valley blockade, which is limited by the orbital splitting, the strength of the electron-electron interaction and the difference in the valley g-factors between the symmetric and antisymmetric two-particle orbital states. Our findings are supported by transport simulations following a rate equation approach.

FRI 11.5 Fri 11:45 ZHG104

Electronic Transport in Twisted Bilayer Graphene: Towards Quantum Moirétronics — •Thomas Stegmann — Instituto de Ciencias Físicas, Universidad Nacional Autónoma de México

We investigate electronic transport in twisted bilayer graphene (TBLG) at small - though not magic - twist angles. In the first part of the talk, we propose a device in which the direction of the current flow can be steered by the twist between the layers. The observed current steering angle exceeds significantly the twist angle itself and arises over a broad range of experimentally accessible parameters. This behavior is attributed to the trigonal warping of the energy bands beyond the van Hove singularity, induced by the moiré pattern. Since the shape of these bands depends on the valley degree of freedom, the resulting current is partially valley-polarized, highlighting potential applications in valleytronics [1]. In the second part, we report anomalous edge states in TBLG at a twist angle of 1.696°. These edge states support electronic transport with conductance values near the conductance quantum and give rise to a nonlocal resistance. Notably, this nonlocal effect is not due to chiral edge transport, but due to the fact that these states are localized only at certain edges of the system, depending on how the nanoribbon has been cut from the bulk [2]. Finally, we discuss briefly how the electronic transport in graphene can be guided along atomically thin current paths through the engineering of Kekulé distortions, offering yet another route toward nanoscale current steering [3].

[1] J. Phys: Mater. 5:024003 (2022)
[2] Phys. Rev. B 110:205432 (2024)
[3] Nano Letters 24:2322 (2024)

FRI 11.6 Fri 12:00 ZHG104

Persistent Haldane Phase in Carbon Tetris Chains — •Anas Abdelwahab[1], Christoph Karrasch[2], and Roman Rausch[2] — [1]Leibniz Univesität Hannover, Institut für Theoretische Physik, Hannover — [2]Technische Universität Braunschweig

We introduce the concept of "tetris chains", which are linear arrays of 4-site molecules that differ by their intermolecular hopping geometry. We investigate the fermionic symmetry-protected topological Haldane phase in these systems using Hubbard-type models. The topological phase diagrams can be understood via different competing limits and mechanisms: strong-coupling $U \gg t$, weak-coupling $U \ll t$, and the weak intermolecular hopping limit $t' \ll t$. Our particular focus is on two tetris chains that are of experimental relevance. First, we show that a "Y-chain" of coarse-grained nanographene molecules (triangulenes) is robustly in the Haldane phase in the whole $t' - U$ plane due to the cooperative nature of the three limits. Secondly, we study a near-homogeneous "Y'-chain" that is closely related to the electronic model for poly(p-phenylene vinylene). In the latter case, the above mechanisms compete, but the Haldane phase manifests robustly and is stable when long-ranged Pariser-Parr-Popple interactions are added. The site-edged Hubbard ladder can also be viewed as a tetris chain, which gives a very general perspective on the emergence of its fermionic Haldane phase. Our numerical results are obtained using the density-matrix-renormalization group as well as the variational uniform matrix-product state (VUMPS) algorithms.

FRI 11.7 Fri 12:15 ZHG104

A Wannier approach to electronic structure in twisted van der Waals bilayers — •Ruven Hübner[1], Matthias Florian[2], and Alexander Steinhoff[1] — [1]Institute for Physics, Faculty V, Carl von Ossietzky University Oldenburg, 26129 Oldenburg, Germany — [2]University of Michigan, Dept. of Electrical Engineering and Computer Science, Ann Arbor, MI, USA

Moiré structures in two-dimensional van der Waals materials offer an interesting platform to explore the interplay of quantum phenomena across vastly different length scales—from the atomic scale, on the order of Ångström, to the supercell scale, reaching up to ~ 40 nm. While DFT calculations have made remarkable progress in handling large systems, they do not readily reveal the dominant mechanisms that govern the electronic structure. In fact, it seems natural to retain much of the electronic structure of the individual monolayers and treat the interlayer interaction as a relatively small perturbation. This view can be well motivated by the model of Koshino, who introduced a tight-binding framework for moiré bilayers where a simple basis transformation reveals dominant interlayer couplings in reciprocal space, enabling a significant reduction in basis states [1]. We take this approach one step further by incorporating the Wannier projection method, based on multiple DFT calculations of untwisted bilayers with different stacking configurations. Besides providing a computationally efficient model, our framework enables analytical insight into moiré band splitting within the original Brillouin zones of the monolayers. [1] Mikito Koshino 2015 New J. Phys. **17** 015014

FRI 12: Quantum Phenomena in Solid-State Devices

Time: Friday 10:45–12:30 Location: ZHG105

FRI 12.1 Fri 10:45 ZHG105

Probing many-body correlations using quantum-cascade correlation spectroscopy — •Thomas Volz — School of Mathematical and Physical Sciences, Macquarie University, Sydney, Australia

In quantum optics, the radiative quantum cascade is of fundamental importance. Two-photon cascaded emission has been instrumental for example to test Bell inequalities and generate entangled photon pairs. These experiments rely on the nonlinear nature of the underlying energy ladder, which enables the direct excitation and probing of specific single-photon transitions. Here we use exciton-polaritons to explore the cascaded emission of photons in the regime where individual transitions are not resolved. We excite a polariton quantum cascade by off-resonant laser excitation and probe the emitted luminescence using a combination of a narrow spectral filter and a Hanbury-Brown and Twiss setup for measuring the second-order autocorrelation function of the photons. The measured photon-photon correlations exhibit a strong dependence on the polariton energy and therefore on the underlying polaritonic interaction strength, with clear signatures of Feshbach resonances due to two- and three-body excitonic complexes, shedding new light on earlier observations of photon autocorrelations in resonant transmission. We not only establish photon cascade correlation spectroscopy as a highly sensitive tool to study the underlying quantum properties of novel semiconductor materials and many-body quantum phenomena. Our findings also highlight the potential of semiconductor exciton-polariton systems for generating single-photon non-linearities.

FRI 12.2 Fri 11:00 ZHG105

X-ray parametric down-conversion reveals EUV-polariton — •Christina Bömer — Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

Spontaneous parametric down-conversion (PDC) of photons is a gateway into the quantum realm. On the occasion of 100 years of Quantum Physics, we present a study of the effect in the x-ray regime and report the observation of a novel hybrid-state of light and matter that emerges from this fundamental nonlinear process. In our experiment, single x-ray photons are spontaneously converted by a diamond crystal into photon pairs. Of each pair, one photon is tuned to the extreme-ultraviolet (EUV) spectral range, where its coupling to the surrounding diamond is so strong that photonic and electronic properties hybridize: This forms the EUV-polariton. Remarkably, the hybridization occurs without an enhancement cavity, which marks a stark contrast to the prevalent paradigm of strong-coupling in cavities. The EUV-polariton links quantum hybridization in the microscopic domain to meso- and macroscopic length scales via its cavity-free propagation. This offers enticing prospects for studying buried interfaces and nanostructures using the polariton itself as a probe.

FRI 12.3 Fri 11:15 ZHG105

Single polycyclic aromatic molecular emitters embedded in a hexagonal boron nitride stack — •Tianyu Fang, Ricardo Gioia Alvarez, and Daqing Wang — Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, 53115 Bonn, Germany

Single polycyclic aromatic hydrocarbon molecules embedded in solid-state matrices have been proven an excellent platform for narrow-linewidth single-photon emission. We extend this host-guest setting to van der Waals materials to leverage the advantages of flexible hybrid integration. By encapsulating perylene molecules between hexagonal boron nitride stacks, we observe spectrally narrow single-photon emission at cryogenic temperatures. We determine the exact emission origins through vibronic spectra assignment and resolve 0-0 zero-phonon-line linewidths down to the GHz scale.

FRI 12.4 Fri 11:30 ZHG105

Electron-hole quantum dots in bilayer graphene — •Christoph Stampfer[1,2], Katrin Hecker[1], Lars Mester[1], Hubert Dulisch[1], Konstantinos Kontogeorgiou[3], Simone Sotgiu[1], Fabian Hassler[3], and Christian Volk[1,2] — [1]JARA-FIT and 2nd Institute of Physics A, RWTH Aachen University, Aachen, Germany, EU — [2]Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich, Jülich, Germany, EU — [3]JARA-Institute for Quantum Information, RWTH Aachen University, 52056 Aachen, Germany, EU

Here we show that bilayer graphene allows the realization of electron-hole double quantum dots that exhibit near-perfect particle-hole symmetry, in which transport occurs via the creation and annihilation of single electron-hole pairs with opposite quantum numbers. We demonstrate that particle-hole symmetric spin and valley textures lead to a protected single-particle spin-valley blockade. The latter will allow robust spin-to-charge and valley-to-charge conversion, which are essential for the operation of spin and valley qubits. By time-resolved measurements where we apply a dual pulse between the (0e, 0h) to (1e, 1h) charge configurations we study unconventional higher order tunneling processes which are able to lift the blockade. Extracting the timescales of blockade lifting and investigating the main mechanisms in the strong lead-quantum dot coupled system, allows us to confirm the state degeneracies. Combined with microwave control, the presented spin-valley blockade will enable the study of spin and valley coherence times by electron spin-resonance or electron dipole spin-resonance techniques, and open the door for spin and valley qubit operation.

FRI 12.5 Fri 11:45 ZHG105

Interplay between Hund's rule and Kondo effect in the third shell of a quantum dot — •Olfa Dani[1], Johannes C. Bayer[1,2], Timo Wagner[1], Gertrud Zwicknagl[3], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Institut für Mathematische Physik, Technische Universität Braunschweig, Braunschweig, Germany

We study electron transport in the third shell [1] of a gate-defined quantum dot in a GaAs/AlGaAs two-dimensional electron gas. The device structure allows the precise determination and controlled variation of the number of electrons (N) occupying the quantum dot [2]. We observe zero-bias anomalies (ZBAs) with unexpected large widths for successive filling of the shell of the quantum dot. The ZBAs display a characteristic particle-hole symmetry for the three spin-degenerate orbital states. The broad widths of the ZBAs are attributed not only to the contribution of a Kondo resonance but also to the presence of excited Hund multiplets [3]. The role of Hund's rule exchange is further supported by the triangular trend of the charging energy as function of N in the third shell. The quantum dot is viewed as a multi-orbital Kondo impurity with Hund's interaction and serves as a model system for a Hund's coupled impurity.

[1] L. P. Kouwenhoven, et. al., Rep. Prog. Phys. 64, 701-736 (2001).
[2] T. Wagner, et. al., Nat. Phys.15, 330-334 (2019).
[3] O. Dani, et. al., arXiv: 2505.21675 (2025).

FRI 12.6 Fri 12:00 ZHG105

Hybrid optomechanics with double quantum dots — •Victor Ceban — Institute of Applied Physics, Moldova State University, Chisinau, Moldova

The quantum dynamics of a hybrid optomechanical device made of a double quantum dot (DQD) interacting with phonons and photons had been investigated. The system dynamics is solved for the cases when one bosonic field is multi-mode and the other is single-mode. The contribution of the multi-mode field is treated via the reservoir theory, within the Born and Markov approximations, and a set of corresponding damping terms are introduced into the master equation which describes the system dynamics. The behaviour of different optomechanical devices can be described via the proposed model where the single-mode field describes either photons in an optical cavity or phonons in a nanomechanical resonator, while the contribution of the multi-mode field is given by the electromagnetic vacuum or a thermal phonon bath. Here we present the effect of the environmental (phonon/photon) reservoir on the single-mode (photon/phonon) field due to the interaction with the DQD.

FRI 12.7 Fri 12:15 ZHG105

Atomic-size contacts obtained from lithographically fabricated electrodes using electromigration at room temperature in ambient condition and under vacuum — •Samanwita Biswas[1], Werner Wirges[1], Thomas Hultzsch[1], Marcel Strohmeier[2], Annika Zuschlag[2], Sarah Loebner[1], Dieter Neher[1], Elke Scheer[2], and Regina Hoffmann-Vogel[1] — [1]University of Potsdam — [2]University of Konstanz

Developing tunable yet stable atomic junctions for molecular electronics has always been challenging. The standard electrode material for molecular electronics is Au because of its electronic simplicity and resistance to chemical reaction making it easy to use. Pd, with its d-bands contributing to the charge transport and its relatively low Fermi energy is interesting for establishing good electrical contact to low-dimensional materials. In our study we explore the charge transport of electron beam lithography patterned Pd nanocontacts with a width of about 100nm.Via electromigration (EM) we have further narrowed them down to a cross section of few atoms and eventually reaching also the one atomic contact limit. We have conducted EM in nitrogen atmosphere in a glove box and under vacuum. The experiments under vacuum have been performed using a mechanically controlled break junction setup in combination. Atomic force microscope and scanning electron microscope measurements indicate successful EM. The conductance histograms from both experiments show comparable results.

Job Market (JOB)

Nicole Schramm
Wiley-VCH GmbH
Boschstraße 12
69469 Weinheim
nschramm@wiley.com

Alexandra Wojtanowska
Wiley-VCH GmbH
Boschstraße 12
69469 Weinheim
awojtanows@wiley.com

During the conference various companies and organisations will present their working fields and career opportunities to all interested participants.

Overview of Invited Talks and Sessions

(Lecture hall ZHG005)

Invited Talks

JOB 1.1	Mon	12:45–13:30	ZHG005	**Aus der Wissenschaft in die Beratung** — •Tobias Weisrock, •Maximilian Kurjahn
JOB 1.2	Mon	13:30–14:15	ZHG005	**Building quantum computers atom by atom** — •Davide Dreon, Julia Koller
JOB 2.1	Thu	12:45–13:30	ZHG005	**Challenge the Limits of Imagination** — •Nils Haverkamp, •Sebastian Vauth
JOB 2.2	Thu	13:30–14:15	ZHG005	**Data-Analytics in der HUK-COBURG – Wie Physiker den Weg in ein datengetriebenes Versicherungsunternehmen mitgestalten** — •Jannik Hofestädt, •Andreas Gleixner, •Thomas Körzdörfer

Sessions

JOB 1.1–1.2	Mon	12:45–14:15	ZHG005	**Job Market I**
JOB 2.1–2.2	Thu	12:45–14:15	ZHG005	**Job Market II**

Sessions

– Invited Talks –

JOB 1: Job Market I

Time: Monday 12:45–14:15 Location: ZHG005

Invited Talk JOB 1.1 Mon 12:45 ZHG005

Aus der Wissenschaft in die Beratung — •Tobias Weisrock und •Maximilian Kurjahn — Basycon Unternehmensberatung GmbH, Welserstr. 1, 81373 München

Beratung bei Basycon heißt, die Vorteile von Forschung und klassischer Unternehmenskarriere zu verbinden. Insbesondere Naturwissenschaftler bringen aufgrund ihrer Ausbildung beste Voraussetzungen mit, um anspruchsvolle Fragestellungen zu lösen.

Die Veranstaltung richtet sich an Studierende der Naturwissenschaften, die nach Abschluss ihrer Hochschulausbildung eine Tätigkeit außerhalb der Universität anstreben und Beratung als Chance verstehen, vielfältige, herausfordernde Fragestellungen mit konkretem Praxisbezug zu bearbeiten und so intensive Einblicke in verschiedene Tätigkeiten / Rollen unterschiedlicher Unternehmen zu erhalten.

Konkret möchten wir Ihnen auf der Veranstaltung einen Einblick in folgende Themen geben:

- Welche Gemeinsamkeiten Forschungs- und Beratungsprojekte haben
- Wie sich Beratungstätigkeiten unterscheiden und welche Schwerpunkte Basycon setzt
- Welche Einstiegsmöglichkeiten und Perspektiven Basycon bietet

Invited Talk JOB 1.2 Mon 13:30 ZHG005

Building quantum computers atom by atom — •Davide Dreon and Julia Koller — PlanQC GmbH, Münchenerstr. 34, 85748 Garching (Munich)

Davide is Head of Product Development at PlanQC. He is an experimental physicist by training, specialized in quantum gases and quantum simulation.

Before joining planqc, he spent over two years at PASQAL as a Research Fellow, managing an R&D team focused on experimental quantum setups.

He completed his PhD at the Laboratoire Kastler Brossel in Paris in the group of Jean Dalibard, focusing on quantum gases of highly magnetic atoms. He then conducted postdoctoral research at ETH Zurich in Tilman Esslinger's group, studying the interaction of Bose-Einstein condensates with light modes inside optical resonators.

JOB 2: Job Market II

Time: Thursday 12:45–14:15 Location: ZHG005

Invited Talk JOB 2.1 Thu 12:45 ZHG005

Challenge the Limits of Imagination — •Nils Haverkamp and •Sebastian Vauth — Carl Zeiss AG

In this talk, Nils and Sebastian will give an overview on how ZEISS is systematically pushing the limits of what is possible. They will give insights into the tools used in organizing this with respect to technology and business development. Further they will show, what the "life of a physicist" can look like at ZEISS.

Invited Talk JOB 2.2 Thu 13:30 ZHG005

Data-Analytics in der HUK-COBURG – Wie Physiker den Weg in ein datengetriebenes Versicherungsunternehmen mitgestalten — •Jannik Hofestädt, •Andreas Gleixner und •Thomas Körzdörfer — HUK Coburg

Ein Überblick über das Data-Analytics Programm bei der HUK-COBURG mit Fokus auf die typischen Aufgabenbereiche von Physikern.

Die Referenten berichten aus ihrem Arbeitsalltag in Forschung und Entwicklung in Telematik (auf Sensordaten basierende Bewertung von Unfallrisiken) sowie der Optimierung von internen Prozessen mit KI (speziell LLMs).

Index of Exhibitors — 2nd Fall Meeting Göttingen 2025

Exhibition venue

Universität Göttingen
Zentrales Hörsaalgebäude (ZHG)
Platz der Göttinger Sieben 5, 37073 Göttingen

Exhibition opening hours

Tuesday, 9 Sep	10:30 — 17:30
Wednesday, 10 Sep	10:30 — 17:30
Thursday, 11 Sep	10:30 — 18:30

Stand-No.

Advanced Quantum GmbH **A30**
Christophstraße 4, 70178 Stuttgart
Offers a wide rage of specialized hardware for measurement control, high-precision sensing, quantum computing based on defect centers in diamond or silicon carbide and quantum physics education kits.

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High Performance Power Supplies, ZERO FLUCS Precision Current Measurements, Beamline Electronic Instrumentation, MicroTCA and FMC.

Consortium FAIRmat c/o Humboldt-Universität zu Berlin **A35**
Zum Großen Windkanal 2, 12489 Berlin
FAIRe Dateninfrastruktur für die Physik der kondensierten Materie und die Chemische Physik von Stoffen.

CryoVac GmbH & Co. KG **A7**
Langbaurghstraße 13, 53842 Troisdorf
Helium-, Bad- und Verdampferkryostate, Temperaturmess- und Regelgeräte.

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Leopoldstraße 244, 80807 München

Munich Quantum Valley promotes quantum science and quantum technologies in Bavaria and offers various research positions, especially in connection to quantum computing.

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Books, Catalogues

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Cavity-based platforms for quantum optics experiments, fiber-based micromirrors, and absorption microscopes

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RPTU in Kaiserslautern, Erwin-Schrödinger-Str., 67663 Kaiserslautern

QUIP and UpQuantVal offer students, graduates, and young scientists worldwide tailored training and careers in quantum tech, linking research and education in Rhineland-Palatinate and Upper Rhine.

Quantum BW Universität Stuttgart – IQST **A21**

Pfaffenwaldring 57, 70569 Stuttgart

QuantumBW brings together a wide range of players from science and industry in the state of Baden-Württemberg, Germany, to promote the transfer of pioneering quantum science to market applications.

Quantum Delft A23+A24

Elektronicaweg 10, 2628 XG Delft, Netherlands

Quantum Delta Delft is the Netherlands' central hub for quantum technology, home to TU Delft, QuTech, and a growing cluster of companies developing quantum computers, networks and sensors.

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Quantum Valley Lower Saxony is a growing ecosystem for quantum technologies in Lower Saxony. It connects leading research institutions, young talents, industry partners, start-ups, and policymakers.

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Produkte zur Quanteninformationsverarbeitung, z.B. verschränkte Photonenpaarquellen

SAES Getters S.p.A. A13

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Wissenschaftliche Bücher und Zeitschriften

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Wissenschaftliche Fachliteratur

TOPAG Lasertechnik GmbH **C2**

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Westfälische Hochschule **A17**

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Das Projekt GE-prof ist darauf ausgelegt, langfristig mehr Menschen für die Wissenschaftskarriere zu begeistern. Wir möchten dabei sowohl Studierende als auch in der Industrie Tätige ansprechen.

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XeedQ develops, manufactures, and provides access to diamond NV-center quantum systems. Our XQ1 quantum computer with 4+ qubits is available now.

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Exhibition DPG Fall Meeting QUANTUM 2025