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**

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 WomenIn-QuantumTech: 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 Helmholtzzentrum 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 su-

perlattices — •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 $\sim$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 non-magnetic 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. König[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 Quantechnologie 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 nonlinear 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 GOEGrid 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 downconversion (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 $50\,\mu$W, 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 $4x10^{-3}$ 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 microstructured 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. Arensktötter, 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 $T_2 = 10$ms [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 $T = 1.7$K.
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-Univerität 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 $0.28\,\mathrm{K}/\sqrt{\mathrm{Hz}}$. 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 $\mathcal{O}(100)\,\mu$as. 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 $\mathcal{O}(100)\,\mu$s 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 microresonator, 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 $\pm\,0.4\,\%$.

[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 end-facets 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 quasiparticle 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.