Q 11: Quantum Information (joint session QI/Q)

Time: Wednesday 16:30–18:30 Location: P

Q 11.1 Wed 16:30 P

Does a disordered isolated Heisenberg spin system thermalize? — •Titus Franz[1], Adrien Signoles[2], Renato Ferracini Alves[1], Clément Hainaut[1], Sebastian Geier[1], Andre Salzinger[1], Annika Tebben[1], Shannon Whitlock[3], Gerhard Zürn[1], Martin Gärttner[4], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Heidelberg, 69120 Heidelberg, Germany — [2]Pasqal, 91120 Palaiseau, France — [3]IPCMS and ISIS, University of Strasbourg and CNRS, 67000 Strasbourg, France — [4]Kirchhoff-Institut für Physik, Universität Heidelberg, 69120 Heidelberg, Germany

The far-from equilibrium dynamics of generic disordered systems is expected to show thermalization, but this process is yet not well understood and shows a rich phenomenology ranging from anomalously slow relaxation to the breakdown of thermalization. While this problem is notoriously difficult to study numerically, we can experimentally probe the relaxation dynamics in an isolated spin system realized by a frozen gas of Rydberg atoms. By breaking the symmetry of the Hamiltonian with an external field, we can identify characteristics of the long time magnetization, including a non-analytic behavior at zero field. These can be understood from mean field, perturbative, and spectral arguments. The emergence of these distinctive features seem to disagree with Eigenstate Thermalization Hypothesis (ETH), which indicates that either a better theoretical understanding of thermalization is required or ETH breaks for the here studied quench in a disordered spin system.

Q 11.2 Wed 16:30 P

How Quantum Evolution with Memory is Generated in a Time-Local Way — •Konstantin Nestmann[1,2], Valentin Bruch[1,2], and Maarten R. Wegewijs[1,2,3] — [1]RWTH Aachen — [2]JARA-FIT — [3]Peter Grünberg Institut

Two widely used approaches to the dynamics of open quantum systems with strong dissipation and memory are the Nakajima-Zwanzig and the time-convolutionless quantum master equation. The first one uses a *time-nonlocal* memory kernel $\mathcal{K}$, whereas the second achieves the same using a *time-local* generator $\mathcal{G}$. Here we show that the two are connected by a simple yet general fixed-point relation: $\mathcal{G} = \hat{\mathcal{K}}[\mathcal{G}]$ [1].

This result provides a deep connection between these two entirely different approaches with applications to strongly interacting open quantum systems [2]. In particular, it explicitly relates two widely used but *distinct* perturbative expansions [3], quantitatively connects the *distinct* non-perturbative Markov approximations they define, and resolves the puzzling issue how these manage to converge to exactly the same stationary state.

Furthermore, our fixed-point equation naturally leads to an iterative procedure to compute the time-local generator directly from the memory kernel producing non-Markovian approximations which are guaranteed to be accurate both at short and long times.

[1] Phys. Rev. X **11**, 021041 (2021)
[2] arXiv:2104.11202
[3] arXiv:2107.08949

Q 11.3 Wed 16:30 P

Tailored Optical Clock Transition in ^{40}Ca^{+} — •Lennart Pelzer[1], Kai Dietze[1], Johannes Kramer[1], Fabian Dawel[1], Ludwig Krinner[1,2], Nicolas Spethman[1], Victor Martinez[2], Nati Aharon[3], Alex Retzker[3], Klemens Hammerer[2], and Piet Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, — [3]Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Israel

Optical clocks based on single trapped ions are often impeded by long averaging times due to the quantum projection noise limit. Longer probe time would improve the statistical uncertainty, but currently, phase coherence of clock laser systems is limiting probe times for most clock candidates. We propose pre-stabilization of the laser to a larger ^{40}Ca^{+} ion crystal, offering a higher signal-to-noise ratio. We engineer an artificial optical clock transition with a two stage continuous dynamical decoupling scheme, by applying near-resonant rf dressing fields. The scheme suppresses inhomogeneous tensor shifts as well as the linear Zeeman shift, making it suitable for multi-ion operation. This tailored transition has drastically reduced magnetic-field sensitivity. Even without any active or passive magnet-field stabilization, it can be probed close to the second-long natural lifetime limit of the $D_{5/2}$ level. This ensures low statistical uncertainty. In addition, we show a significant suppression of the quadrupole shift on a linear five-ion crystal by applying magic angle detuning on the rf-drives.

Q 11.4 Wed 16:30 P

Experimental exploration of fragmented models and non-ergodicity in tilted Fermi-Hubbard chains — •Clara Bachorz[1], Sebastian Scherg[1,2], Thomas Kohlert[1,2], Pablo Sala[3], Frank Pollmann[3], Bharath Hebbe Madhusudhana[1,2], Immanuel Bloch[1,2], and Monika Aidelsburger[1] — [1]LMU Munich, Germany — [2]Max-Planck institut fur Quantenoptik, Garching, Germany — [3]TUM Munich, Germany

Thermalization of isolated quantum many-body systems is deeply related to redistribution of quantum information in the system. A question of fundamental importance is when do quantum many-body systems fail to thermalize, i.e., feature non-ergodicity. A test-bed for the study of non-ergodicity is the tilted Fermi-Hubbard model, which is directly accessible in experiments with ultracold atoms in optical lattices. Here we experimentally study non-ergodic behavior in this model by tracking the evolution of an initial charge-density wave [1]. In the limit of large tilts, we identify the microscopic processes which the observed dynamics arise from. These processes constitute an effective Hamiltonian and we experimentally show its validity [2]. This effective Hamiltonian features the novel phenomenon of Hilbert space fragmentation. For intermediate tilts, while these effective models are no longer valid, we show that the features of fragmentation are still vaguely present in the dynamics. Finally, we explore the relaxation dynamics of the imbalance in a 2D tilted Fermi-Hubbard system.

[1.] Sebastian Scherg et al. arXiv:2010.12965
[2.] Thomas Kohlert et al. arXiv:2106.15586

Q 11.5 Wed 16:30 P

Quantifying necessary quantum resources for nonlocality — •Lucas Tendick, Hermann Kampermann, and Dagmar Bruss — Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, D-40225 Düsseldorf, Germany

Nonlocality is one of the most important resources for quantum information protocols. The observation of nonlocal correlations in a Bell experiment is the result of appropriately chosen measurements and quantum states. We study quantitatively which quantum resources within the state and measurements are needed to achieve a given degree of nonlocality by exploiting the hierarchical structure of the resources. More explicitly, we quantify the minimal purity to achieve a certain Bell value for any Bell operator. Since purity is the most fundamental resource of a quantum state, this enables us also to quantify the necessary coherence, discord, and entanglement for a given violation of two-qubit correlation inequalities. Our results shine new light on the CHSH inequality by showing that for a fixed Bell violation an increase in the measurement resources does not always lead to a decrease of the minimal state resources.

Q 11.6 Wed 16:30 P

Floquet Hamiltonian Engineering of an Isolated Many-Body Spin System — •Sebastian Geier[1], Nithiwadee Thaicharoen[1,2], Clément Hainaut[1], Titus Franz[1], Andre Salzinger[1], Annika Tebben[1], David Grimshandl[1], Gerhard Zürn[1], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Research Center for Quantum Technology, Faculty of Science, Chiang Mai University 239 Huay Kaew Road, Muang, Chiang Mai, 50200, Thailand

Controlling interactions is the key element for quantum engineering of many-body systems. Using time-periodic driving, a naturally given many-body Hamiltonian of a closed quantum system can be transformed into an effective target Hamiltonian exhibiting vastly different dynamics. We demonstrate such Floquet engineering with a system of spins represented by Rydberg states in an ultracold atomic gas. Applying a sequence of spin manipulations, we change the symmetry properties of the effective Heisenberg XYZ Hamiltonian. As a consequence, the relaxation behavior of the total spin is drastically modified. The observed dynamics can be qualitatively captured by a semi-classical simulation. Synthesising a wide range of Hamiltonians opens vast opportunities for implementing quantum simulation of non-equilibrium dynamics in a single experimental setting.

Q 11.7 Wed 16:30 P

Detecting Genuine Multipartite Entanglement Using Quantum Teleportation — •Sophie Egelhaaf, Harry Giles, and Paul Skrzypczyk — University of Bristol, Bristol, UK

In the standard quantum teleportation protocol one party is given an unknown quantum state that is teleported to another party, using a shared entangled state, a Bell state measurement and classical communication. In this work, we consider adding a third party, whose role is to act as a 'gatekeeper', either allowing or blocking the teleportation between the other two parties.

We show that the capabilities of the gatekeeper depend upon the type of multipartite entanglement they share with the other two parties. In particular, we show that a sufficiently ideal performance can only be achieved if the shared state is genuine multipartite entangled.

Q 11.8 Wed 16:30 P

Coupling Erbium Dopants to Silicon Nanophotonic Structures — Andreas Gritsch[1], Lorenz Weiss[1], •Johannes Früh[1], Stephan Rinner[1], Florian Burger[1], and Andreas Reiserer[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Ludwig-Maximilians-Universität, München, Germany

Erbium dopants are promising candidates for the implementation of large-scale quantum networks since they can combine second-long ground state coherence with coherent optical transitions at telecommunication wavelength. Among the potential host crystals for erbium, silicon stands out because it allows for the scalable fabrication of nanophotonic devices based on established processes of the semiconductor industry. In contrast to observations of previous studies, we have shown that erbium ions implanted into silicon nanostructures can be integrated at well-defined lattice sites with narrow inhomogeneous (~1 GHz) and homogeneous (<0.1 GHz) linewidths [1]. By optimizing the sample preparation, we have recently improved the homogeneous linewidth down to 20 kHz. As the long lifetime of the optically excited state (~0.25 ms) would limit the achievable rates, we designed and fabricated photonic crystal cavities which may reduce the lifetime by more than three orders of magnitude. This will allow us to control individual dopants, making our system a promising candidate for the implementation of distributed quantum information processing.

[1] L. Weiss, A. Gritsch, B. Merkel, and A. Reiserer, Optica, 8, 40-41(2021)

Q 11.9 Wed 16:30 P

Site-specific Rydberg excitation in a multi-site quantum register of neutral atoms — •Tobias Schreiber, Dominik Schäffner, Jan Lautenschläger, Malte Schlosser, and Gerhard Birkl — Institut für Angewandte Physik, TU Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany

Applications in quantum technologies, such as quantum information science and metrology, demand for scalable platforms of identical quantum systems. Additionally, precise spatial control and fast switching of quantum states and of qubit coupling constitute milestones for quantum computing and simulation.

We present a micro-optical platform for defect-free assembled 2D clusters of more than 100 single-atom quantum systems [1] and demonstrate site-resolved excitations into various Rydberg states [2]. Together with fast addressing of individual array sites at a microsecond timescale, we gain real-time control over interactions between next neighbors in the quantum register. This allows the demonstration of Rydberg blockade with tunable blockade strength dependent on the respective state and atom separation. In combination with long coherence times for the prepared hyperfine states of the atoms, this technique leads the way to quantum computing and simulation with neutral atoms in our experimental setup.

[1] D. Ohl de Mello et. al., Phys. Rev. Lett. **122**, 203601 (2019).
[2] M. Schlosser et. al., J. Phys. B: At. Mol. Opt. Phys. **53** 144001 (2020).

Q 11.10 Wed 16:30 P

Characterising which causal structures might not support a classical explanation based on any underlying physical theory — •Shashaank Khanna and Matthew Pusey — Department of Mathematics, University of York, Heslington, UK

A causal relationship can be described using the formalism of Generalised Bayesian Networks. This framework allows the depiction of cause and effect relations (causal scenarios) effectively using generalised directed acyclic graphs (GDAGs). A GDAG is "not interesting" if the causal relations existing can be explained classically regardless of the underlying physical theory. Henson, Lal and Pusey (HLP) have proposed a sufficient condition to check whether a causal scenario is "not interesting". With their methods and some more developments the problem of identifying "interesting" causal structures has been solved for GDAGs of 6 nodes. But the problem of identifying "interesting" causal scenarios for GDAGs of 7 nodes is still open. We propose a new graphical theorem (and call it the E-separation theorem) to check several of the GADGs of 7 nodes which couldn't be checked by HLP's condition. Finally we also use "fine-grained" entropic inequalities to check whether the remaining GDAGs (of 7 nodes) are interesting or not.

Q 11.11 Wed 16:30 P

Average waiting times for entanglement links in quantum networks — •Lisa Weinbrenner, Lina Vandré, and Otfried Gühne — Universität Siegen, Deutschland

In quantum communication protocols using noisy channels the error probability typically scales exponentially with the length of the channel. To reach long-distance entanglement distribution, one can use quantum repeaters. These schemes involve first a generation of elementary bipartite entanglement links between two nodes and then measurements to join the elementary links. Since the generation of an elementary link is probabilistic and quantum memories have a limited storage time, the generation of a long-distance entangled link is probabilistic, too [1].

While the average waiting time for the generation of such a link in the case of just two elementary links is well understood [2], there is no analytical expression known for more than two links. The aim of this contribution is to explore estimations on the average waiting time for a long-distance entangled link for arbitrary network sizes.

[1] S. Khatri et al., Phys. Rev. Research 1, 023032 (2019)
[2] O. A. Collins et al., Phys. Rev. Lett 98, 060502 (2007)

Q 11.12 Wed 16:30 P

A perceptron quantum gate for quantum machine learning — •Patrick Huber[1], Erik Torrontegui[2], Johann Haber[3], Patrick Barthel[1], Juan Jose Garcia Ripoll[2], and Christof Wunderlich[1,3] — [1]Universität Siegen, Walter-Flex-Straße 3, 57068 Siegen — [2]Instituto de Física Fundamental IFF-CSIC - Calle Serrano 113b, 28006 Madrid, Spain — [3]eleQtron GmbH, Martinshardt 19, 57074 Siegen

As quantum computing advances towards the implementation of noisy intermediate-scale quantum computers (NISQs), the number of applications and scientific use cases keep growing. A recent addition is machine learning. We demonstrate the implementation of a perceptron on an ion-based quantum computer comprised of three qubits, a bias qubit, a control qubit, and a target qubit, the latter of which encodes the output state of the perceptron. The system uses magnetic gradient induced coupling (MAGIC) which allows for the control of the qubits by microwave radiation. The magnetic gradient also induces an Ising-like interaction between individual ions. This property is exploited in order to implement the perceptron. We demonstrate both the working of the basic perceptron quantum gate as predicted in [1], and show that by successive application of the perceptron more sophisticated multi-qubit quantum gates can be implemented easily and straightforwardly.

[1] Unitary quantum perceptron as efficient universal approximator, E. Torrontegui and J. J. García-Ripoll EPL, 125 3 (2019) 30004 DOI: https://doi.org/10.1209/0295-5075/125/30004

Q 11.13 Wed 16:30 P

Spatial entanglement dynamics between two quantum walkers with symmetric and anti-symmetric coins — •Ibrahim Yahaya Muhammad[1], Tanapat Deesuwan[1], Sikarin Yoo-Kong[2], Suwat Tangwancharoen[1], and Monsit Tanasittikosol[1] — [1]Department of Physics, Faculty of Science, King Mongkut's University of Technology Thonburi, Bangkok, Thailand — [2]The Institute for

Fundamental Study (IF), Naresuan University, Phitsanulok, Thailand

We investigate the dynamics of the spatial entanglement between two initially independent walkers that individually and identically perform discrete-time quantum walk with symmetric and anti-symmetric initial coin states. The numerical results show that the spatial entanglement between the two walkers behaves similarly to the dynamics of an underdamped oscillator. By considering the symmetry associated with the setting and post-selecting the states of the two coins accordingly, we show both numerically and analytically that, for the anti-symmetric initial coin state, the entanglement dynamics corresponding to all the "triplet" results are constant, and the damping behaviour only shows up in the "singlet" result. On the other hand, for the symmetric initial coin state, the relationships between the entanglement dynamics and the post-selecting results are the other way around. Moreover, we obtain the relationship between the period of oscillation (T) and the coin operator parameter (θ) for the damping case as T = π/θ. Our findings reveal some interesting aspects of symmetry and quantum walks, which may be useful for applications in quantum communication and other quantum technology.

Q 11.14 Wed 16:30 P

Vibrationally-decoupled cryogenic surface-electrode ion trap for scalable quantum computing and simulation — •Niklas Orlowski[1], Timko Dubielzig[1], Sebastian Halama[1], Chloe Allen-Ede[1], Niels Kurz[1], Celeste Torkzaban[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

We present an overview of the necessary experimental infrastructure to perform experiments with an integrated microwave near-field surface-electrode ion trap at cryogenic temperatures for quantum logic applications [1]. We describe the measures to isolate the ions from environmental influences, like vibrational decoupling and XUHV-conditions. We discuss the loading scheme involving lasers for ablation and ionization as well as Doppler cooling, repumping and detection of $^9Be^+$-ions. State preparation and manipulation procedures with precisely timed and tuned microwave and laser pulses are presented. Finally, we report on thermal stabilization as required for reproducible radial sideband spectroscopy. The achieved stability of the radial sideband modes will allow for implementation of microwave sideband-cooling and microwave quantum gates [2].

[1] Dubielzig et al. RSI **92.4** (2021): 043201
[2] Zarantonello et al. PRL **123**, 260503

Q 11.15 Wed 16:30 P

Retrieval of single photons from solid-state quantum transducers — •Tom Schmit[1], Luigi Giannelli[1,2,3], Anders S. Sørensen[4], and Giovanna Morigi[1] — [1]Theoretical Physics, Department of Physics, Saarland University, 66123 Saarbr+cken, Germany — [2]Dipartimento di Fisica e Astronomia "Ettore Majorana", Universit\a di Catania, Via S. Sofia 64, 95123 Catania, Italy — [3]INFN, Sez. Catania, 95123 Catania, Italy — [4]enter for Hybrid Quantum Networks (Hy-Q), Niels Bohr Institute,University of Copenhagen, Blegdamsvej 17, DK-2100 Copenhagen Ø, Denmark

Quantum networks using photonic channels require control of the interactions between the photons, carrying the information, and the elements comprising the nodes. In this work, we theoretically analyse the spectral properties of an optical photon emitted by a solid-state quantum memory, which acts as a converter of a photon absorbed in another frequency range. We determine explicitly the expression connecting the stored and retrieved excitation taking into account possible mode and phase mismatching of the experimental setup. The expression we obtain describes the output field as a function of the input field for a transducer working over a wide range of frequencies, from optical-to-optical to microwave-to-optical. We apply this result to analyse the photon spectrum and the retrieval probability as a function of the optical depth for microwave-to-optical transduction. In the absence of losses, the efficiency of the solid-state quantum transducer is intrinsically determined by the capability of designing the retrieval process as the time-reversal of the storage dynamics.

Q 11.16 Wed 16:30 P

On the Advantage of Sub-Poissonian Single Photon Sources in Quantum Communication — •Daniel Vajner, Timm Gao, and Tobias Heindel — Institute of Solid State Physics, Technical University Berlin, 10623 Berlin

Quantum Communication in principle enables a provably secure transmission of information. While the original protocols envisioned single photons as the quantum information carrier [1], nowadays implementations and commercial realizations make use of attenuated laser pulses. There are, however, a number of advantages of using single photon sources. They are not limited by the Poisson statistics and suffer less under finite-key length corrections [2]. In addition, the second order interference visibility of true single photons can exceed the classical value of 50% which will be benefitial for all quantum information processing schemes, as well as measurment device independent QKD schemes, that rely on Bell state measurements of photons from different sources [3]. Given recent advances in the development of engineered semiconductor QD-based light sources, harnessing these advantages is within reach. We present an overview of different scenarios in which employing single photon sources improves the communication rate and distance.

[1] Bennett et al. *Proceedings of the IEEE International Conference on Computers, Systems and Signal Processing* (1984)
[2] Cai et al. *New Journal of Physics* 11.4 (2009): 045024
[3] Mandel, L. *Physical Review A* 28.2 (1983): 929

Q 11.17 Wed 16:30 P

Multi-rail optical memory in warm Cs vapor — •Leon Messner[1,2,3], Luisa Esguerra[2,3], Mustafa Gündoğan[1,2], and Janik Wolters[2,3] — [1]Institut für Physik, Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Germany — [2]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institute of Optical Sensor Systems, Rutherfordstr. 2, 12489 Berlin, Germany — [3]Technische Universität Berlin, Institut für Optik und Atomare Physik, Str. des 17 Juni 135, 10623 Berlin, Germany

Mapping quantum states of light onto long-lived matter excitations is considered an important step in the realization of optical quantum communication and computation architectures [1]. In quantum communication the manifold approaches to this task are subsumed under the topic of quantum memories [2]. Multiplexing of these memories helps to achieve higher communication rates per link and is especially important on links that exhibit high loss [3].

We present a multi-rail EIT memory [4] within a single Cs vapor cell at room temperature. By deflecting the co-propagating signal and control beams, multiple non-interacting volumes within a single Cs vapor cell are addressed. Storing to and retrieving from randomly selected rails is then demonstrated by changing the AOM driving frequency.

[1] Kimble, H., Nature **453**, 1023 (2008)
[2] Heshami, K. et al., JModOpt **63**, 2005 (2016)
[3] Gündoğan, M. et al., arXiv:2006.10636 (2020)
[4] Wolters, J. et al., PRL, **119**, 060502 (2017)

Q 11.18 Wed 16:30 P

Toward a Photon-Photon Quantum Gate Based on Cavity Rydberg EIT — Thomas Stolz, •Hendrik Hegels, Bianca Röhr, Maximilian Winter, Ya-Fen Hsiao, Stephan Dürr, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann Str. 1, 85748 Garching, Germany

All realizations of optical photon-photon quantum gates to date suffer from low efficiency [1]. Theory suggests that this limitation can be overcome using Rydberg electromagnetically induced transparency (EIT) in an optical cavity of moderate finesse [2]. We have set up a new vacuum system, which houses a cavity, in which an ultracold atomic ensemble is held in an optical dipole trap. The ensemble is cooled in multiple stages to a temperature of 0.2 μK. This low temperature is needed to achieve a long coherence time [3]. We report on the observation of cavity Rydberg EIT. This is a promising step on the way to a future realization of a photon-photon gate.

[1] K. Kieling et al. NJP 12, 013003 (2010), B. Hacker et al. Nature 536, 193 (2016), D. Tiarks et al. Nat. Phys. 15, 124 (2019).
[2] Y. Hao et al. Sci. Rep. 5, 10005 (2015), S. Das et al. PRA 93, 040303 (2016).
[3] S. Schmidt-Eberle et al. PRA 101, 013421 (2020).

Q 11.19 Wed 16:30 P

Towards Cavity-Enhanced Spectroscopy of Single Europium Ions in Yttria Nanocrystals — Timon Eichhorn[1], •Sören Bieling[1], Christian Rentschler[2], Shuping Liu[3], Alban Ferrier[3], Philippe Goldner[3], and David Hunger[1] — [1]Karlsruher Institut für Technologie, 76131 Karlsruhe, Germany — [2]CFEL/DESY, 22607 Hamburg, Germany — [3]Chimie Paris Tech, 75231 Paris, France

A promising approach for realizing scalable quantum registers lies in the efficient optical addressing of rare-earth ion spin qubits in a solid state host. Within the EU Quantum Flagship project SQUARE we study Eu^{3+} ions doped into Y_2O_3 nanoparticles (NPs) as a coherent qubit material and work towards efficient single ion detection by coupling their emission to a high-finesse fiber-based Fabry-Pérot microcavity. A beneficial ratio of the narrow homogeneous line to the inhomogeneous broadening of the ion ensemble at temperatures below 10K makes it possible to spectrally address and readout single ions. The coherent control of the single ion $^5D_0-^7F_0$ transition then permits optically driven single qubit operations on the Europium nuclear spin states. A Rydberg-blockade mechanism between ions within the same nanocrystal permits the implementation of a two-qubit CNOT gate to entangle spin qubits and perform quantum logic operations. Theoretical simulations of the single and two-qubit gate operations predict fidelities of up to 98.2% and 96.5%, respectively, with current material properties. We report on our progress to experimentally implement this scheme.

Q 11.20 Wed 16:30 P

Controlling single erbium dopants in a Fabry-Perot resonator — •Alexander Ulanowski[1], Benjamin Merkel[1], and Andreas Reiserer[1,2] — [1]MPI of Quantum Optics, Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Ludwig-Maximilians-Universität München, München, Germany

Erbium dopants exhibit unique optical and spin coherence lifetimes and show great promise for long-distance quantum networks, as their emission lies in the minimal-loss window of optical fibers. To achieve an efficient spin-photon interface for single dopants, we integrate thin host crystals into cryogenic Fabry-Perot resonators. With a Finesse of $1.2 \cdot 10^5$ we can demonstrate up to 58(6)-fold Purcell enhancement of the emission rate, corresponding to a two-level cooperativity of 530(50). Our approach avoids interfaces in the proximity of the dopants and therefore preserves the optical coherence up to the lifetime limit. [1]

Using this system, we resolve individual Erbium dopants which feature an ultra-low spectral diffusion of less than 100 kHz, being limited by the nuclear spin bath. This should facilitate frequency-multiplexed spin-qubit readout, control and entanglement, opening unique perspectives for the implementation of quantum repeater nodes.

[1] B. Merkel, A. Ulanowski, and A. Reiserer, Phys. Rev. X 10, 041025 (2020)

Q 11.21 Wed 16:30 P

A multi-site quantum register of neutral atoms with single-site controllability — •Lars Pause, Tilman Preuschoff, Stephan Amann, Malte Schlosser, and Gerhard Birkl — Institut für Angewandte Physik, TU Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany

Assembled arrays of neutral atoms are a versatile platform for quantum techologies. As effectively non-interacting particles with identical intrinsic properties they also feature switchable interactions when excited to Rydberg states. This makes neutral atoms well suited for quantum simulation, computation, and metrology.

We present our unique micro-optical implementation of triangular arrays of optical tweezers. Combined with a digital micromirror device (DMD), site-selective manipulation of the trapping potentials is possible while utilizing the robust architecture of microlens-based systems. The addition of a single movable optical tweezer enables atom sorting for achieving defect-free structures of individual atoms. We also discuss recent work with microlens arrays fabricated by femtosecond direct laser writing [1].

In addition, we present our open-source digital controllers for laser frequency and intensity stabilization [2]. Using the STEMlab (originally Red Pitaya) platform we achieve a control bandwidth of up to 1.25 MHz resulting in a laser line width of 52(1) kHz (FWHM) and intensity control to the $1 \cdot 10^{-3}$ level.

[1] D. Schäffner et. al., Opt. Express **28**, 8640-8645 (2020).
[2] T. Preuschoff et. al., Rev. Sci. Instrum. **91**, 083001 (2020).

Q 11.22 Wed 16:30 P

Ultra-stable open micro-cavity platform for closed cycle cryostats — •Michael Förg[1,2], Jonathan Noé[1,2], Manuel Nutz[1,2], Theodor Hänsch[2], and Thomas Hümmer[1,2] — [1]Qlibri project, Faculty of Physics, Ludwig-Maximilians-Universität Munich, Germany — [2]Faculty of Physics, Ludwig-Maximilians-Universität Munich, Germany

We present a fully 3D-scannable, yet highly stable micro-cavity setup, which features a stability on the sub-pm scale under ambient conditions and unprecedented stability inside closed-cycle cryostats. An optimized mechanical geometry, custom built stiff micro-positioning, vibration isolation and fast active locking enables quantum optics experiments even in the strongly vibrating environment of closed-cycle cryostats. High-finesse, open-access, mechanical tunable, optical micro-cavities offer a compelling system to enhance light matter interaction. Combining a scannable microscopic fiber-based mirror and a macroscopic planar mirror creates a versatile experimental platform. A variety of solid-state quantum systems can be brought onto the planar mirror, addressed individually, and (strongly) coupled to the cavity. With mechanical tuning of the cavity length, the resonance frequency can be adapted to the quantum system. However, the flexibility of the mechanical degrees of freedom bears also downsides. Inside close-cycle cryostats, fluctuations of the cavity length on the picometer scale are often enough to prevent the use of high-finesse cavities for quantum optics experiments. Our system enables the use of a flexible micro-cavity system for quantum applications even in this adversarial environment.

Q 11.23 Wed 16:30 P

Engineering of Vibrational dynamics in a two-dimensional array of trapped ions — •Deviprasath Palani, Philip Kiefer, Lennart Guth, Florian Hasse, Robin Thomm, Ulrich Warring, and Tobias Schaetz — Physikalisches Institut, University of Freiburg

Trapped ions present a promising system for quantum simulations [1]. Surface-electrode traps in contrast to conventional ion traps offer the advantage of scalability to larger system size and dimension while maintaining individual control: Dedicated radio-frequency electrode shapes allow the creation of two-dimensional trap arrays [2] while control electrodes allow localized manipulation of the trapping potential by tuning motional frequencies and mode orientations [3]. Our setup consists of an array of three Mg+ ions individually trapped in an equilateral triangle with 40 μm inter-site distance. We present the first realization of inter-site coupling, until now only realized for 1D arrangements. We demonstrate its tuning in real-time and show interference of large coherent states [4] and employ modulation of the local trapping potentials to realize phonon-assisted tunneling between adjacent sites [5]. Furthermore, with an identical prototype setup, we investigate methods such as surface cleaning to decrease noise field contributions [6].

[1] K. R. Brown et al., Nature 471 (2011). [2] T. Schaetz et al., N. J. Phys. 15, 085009 (2013). [3] M.Mielenz et al., Nat. Com. 7, 11839 (2016). [4] Hakelberg, F. et al. Phys. Rev. Lett. 123, 100504 (2019). [5] Kiefer, P. et al. Phys. Rev. Lett. 123, 213605 (2019). [6] U. Warring et al., Adv. Quantum Technol. 2020, 1900137.

Q 11.24 Wed 16:30 P

Characteristic dynamics of the bosonic quantum east model — •Andreas Geissler and Juan Garrahan — School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, UK

Kinetically constrained models like the East model are among the simplest systems to give insight into the dynamics of glass formers. In these models local spin flips are only possible if neighboring spins satisfy a condition, for example in the East model if the neighbor to the left points up. Here, we consider a bosonic quantum version of the East model using the Holstein-Primakoff-transformation. A comparison of exact diagonalzation and the flucuation operator expansion reveals a ground state phase diagram reminiscent of the spin half case. Using a Gross-Pitaevskii like limit for large spin we are able to perform dynamics for large system sizes. These reveal different dynamical regimes. We use open boundary conditions with the first site fixed to any non-zero occupation. We then observe two types of chaotic behavior in the active regime, depending on the energy of the local generator, and nontrivial localization dynamics in the inactive regime.

[1] M.C. Banuls et al., PRL, 123, 200601 (2019)

Q 11.25 Wed 16:30 P

Optimized diamond inverted nanocones for enhanced color center to fiber coupling — •Cem Güney Torun[1], Philipp-Immanuel Schneider[2,3], Martin Hammerschmidt[2,3], Sven Burger[2,3], Tommaso Pregnolato[1,4], Joseph. H. D. Munns[1], and Tim Schröder[1,4] — [1]Integrated Quantum Photonics, Humboldt-Universität zu Berlin, Berlin — [2]JCMwave GmbH, Berlin — [3]Zuse Institute Berlin (ZIB), Berlin — [4]Diamond Nanophotonics, Ferdinand-Braun-Institut, Berlin

Fiber coupling of the emission from color centers in diamond, a promising candidate for quantum nodes, is challenging due to the mode mismatches and reduced light outcoupling caused by the total internal reflections. Nanostructures are popular tools utilized to overcome these challanges. Nevertheless, while the fiber coupling properties are crucial for a single mode of indistinguishable photons, this performance of nanostructures is rarely investigated. Here, we simulate the emission of color centers and overlap of this emission with the fundamental fiber modes for a novel nanostructure called **inverted nanocone**. Using different figures of merit, the parameters are optimized to maximize fiber coupling efficiency, free-space collection efficiency or emission rate enhancement. The optimized inverted nanocones show promising results, with 66% fiber coupling or 83% free-space collection efficiency at the tin-vacancy center zero-phonon line wavelength of 619 nm. For maximum emission rate into a fiber mode, a design with a Purcell factor of 2.34 is identified. Moreover, these designs are analyzed for their broadband performance and robustness against fabrication errors.

Q 11.26 Wed 16:30 P

Construction of a reliable laser light source for resonant excitation of tin-vacany centers — •Franziska M. Herrmann[1], Joseph H.D. Munns[1], and Tim Schröder[1,2] — [1]Integrated Quantum Photonics, Institut für Physik, Humboldt-Universität zu Berlin, Berlin — [2]Diamond Nanophotonics, Ferdinand-Braun-Institut, Berlin

Tin-vacancy colour centres in diamond are promising candidates for nodes in quantum networks, due to their suitable optical and spin properties. However, with a zero phonon line wavelength of 619 nm, resonant excitation cannot be achieved easily by commercially available and affordable laser systems. At 1238 nm however, suitable narrow-band lasers are available and the targeted 619 nm can be reached by frequency doubling. The conversion is achieved based on second harmonic generation in an MgO:PPLN crystal pumped with infrared laser light. Here we introduce the setup and investigate the stability and tunability of this laser system and demonstrate how several PID controlled feedback loops can ensure usability for future quantum control applications.

Q 11.27 Wed 16:30 P

Shorcuts to adiabaticity with quantum non-demolition measurements — •Raphael Menu and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, German

The realization of quantum adiabatic dynamics is at the core of implementations of adiabatic quantum computers. One major issue is to efficiently compromise between the long time scales required by the adiabatic protocol and the detrimental effects of the environment, which set an upper bound to the time scale of the operation. In this work we propose a protocol which achieves fast adiabatic dynamics by coupling the system to an external environment by the means of a quantum-non-demolition (QND) Hamiltonian. We analyse the infidelity of adiabatic transfer for a Landau-Zener problem in the presence of QND measurement, where the qubit couples to a meter which in turn quickly dissipates. We analyse the protocol's fidelity as a function of the strength of the QND coupling and of the relaxation time of the meter. In the limit where the decay rate of the ancilla is the largest frequency scale of the dynamics, the QND coupling induces an effective dephasing in the adiabatic basis. Optimal conditions for adiabaticity are found when the coupling with the meter induces dissipative dynamics which suppresses unwanted diabatic transitions.