Q 23: Poster I

Time: Tuesday 17:00–19:00 Location: Tent B

Q 23.1 Tue 17:00 Tent B

Continuous entanglement generating superradiant SU(4) laser — Jarrod Reilly[1], •Gage Harmon[2], John Wilson[1], Murray Holland[1], and Simon Jäger[3] — [1]University of Colorado Boulder — [2]Saarland University — [3]University of Kaiserslautern-Landau

We present a cross-cavity system in which steady-state superradiance is achieved with solely collective dissipative dynamics. The cavities symmetrically couple an ensemble of four-level atoms by driving transitions between two electronic and two motional states. We demonstrate that the system continuously generates both interparticle entanglement between the constituent particles and intraparticle entanglement between the internal and external degrees of freedom. We use innovative techniques to examine the two types of entanglement and, remarkably, we find that the system in steady-state is Heisenberg limit scaled with nearly maximal entanglement entropy between the internal and external degrees of freedom. Lastly, we discuss potential applications of our proposed model to the prominent fields of quantum metrology and quantum information science.

Q 23.2 Tue 17:00 Tent B

Speeding Up Squeezing with a Periodically Driven Dicke Model — Jarrod T. Reilly[1], •Simon B. Jäger[2], John D. Wilson[1], John Cooper[1], Sebastian Eggert[2], and Murray J. Holland[1] — [1]JILA, NIST, and Department of Physics, University of Colorado Boulder — [2]Physics Department and Research Center OPTIMAS, University of Kaiserslautern-Landau

We present a simple and effective method to create highly entangled spin states on a faster timescale than that of the commonly employed one-axis twisting (OAT) model. We demonstrate that by periodically driving the Dicke Hamiltonian at a resonance frequency, the system effectively becomes a two-axis countertwisting Hamiltonian which is known to quickly create Heisenberg limit scaled entangled states. For these states we show that simple quadrature measurements can saturate the ultimate precision limit for parameter estimation determined by the quantum Cramér-Rao bound. An example experimental realization of the periodically driven scheme is discussed with the potential to quickly generate momentum entanglement in a recently described experimental vertical cavity system. We analyze effects of collective dissipation in this vertical cavity system and find that our squeezing protocol can be more robust than the previous realization of OAT.

Q 23.3 Tue 17:00 Tent B

Quantum Master Equation for Self-organization in Cavity QED — •Tom Schmit[1], Simon Jäger[2], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany — [2]Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

Ensembles of atoms strongly coupled with the electric field of an optical cavity offer a formidable laboratory for studying the out-of-equilibrium dynamics of long-range interacting systems in the quantum regime. In this work, we extend the theoretical framework of Refs. [1,2] to derive a unifying quantum master equation describing cavity cooling and self-organization of atomic ensembles in high-finesse resonators. Our approach is valid for a broad range of parameters, from temperatures of laser-cooled atoms to the ultra-cold quantum degenerate regime. We discuss in detail the validity of our description as a function of the cavity's detuning and lifetime. At ultra-low temperatures, the model predicts that the coupling with the dissipative resonator gives rise to an effective, long-range decoherence that tends to heat up the atoms. We determine the dynamics for a small system and analyse the effect of long-range cavity-induced dissipative forces on metastability.

[1] S. Schütz, H. Habibian, and G. Morigi, Phys. Rev. A **88**, 033427 (2013).
[2] S. B. Jäger, T. Schmit, G. Morigi, M. J. Holland, and R. Betzholz, Phys. Rev. Lett. **129**, 063601 (2022).

Q 23.4 Tue 17:00 Tent B

A Tensor Network Perspective on the Micromaser — •Andreas J. C. Woitzik[1], Edoardo Carnio[1,2], and Andreas Buchleitner[1,2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg im Breisgau, Federal Republic of Germany — [2]EUCOR Centre for Quantum Science and Quantum Computing, Albert-Ludwigs-Universität Freiburg, Freiburg im Breisgau, Federal Republic of Germany

The one-atom (or micro-) maser – in which a stream of (Rydberg) atoms interacts sequentially and in resonance with a quantized mode of a high-quality cavity – is a pioneering experiment on the interaction between light and matter at the level of single quanta, and the archetypal quantum collision model. Our contribution introduces a tensor network model for the micromaser that represents the incoming atomic string as a Matrix Product State (MPS). We leverage the tensor network formalism, employing a DMRG-like optimization technique, to identify optimal atomic strings to prepare the cavity in a sought-after target state. When the target state of the cavity is a Fock state, we find an analytic relation between its Fock number and the bond dimension of the optimal MPS.

Q 23.5 Tue 17:00 Tent B

Quantum optics model mapping for thin-film x-ray cavities — •Julien Spitzlay[1], Hanns Zimmermann[1,2], Fabian Richter[1], and Adriana Pálffy[1] — [1]Julius-Maximilians-Universität Würzburg — [2]Universität der Bundeswehr München

Thin-film cavities with one or several embedded layers of Mössbauer nuclei are promising platforms for the quantum control of x-ray photons. At grazing incidence, incoming resonant x-rays couple evanescently to the cavity, while the resulting cavity field drives the nuclear transitions. Several quantum optics models have been developed in the past decade to describe the resonant x-ray scattering in these nanostructures, for instance a cavity QED model [1] or an ab-initio formalism based on the electromagnetic Green's function [2,3].

In this work we investigate parallels between the x-ray thin-film cavity models and well-known quantum optics models for coherent phenomena in few-level systems such as electromagnetically induced transparency (EIT) or Autler-Townes-Splitting (ATS). The aim is to identify parameter regimes where thin-film x-ray cavities can display a behaviour reminiscent to these phenomena and the relations between the coupling constants of the respective underlying quantum optics models.

[1] K. Heeg and J. Evers, Phys. Rev. A 88, 043828 (2013)
[2] D. Lentrodt, K. Heeg, C. H. Keitel, J. Evers, Phys. Rev. Research 2, 023396 (2020)
[3] X. Kong, D. Chang, A. Pálffy, Phys. Rev. A 102, 033710 (2020)

Q 23.6 Tue 17:00 Tent B

Coupled states of cold Yb atoms in a high-finesse cavity — •Saran Shaju, Dmitriy Sholokhov, Simon B Jäger, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken

We study the atom-cavity interaction of cold Yb atoms inside a 5-cm long optical high-finesse cavity that is resonant with its $^1S_0 \rightarrow {}^3P_1$ intercombination transition at 556 nm wavelength. The atoms are magneto-optically trapped and cooled on their $^1S_0 \rightarrow {}^1P_1$ transition at 399 nm. We record the cavity output as well as the free-space fluorescence when a probe on $^1S_0 \rightarrow {}^3P_1$ drives the cavity on axis. By varying the cavity and probe frequency, we observe coupled atom-cavity states with atom number-dependent splitting. We associate the observation to the existence of collective strong coupling of the atoms with the single mode of the resonator. We extend our understanding by simulating the problem using a quantum mechanical mean-field model.

Q 23.7 Tue 17:00 Tent B

Chiral cavities: an extendible and simple theoretical model — •Carlos Bustamante, Dominik Sidler, Michael Ruggenthaler, and Angel Rubio — Max Planck Institute for the Structure an Dynamics of Matter, Hamburg, Germany.

Over the past decade, we have witnessed a huge growth in cavity quantum electrodynamics phenomena. This growing interest is centered around the formation of polaritons in these cavities –a hybrid quantum state resulting from the strong interaction between light and matter. Polaritons' hybrid nature offers a new alternative to change matter properties by tailoring light. For instance, it is possible to impart spin-angular momentum on photon modes to get circularly polarized

light (CPL). Cavities capable of confining CPL are known as chiral cavities. Despite the absence of experimental results, some theoretical studies have already shown that this kind of cavities could be useful in chemistry. However, the simulations conducted thus far are quite challenging due to the necessity of employing beyond-dipole approximations and high levels of accuracy. In this work, we propose a chiral cavity Hamiltonian derived using dipole approximation and a hybrid gauge. To test this Hamiltonian, we worked with a one-dimensional atom, placed in a spring topology, in order to get a chiral symmetry. The results demonstrate that, despite some limitations of the model, our Hamiltonian can capture properties dependent on the polarization of the cavity or the chirality of the matter system. The simplicity of our Hamiltonian offers an efficient way to explore the fundamental physical properties of these systems.

Q 23.8 Tue 17:00 Tent B

Towards deterministic strong coupling between single trapped atoms and a Whispering-Gallery-Mode microresonator — •xinxin hu, luke masters, gabriele maron, arno rauschenbeutel, and juergen volz — Department of Physics, Humboldt-Universität zu Berlin, Berlin, Germany

In the past decades, coupling between single trapped atoms and high Q factor microresonators has been a strong research focus because a resonator can significantly enhance of light-atom interaction and realize strong coupling. More recently, aided by the progress of materials and microfabrication technology, more integratable resonator types, e.g. photonic crystal cavities and optical nanofiber-based cavities, have been explored in single-atom CQED systems, and many breakthroughs have been achieved in such systems. Of particular interest are whispering-gallery-mode resonators, such as microsphere or microtoroid resonators that exhibit extremely high Q-factors exceeding 10^9. Here, we present the work of our group towards deterministic strong coupling of single trapped atoms to a bottle-type WGM microresonator. In our experiment we load a single atom from a magneto optical trap into an optical tweezer. Subsequently, using a focus tunable lens, we move the trapped atoms over a distance of ~1mm into the evanescent field of the WGM resonator. We will report on the efficiency of the atom transport close to and into the evanescent field of the resonator.

Q 23.9 Tue 17:00 Tent B

Design and realization of a high-finesse optical resonator for cavity-assisted readout of atomic arrays — •Jacopo De Santis[1,2], Mehmet Öncu[1,2], Balázs Dura-Kovács[1,2], Sebastian Ruffert[1,2], and Johannes Zeiher[1,2] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), 80799 München, Germany

The ability to read out a subset of a quantum register during the execution of an algorithm is a fundamental ingredient for fault tolerant quantum computation. But for this mid-circuit measurement to be effective, it should satisfy some specific requirements: be fast compared to the qubit decoherence time, have low error rates and be nondestructive of the qubits which are not being read out. However, free space measurements of qubits encoded in neutral atoms are rather slow, or destructive of nearby atoms due to the heating associated with scattered photons. Coupling an atomic array to a high-finesse optical resonator is a promising solution to these problems: thanks to the Purcell effect, not only can we detect a higher fraction of the fluoresced photons, but the directionality of the emission makes it less likely for the scattered photons to be reabsorbed by other atoms in the array. In this poster I will focus on the design criteria for such a cavity and describe how it can be used for qubit readout. Lastly, I will present some of the more practical aspects in the realization of a high-finesse optical resonator. In particular, I will introduce the setup I developed for testing and assembling a near-concentric cavity with cooperativity $C \geq 7$.

Q 23.10 Tue 17:00 Tent B

A cavity-integrated microwave antenna for spin manipulation of Nitrogen-Vacancy center in diamond — •Andras Lauko[1], Kerim Köster[1], Jeremias Resch[1], Julia Heupel[2], Cyril Popov[2], and David Hunger[1] — [1]Karlsruher Institut für Technologie, Karlsruhe, DE — [2]Universität Kassel, Kassel, DE

In the competitive field of research for the realization of a quantum repeater, nitrogen-vacancy color centers in diamonds are a promising candidate for their optically addressable spin states. A possible platform to enhance the spin-photon interactions is an optical fiber based, tuneable Fabry-Perot cavity, allowing for an open access to the sample. This motivates the integration of a microwave antenna into the resonator, combining the sophisticated coherent control of the spin states of the nitrogen-vacancy center with the benefits provided by the cavity, namely the spatially and spectrally improved emission.

This work arrives at the cavity-integrated microwave antenna in two stages. First, a widely used antenna design, called the wire loop antenna design is modified and fabricated. Then the antenna is integrated into a confocal microscopy setup and experiments involving the measurement of Rabi oscillations are presented.

Lastly, the antenna is mounted into an optical fiber-based microcavity and Rabi frequencies surpassing 10 MHz are measured. The optical performance is unaffected by the antenna and the thermal effects on the cavity caused by the microwave excitation are investigated.

Q 23.11 Tue 17:00 Tent B

Self-consistent Red Shift – an Alternative Feature of Light-matter Coupling? — •Jacob Horak, Dominik Sidler, Michael Ruggenthaler, and Angel Rubio — Max Planck Institute for the Structure and Dynamics of Matter and Center for for Free-Electron Laser Science, Luruper Chaussee 149, 22761 Hamburg, Germany

Polaritonic chemistry is a new field which was established when experiments showed a change in chemical reactivity merely due the different electromagnetic environment inside an optical cavity. The effect is attributed to the formation of hybrid particles, polaritons, made up of a molecular excitation strongly coupled to the resonance mode of a cavity. Compared to an empty cavity, resonances are always shifted depending on the filling and this has been used to monitor the progress of reactions, e.g, with IR spectroscopy.[1]

Here, we show that an analytic expression of the self-consistent red shift derived from the Pauli-Fierz Hamiltonian for harmonic molecules deviates from the Lorentz model. Traditionally, observing a Rabi split, i.e., the energy separation between the polaritons, has been the hallmark of experimentally quantifying light-matter coupling. Could measuring the red shift become another avenue to monitor strong light-matter coupling experimentally?

[1] A. Thomas, J. George, A. Shalabney, M. Dryzhakov, S. J. Varma, J. Moran, T. Chervy, X. Zhong, E. Devaux, C. Genet, J. A. Hutchison, T. W. Ebbesen, *Angew. Chem. Int. Ed.* **2016**, 55, 11462-11466.

Q 23.12 Tue 17:00 Tent B

Spectral properties of a cold-atom laser — Dmitriy Sholokhov, Saran Shaju, •Ke Li, and Jürgen Eschner — Universität des Saarlandes

We investigate optical gain and lasing emission from an ensemble of a few thousand Ytterbium-174 atoms which are magneto-optically trapped, using the $^1S_0$ - $^1P_1$ transition at 399 nm, inside a 5-cm long high-finesse cavity. When the atoms are pumped on the $^1S_0$ - $^3P_1$ intercombination transition at 556 nm, continuous-wave lasing on the same transition is observed [1]. By heterodyne analysis, we measure the cavity output spectra for a range of trap and pump light powers and detuning. From the data, we extract the gain profile for the cold ytterbium laser and compare its properties with our theoretical model.

Q 23.13 Tue 17:00 Tent B

A Superradiant Gas of Driven-Dissipative Two-Level Atoms as a Source of Non-Classical Light — •Christopher Mink and Michael Fleischhauer — University of Kaiserslautern-Landau, Kaiserslautern, Germany

Motivated by the recent experimental observation of non-Gaussian correlations in the light emitted by a driven-dissipative cigar shaped cloud of two-level atoms [Ferioli et. al, arXiv:2311.13503] we theoretically investigate the dynamics and steady state properties of this system using a dissipative extension of the well-established Discrete Truncated Wigner Approximation. This allows us to determine the interatomic correlations as well as the radiated light field and its symmetrically ordered first and second order correlation functions $g^{(1)}(\tau)$ and $g^{(2)}(\tau)$. We verify a violation of the Siegert relation for the light emitted along the main axis of the cloud. Furthermore we show that in the steady state the atoms emit a negligible electric field which therefore does not contribute to the reduction of $g^{(2)}(\tau)$. This is instead due to non-Gaussian statistics. Finally, the Wigner function of the radiated field is extracted and the quadratures are investigated to demonstrate generation of non-classical light.

Q 23.14 Tue 17:00 Tent B

Optimal control of arbitrary perfectly entangling gates for

open quantum systems — •Adrian Köhler and Christiane P. Koch — Freie Universität Berlin, Berlin, Germany

Perfectly entangling gates (PE) are crucial for various applications in quantum information. One method to realize these gates is with the help of an external control field, whose concrete shape is found using optimal control theory. Instead of optimizing the shape that realizes a specific gate, the optimization target can be extended to the full set of PE. This increases the flexibility of optimization and allows to find the best PE from the set of all PE. For unitary dynamics, the PE optimization functional can readily be evaluated. In contrast, for non-unitary dynamics, one has to approximate the unitary part of the dynamics first. We employ this technique to superconducting qubits, where we apply a cross-resonant drive to two coupled fixed-frequency transmons to generate entangled states.

Q 23.15 Tue 17:00 Tent B

A graph-based approach to dissipative production of multipartite entangled states in trapped ions — •Antoine Guinchard, Karl Horn, Daniel Reich, and Christiane Koch — Freie Universität Berlin, Berlin, Deutschland

Entanglement is a key ingredient for quantum technologies. We study the creation of entangled states on trapped ion qubits, where logical states are encoded in the ionic hyperfine states which are coupled via common vibrational modes. By leveraging dissipative processes in this system, schemes to generate both two- and three-partite entanglement have recently been developed by Karl P Horn et al [2018 New J. Phys. 20 123010] and Daniel C Cole et al [2021 New J. Phys. 23 0730].

We developed a graph-theoretical approach which allows us to find dissipative protocols to generate entangled states in a computationally efficient way by representing the population flow on the logical state space. This method allows us to both reproduce the previously derived protocols for the three-qubit case and even find entirely new schemes. By adding an extra transition per qubit, we are able to show that one of our new schemes is scalable to an arbitrary number of qubits. Due to the graph-based and system-agnostic nature of our method, our protocols can be generalised to a wide variety of experimental setups.

Q 23.16 Tue 17:00 Tent B

Role of dephasing in optimal transport of spin excitations in a two-dimensional, lossy lattice — •Andrei Skalkin, Razmik Unanyan, and Michael Fleischhauer — RPTU, Kaiserslautern

Noise is commonly regarded as an adverse effect disrupting communication and limiting efficiency of many processes. However, it has been shown [P. Rebentrost et al., New Journal of Physics 11, 2009] that decoherence processes can play a significant role in quantum transport facilitation. We study how a dephasing noise, acting on all sites with equal rate, improves spin excitation transport efficiency in a two-dimensional lattice with dipole-dipole long-range interaction. We provide a new mechanism of dephasing-assisted transport in ordered systems. The study includes both numerical and analytical approaches and may serve as a benchmark for experiments in the framework of optical lattices.

Q 23.17 Tue 17:00 Tent B

Fermionic coherent state path integral for ultrashort laser pulses and transformation to a field theory of coset matrices including disorder-noise — •Bernhard Mieck — Keine Institution

A coherent state path integral of anti-commuting fields is considered for a two-band, semiconductor-related solid including an ensemble-average with disorder-noise. A ultrashort, classical laser field is the driving source term for the initial states. We describe the generation of exciton quasi-particles from the driving laser field as anomalous pairings of the fundamental, fermionic fields. This gives rise to Hubbard-Stratonovich transformations from the quartic, fermionic interaction to various Gaussian terms of self-energy matrices; the latter self-energy matrices are solely coupled to bilinear terms of anomalous-doubled, anti-commuting fields which are subsequently removed by integration and which create the determinant with the one-particle operator and the prevailing self-energy. We accomplish path integrals of even-valued self-energy matrices with Euclidean integration measure where three cases of increasing complexity are classified (scalar self-energy variable, density-related self-energy matrix and also a self-energy including anomalous doubled terms). The SSB is performed with hinge-fields which factorizes the total self-energy matrix by a coset decomposition into density-related, block diagonal self-energy matrices of a background functional and into coset matrices with off-diagonal block generators for the anomalous pairings of fermions. This allows to derive a classical field theory for the self-energy matrices.

Q 23.18 Tue 17:00 Tent B

Selfconsistent diagrammatic transport for light includingtime reversal symmetric entropy production — •Regine Frank[1,2] and Bart A. van Tiggelen[3] — [1]College of Biomedical Sciences, Larkin University, Miami, Florida, USA — [2]Donostia International Physics Center, 20018 Donostia-San Sebastian, Spain — [3]University Grenoble Alpes, Centre National de la Recherche Scientifique, LPMMC, Grenoble, France

We present novel theory and numerics for transport of light in random complex media, where the production of entropy is positive under time reversal, an Onsager scenario. Time and space resolved numerical solutions based on weighted essentially non-oscillatory solvers (WENO) are introduced and discussed with respect to Anderson localization. [1] R. Frank, A. Lubatsch, Phys. Rev. Research 2, 013324 (2020). [2] D. Vollhardt and P. Woelfle, Phys. Rev. B 22, 4666 (1980). [3] P. D. Lax and R. D. Richtmyer, Commun. Pure Appl. Math. 9, 267 (1956). [4] A. Lubatsch, J. Kroha, K. Busch, Phys. Rev. B.71, 184201 (2005) [5] R. Frank, A. Lubatsch, J. Kroha, Phys. Rev. B 73, 245107 (2006). [6] B. A. van Tiggelen, A. Lagendijk, and A. Tip, Phys. Rev. Lett.71, 1284 (1993). [7] B. A. Van Tiggelen, Diffuse Waves in ComplexMedia, 1-60 (1999)

Q 23.19 Tue 17:00 Tent B

A vacuum-integrated fiber cavity setup for characterizing Q-optimized polymer-based mechanical resonators — •Florian Giefer, Daniel Stachanow, Lukas Tenbrake, Sebastian Hofferberth, and Hannes Pfeifer — Institute of Applied Physics, University of Bonn, Germany

Optomechanical platforms with high-quality mechanical and optical resonators have a wide application potential ranging from quantum limited sensing to long-lived storage of quantum information. Whilst exceptionally high quality factors have been realized with structures in thin layers of dielectric or semiconducting materials, their geometries are limited by the capacity of lithographic fabrication. Recent developments in polymer-based 3D direct laser-written structures allow for new paradigms in manufacturing micromechanical resonators, but so far suffer from strong mechanical dissipation. We show viable routes for improving this platform, including dissipation dilution, and present a scanable vacuum-integrated fiber cavity setup for probing high quality-factor mechanical resonators. To interface resonators we build a platform for flexible cavity construction between a fiber mirror and a DBR substrate in vacuum. Compared to previous designs, we improved the locking quality and flexibility of the optical cavity and added several additional features. Using this tool, optimized mechanical resonators and multi-resonator structures will be investigated in the near future.

Q 23.20 Tue 17:00 Tent B

Otto cycles with a quantum rotor as the working medium — •Michael Gaida and Stefan Nimmrichter — Universität Siegen, Deutschland

Quantum rotors possess genuine features such as a non-uniform energy level spectrum and quantum revivals under free rotation. Experimental progress in levitated optomechanics has made the orientation of anisotropic nanoparticles amenable to optical control and cooling and promises to reach the quantum regime in the near future. We investigate how the working regimes of an Otto engine changes due to quantum effects. As the main result we present two Otto cycles with a planar rotor as the working medium. We distinguish between the three operation modes Engine, refrigerator and heater. A comparison of a quantum rotor with its classical counterpart reveals significant changes in the operation regimes: While one of the presented Otto cycles shows genuine quantum disadvantage, the other becomes only useful in the quantum case.

Q 23.21 Tue 17:00 Tent B

Controlled phonon dynamics in optomechanical systems — •Victor Ceban — Institute of Applied Physics, Moldova State University, Academiei str. 5, Chisinau, Moldova

There is a plethora of quantum optic phenomena enabling the control of the spontaneous emission effect, which results in suppression or increase of the spontaneous emission decay rate. Here, we show that this kind of phenomena can be explored in order to control the phonon behaviour in an optomechanical setup. Namely, the phonons seams to follow the changes introduced to the population decay dynamics of a considered emitter. Two different open quantum systems are presented.

In the first case, long-lived phonons are obtained when slowing-down the atomic decay of an emitter. An optomechanical setup made of an aromatic molecule embedded within an organic crystal is considered. Spontaneous emission suppression is achieved by placing the setup in a cavity and by modulating the emitter*s transition frequency. This effect becomes prominent for mechanical resonators with high damping rates, such as organic crystals.

In the second case, fast phonon dynamics is obtained when superradiant conditions are considered. An optomechanical system made of a collection of closely-spaced quantum dots placed on a vibrating membrane is considered. The quantum dot sample exhibits superradiance features which are transferred to the phonon dynamics

Q 23.22 Tue 17:00 Tent B

Enhancing the purity of single photons in parametric down-conversion through simultaneous pump-beam and crystal-domain engineering — •Baghdasar Baghdasaryan[1], Fabian Steinlechner[1,4,5], and Stephan Fritzsche[1,2,3] — [1]FSU Jena — [2]HI Jena — [3]TPI Jena — [4]Fraunhofer IOF, Jena — [5]IAP Jena

Spontaneous parametric down-conversion (SPDC) has shown great promise in the generation of pure and indistinguishable single photons. Photon pairs produced in bulk crystals are highly correlated in terms of transverse space and frequency. These correlations limit the indistinguishability of photons and result in inefficient photon sources. Domain-engineered crystals with a Gaussian nonlinear response have been explored to minimize spectral correlations. Here we study the impact of such domain engineering on spatial correlations of generated photons. We show that crystals with a Gaussian nonlinear response reduce the spatial correlations between photons. However, the Gaussian nonlinear response is not sufficient to fully eliminate the spatial correlations. Therefore, the development of a comprehensive method to minimize these correlations remains an open challenge. Our solution to this problem involves simultaneous engineering of the pump beam and crystal. We achieve purity of single-photon state up to 99% without any spatial filtering. Our findings provide valuable insights into the spatial waveform generated in structured SPDC crystals, with implications for applications such as boson sampling.

Q 23.23 Tue 17:00 Tent B

Weyl su(3) diamonds are knit and woven — •Carsten Henkel — Universität Potsdam, Institut für Physik und Astronomie

Multiplets of the symmetry groups SU(2) (rotations) and SU(3) (color or flavour symmetry) are well-known examples where the abstract theory of group representations (actually of the Lie algebra) provides an organising viewpoint for physical applications [1]. We discuss an explicit algorithm that constructs the matrices that represent the su(3) generators in an arbitrary irreducible representation [2]. They can be visualised with the help of "ladder operators" (also known as "roots" in representation theory) that map one basis state to another one. The two-dimensional multiplets of su(3) (quark triplets, meson octets or a baryon decuplets, for example) "hide" certain selection rules for the ladder operators that can be visualised intuively in a three-dimensional projection: multiplets become polyhedra that look like diamonds.

[1] Hermann Weyl, *Gruppentheorie und Quantenmechanik* (Hirzel 1928)

[2] S. Coleman, Fun with SU(3), in: High-Energy Physics and Elementary Particles, (IAEA proceedings, Vienna 1965), pp331–52

Q 23.24 Tue 17:00 Tent B

Direct measurement of pseudothermal light violating Siegert relation — •Xi Jie Yeo[1], Mingze Qing[1], Justin Peh[1], Darren Koh[1], Jaesuk Hwang[1], Christian Kurtsiefer[1,2], and Peng Kian Tan[1] — [1]Centre for Quantum Technologies, Singapore, Singapore — [2]National University of Singapore, Singapore, Singapore

We present a technique to directly measure the violation of Siegert relation, relating the first and second order photon correlation of thermal light. Specifically, we extract correlations between photoevents detected at the output ports of an asymmetric Mach-Zehnder interferometer. Using this technique, we observe a violation of Siegert relation by laser light scattered off a rotating ground glass, while Siegert relation is obeyed for light from a mercury vapor lamp.

Q 23.25 Tue 17:00 Tent B

Dimensional Reduction in Quantum Optics — •Jannik Ströhle and Richard Lopp — Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, Albert-Einstein-Allee 11, D-89069 Ulm, Germany

One-dimensional quantum optical models usually rest on the intuition of large scale separations associated with the different spatial dimensions, for example when studying quasi one-dimensional atomic motion, potentially resulting in the violation of $3+1$D Maxwell's theory. In this paper, we provide a rigorous foundation for this approximation by means of the light-matter interaction. We show how the quantized electromagnetic field can be decomposed – without approximation – into an infinite number of one-dimensional *subfields* when studying axially symmetric setups, such as a fiber cavity, a laser beam or a waveguide. The *dimensional reduction* approximation then corresponds to a truncation in the number of such subfields that in turn, when considering the interaction with for instance an atom, corresponds to an approximation to the atomic spatial profile. We explore under what conditions the standard dimensional reduction approximation of a single subfield is justified, and when corrections are necessary in order to account for the dynamics due to the neglected spatial dimensions. In particular we will examine what role vacuum fluctuations play in the validity of the approximation.

Q 23.26 Tue 17:00 Tent B

Influence of direct dipole-dipole interaction on the optical response of 2D materials in inhomogeneous infrared cavity fields — •Sofia Ribeiro[1,2], Javier Aizpurua[2], and Ruben Esteban[2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Centro de Física de Materiales, Centro Mixto CSIC-UPV/EHU, Donostia, Spain

The interaction between light and matter can be strongly enhanced by using nanophotonic cavities that localize light at the nanoscale. Our work considers a 2D material formed, by a self-assembled molecular monolayer or by a single layer of a Van der Walls material, coupled to an infrared nanophotonic cavity, potentially reaching the strong coupling regime. Important effects can arise from the direct dipole-dipole interactions between the molecules, such as the emergence of new collective modes. The main effect of considering direct dipole-dipole interactions on the optical properties of the hybrid system for homogeneous or slowly varying cavity fields is the renormalization of the effective energy of the bright collective mode of the 2D material that couples with the nanophotonic mode. However, we find that, for situations of extreme field confinement, fully including the direct interactions within the 2D material becomes critical to correctly capture the optical response, with many collective vibrational states participating in the response. Further, we derive a simple analytical equation which establishes the criteria for the need of dipole-dipole interactions in the description of the hybrid system beyond the standard renormalization.

Q 23.27 Tue 17:00 Tent B

Wave-particle duality in weighted two-way interferometers: Which-way knowledge increase via delayed observable choice — •Elisabeth Meusert, Marc-Oliver Pleinert, and Joachim von Zanthier — Quantum Optics and Quantum Information Group, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 1, 91058 Erlangen, Germany

The concept of wave-particle duality lies at the heart of quantum mechanics and appears, for example, in Young's well-known double slit experiment. There, the simultaneous observations of a visible interference pattern and the acquisition of which-way knowledge about the photon's path are limited by an inequality, dubbed the duality relation. Previous studies on symmetric interferometers showed that the obtained which-way knowledge can be correlated to the quantum object's phase for certain observables, and used this phase-dependency to increase the which-way knowledge above the duality relation-limit via delayed observable choice.

Our studies generalize these findings to arbitrarily weighted interferometers. We find again that the now weight- and phase-dependent which-way knowledge can be increased beyond the duality-relation limit. Moreover, we find that specific observables provide the highest improvement in which-way knowledge at asymmetric interferometer weights. These findings suggest that both the maximum achievable which-way knowledge and the highest possible knowledge increase might be available in unbalanced interferometers, at a value not obtainable from symmetry arguments.

Q 23.28 Tue 17:00 Tent B

Many-particle coherence and higher-order interference — •Marc-Oliver Pleinert[1], Eric Lutz[2], and Joachim von Zanthier[1] — [1]Quantum Optics and Quantum Information Group, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 1, 91058 Erlangen, Germany — [2]Institute for Theoretical Physics I, University of Stuttgart, 70550 Stuttgart, Germany

Quantum mechanics is based on a set of only a few postulates, which can be separated into two parts: one part governing the inner structure, i.e., the definition and dynamics of the state space, the wave function and the observables; and one part making the connection to experiments. The latter is known as Born's rule, which simply put relates detection probabilities to the modulus square of the wave function. The resulting structure of quantum theory permits interference of indistinguishable paths; but, at the same time, limits such interference to certain interference orders. In general, quantum mechanics allows for interference up to order 2M in M-particle correlations. Depending on the mutual coherence of the particles, however, the related interference hierarchy can terminate earlier. Here, we show that mutually coherent particles can exhibit interference of the highest orders allowed. We further demonstrate that interference of mutually incoherent particles truncates already at order M+1 although interference of the latter is principally more multifaceted. Finally, we demonstrate the disparate vanishing of such higher-order interference terms as a function of coherence in experiments with mutually coherent and incoherent sources.

Q 23.29 Tue 17:00 Tent B

Quantum dynamics of nuclear many-body systems driven by an XFEL — •Miriam Gerharz and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Ensembles of Mössbauer nuclei form a promising platform for quantum optics in extreme parameter regimes because of their narrow transitions in the hard x-ray regime. These narrow transitions feature long lifetimes, which results in the system being essentially decoherence free. However, because of those narrow resonances at synchrotrons on average there is less than one resonant photon per pulse. This situation has recently changed with first experiments at X-ray free electron lasers (XFEL), where there are up to hundreds of resonant photons per pulse, such that qualitatively new regimes of higher nuclear excitations can be explored. Here we present recent progress in the theoretical modelling of the dissipative nuclear many-body dynamics after XFEL excitation.

Q 23.30 Tue 17:00 Tent B

A Fiber-based Microcavity Platform to Purcell-enhance Diamond Color Centers — •Yanik Herrmann[1], Julius Fischer[1], Julia M. Brevoord[1], Stijn Scheijen[1], Colin Sauerzapf[1,2], Leonardo G. C. Wienhoven[1], Laurens J. Feije[1], Matteo Pasini[1], Martin Eschen[1,3], and Ronald Hanson[1] — [1]QuTech and Kavli Institute of Nanoscience, Delft University of Technology, 2628 CJ Delft, The Netherlands — [2]Present address: 3rd Institute of Physics and Research Center SCoPE, University of Stuttgart, 70049 Stuttgart, Germany — [3]Netherlands Organisation for Applied Scientific Research (TNO), P.O. Box 155, 2600 AD Delft, The Netherlands

Quantum networks are promising both for applications like secure communication and for basic science tests of quantum mechanics at a large scale. Color centers in diamond, like the Nitrogen- or Tin-Vacancy center are excellent node candidates, because of their optically accessible spin with a long coherence time, but the collection of coherent photons is limited. Integration into an optical cavity can boost both the coherent emission via the Purcell effect and the collection efficiency due to a well-defined cavity mode. Here we present a low temperature platform, which is in particular designed to provide a low vibration level while maintaining high flexibility over the cavity and fiber control. Such a system is expected to significantly speed up entanglement rates in present day networks, a critical step towards large scale quantum networks with solid state emitters.

Q 23.31 Tue 17:00 Tent B

Recent developments on microfabricated Penning trap electrodes for matter-antimatter comparison tests. — •Nima Hashemi[1,2,3], Julia-Aileen Coenders[1,2], Jacob Stupp[1,2], Friederike Giebel[3], Jan Schaper[1,2], Juan Manuel Cornejo[1,2], Stefan Ulmer[4,5], and Christian Ospelkaus[1,2,3] — [1]Leibniz Universität Hannover, Germany — [2]LNQE, Hannover, Germany — [3]Physikalisch Technische Bundesanstalt, Braunschweig, Germany — [4]Ulmer Fundamental Symmetries Laboratory, Riken, Japan — [5]Heinrich-Heine-Universität Düsseldorf, Germany

Penning ion traps have proven to be an excellent tool for g-factor comparison tests of matter and antimatter in the baryonic sector of the Standard Model [1,2]. At Leibniz University of Hannover, within the BASE collaboration [3], we are working on the development of quantum-logic inspired methods based on Coulomb coupling of single (anti-)protons to a laser-cooled beryllium ion for better particle localization and detection on these g-factor experiments [4]. Microfabricated Penning trap electrodes of $800\,\mu$m inner diameter and a thickness of $200\,\mu$m are necessary to gain full control over the coupling process. A challenging part of the microfabrication are the processes of photolithography because of three-dimensional structures and double-sided geometry of the electrodes. In this contribution recent methods for optimization of these processes are analyzed and evaluated.

[1] G. Schneider et al., Science 358, 1081 (2017) [2] C. Smorra et al., Nature 550, 371 (2017) [3] Eur. Phys. J. Spec. Top. 224, 3055-3108 (2015) [4] Juan M Cornejo et al 2021 New J. Phys. 23 073045

Q 23.32 Tue 17:00 Tent B

Nonlinear characterization of in-house fabricated thin film lithium niobate waveguides — •Alexej Widajko, Laura Bollmers, Harald Herrmann, Laura Padberg, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Str. 100, D-33098 Paderborn

Thin film lithium niobate (TFLN) is an evolving platform for photonic circuits for different application areas. In particular, the high nonlinearity and the wide transparency range of $LiNbO_3$ together with the tight confinement in nanophotonic waveguides enable the realization of efficient frequency converters e.g. for applications in quantum computing and quantum cryptography.

However, to exploit the full potential of nonlinear TFLN devices the fabrication process, which includes the fabrication of the optical waveguides and the periodic poling for phase-matching of the targeted nonlinear process, must be optimized.

In this work we are focussing on the development of an efficient nonlinear characterization setup for TFLN, which allows to assess the quality of the devices. We primarily use second harmonic generation (SHG) with the fundamental wave in the telecom wavelength range to study the nonlinear properties of in-house fabricated TFLN devices. We give a short overview of the fabrication process, discuss some first results on SHG characterization and initial work on photon pair generation via parametric down-conversion using the fabricated devices.

Q 23.33 Tue 17:00 Tent B

Integrated electro-optic modulators in $LiNbO_3$ as fundamental building blocks for quantum photonic circuits — •Noel Heinen, Michelle Kirsch, Sattibabu Romala, Sebastian Lengeling, Harald Herrmann, Laura Padberg, and Christine Silberhorn — Universität Paderborn, Integrierte Quantenoptik, Institut für Photonische Quantensysteme, Warburger Str. 100, D-33098 Paderborn

Numerous applications in quantum communication and quantum processing require electric manipulation of photonic quantum states. Thus, electro-optic modulators (EOMs) are key components for photonic integrated circuits (PICs). A suitable and widely used material platform for EOMs is lithium niobate (LN) due to its high electro-optic coefficient and broad transparency window. Recent developments in integrated optics show that thin film lithium niobate (TFLN) is a highly versatile and promising material platform. Due to a drastically higher mode confinement than in titanium indiffused LN waveguides, nonlinear effects and integration density are further enhanced. The increase in modulation efficiency leads to higher modulation speeds and power efficiencies, as lower modulation voltages are required. Therefore programmable circuits for quantum information processing can be realized, as fast modulation is needed. As the fundamental building block of EOMs are phase shifters, we cover the fabrication process of TFLN phase modulators and compare their benefits over conventional diffused LN phase modulators with respect to their optical and electrical properties.

Q 23.34 Tue 17:00 Tent B

N Scaling of Large-Sample Collective Decay in Inhomogeneous Ensembles — Sergiy Stryzhenko[1,2], Alexander Bruns[1], and •Thorsten Peters[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstraße 6, 64289 Darmstadt, Germany — [2]Institute of Physics, National Academy of Science of Ukraine, Nauky Avenue 46, Kyiv 03028, Ukraine

We experimentally study collective decay of an extended disordered ensemble of N atoms inside a hollow-core fiber. We observe up to 300-fold enhanced decay rates, strong optical bursts and a coherent ringing. Due to inhomogeneities limiting the synchronization of atoms, the data does not show the typical scaling with N. We show that an effective number of collective emitters can be determined to recover the N scaling known to homogeneous ensembles over a large parameter range. This provides physical insight into the limits of collective decay and allows for its optimization in extended ensembles as used, e.g., in quantum optics, precision time-keeping or waveguide QED.

Q 23.35 Tue 17:00 Tent B

Second-order correlations of scattering electrons — •Florian Fleischmann[1], Mona Bukenberger[2], Raul Corrêa[3], Anton Classen[4], Simon Mährlein[1], Marc-Oliver Pleinert[1], and Joachim von Zanthier[1] — [1]Friedrich-Alexander-Universität Erlangen-Nürnberg, Quantum Optics and Quantum Information, 91058 Erlangen, Germany — [2]ETH Zürich, Department of Environmental Systems Science, 8092 Zürich, Switzerland — [3]Federal University of Minas Gerais, Departamento de Física, 31270-901 Belo Horizonte, Brazil — [4]University of Utah, Health Science Core, UT 84112 Salt Lake City, USA

We investigate the spatial second-order correlation function of two scattering electrons in the far field. First, we consider semi-classically the effects of the Pauli exclusion principle and Coulomb repulsion on the expected correlation pattern. This is followed by a full quantum-mechanical treatment of the problem. For this, we separate the system into center-of-mass and relative coordinates in analogy to the hydrogen atom ansatz. While the center-of-mass system is described as a free particle, we solve the Coulomb scattering problem in the relative system. We expand the respective initial state of the electrons in the eigenstates of the scattering problem. After incorporating the time evolution, the function is evaluated in the far field. We show the formal solution to the problem and discuss the current state of the numerical investigations.

Q 23.36 Tue 17:00 Tent B

Cryogenic spectroscopy of novel organic molecules doped with Yb3+ for quantum information processing applications — •Robin Wittmann[1], Jannis Hessenauer[1], Sören Schlittenhardt[1], Senthil Kumar Kuppusamy[1], Mario Ruben[1,2], and David Hunger[1] — [1]KIT, Karlsruhe, Germany — [2]CNRS-Université, Strasbourg, France

Rare earth ions (REI) doped into crystals have proven to be a promising system for quantum information processing due to their long optical coherence time stemming from the shielding of the partially filled 4f electron shell by the fully occupied 5s and 5p orbitals. Yb3+ is a REI that is particularly interesting as a microwave to optical photon interface due to it being a Kramers ion with an electron spin of 1/2. Benefits of trivalent Ytterbium are its simple energy level structure consisting of only two electronic multiplets, as well as its favorable branching ratio. In addition, long electron spin coherence times were observed for Yb171 due to its zero magnetic field clock transition in low symmetry crystals. Here we investigate the optical lifetime, coherence time and optical linewidth of novel organic molecules tailored to host REIs. Measurements are done at cryogenic temperatures on ensembles of Yb3+ doped molecular crystal powder to test its viability for quantum information processing tasks. We observe narrow inhomogeneous linewidths and individually addressable subspecies sensitive to different excitation wavelengths.

Q 23.37 Tue 17:00 Tent B

A nanosecond pulsed light source as pump source for narrowband, decorrelated photon pairs — •Jasmin Sommer, Michelle Kirsch, Kai Hong Luo, Harald Herrmann, and Christine Silberhorn — Universität Paderborn, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Str. 100, D-33098 Paderborn

Narrowband and spectrally decorrelated photon pairs are a prerequisite for many applications in quantum processing. A common way to generate single photon pairs is to use parametric down conversion (PDC) sources. Exploiting clustering within a cavity allows the generation of spectrally narrowband photon pairs. Decorrelated pure states can be further obtained by pumping the source with pulses of well-defined properties. We have developed a pump source dedicated for pumping cavity-enhanced PDC in a periodically poled waveguide in $LiNbO_3$. To generate photon pairs in the telecom range, this requires Gaussian shaped pulses around 775 nm with an adjustable pulse length in the nanosecond range. We have constructed such a pump source starting with a cw laser at 1550 nm. An electro-optical modulator is used to generate specifically tailored pulses of well-defined duration. These are amplified in erbium doped fiber amplifiers and converted to the 775 nm range via second harmonic generation in a periodically poled bulk $LiNbO_3$ crystal. We report details on the design and characterization of the pump source and initial experiments towards the generation of decorrelated photon pairs.

Q 23.38 Tue 17:00 Tent B

Quantum pulse gate conversion efficiency — •Dana Echeverría-Oviedo[1], Hiroko Tomoda[2], Felix Moor[1], Michael Stefszky[1], Benjamin Brecht[1], and Christine Silberhorn[1] — [1]Paderborn University, Integrated Quantum Optics, Institute of Photonic Quantum Systems (PhoQS), Warburger Str. 100, 33098, Paderborn, Germany. — [2]Department of Applied Physics, School of Engineering, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan

The quantum pulse gate (QPG) is a dispersion-engineered guided-wave device, based on sum-frequency generation (SFG) between spectrally shaped light pulses. It can implement time-frequency mode-selective projections of single photons on user-defined modes. These are useful for quantum applications in, e.g., metrology, communications and simulations, where high efficiencies are crucial. The SFG conversion efficiency η, that is the ratio between the number of upconverted photons over the number of input photons (assuming no pump depletion and neglecting propagation losses), is given by $\eta = \sin^2(\sqrt{\eta_{norm} P_p}\, L)$, where η_{norm} is η normalized per pump power P_p and sample length L. Considering identical experimental conditions (geometry and material of the waveguide; spatial, temporal and spectral overlap; and pulse characteristics) to increase η it is necessary to increase L, which is a challenge due to the accumulation of fabrication inhomogeneities of longer samples. In this work, we measured η of a 71 mm long QPG, the longest reported until now, which reaches η of up to 64% for a P_p of only 12.5 mW. Here, we report on the progress of the project.

Q 23.39 Tue 17:00 Tent B

Hong-Ou-Mandel interference in the spectral domain — •Patrick Folge, Abhinandan Bhattacharjee, Michael Stefszky, Benjamin Brecht, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Straße 100, 33098 Paderborn, Germany

The Hong-Ou-Mandel (HOM) effect describes the quantum interference of indistinguishable photons on a beam splitter, and is one of the most celebrated effects in quantum optics. It provides a fundamental building block of many technological applications, including linear optical quantum computation and (Gaussian) boson sampling. In this work we explore the implementation of HOM type effects in the spectral domain of optical fields, which could help in the efforts of scaling up the dimensionality of the mentioned technologies. Our spectral domain approach achieves the required beam splitter like operation between different frequency bins, using a so called multi-output quantum pulse gate (mQPG). This is a frequency conversion based device, implemented in dispersion engineered $LiNbO_3$ waveguides, which allows to interfere programmable superpositions of frequency bins in different output frequency channels. In our scheme we consider frequency entangled photon pairs generated in a type-0 parametric down conversion source as the input to the frequency beam splitter to observe the bunching in the output channels of the mQPG. Here, we report the progress of this ongoing project.

Q 23.40 Tue 17:00 Tent B

Designing a two-output Quantum Pulse Gate — •Theresa Keuter, Patrick Folge, Laura Serino, Benjamin Brecht, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute of Photonic Quantum Systems (PhoQS) Warburger Str. 100, 33098 Germany

Time-frequency modes serve as a versatile basis for numerous quantum technology protocols. Yet, the simultaneous detection of distinct time-frequency modes poses a significant challenge. Addressing this issue, a multi-output quantum pulse gate (mQPG) has recently been implemented, which has the capability to map different time-frequency modes to distinct output frequencies, enabling their separation. The mQPG was implemented in dispersion-engineered periodically poled $LiNbO_3$ waveguides by alternating between poled and unpoled regions, generating multiple phase-matching peaks corresponding to different output frequencies. However, this approach is not optimized for maximal conversion efficiencies due to the presence of unpoled regions in the waveguide. In scenarios where the mQPG operates on quantum states, such as those generated by parametric down conversion, maximizing conversion efficiencies is desireable. Here, we explore an alternative approach by modulating the poling structure with a square wave, which promises higher efficiencies. We focus on the design and optimization of mQPGs with two output channels. We investigate the influence of various parameters on the resulting efficiencies and report on the progress of our ongoing project.

Q 23.41 Tue 17:00 Tent B

Fabrication of a surface-electrode ion trap for quantum information processing — •Nora D. Stahr[1,3], Jacob Stupp[1,3], Eike Iseke[2], Nila Krishnakumar[2], Friederike Giebel[2], Konstantin Thronberens[2], Chloë Allen-Ede[1,3], Amado Bautista-Salvador[2], and Christian Ospelkaus[1,2,3] — [1]Leibniz Universität Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Laboratory of Nano and Quantum-Engineering, Hannover, Germany

Surface-electrode ion traps are a promising platform for the realisation of quantum computers, as the underlying microfabrication techniques are scalable [1]. The MIQRO project is developing surface-electrode ion traps for scalable quantum computers that utilise microwave fields and static magnetic fields for quantum logic gates [2]. For future applications, the number of integrated electrodes needs to be increased and additional functional units are required to be integrated into the ion trap substrates to enable better connectivity and optimised optical access. In addition, the assembly and connection technology needs to be adapted to the increasing requirements. We present microfabrication techniques for the production of multi-layer quantum processor chips [3] with the aim of implementing different technologies in one process flow.

[1] S. Seidelin et al., Physical Review Letters 96, 253003 (2006). [2] F. Mintert, & C. Wunderlich, Physical Review Letters 87, 257904 (2001). [3] A. Bautista-Salvador et al., New Journal of Physics 21, 043011 (2019).

Q 23.42 Tue 17:00 Tent B

Phase transition and higher-order mean-field theory of chiral waveguide QED — •Kasper Jan Kusmierek[1], Max Schemmer[2], Sahand Mahmoodian[3], and Klemens Hammerer[4] — [1]Institute for Theoretical Physics, Leibniz University Hannover, Germany — [2]Istituto Nazionale di Ottica del Consiglio Nazionale delle Ricerche (CNR-INO), 50019 Sesto Fiorentino, Italy — [3]Centre for Engineered Quantum Systems, School of Physics, The University of Sydney, Sydney, NSW 2006, Australia — [4]Institute for Theoretical Physics, Leibniz University Hannover, Germany

Waveguide QED with cold atoms provides a potent platform for the study of non-equilibrium, many-body, and open-system quantum dynamics. Even with weak coupling and strong photon loss, the collective enhancement of light-atom interactions leads to strong correlations of photons arising in transmission. Here we apply an improved mean-field theory based on higher-order cumulant expansions to describe the experimentally relevant, but theoretically elusive, regime of weak coupling and strong driving of large ensembles. We determine the transmitted power, squeezing spectra and the degree of second-order coherence. In the regime of very large drive and atom numbers we observe an non-equilibrium phase transition. This reveals the important role of many-body and long-range correlations between atoms in steady state.

Q 23.43 Tue 17:00 Tent B

Superradiant bursts of light from cascaded quantum emitters: Theoretical modelling of photon-photon correlations — Constanze Bach, Christian Liedl, Arno Rauschenbeutel, Philipp Schneeweiss, and •Felix Tebbenjohanns — Department of Physics, Humboldt-Universität zu Berlin, 10099 Berlin, Germany

A fully inverted ensemble of two-level emitters coupled to a common radiation mode emits its energy as a superradiant burst of light [1]. Recently, we have observed experimentally that a similar collective dynamics prevails in the case of a cascaded quantum system [2]. Due to the large number of up to 1200 emitters, the theoretical modeling of our experiments is challenging. Here, we present two novel numerical models with favorable computational complexity that allow us to quantitatively predict the observed burst dynamics. The first model approximates the light field between adjacent atoms as a probabilistic mixture of coherent states. This mixed coherent state approximation (MCSA) correctly predicts the emitted power and the field-field correlations. In addition, we implement the discrete truncated Wigner approximation, which was recently developed in [3]. This inherently stochastic model agrees with the predictions of our MCSA and additionally computes the photon-photon correlations, in agreement with our experimental data. In the future, we plan to test the applicability of our models to other experiments with cascaded quantum systems.

[1] R. H. Dicke, Phys. Rev. 93, 99 (1954).
[2] C. Liedl et al., arXiv:2211.08940 (2023).
[3] C. D. Mink and M. Fleischhauer, arXiv:2305.19829 (2023).

Q 23.44 Tue 17:00 Tent B

Chromatic suppression of spontaneous emission — •Thomas Lafenthaler[1], Yannick Weiser[1], Tommaso Faorlin[1], Lorenz Panzl[1], Rainer Blatt[1,2], Thomas Monz[1,3], and Giovanni Cerchiari[1,4] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstrasse 25, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Technikerstrasse 21a, 6020 Innsbruck, Austria — [3]AQT, Technikerstraße 17, 6020 Innsbruck, Austria — [4]Department of Physics, University of Siegen, Walter-Flex-Str. 3, 57068 Siegen, Germany

We control the spontaneous emission of trapped Ba+ Ions with reflective boundary conditions. By reflecting the fluorescence light of the ion onto itself, the single photons emitted by the ions interfere with themselves, making it possible to control the emission rate. The control depends on the solid angle in which the emitted photons are retroreflected and, to achieve complete control, we utilize a hemispherical mirror that can oversee the ion from every direction of space. When the mirror radius is adjusted to obtain destructive interference at the emitted photons wavelength, fluorescence, and consequently, the corresponding energy transition, can be suppressed. Here, I present our current effort to control the decay of the $6p_{1/2}$ state of the Ba+ ion which can relax by emitting 493 nm or 650 nm photons. Our aim is to demonstrate control over the decay branching ratio, which could find application in other experiments, for example, to suppress an unwanted relaxation branch or simplify its energy structure.

Q 23.45 Tue 17:00 Tent B

Multi-commodity transport and the role of the dynamical metric — •Joshua Ganz, Giovanna Morigi, and Frederic Folz — Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany

The interplay of nonlinear dynamics and noise is at the basis of coherent phenomena, such as stochastic resonance, synchronization, and noise-induced phase transitions. While the effect of noise in these phenomena has been partially analyzed, the impact of the specific form of the nonlinear dynamics on noise-induced phase transitions is unknown. In this work, we analyze multi-commodity transport on a noisy network where the nonlinearity enters through a dynamical metric that depends nonlinearly on the local current. We determine network self-organization for different functional forms of the metric in a geometry of constraints simulating two transportation demands. We perform an extensive study of the emerging network topologies for the deterministic case and for the case of adding Gaussian noise to the nonlinear dynamics. To characterize the network topologies, we introduce performance measures such as robustness. We show that the resulting dynamics exhibits noise-induced resonances, which manifest as self-organization into the most robust network with a resonant response to a finite value of the noise amplitude. We analyze in detail the specific features and perform a comparative assessment. Our study sheds light on the interplay between nonlinear dynamics and stochastic forces, highlighting how their joint effect determines noise-induced coherence.

Q 23.46 Tue 17:00 Tent B

Multiwavelength Characterization of Polarization Optics for Broadband Superconducting Detector Calibration — •Isabell Mischke, Timon Schapeler, and Tim Bartley — Institute for Photonic Quantum Systems, Department of Physics, Paderborn University, Warburger Str. 100, 33098 Paderborn, Germany

Intrinsically, superconducting detectors can detect a broad spectrum. But it remains an open question whether the detector behaves the same to one photon at a certain energy or two photons of half the energy.

To investigate the difference in the behaviour, it is important to understand the operation of the detector for different wavelengths. Our aim is the multiwavelength characterization of superconducting nanowire single-photon detectors (SNSPDs), with respect to the polarization and wavelength dependence of the setup. This requires exploring the wavelength and polarization dependence of all components, to extract the intrinsic spectral response of the SNSPD alone. We present initial data towards this aim.

Q 23.47 Tue 17:00 Tent B

Light propagation through ensembles of nuclear two-level systems — •Deniz Adigüzel, Miriam Gerharz, and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Recent experiments at X-ray free electron lasers allow one to access new excitation regimes. The light-matter interactions can be studied by solving the optical-Bloch equations. Observing an ensemble of atoms, the light is scattered off of these atoms either coherently or incoherently. By comparing the intensities of these quantities, one can show that in the low-excitation regime their ratio remains constant in time[1]. However, [1] focused on settings in which propagation effects could be neglected. Here we study the light propagation through an ensemble of atoms beyond the low excitation regime in situations in which propagation effects are of relevance and compare the coherent/incoherent radiation.

[1] L. Wolff and J. Evers. "Characterization and detection method for x-ray excitation of Mössbauer nuclei beyond the low-excitation regime", Physical Review A 108(4), 043714 (2023)

Q 23.48 Tue 17:00 Tent B

Fabrication of Solid Immersion Lenses for the cryogenic Investigation of the NV center — •Judith de Vries, Katharina Senkalla, Stefan Dietel, Michael Olney-Fraser, Lev Kazak, and Fedor Jelezko — Institute for Quantumoptics, Ulm University, Ulm, Germany

The Nitrogen-Vacancy (NV) center in diamond has shown great potential for applications in quantum information processing, sensing, and imaging. A known application of NV center in cryogenic environment is the quantum repeater. As the entanglement rate is limited by the photon-collection efficiency of the NV centers, improving this efficiency through the use of solid immersion lenses can greatly enhance the performance of quantum repeaters. Here we investigate the performance of the fabricated SILs in particular in cryogenic environment.

Q 23.49 Tue 17:00 Tent B

Investigations of fluorescence lifetimes, thermal lensing, and laser performance of directly diode pumped cw ruby laser — Carsten Reinhardt and •Sönke Metelmann — Hochschule Bremen City University of Applied Sciences

Recently, the first laser ever, Maiman*s 694 nm ruby laser, regained new interest due to successful cw operation by pumping with high-power 405 nm laserdiodes [1]. Investigation on compact plane-plane Ruby laser[2] indicate stabilization of the resonator by thermal lensing, induced by the pump laser diode. Here we present results of studies on pump laserdiode performances for optical pumping of ruby crystals. Temperature dependend fluorescence lifetimes have been measured for different pump powers. First results on measurements of thermal lensing are presented. [1] W. Luhs, B. Wellegehausen; Diode pumped cw ruby laser, OSA Continuum 184, Vol.2, No.1 (2019) [2] W. Luhs, B. Wellegehausen; Diode pumped compact single frequency cw ruby laser, J. Physics Communications 7 (2023) 0055007

Q 23.50 Tue 17:00 Tent B

Bridging Quantum Optics and Environmental Physics: Insights into Argon Trap Trace Analysis — •Magdalena Winkelvoss and Alexandra Beikert — Kirchhoffinstitut für Physik Heidelberg

Tracer experiments are an important tool to understand environmental transport processes. A particularly widely used class of tracers are radioactive isotopes, which can be used for dating. ^{39}Ar has a half life of 268 years making it suitable for the time range of 50 to 1000 years and dating processes like ocean circulation or glacier flow. But as the relative abundance of ^{39}Ar is in the range of 10^{-16}, a ultra sensitive and selective detection method is required. This can be done by Argon Trap Trace Analysis (ArTTA), by capturing single ^{39}Ar atoms in a magneto-optical trap (MOT). Here, the slight difference in excitation frequencies between the different isotopes is exploited. In combination with the high number of scattered photons, this gives a high isotopic selectivity and makes ArTTA an ideal method for dating ^{39}Ar.

Opposed to many other atom trapping experiments the amount of ^{39}Ar is limited due to sample size, thus it is important to capture a high percentage of the atoms. With this poster we present the working principle of the ArTTA technique and will highlight the challenges of addressing argon atoms. Specifically, we will address the most crucial challenges of the measurement technique: the atom beam collimation and focusing apparatus to reach a high trapping rate in the MOT.