Q 40: Poster: Quantum Optics and Photonics III

Time: Tuesday 16:15–18:15 Location: Zelt West

Q 40.1 Tue 16:15 Zelt West

Inferring two-qubit causal structures — •Jonas Kübler and Daniel Braun — Institut für theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany

The rise of quantum information theory and machine learning has led to increasing interest in causal inference in quantum mechanics. Here we study a set-up proposed by Ried et al. [Nat. Phys. 11, 414 (2015)] in which a common-cause scenario can be mixed with a cause-effect scenario, and for which it was found that quantum mechanics can bring an advantage in distinguishing the two scenarios: Whereas in classical statistics, interventions such as randomized trials are needed, a pure observational scheme is enough to detect the causal structure if initial entanglement is available.

We analyze this setup in terms of the geometry of unital positive but not completely positive qubit-maps, arising from the mixture of qubit channels and steering maps. We find the range of mixing parameters interpolating between cause-effect and common-cause that can generate given correlation by establishing new bounds on signed singular values of sums of matrices. We prove a quantum advantage in a more general setup allowing arbitrary unital channels and initial states with fully mixed reduced states. Based on the geometry, we quantify the quantum advantage depending on the observed correlations and find the number of additional constraints needed for the complete solution of the causal inference problem.

Q 40.2 Tue 16:15 Zelt West

Shannon entropy of quantum random walks — •Shahram Panahiyan[1] and Stephan Fritzsche[1,2] — [1]Helmholtz-Institut Jena, Germany — [2]Friedrich-Schiller-Universität Jena, Germany

Recently, there has been a great interest in quantum random walk which is the counter part of the classical random walk. This interest arises from the particular properties of these walks, such as their spread which may arise quadratically faster than classical random walks, their nonclassical probability distribution. These properties make the quantum random walk promising for quantum computing and engineering quantum algorithms [1]. On the other hand, Shannon entropy has been introduced as a tool for determining the amount of uncertainty in the state of a physical system. In fact, (Shannon) entropy is a natural measure of uncertainty, perhaps even more appropriate than the standard deviation [2]. It naturally captures the amount of information about a measurement outcome. Here, we investigate the Shannon entropy of quantum random walks. Our aim is to understand the evolution of entropy as a function of: coin, initial state and steps.

[1]: S. E. Venegas-Andraca, Quant. Info. Process. 11, 1015 (2012).
[2]: P. J. Coles et al., Rev. Mod. Phys. 89, 015002 (2017).

Q 40.3 Tue 16:15 Zelt West

Multilayer ion trap for scalable quantum simulation and quantum information processing — •Giorgio Zarantonello[1,2], Henning Hahn[1,2], Sebastian Grondkowski[1], Timko Dubielzig[1], Fabian Ude[1], Martina Wahnschaffe[1,2], Amado Bautista-Salvador[1,2], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [2]PTB, Bundesallee 100, 38116 Braunschweig

Based on recent advances in surface-electrode trap fabrication in our group, we present a novel trap design with embedded multi-layer waveguides to implement quantum control using the microwave near-field gradient approach [1-3]. This new multilayer trap represents a significant development from the previous generations in terms of both scalability and performance. We will present the main results from the finite element simulations of the microwave near-fields and compare it with the previous single-layer design [4]. The new room temperature experimental setup housing the trap structure will also be presented.

[1] C. Ospelkaus *et al.*, Nature **476**, 181 (2011).
[2] C. Ospelkaus *et al.*, Phys. Rev. Lett. **101**, 090502 (2008).
[3] M. Carsjens *et al.*, Appl. Phys. B **114**, 243 (2014).
[4] M. Wahnschaffe *et al.*, Appl. Phys. Lett. **110**, 034103 (2017).

Q 40.4 Tue 16:15 Zelt West

Device-independent secret key rate from optimized Bell inequality violation — •Sarnava Datta, Hermann Kampermann, and Dagmar Bruss — Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, Universitätstraße 1, D-40225, Düsseldorf, Germany

Quantum Key distribution (QKD) is well established and starts entering in the commercial realm. However, due to divergence between theoretical models and practical devices, the security of such systems cannot be ensured. We consider the device-independent (DI) scenario, which avoids these problems. Our goal is to find an improved optimal Bell inequality violation using classical measurement data of a DIQKD protocol and to use this to find optimized bounds on the achievable DI secret key rate [1].

Reference

[1] L. Masanes, S. Pironio, and A. Acín , Nat. Commun. 2, 238 (2011).

Q 40.5 Tue 16:15 Zelt West

Technological Advances in Scalable Trapped Ion Quantum Computing — •Vidyut Kaushal, Janine Nicodemus, Daniël Pijn, Thomas Ruster, Björn Lekitsch, Ulrich Poschinger, and Ferdinand Schmidt-Kaler — Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Recent advances in trapped ion quantum technology have led to impressive results including the demonstration of four qubit GHZ states using subsequent entanglement gates [1] and a dc magnetometer with quantum enhanced sensitivity [2]. We will present the underlying technological advancements, starting with a high-speed multi-channel waveform generator developed in Mainz. The system delivers voltages and waveforms required for high-fidelity gate operations and fast ion transport, splitting and rearrangement of multiple ions. Voltage waveforms are computed using a custom developed software framework, which is capable of automatically generating ideal waveforms for various ion transport operations. In addition, we will discuss improvements of the quantizing magnetic field stability, which is critical for high qubit state coherence times. Electric coils were replaced using dual-type permanent magnets and the setup extended with a mu-metal chamber, leading to a significant improvement of coherence times [3].

[1] H. Kaufmann et al., Phys. Rev. Lett. 119, 150503 (2017)
[2] T. Ruster et al., Phys. Rev. A 90, 033410, 033410 (2014)
[3] T. Ruster et al., Appl. Phys. B 122:254 (2016)

Q 40.6 Tue 16:15 Zelt West

Simultaneous single ion addressing for quantum information processing — •Julian Rickert, Alexander Erhard, Roman Stricker, Lukas Postler, Esteban Martinez, Thomas Monz, Philipp Schindler, and Rainer Blatt — Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria

Single ion addressing is a major challenge for building a trapped ion quantum computer. We propose a novel single ion addressing scheme which allows simultaneous manipulation of multiple ions. This newly developed scheme will enable us to perform arbitrary operations on each ion in the trap simultaneously. This will enable the generation of entanglement between ions in an arbitrary subset of all ions in one trap. The addressing scheme is implemented via an array of fibers where each fiber is imaged onto a single ion. Adjustment to the ion spacing is performed with a micro mirror array, where each fiber output beam hits a single mirror of the array. A telescope between mirror array and objective forms the laser beam such that we can get spot sizes of around one micrometer, smaller than the inter-ion distance. Timing control is obtained by a separate fiber AOM for each fiber output, providing full phase, intensity and frequency control.

Q 40.7 Tue 16:15 Zelt West

Scalable quantum computation - Keeping a qubit alive — •Lukas Gerster[1], Martin van Mourik[1], Matthias Brandl[1], Lukas Postler[1], Thomas Monz[1], Philipp Schindler[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften , Austria

Trapped ions are a promising platform to host a future quantum computer.

In our setup we use a planar segmented trapping architecture in a cryostat to demonstrate scalable quantum manipulation. The setup has been designed to reduce magnetic field noise and mechanical vibrations which both can induce errors. [1] Two species, $^{40}Ca^{+}$ and $^{88}Sr^{+}$, are co-trapped, allowing for recooling of ion crystals during sequences. We have modified the setup to host a high optical access trap [2], featuring in vaccum-optics with high collection efficiency for high fidelity state readout.

We further present ion crystal rotation of both single and multi species ion crystals with only few phonons accumulated per rotation, similar to [3]. These operations expand the available toolbox, enabling quantum error correction protocols in the future.

[1] M. Brandl et al, *Cryogenic setup for trapped ion quantum computing*, 10.1063/1.4966970

[2] P. Maunz, *High Optical Access Trap 2.0*, 10.2172/1237003

[3] H. Kaufmann et al, *Fast ion swapping for quantum-information processing*, 10.1103/PhysRevA.95.052319

Q 40.8 Tue 16:15 Zelt West

Microfabricated linear ion trap arrays for quantum simulation — •Gerald Stocker[1,2], Philip Holz[1], Kirill Lakhmanskiy[1], Yves Colombe[1], Rainer Blatt[1,3], Clemens Rössler[2], and Sokratis Sgouridis[2] — [1]Institut für Experimentalphysik, Uni Innsbruck, Österreich — [2]Infineon Technologies Austria AG, Villach, Österreich — [3]Institut für Quantenoptik und Quanteninformation, Innsbruck, Austria

Linear chains of trapped ions are used for quantum simulation of 1D spin systems [1]. 2D arrays of ion traps may allow to extend the range of accessible simulations to systems with more than one spatial dimension. Here we report on the design and fabrication of linear ion traps that are arranged in a two-dimensional lattice on a microchip. The linear traps are segmented to create multiwells along the trap axes. An interaction zone allows to reduce the distance between adjacent wells along the axis to about $40\,\mu m$ using DC control fields. In this way, coherent operations mediated by the Coulomb interaction should become possible [2]. Similarly, the distance between adjacent multiwells can be reduced in the direction perpendicular to the trap axes by tuning the RF voltage [3]. Additionally, the multiwells can be moved independently of each other along the trap axes. This scheme should enable digital simulation of spin systems with next-neighbor interactions on a square lattice as well as triangular lattices. [1] C. Monroe et al., Proceedings of the International School of Physics 'Enrico Fermi', Course 189, pp. 169-187 (2015) [2] A.C. Wilson et al., Nature 512, 57-60 (2014) [3] M. Kumph et al., New J. Phys. 18, 023047 (2016)

Q 40.9 Tue 16:15 Zelt West

Security of multipartite QKD protocols with finite resources — •Federico Grasselli, Hermann Kampermann, and Dagmar Bruss — Institut für Theoretische Physik III, Heinrich-Heine-Universität, Düsseldorf, Deutschland

We analyze the security of multipartite quantum key distribution protocols implemented with genuine multipartite entangled states as resources [1]. In particular, we focus on finite-size effects.

For this purpose, we consider the generalizations of the notions of security, correctness, secrecy and leakage of a protocol in the multipartite scenario. We then extend the upper bounds to the key length and to the leakage of an optimal error correction scheme -known for bipartite protocols- to the multipartite case.

Furthermore, we present a computable secret key rate for finite resources in the presence of coherent attacks, extending similar results already obtained in the bipartite case [2].

[1]: M. Epping, H. Kampermann, C. Macchiavello, D. Bruß. New J. Phys. 19 093012, 2017.

[2]: M. Mertz, H. Kampermann, S. Bratzik, D. Bruß. Phys. Rev. A 87 012315, 2013.

Q 40.10 Tue 16:15 Zelt West

Prevention of Side-Channel Attacks in Timebin-Entanglement Based QKD Protocols — •Alexander Sauer and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt

Bell tests are a crucial part of many key distribution protocols in quantum cryptography. To prevent side-channel attacks, it is necessary to close all loopholes in these tests, which might be exploited by an adversary. We investigate schemes based on timebin-entanglement with respect to their vulnerability to the fair-sampling loophole and the impact of detector inefficiencies. We propose a modified experimental setup to overcome the arising limitations of Franson-type interferometers [1].

[1] J. D. Franson, Phys. Rev. Lett. 62, 2205 (1989)

Q 40.11 Tue 16:15 Zelt West

Overview over recent quantum key distribution activities at MPL — Ömer Bayraktar[1,2], Dominique Elser[1,2], Tobias Frank[1,2], •Kevin Günthner[1,2], Kevin Jaksch[1,2], Imran Khan[1,2], Christian R. Müller[1,2], Jonas Pudelko[1,2], Stefan Richter[1,2], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Staudtstraße 2, 91058 Erlangen, Germany — [2]IOIP, Friedrich-Alexander University Erlangen-Nuremberg (FAU), Staudtstr. 7/B2, 91058 Erlangen, Germany

Quantum key distribution (QKD) can provide secure communication, even in the upcoming era of quantum computers. Thus, QKD is one of the most highlighted and developed quantum technologies. Over the last years, this research area has been investigated intensively at the Max Planck Institute for the Science of Light (MPL) in Erlangen. On this poster, we give an overview of these activities. We study both fiber-based QKD, being compatible with existing telecom technology [1], as well as free-space channels. Here, we analyze urban scenarios using our free-space link in Erlangen [2] as well as long-haul satellite quantum communication [3]. Additionally, we present our plans for the spin-off InfiniQuant, aiming towards commercialization of our QKD systems.

[1] I. Khan et al., QCrypt 2016

[2] B. Heim et al., New J. Phys. **16**, 113018 (2014)

[3] K. Günthner et al., Optica **4**, 611-616 (2017)

Q 40.12 Tue 16:15 Zelt West

Quantum key distribution with small satellites — Peter Freiwang[2] and •QUBE Konsortium[1,2,3,4,5] — [1]Deutsches Zentrum für Luft- und Raumfahrt IKN, Oberpfaffenhofen — [2]Ludwig-Maximilians-Universität, München — [3]Max-Planck-Institut für die Physik des Lichts, Erlangen — [4]OHB System AG, Oberfaffenhofen — [5]Zentrum für Telematik, Würzburg

Quantum Key Distribution (QKD) over long distances becomes possible using optical links between satellites and ground stations on earth. Connecting to different ground stations one after the other enables secure key exchange on a global scale. Here we present a concept for a simple and compact nano-satellite QKD-payload allowing for the generation of BB84 polarization encoded faint laser pulses. A new level of integration was achieved by using micro optical components and a waveguide circuit resulting in a robust and stable optical unit with the size of a match. The micro optical packaging and the control electronics are combined on a 9 x 9 cm* printed circuit board. We describe the concept of the nano-satellite, a so called cube-satellite as small as 10 x 10 x 30 cm3. Because of their size and weight, cube-satellites represents an economical platform for testing of technologies in space in general. Thanks to the low costs, they have the potential to form flotillas to become the backbone for a global QKD network.

Q 40.13 Tue 16:15 Zelt West

Towards Single Neutral Atoms in Crossed Fiber Cavities — •Joseph Dale Christesen, Dominik Niemietz, Manuel Brekenfeld, Manuel Uphoff, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Cavity quantum electrodynamics provides a rich toolbox for the investigation of fundamental phenomena in quantum physics through increased light-matter coupling which enables many intriguing applications in quantum information processing. One method to further increase the light-matter coupling for a neutral atom trapped in a cavity is to decrease the cavity mode volume. Limits on the reduction of the cavity mode volume imposed by traditional manufacturing processes of the cavity mirrors have been overcome with the introduction of fiber cavities [1], where fiber end facets are machined by means of CO_2 laser ablation. Besides small mode volumes and larger coupling rates, fiber cavities also allow for new cavity geometries due to their smaller dimensions, including coupling a single emitter to two independent and perpendicular cavity modes. We are currently setting up a new experiment consisting of two crossed fiber cavities which realizes this unique cavity geometry and also constitutes an important step towards the implementation of an integrated quantum repeater [2].

We will present the current status and future plans for our apparatus including fabrication results of elliptical and spherical fiber mirrors.

[1] Hunger *et al.*, NJP **12**, 065038 (2015)
[2] Uphoff *et al.*, Appl. Phys. B **122**, 46 (2016)

Q 40.14 Tue 16:15 Zelt West

Sagnac-type setup for the generation of tunable polarizationentangled photon pairs — •Golnoush Shafiee[1,2], Gerhard Schunk[1,2], Florian Sedlmeir[1,2], Alexander Otterpohl[1,2], Ulrich Vogl[1,2], Dmitry Strekalov[1,2], Harald G. L. Schwefel[3], Gerd Leuchs[1,2], and Christoph Marquardt[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Institute of Optics, Information and Photonics, University Erlangen-Nürnberg, Erlangen, Germany — [3]The Dodd-Walls Centre for Photonic and Quantum Technologies, Department of Physics, University of Otago, Dunedin, New Zealand

Single photons and photon pairs are an important resource for quantum information processing. Our compact source of photon pairs [1] and squeezed light [2] is based on spontaneous parametric down conversion (SPDC) in a triply resonant whispering-gallery resonator (WGR) made of lithium niobate. Single-mode operation of this source has been demonstrated. The central wavelength of the emitted light can be tuned over hundreds of nanometer [3]. Currently, we investigate PDC in counter-propagating modes of one WGR. Here we study interference of the counter-propagating signals above and below the oscillation threshold. This system opens up novel possibilities for the creation of polarization-entangled photon pairs for proposed quantum repeater schemes.

[1] M. Förtsch et al., Nat. Commun. 4, 1818 (2013). [2] J. U. Fürst et al., Phys. Rev. Lett. 106, 113901(2011). [3] G. Schunk et al., Optica 2, 773-778 (2015).

Q 40.15 Tue 16:15 Zelt West

Towards a long lived multi-mode memory for photonic qubits — •Stefan Langenfeld, Matthias Koerber, Olivier Morin, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany

Quantum memories can preserve qubits for an extended duration. In combination with the capability to map photonic qubits into and out of the memory, this has important applications in quantum computation and communication. For instance, quantum repeater protocols rely on long storage times and the ability to access multiple qubits independently. After recently demonstrating a qubit memory featuring a coherence time compatible with global scale communication [1], we now are interested in implementing multi-qubit storage capabilities in the same system. This would promote single neutral atoms to a truly scalable architecture. Our system consists of several ^{87}Rb atoms trapped in a two-dimensional optical lattice in a high-finesse optical resonator. We use an imaging system capable of resolving single atoms [2]. In combination with an acousto-optic deflector this allows us to select an atom and steer an optical beam onto it independent of its non-deterministic position in the optical lattice. We will discuss our progress on the optical addressing and show first results demonstrating multi-qubit storage capabilities.

[1] M. Körber, O. Morin, S. Langenfeld et al., accepted for publication in Nat. Photonics
[2] A. Neuzner et al., Nat. Photonics 10, 303-306 (2016)

Q 40.16 Tue 16:15 Zelt West

Coupling individual Erbium ions to single telecom photons — •Lorenz Weiss, Natalie Wilson, Benjamin Merkel, and Andreas Reiserer — Max Planck Institute of Quantum Optics, Garching, Germany

Erbium ions in suited host crystals are promising candidates for large-scale quantum networks since they combine second-long ground state spin coherence times with coherent optical transitions at telecommunication wavelengths. Unfortunately, the extremely long lifetime of the excited state (14 ms) makes it difficult to spectrally resolve and control individual ions in order to harness them for quantum networks. To overcome this challenge, we employ Fabry-Perot cavities that contain micrometer-thin, erbium-doped yttrium orthosilicate (Y_2SiO_5) crystals. In initial experiments, we have observed a cavity finesse of 36 000. To achieve both a smaller mode volume and a higher resonator quality factor, we have then optimized both the sample surface roughness (below 0.2 nm rms) and the resonator size (to a few cubic wavelengths) by fabricating low-roughness depressions of small radius of curvature in fused silica. At cryogenic temperature, we thus expect to shorten the radiative lifetime of the optical transitions by three orders of magnitude via the Purcell effect. This will enable deterministic interactions between individual spins and single telecom photons, opening unique prospects for the realization of entanglement between spins over distances exceeding 100 km.

Q 40.17 Tue 16:15 Zelt West

Coupling of quantum emitters in Si_3N_4 photonic crystal nanobeam cavities — •Jan Olthaus[1], Doris E. Reiter[1], Philip Schrinner[2], and Carsten Schuck[2] — [1]Institut für Festkörpertheorie, Universität Münster, 48149 Münster, Germany — [2]Physikalisches Institut, Universität Münster, 48149 Münster, Germany

The efficient integration of single-quantum emitters with photonic circuits is a major challenge for the development of quantum technologies. A scalable implementation of single-photon emitters on a chip requires a low-loss interface and strong light-matter interactions. Here, we present results for geometry optimisations based on 3D-FDTD simulations of photonic crystal nanobeam cavities embedded with a Si_3N_4 waveguide. Our goal is to optimise the structure in terms of a low, wavelength-scale mode volume in combination with a high Q-factor of the localised cavity mode. Based on this geometry we analyze the coupling strength between the single-photon emitter and the dielectric waveguide dependent on the position and polarization of the source. Our results pave the way for an efficient integration of single-photon sources into photonic circuits.

Q 40.18 Tue 16:15 Zelt West

Towards cavity-enhanced detection of single rare earth ions — •Julia Benedikter[1,2], Bernardo Casabone[3], Thomas Hümmer[1], Alban Ferrier[4], Philippe Goldner[4], Theodor W. Hänsch[1,5], and David Hunger[2] — [1]Ludwig-Maximilians-Universität München, Germany — [2]Karlsruher-Institut für Technologie, Germany — [3]Institut de Ciències Fotòniques, Barcelona, Spain — [4]Chimie ParisTech, ENS, Paris, France — [5]Max-Planck-Institut für Quantenoptik, Garching, Germany

Rare earth ions doped into solids provide outstanding optical and spin coherence properties, which renders them as promising candidates for optically adressable quantum memories and multi-qubit registers. However, due to the dipole-forbidden nature of the coherent transitions, they couple only weakly to optical fields. This limits most experiments to macroscopic ensembles, where inhomogeneous broadening complicates and limits quantum control.

Here we present an approach to get efficient access to individual ions or small ensembles by coupling them to a high-finesse optical microcavity. We employ fiber-based Fabry-Perot cavities with high finesse and a free-space mode volume as small as a few λ^3 to achieve substantial Purcell enhancement. This offers the potential to boost the spontaneous emission rate by several orders of magnitude (up to 104), thereby making the weak transitions bright.

We report on the current status of our experiment, where we investigate Eu^{3+} : Y_2O_3 nanocrystals coupled to a cavity in a cryogenic environment.

Q 40.19 Tue 16:15 Zelt West

Nano-photonic circuits with integrated quantum emitter — •Philip Schrinner, Marius Otte, Rene Henke, and Carsten Schuck — Physikalisches Institut and Center for Nanotechnology, WWU Münster, Germany

Realizing quantum information processing technologies on a scalable platform are expected to have a disruptive impact on cryptography, communication and computing. Advanced CMOS fabrication is a promising tool for integrating large-scale quantum photonic circuits on silicon. We consider such a system, where single photons are manipulated in nano-photonic waveguide devices. The implementation consists of single photon sources (SPS), nano-photonic circuits and single photon detectors. In this work we aim on coupling nano-scale quantum emitters with waveguide devices to supply single-photons into photonic integrated circuits. We present techniques to deterministically place the nano emitters in the evanescent field of an optical waveguide, where nitrogen vacancy centers in nano diamonds serve as an example. Additionally, suitable nano-photonic devices for the integration of nano emitters are rapidly prototyped by employing nanofabrication routines and automated fiber-optic measurement capabilities. The spectral and statistical properties of quantum emitters are at first investigated in confocal microscopy. After the positioning process the coupling between the quantum emitter and an optical waveguide is investigated. Integration of single-photon sources with SNSPDs linked via nanophotonic circuits on a silicon chip will then constitute a key step towards scalable quantum information processing.

Q 40.20 Tue 16:15 Zelt West

Resonant excitation of defect centers in hexagonal Boron Nitride (hBN) — •Markus Bürk[1], Andreas Dietrich[1], Igor Ahoronovich[2], Kerem Bray[2], Fedor Jelezko[1], and Alexander Kubanek[1] — [1]Insitute for Quantum Optics, Ulm University, D-89081 Ulm — [2]School of Mathematical and Physical Sciences, University of Technology Sydney, Ultimo, NSW, 2007, Australia

Recent experiments demonstrated resonant excitation of single defect centers in 2D-material hexagonal Boron Nitride [1]. We present our recent results on resonant excitation of different defect centers in hBN in absence of spectral diffusion or dephasing for as long as 30 s at cryogenic temperatures (4 K). Our investigations include resonant photoluminescence excitation (PLE) of single photon emitters in a wide optical range. Furthermore, we investigated the polarization properties and phonon side band features of the defects. Together with a long coherence time [2] these properties make hexagonal Boron Nitride a promising candidate for quantum optical applications like quantum repeaters.

[1] Tran, Toan Trong, et al. "Resonant excitation of quantum emitters in hexagonal boron nitride." ACS Photonics (2017).

[2]Abdi, Mehdi, et al. "Spin-mechanics with color centers in hexagonal boron nitride membranes." arXiv preprint arXiv:1704.00638 (2017).

Q 40.21 Tue 16:15 Zelt West

Surface treatment of hBN towards stable spectral lines — •Michael Koch, Andreas Dietrich, Richard Waltrich, Lukas Hartung, Stefan Häussler, Fedor Jelezko, and Alexander Kubanek — Institute for Quantum Optics, Ulm University, D-89081 Ulm, Germany

Due to its promising spectral properties [1, 2], hBN is a bright candidate for quantum optical applications like quantum repeaters. Spectral stability is a crucial property for single photon emitters and therefore spectral diffusion is a limiting factor especially for hBN. We present techniques to improve the spectral properties of defect centers in hBN by different surface treatment and annealing methods. We gain indepth insight into the underlying physical processes leading to spectral instability.

[1] Tran, Toan Trong, et al. "Quantum emission from hexagonal boron nitride monolayers." Nature nanotechnology 11.1 (2016):37-41.

[2] Tran, Toan Trong, et al. "Resonant excitation of quantum emitters in hexagonal born nitride." ACS Photonics (2017).

Q 40.22 Tue 16:15 Zelt West

A close look on second order correlation measurements of quantum emitters in hexagonal boron nitride and their implications for the underlying level system — •Bernd Sontheimer[1], Merle Braun[1], Mehran Kianinia[2], Igor Aharonovich[2], and Oliver Benson[1] — [1]Institut für Physik, Humboldt-Universität zu Berlin, — [2]School of Mathematical and Physical Sciences, University of Technology Sydney

Single photon sources (SPSs) are prime candidates for a myriad of applications in integrated quantum optics and information processing. Quantum emitters in hexagonal boron nitride (hBN), a wide-band-gap two-dimensional material, have recently emerged as promising SPSs. While the origin and atomic structure of these emitters are still under debate, they can exhibit remarkable properties including the ability of sub-band-gap excitation at room temperature, high brightness and short excited state lifetime. Here, we present our latest insights on the underlying level system and rate models gained from second-order correlation measurements of single photon streams emitted by isolated defects. By performing measurements at different excitation laser powers, we can carefully match the resulting graphs to theoretical predictions for different models and extract transition rates as well as saturation behaviors of the participating electronic states. We find at least one exceptionally long-lived metastable state and repumping mechanisms that can be exploited in super-resolution microscopy schemes.[1] Furthermore, our results experimentally complement density functional theory modeling of the emitters atomic structure. [1]arXiv:1709.08683

Q 40.23 Tue 16:15 Zelt West

Single Praseodymium Ions in the Solid State: Towards a Long-Lived Quantum Memory — •André Pscherer[1,2], Emanuel Eichhammer[1], Tobias Utikal[1], Stephan Götzinger[2,1], and Vahid Sandoghdar[1,2] — [1]Max Planck Institute for the Science of Light, D-91058 Erlangen, Germany — [2]Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), D-91058 Erlangen

Rare earth ions embedded in solid state crystals are very attractive for quantum information processing due to their exceptionally long spin coherence time which can reach up to six hours [1]. Despite long fluorescence lifetimes, in the past years several groups have demonstrated the optical detection of single rare-earth ions at cryogenic temperatures by spatial or spectral selection [2]. However high resolution spectroscopy has revealed spectral diffusion as the main obstruction for quantum information processing at the single ion level. Here we report on our recent efforts to minimize spectral diffusion by reducing the crystal defect density and the temperature to superfluid helium.

[1] M. Zhong, *et al.* Nature 517 (2015): 177 – 180.

[2] T. Utikal, *et al.* Nature Communications 5 (2014): 3627.

Q 40.24 Tue 16:15 Zelt West

Localized Modes in leaky dielectric nanoresonators: a general optimization strategy for photon extraction — •Niko Nikolay[1], Günter Kewes[1], Felix Binkowski[2], Lin Zschiedrich[2], Sven Burger[2], and Oliver Benson[1] — [1]Institut für Physik, Humboldt-Universität zu Berlin — [2]Zuse Institute Berlin

When considering solid state emitters and their emitted photons to act as qubits and flying qubits in a quantum network, it is crucial to efficiently link both. A technical realization of this link is an antenna. Current design concepts often suffer from a large footprint, quenching or a complex fabrication process [1-3]. Here we show another very general design concept where the Kerker effect [4] is used to redirect and collimate emission from single emitters, exemplary discussed on a nitrogen vacancy (NV) center. The antenna is an easy to fabricate cylindrical protrusion (a nanodisk with small aspect ratio) made from a medium of moderate or high refractive index (e.g., diamond, ZnO, SiN or GaAs) etched into a substrate of the same material. Such a simple structure supports leaky localized modes that lead to directed emission by de- and constructive interference. To analyze the antenna we employ a versatile optimized quasi normal mode method that gives a clear view on the otherwise obscured underlying physics of this antenna type. Emitters may be incorporated inside the antenna or placed on top.

[1] P. Muehlschlegel, science 308.5728, 1607-1609 (2005)
[2] K. G. Lee, Nature Photonics 5.3, 166-169 (2011)
[3] M. Gschrey, Nature communications 6 (2015)
[4] M. Kerker, JOSA 73.6, 765-767 (1983)