Q 41: Poster: Quantum Optics and Photonics II

Time: Wednesday 16:15–18:15 Location: S Fobau Physik

Q 41.1 Wed 16:15 S Fobau Physik

Filter effects in quantum optimal control using Krotov's method — •Matthias Krauss, Sabrina Patsch, Daniel M. Reich, and Christiane P. Koch — Theoretische Physik, Universität Kassel, Heinrich-Plett-Straße 40, D-34132 Kassel, Germany

The experimental implementation of pulse shapes obtained via optimal control theory is often complicated due to a distortion of the computed pulses, caused by a transition function characterizing the pulse generation hardware. We propose an extension to Krotov's method, which incorporates these filter functions and thus accounts for the distortion of the pulse already during the optimization process. This makes it possible to circumvent the problems arising in classical deconvolution which occur for filter functions with zeros in their spectra. We apply this algorithm to the reset of a qubit connected to a reservoir [Basilewitsch et al., New J. Phys. 19, 113042 (2017)] and to the propagation of a circular Rydberg state [Patsch et al., Phys. Rev. A 97, 053418 (2018)]. The relevant filter functions in these cases can not easily be deconvoluted. We demonstrate successful optimization for this class of filter functions.

Q 41.2 Wed 16:15 S Fobau Physik

Estimating the Unpredictability in a Quantum Random Number Generator — •Johannes Seiler[1], Thomas Strohm[2], and Wolfgang P. Schleich[1] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ^{ST}), Universität Ulm — [2]Robert Bosch GmbH

For random number generators, unpredictability, i.e. the condition that the random numbers are neither predictable by any model, nor an attacker can obtain enough information in order to predict them, often plays an important role, e.g. when they are used in secure communication protocols. Due to the physical nature of the generation process and the inherent indeterminism of quantum theory, a quantum random number generator (QNRG) offers at least theoretically the possibility to create such unpredictable random numbers. Unfortunately, real life implementations of QRNGs usually suffer from imperfections that open the door for an attacker to get at least partial information about the generated numbers. We discuss the unpredictability of a realistic QRNG by exploiting an elementary two-qubit scheme, modeling the random number generator and its environment. We show that the unpredictability crucially depends on the entanglement of these qubits. Based on a fully quantum mechanical calculation we provide an upper bound for the information accessible to an attacker, when the user knows the density matrix of his subsystem, independent of any further restrictions. Moreover, for certain restrictions on the attacker's measurement, we propose a procedure on how to reduce this upper bound.

Q 41.3 Wed 16:15 S Fobau Physik

Genuine hidden nonlocality of three-qubit bound entangled quantum states — •Lucas Tendick, Hermann Kampermann, and Dagmar Bruss — Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, D-40225 Düsseldorf, Germany

We discuss the relation between entanglement and nonlocality in the hidden nonlocality scenario, with respect to three-qubit bound entangled states. Hidden nonlocality is the activation of nonlocality by the use of local filters for a given state that admits a local hidden-variable model in the simple Bell scenario. We present some fully-biseparable three-qubit bound entangled state with a local model for the most general (non-sequential) measurements. Hence, we are dealing with the most general form of hidden nonlocality, so-called genuine hidden nonlocality. However, the local model breaks down when suitable local filters were applied, witnessed by the violation of a simple tripartite Bell inequality. This shows that the state reveals its nonlocal properties, when a sequence of suitable measurements are applied. Hence, genuine hidden nonlocality does not imply entanglement distillability.

Q 41.4 Wed 16:15 S Fobau Physik

Using Langevin Dynamics in Artificial Neural Networks to Represent Quantum Spin Systems — •Felix Behrens, Stefanie Czischek, Martin Gärttner, and Thomas Gasenzer — Kirchhoff-Institut für Physik, INF 227, 69120 Heidelberg, Germany

The idea of connecting artificial neural networks and quantum mechanics gained a lot of interest over the last years. A representation of quantum spin-1/2 states using a specific kind of artificial neural network, the restricted Boltzmann machine, has been introduced by G. Carleo et al. (Science 355, 2017). With an unsupervised learning approach, ground states and dynamics in the system can be found. We implement this ansatz and point out its limitations in the vicinity of a quantum phase transition in the transverse-field Ising model. By varying the setup of the artificial neural network, we find a more flexible representation of quantum many-body systems which can be extended to deeper networks and provides measurements in different spin-bases. Using Langevin-like dynamics, we bring our artificial neural network into a spiking-neural-network-form, which can be implemented on a neuromorphic hardware such as the BrainScaleS system. From this hardware implementation we expect a speedup in the simulations, which offers the possibility of efficiently simulating quantum spin-1/2 systems.

Q 41.5 Wed 16:15 S Fobau Physik

Violation of Bell inequalities with discretized continuous variables — •Alexander Sauer, Zsolt Bernad, and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt

Bell tests are a crucial part of many key distribution protocols in quantum cryptography. As their implementation is highly demanding on the experimental setups, less demanding continuous variable protocols have been proposed. It has been shown that photodetection and homodyne measurements can be discretized to achieve violations of a Bell inequality [1]. We further investigate the maximally possible violations by this discretization for multipartite scenarios, also taking into account device imperfections.

[1] M. T. Quintino, M. Araujo, D. Cavalcanti, M. F. Santos and M. T. Cunha, J. Phys. A: Math. Theor. 45, 215308 (2012)

Q 41.6 Wed 16:15 S Fobau Physik

Towards a cryogenic surface-electrode ion trap apparatus for high-fidelity microwave quantum simulation — •Sebastian Grondkowski[1], Timko Dubielzig[1], Giorgio Zarantonello[2], Henning Hahn[2], Amado Bautista-Salvador[2], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universtiät Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

We report on the progress made in setting up a cryogenic surface-electrode ion trap with integrated microwave conductors for near-field quantum control of $^9Be^+$. These traps are promising systems for analog quantum simulators and for quantum logic applications. Our group developed a trap with an integrated meander-like microwave guide for driving motional sidebands on a $^9Be^+$ ion [1]. To suppress electrical field noise, acting on the ion and originating from thermal effects [2], the trap will be operated in a cryogenic vacuum chamber. We will discuss the vibration isolated closed cycle cryostat and the design of the vacuum chamber with all electrical supplies necessary to apply two different microwave currents, DC- and RF-voltages. We will also discuss magnetic-field coils producing a magnetic field at 22.3 mT and the resulting field-independent hyperfine qubit. Furthermore we will present the cryogenic, high aperture and fully acromatic imaging system.

[1] Applied Physics B - 10.1007/s00340-013-5689-6 (2013)
[2] J. Chiaverini and J. M. Sage, PRA 89, 012318 (2014)

Q 41.7 Wed 16:15 S Fobau Physik

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 to enter the commercial market. However, due to the deviation between theoretical models and practical devices, the security of such systems cannot be ensured. We consider the device-independent (DI) scenario where the security is not based on any assumptions about the intrinsic properties of the devices and the quantum signals. Rather it is based on the loophole-free violation of a Bell inequality. We introduce a Device-Independent Quantum Key Distribution (DIQKD) scenario in which a Bell inequality will be constructed from the performed measurement data. Given the observed data of a DIQKD protocol involving n parties, m measurement settings per party and k outcomes per measurement, our goal is to find an optimal general (n,m,k) Bell inequality to maximize the achievable DI secret key rate [1].

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

Q 41.8 Wed 16:15 S Fobau Physik

Trap chip for 2D arrays of atomic ions interacting via MAGIC — •Ivan Boldin, Alexander Kraft, Moritz Porst, Elham Esteki, Bogdan Okhrimenko, and Christof Wunderlich — University of Siegen, Siegen, Germany

We designed a novel chip for trapping atomic ions in a 2-dimensional array with electrodynamic fields. The electrode structures allow for varying the the ion-surface separation and the trap chip has resonant structures incorporated to enhance the microwave-frequency magnetic fields to be used for all coherent operations on the hyperfine manifold of Yb+ ions. The ions interact via magnetic gradient induced coupling (MAGIC) (1). For this experiment a custom aluminum vacuum chamber is used to reduce the effect of the chamber on ambient magnetic fields at the trapped ions* location. In addition, a mu-metal shield is integrated inside the chamber to protect hyperfine states from magnetic field noise. The experimental setup also includes an Ar+ ion gun for in situ cleaning of the ion trap surface in order to decrease electric field noise from the surface of the electrodes. We present the current status of this experiment.

References: 1) Ch. Piltz, Th. Sriarunothai, S. Ivanov, S. Wölk, Ch. Wunderlich, Science Advances 2 e1600093 (2016).

Q 41.9 Wed 16:15 S Fobau Physik

Schrödinger equation for quaternionic quantum mechanics — •Jonathan Steinberg and Matthias Kleinmann — Universität Siegen, Siegen, Deutschland

Standard quantum mechanics is formulated over complex Hilbert spaces with normalized vectors representing states and observables corresponding to hermitian operators. The time evolution is determined by the Schrödinger equation, where $-iH/\hbar$ takes the role of a generator for time shifts. Even in this well known setting the origin of the correspondence between the energy observable H and the generator $-iH/\hbar$ needs to be discussed. We provide arguments showing that this is the only sensible choice, with the only remaining freedom being the numeric value of $\hbar$. If one now replaces complex Hilbert spaces by quaternionic Hilbert modules, an analogous analysis becomes crucial to identify the correct Schrödinger equation for quaternionic quantum mechanics. By using a quaternionic version of Stone's theorem for strongly continuous one-parameter groups, we show that there cannot exist a global correspondence between the energy observable and the generator of time shifts for dimensions larger than two. However, for the evolution for two-dimensional quaternionic systems there exist a variety candidates for a Schrödinger equation and we discuss their relations and properties.

Q 41.10 Wed 16:15 S Fobau Physik

Resource theory of coherence based on positive-operator-valued measures — •Felix Bischof, Hermann Kampermann, and Dagmar Bruss — Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf

Quantum coherence is a fundamental feature of quantum mechanics and an underlying requirement for most quantum information tasks. In the resource theory of coherence, incoherent states are diagonal with respect to a fixed orthonormal basis, i.e., they can be seen as arising from a von Neumann measurement. Here, we introduce and study a generalization to a resource theory of coherence defined with respect to the most general quantum measurements, i.e., to arbitrary positive-operator-valued measures (POVMs). We establish POVM-based coherence measures and POVM-incoherent operations which coincide for the case of von Neumann measurements with their counterparts in standard coherence theory. We provide a semidefinite program that allows to characterize interconversion properties of resource states, and exemplify our framework by means of simple POVMs, for which we also show analytical results.

Q 41.11 Wed 16:15 S Fobau Physik

Threetangle in the one-dimensional XY-model in integrability breaking magnetic field — •Jörg Neveling and Andreas Osterloh — Universität Duisburg-Essen, Lotharstrasse 1, 47057 Duisburg

We focused on the one-dimensional XY-model in a magnetic field that is not only in transverse direction but has also an in-plane orthogonal component. Therefore the model is beyond integrability. We analyze the behavior of the concurrence and the threetangle with growing in-plane component of the field. We furthermore emphasize on a fundamental simplification in calculations of the convex-roof in certain regimes and extend the threetangle in the exactly solved case of rank-two mixtures of W and GHZ state beyond the two pyramids in the Bloch sphere pointing in the direction of the two states.

Q 41.12 Wed 16:15 S Fobau Physik

Technological Advances in Trapped Ion Quantum Processing Nodes — •Alexander Stahl, Björn Lekitsch, Janine Nicodemus, Daniël Pijn, Vidyut Kaushal, Oliver Gräb, Andreas Conta, Ulrich Poschinger, and Ferdinand Schmidt-Kaler — Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

We present technological advances towards a fault tolerant shuttling-based trapped-ion quantum processing node. Recently we have successfully demonstrated four-qubit GHZ states using sequential entangling gates [1] and a dc magnetometer with quantum enhanced performance [2]. One essential component to realise these experiments is a custom-made high-speed multi-channel waveform generator. Voltage waveforms required for such operations are computed using a versatile software framework, which is capable of automatically generating optimized waveforms for various ion transport operations. We also report advances made on the generation of the quantizing magnetic field and its stability, using alignable permanent magnets inside a mu-metal chamber, which is essential to reach high coherence times [3]. Finally, we will present results of ongoing work on a fault-tolerant error syndrome measurement scheme using six trapped-ions.

[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 41.13 Wed 16:15 S Fobau Physik

Microwave-driven quantum logic with trapped $^9Be^+$ ions in microfabricated ion traps — •Jonathan Morgner[1,2], Giorgio Zarantonello[1,2], Henning Hahn[1,2], Amado Bautista-Salvador[1,2], and Christian Ospelkaus[1,2] — [1]Leibniz Universität Hannover, Germany. — [2]Physikalisch-Technische Bundesanstalt, Braunschweig Germany.

Scalable quantum information processing relies on successful implementation of high-fidelity universal gate sequences. In this context, multi-qubit gates induced by microwave near-fields [1] provide a promising technique with potential for high fidelities [2].

Here we give a brief overview about our recent efforts to integrate microwave conductors in microfabricated traps to drive entangling gates on $^9Be^+$ hyperfine qubits. We further discuss benefits and future applications of a novel trap fabrication technique based on multiple metal layers. Additionally, we present a next generation vacuum setup utilizing Ar^+ bombardement to clean the trap surfaces and thus, reduce gate errors caused by motional mode heating [3].

[1] C. Ospelkaus et al., Nature, **476**, 181-184 (2011)
[2] T. P. Harty et al., Phys. Rev. Lett. **117**, 140501 (2016)
[3] D. A. Hite et al., Phys. Rev. Lett. **109**, 103001 (2012)

Q 41.14 Wed 16:15 S Fobau Physik

Opto-electronic switch for fast error-correction in blind quantum computation — •Marco Marcozzi[1,2], Michal Vyvlecka[1], Alessandro Trenti[1], and Philip Walther[1] — [1]Faculty of Physics, University of Vienna, Boltzmanngasse 5, 1090 Vienna, Austria — [2]School of Science and Technology, Physics Division, University of Camerino, I-62032 Camerino (MC), Italy

One-way quantum computing allows to implement arbitrary quantum computation using only sequential single-qubit measurements with classical feed forward of their outcomes in implementing quantum gates. To control the correctness of the algorithm fast error-correction heralded by classical feed forward is crucial. Furthermore, this scheme also enables the implementation of blind quantum computation (BQC), where a random measurement basis is used to encrypt hidden computation. In our experiment we implement classical feed forward to run a BQC protocol on a four-photon cluster state using a Pockels cell driven by a field programmable gate array (FPGA). Coincidence measurement on the first three qubits is used to activate a Pockels cell which controls the state of the fourth photon. The outcome is feed forwarded to the polarization-flipping stage. To synchronize this process the fourth photon has to be delayed. To allow for a fast computation and to minimize losses low switching times are required. We are able to achieve this fast error-correction because a Pockels cell is a very fast optical switch and FPGAs can parallelize processes, so that it takes only one clock cycle to achieve different tasks simultaneously.

Q 41.15 Wed 16:15 S Fobau Physik

Robust holographic generation of arbitrary light patterns for quantum walk experiments — •Weiqi Zhou-Hanf, Falk-Richard Winkelmann, Andrea Alberti, Wolfgang Alt, and Dieter Meschede — Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, 53115 Bonn

In the two-dimensional (2D) quantum-walk experiment in Bonn, we plan to study topologically protected transport of atoms along the edges separating different topological phases [1]. To realize sharp edges, we use structured intensity patterns, which are holographically projected onto the atoms trapped in a 2D state-dependent optical lattice. We have extended the popular Gerchberg-Saxton algorithm to overcome stagnation at suboptimal intensity patterns impaired by optical vortices and to suppress speckles. Computer-generated holograms corresponding to the desired intensity patterns can be calculated with high computational efficiency and the intensity patterns can be reconstructed with high fidelity. The computed holograms are tested experimentally using a phase-only spatial light modulator (10-bit LCoS in PAN configuration), which we have gamma-corrected and phase-calibrated beforehand (phase RMS ~ $\lambda/80$) using phase-shifting interferometry. [1] M.Sajid, J.K.Asbóth, D.Meschede, R.Werner, A.Alberti, Creating Floquet Chern insulators with magnetic quantum walks, 2018, arXiv:1808.08923v1

Q 41.16 Wed 16:15 S Fobau Physik

Advanced Positioning Control for Trapped Ions in Segmented Traps — •Oliver Torsten Gräb, Janine Hilger, Ferdinand Schmidt-Kaler, and Ulrich Poschinger — QUANTUM, Institut für Physik, Staudingerweg 7, 55129 Mainz

I will present recent work towards the automated and scalable generation of voltage ramps for the reconfiguration of trapped-ion registers in segmented ion traps. With large Coulomb crystals offering limited scalability for use in quantum computation experiments [1], segmented ion traps offer a solution to this problem by storage of small ion crystals and dynamical reconfiguration of the arrangement [2].

While previous work demonstrating different types of shuttling operations relied on custom voltage ramps [3], versatile operations on larger registers ultimately requires automated generation of such ramps. Our approach relies on quadratic programming yielding a set of predefined temporally varying potential wells based on the trap geometry and subject to relevant hardware constraints. The software framework created for this purpose is efficient and scalable, i.e. voltage ramp solutions are rapidly obtained and the computation time scales favorably with the trap and register sizes.

[1] Wineland, D. J., et al. J. Res. Natl. Inst. Stan. **103.3** (1998): 259.

[2] Palmero, M., et al. New. J. Phys. **17.9** (2015): 093031.

[3] Kaufmann, H., et al. New. J. Phys. **16.7** (2014): 073012.

Q 41.17 Wed 16:15 S Fobau Physik

Robust two-qubit gates using pulsed dynamical decoupling — •Patrick Barthel[1], Jorge Casanova[2], Patrick Huber[1], Theeraphot Sriarunothai[1], Gouri Giri[1], Martin Plenio[2], and Christof Wunderlich[1] — [1]Department Physik, Universität Siegen, 57068 Siegen, Germany — [2]Institut für Theoretische Physik, Albert-Einstein-Allee 11, Universität Ulm, D-89069 Ulm, Germany

To extend the coherence time of qubits, for example in trapped atomic ions, continuous or pulsed dynamical decoupling (DD) schemes have been successfully applied. Recently, a novel DD sequence was proposed to generate robust high-fidelity two-qubit phase gates with trapped ions, and, by using both motional modes of a two-ion crystal, allow for faster gate speeds than a single-mode bus qubit [1]. Here we report on the experimental implementation of this sequence, demonstrating the realization of a $\frac{\pi}{4}$-gate using microwave driving fields on a set of two $^{171}Yb^{+}$ ions in a linear Paul trap. The interaction between motional states and internal qubit states necessary for conditional quantum logic is provided by magnetic gradient induced coupling (MAGIC) [2]. While the current experimental setup does not allow yet to exploit a considerable speed-up, the robustness of the sequence to errors in Rabi and trap frequencies up to 2%, and to ion temperature is demonstrated, as well as its applicability for Controlled NOT operations and the creation of Bell states.

[1] I. Arrazola et al., Phys. Rev. A **97**, 052312 (2018)

[2] T. Sriarunothai et al., 2018, Quantum Sci. Technol., DOI: 10.1088/2058-9565/aaef5e

Q 41.18 Wed 16:15 S Fobau Physik

Automation of Trapped Ion Experiment Controls — •Marc Georg Bussjäger[1], Alexander Erhard[1], Michael Meth[1], Lukas Postler[1], Roman Stricker[1], Martin Ringbauer[1], Thomas Monz[1], Philipp Schindler[1], and Rainer Blatt[1,2] — [1]Universität Innsbruck, Institut für Experimentalphysik, Technikerstraße 25, Innsbruck — [2]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences

We present a new experiment control system which is currently being integrated in our ion trap quantum computer. The hardware performs the generation, shaping and real-time execution of pulsed radio frequency signals (RF), which are used to drive acousto-optic modulators (AOMs), to allow precise addressing of a single ion, as well as simultaneous addressing of multiple ions. With the growing complexity of the systems, it is important to automate as many subroutines as possible to push towards a hands-free 24/7 operation of the system. Furthermore, remote access to the system is an important aspect of the quantum computer and has been incorporated into the control.

Q 41.19 Wed 16:15 S Fobau Physik

Microfabricated 2D array of ion traps based on a multi-metal-layer structure — •Silke Auchter[1,2], Philip Holz[1], Gerald Stocker[1,2], Kirill Lakhmanskiy[1], Yves Colombe[1], Rainer Blatt[1,3], Clemens Rössler[2], and Elmar Aschauer[2] — [1]Institut für Experimentalphysik, Uni Innsbruck, Austria — [2]Infineon Technologies Austria AG, Villach, Austria — [3]Institut für Quantenoptik und Quanteninformation, Innsbruck, Austria

Two-dimensional configurations are essential for scalable quantum computation and simulation [1, 2]. We present the concept, fabrication and preliminary results of a 2D ion trap array consisting of parallel 1D ion trap arrays on a microchip. The fabrication is carried out in a state-of-the-art industrial facility ensuring a high process reproducibility. A three-metal-layer structure provides shielding of the substrate and addressing of the DC electrodes across the chip. The design of the 1D arrays allows ion shuttling as well as tuning of the ion-ion distance in the arrays. Additionally, the distance between 1D arrays can be reduced by lowering an RF voltage. These capabilities should enable Coulomb ion-ion coupling in and between the 1D arrays [3].

[1] D. Kielpinski et al., Nature 417, 709 (2002)

[2] I.M. Georgescu et al., Rev. Mod. Phys. 86, 153 (2014)

[3] Brown et al., Nature 471, 196 (2011)

Q 41.20 Wed 16:15 S Fobau Physik

Propagation of generalized Pauli errors in qudit Clifford circuits — •Daniel Miller, Timo Holz, Hermann Kampermann, and Dagmar Bruss — Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, D-40225 Düsseldorf, Germany

It is important for performance studies in quantum technologies to analyze quantum circuits in the presence of noise. We introduce an error probability tensor, a tool to track generalized Pauli error statistics of qudits within quantum circuits composed of qudit Clifford gates. Our framework is compatible with qudit stabilizer quantum error-correcting codes. We show how the error probability tensor can be applied in the most general case, and we demonstrate an error analysis of bipartite qudit repeaters with quantum error correction. We provide an exact analytical solution of the error statistics of the state distributed by such a repeater. For a fixed number of degrees of freedom, we observe that higher dimensional qudits can outperform qubits in terms of distributed entanglement.

We have published a paper with the same title: DOI: 10.1103/PhysRevA.98.052316

Q 41.21 Wed 16:15 S Fobau Physik

Development of a coherent spin photon interface for quantum repeaters using NV centers in diamond — •Maximilian Pallmann[1], Julia Benedikter[1,2], Evgenij Vasilenko[1], and David Hunger[1] — [1]Karlsruher Institut für Technologie — [2]Ludwig-Maximilians Universität München

NV color centers in diamond can be a promising source of indistinguishable photons entangled to either the electron or nuclear spin of a single NV center. The weak (~3%) branching ratio into the coherent zero-phonon line (ZPL) however strongly limits the efficiency of the spin-photon interface. To increase the efficiency as required for large distance quantum networks, the ZPL of the NV centers can be coupled to a optical microcavity and thereby strongly enhanced by the Purcell effect. We use a fiber-based microcavity, which combines a small mode volume (few λ^3) with a high quality factor ($\sim 10^6$) and tunability. The NV centers are located in a diamond membrane (few-μm thickness) which is bonded onto a plane mirror. Depending on the surface roughness of the diamond membrane we expect to reach a Finesse $> 10^4$, leading to an extraction efficiency of ZPL photons of up to 80%.

Q 41.22 Wed 16:15 S Fobau Physik

Solid State Quantum Memory for Single Photons — •Peter-Maximilian Ney, Luigi Giannelli, Tom Schmit, and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany

We numerically analyse the dynamics of a single photon propagating in free space and incident on the mirror of an optical cavity, in which a solid state medium is confined. The relevant electronic states of each atom of the medium form a three-level Λ-system: one transition is coupled to the quantized field of the cavity via Jaynes-Cummings interaction, while the other transition is driven by a classical control field $\Omega(t)$ [1] with the intent of storing the single photon in a collective excitation of the atoms. Our purpose is to study the effect of inhomogenous broadening of the atomic levels. Furthermore we compare the efficiencies when two different types of optical cavities are used: a linear cavity (described by a single mode) and a ring cavity (described by two counter-propagating modes). We consider dissipative processes and inhomogenous broadening of the excited and metastable states of the atom, such as in [2].

[1] M. Fleischhauer, et al., Opt. Commun. 179, 395 (2000).
[2] Susanne Blum, et al., Phys. Rev. A 91, 033834 (2015).

Q 41.23 Wed 16:15 S Fobau Physik

Ein Silizium Farbzentrum gekoppelt an einen Faserresonator als Quantenrepeater-Knoten — •Yanik Herrmann, Marcel Salz und Ferdinand Schmidt-Kaler — WA QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz

Wir berichten über den Fortschritt bei der Realisierung eines Quantenrepeater-Knoten im Verbundprojekt [1]. Negativ geladene Silizium Farbzentren (SiV^-) wurden in einer Diamantmembran [2] implantiert [3] und diese in einen faser-optischen Mikroresonator [4] eingebracht, um eine effiziente Photonen-Schnittstelle zu erreichen. Das SiV verfügt über eine schmale Emissionslinie bei 737 nm, und bei Temperaturen $<$ 100 mK für einen Quantenrepeater-Knoten ausreichend lange Spinkohärenzzeiten [5], was die Integration des Aufbaus in einen Mischkryostaten erfordert.

[1] Q.Link.X, QR-D, *https://qlinkx.de*
[2] A. Piracha et al. *Nano Lett.* **16**, 5 (2016), Kollaboration mit M. Jakob, A. Nadarajah, S. Prawer, Univ. Melbourne
[3] E. Janitz et al. *Phys. Rev. A.* **92**, 043844 (2015), Kollaboration mit J. Meijer, Univ. Leipzig
[4] J. Benedikter et al. *Phys. Rev. App.* **7**, 024031 (2017) Kollaboration mit D. Hunger, KIT
[5] D. D. Sukachev et al. *Phys. Rev. Lett.* **119**, 223602 (2017)

Q 41.24 Wed 16:15 S Fobau Physik

Quantum Key Distribution with Small Satellites — •Peter Freiwang[3], Wenjamin Rosenfeld[3], Harald Weinfurter[3,5], and Qube Consortium[1,2,3,4,6] — [1]Center for Telematics (ZfT), Würzburg, Germany — [2]German Aerospace Center (DLR) IKN, Oberpfaffenhofen, Germany — [3]Ludwig-Maximilian-University (LMU), Munich, Germany — [4]Max Planck Institute for the Science of Light (MPL), Erlangen, Germany — [5]Max Planck Institute of Quantum Optics (MPQ), Garching, Germany — [6]OHB System AG, Oberpfaffenhofen, Germany

QKD to satellites can enable global secure communication. After the first successful demonstration by the Chinese satellite MICIUS, the question arises how small a satellite can be designed. We show our concept for a BB84 QKD payload for the nano-satellite mission QUBE. Faint laser pulses from four VCSELs at 850 nm are polarized using an array of polarizer foils and focused into a waveguide chip, which couples the four input modes into a single mode fiber. The optical QKD-unit will be hermetically sealed and mounted onto a 9x9 cm^2 PCB. Together with a second quantum payload to evaluate CV-QKD and quantum random number generation, this mission will study the feasibility of cost effective QKD with nano-satellites in low-earth-orbits (~ 500 km altitude). In the first phase, the satellite with a planned size of only 30x10x10 cm^3 will use an optical terminal (OSIRIS - Optical Space Infrared Downlink System) with an aperture of 20 mm for downlink to the optical ground station with a planned telescope size of 80 cm to achieve high coupling efficiency.

Q 41.25 Wed 16:15 S Fobau Physik

Towards long-time entanglement between a single optically trapped atom and a single photon — •Wei Zhang[1], Robert Garthoff[1], Tim van Leent[1], Kai Redeker[1], Paul Koschmieder[1], Wenjamin Rosenfeld[1,2], and Harald Weinfurter[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, Munich, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany

The most fundamental task for a quantum network is to generate atom-photon entanglement with long coherence time.

At present, for atom-photon states of a single optically trapped Rb-87 atom and its emitted photons, there are two decoherence mechanisms. One is motional decoherence in the dipole trap and the other is magnetic decoherence caused by the fluctuation of external magnetic fields. The proposed method is to use a standing-wave dipole trap to confine the atom in space thus reducing motional decoherence. At the same time, this optics can be used to apply stimulated Raman adiabatic passage to coherently transfer the entangled atomic state to the new atomic states which is 500 hundred times less-sensitive to magnetic-field fluctuations.

The coherence time for an atom-photon entangled state is expected to be increased by 2 orders of magnitude, from the (current) 100 microseconds to 10 milliseconds, which would be sufficient for communications over more than 100 km.

Q 41.26 Wed 16:15 S Fobau Physik

All-fiber source for time-bin entangled photon pairs at 1550 nm — Maximilian Tippmann, Oleg Nikiforov, Erik Fitzke, and •Thomas Walther — TU Darmstadt, Institute for Applied Physics, 64289 Darmstadt

We are working on a system for quantum key distribution in commercial telecommunication networks. One of our goals is to develop a robust fiber-based photon pair source for entanglement-based protocols. We present our recent progress of the construction of an all-fiber, frequency-doubled EDFA system for the creation of photon pairs at 1550 nm. The system consists of a stabilized laser seeding a fourier-limited pulsed first amplifier, a second amplifier stage and a frequency conversion module. This system was developed to enhance the capabilities of our QKD system to meet the challenges of the planned field test in a metropolitan network.

Q 41.27 Wed 16:15 S Fobau Physik

An FPGA based time-acquisition system for QKD — •Kai Roth, Stefan Schürl, Erik Fitzke, Oleg Nikiforov, and Thomas Walther — AG Laser und Quantenoptik, Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt, Germany

Quantum Key Distribution offers information-theoretical security for communication, superior to the majority of contemporary classical key distribution schemes. We are working on a robust system for quantum key distribution in a real-world commercial telecommunication network.

In order to evaluate detection times of photon pair incidents and to extract the key, we develop a low-cost FPGA-based two channel system for timing difference acquisition of TTL signals with a resolution below 500 ps. This resolution is achieved using programmable delay-lines in an FPGA. Afterwards, the detected events are processed by a Raspberry Pi computing the secure key.

Q 41.28 Wed 16:15 S Fobau Physik

Towards a Suburban Quantum Network Link — •Tim van Leent[1], Robert Garthoff[1], Kai Redeker[1], Paul Koschmieder[1], Wei Zhang[1], Wenjamin Rosenfeld[1,2], and Harald Weinfurter[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, Munich, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany

Quantum repeaters will allow scalable quantum networks, which is essential for large scale quantum communication and distributed quantum computing. Yet, one of the experimental challenges is still to achieve entanglement between quantum memories over long distances.

Here we describe an experimental setup which employs the entanglement swapping protocol to generate entanglement between two Rubidium 87 atoms, currently separated by a distance of 400 meters [1]. We report on results increasing this distance by at least an order of magnitude with the goal, for example, to establish a quantum network link between down-town Munich and Garching (14 km).

Essential steps in this process are first implementing a quantum frequency converter using a nonlinear waveguide crystal in a Sagnac-type interferometer configuration [2,3]. Second, improving the collection efficiency of the emitted photons with a custom made microscope (NA 0.5), which will increase the atom-atom entanglement rate by at least an order of magnitude.

[1] W. Rosenfeld et al., Phys. Rev. Lett. **119**, 010402 (2017)
[2] M. Bock et al., Nat. Comm. **9**, 1998 (2018)
[3] R. Ikuta et al., Nat. Comm. **9**, 1997 (2018)

Q 41.29 Wed 16:15 S Fobau Physik

Polarization-Preserving Quantum Frequency Conversion of $^{40}Ca^+$-Resonant Photons to the Telecom C-Band — •Tobias Bauer, Matthias Bock, Stephan Kucera, Benjamin Kambs, Jürgen Eschner, and Christoph Becher — Universität des Saarlandes, FR Physik, Campus E2.6, 66123 Saarbrücken

In quantum communication networks, the information is stored in quantum nodes, which can be realized e.g. in trapped ions like $^{40}Ca^+$. By transferring the states onto photons, it is possible to exchange information between these nodes over long distances via optical fiber links. In order to minimize attenuation in fibers, which is particularly high for typical transition frequencies of trapped ions, quantum frequency down-conversion to low-loss telecom bands is utilized.

We present a scheme for polarization-preserving quantum frequency conversion of $^{40}Ca^+$-resonant photons to the telecom C-band. It relies on the difference frequency generation process $854\,nm - 1904\,nm = 1550\,nm$ [1] in a PPLN waveguide, which is arranged in a Sagnac configuration to achieve polarization preservation. We will show the characterization of several key components as well as first results on conversion efficiency and noise count rates.

[1] Krutyanskiy, V. et al., Appl. Phys. B (2017) 123: 228.

Q 41.30 Wed 16:15 S Fobau Physik

Creation of optical coherent state superpositions with full parameter control — Hacker Bastian[1], Welte Stephan[1], Daiss Severin[1], •Hartung Lukas[1], Shaukat Armin[1], Stephan Ritter[1,2], Lin Li[1,3], and Gerhard Rempe[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]Present address: TOPTICA Photonics AG, Lochhamer Schlag 19, 82166 Gräfelfing, Germany — [3]Present address: Huazhong University of Science and Technology, Wuhan 430074, China

Coherent state superpositions (CSS) promise to be useful tools for communication in quantum networks. They offer the possibility to encode qubits in flying continuous-variable states and to implement error correction codes as already demonstrated for superconducting circuits [1]. Here, we demonstrate the creation of CSS in the optical regime using a strongly coupled atom–cavity system. We have full control over all degrees of freedom, such as the optical phase or the population fractions of the contributing states. As a first application we implement a universal quantum-logic gate between such continuous-variables states and the spin of a single atom trapped in an optical cavity, showing the usefulness of CSS in the context of interfacing flying and stationary qubits.

[1] N. Ofek, *Nature* **536**, 441-445 (2016)
[2] B. Wang and L.-M. Duan, *Phys. Rev. A* **72**, 022320 (2005)

Q 41.31 Wed 16:15 S Fobau Physik

Controlled photon generation and absorption in ion-cavity systems for quantum networks — •Maria Galli[1], Dario A. Fioretto[1], Konstantin Friebe[1], Yunfei Pu[1], Markus Teller[1], Klemens Schüppert[1], Viktor Messerer[1], Yueyang Zou[1], Rainer Blatt[1,2], and Tracy E. Northup[1] — [1]Universität Innsbruck, Institut für Experimentalphysik, Technikerstrasse 25, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaften, 6020 Innsbruck, Austria

The problem of scalability is an outstanding challenge in the field of quantum computing. One solution is to interconnect multiple computers and consider each computer as a node of a quantum network. Our implementation of such a quantum network node is an ion trap interfaced with a cavity. Here, the cavity has the role of efficiently collecting photons produced by ions in the network. Quantum information is encoded in those photons and thus transferred between the nodes. Our work focuses specifically on sending and receiving photons at the nodes. Those photons are generated via a lambda-type scheme known as a cavity-mediated Raman transition, in which a laser drive is applied to one branch of the lambda transition, and the cavity enhances the efficiency of photon emission and collection on the other branch. First, we show how manipulating the temporal intensity profile of the laser drive allows us to control the temporal wavepacket of the photon leaving the node; secondly, we present preliminary simulation results regarding the photon absorption process at the receiving node.

Q 41.32 Wed 16:15 S Fobau Physik

Spectral characterization of a entangled photon pair source for QKD — •Daniel Hofmann, Erik Fitzke, Oleg Nikiforov, and Thomas Walther — AG Laser und Quantenoptik, Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt, Germany

We are developing a quantum key distribution system with energy-time entangled photon pairs. Our system enables quantum-secure communication in real-world standard telecommunication networks. In order to achieve stable operation under realistic environmental conditions, the influence of the transmission through several kilometers of real telecommunication-fiber on the photons needs to be investigated and the quantum bits need to be characterized.

Thus, we developed tools to be applied outside of a controlled laboratory environment. We present a method for the spectral characterization of the photons based on chromatic dispersion in a fiber in combination with measurement of the arrival time of photons. We compare the results to measurements conducted by other techniques such as using a spectrograph or a Hong-Ou-Mandel interferometer.

Q 41.33 Wed 16:15 S Fobau Physik

A theoretical analysis of QR-PUFs — •Giulio Gianfelici, Hermann Kampermann, and Dagmar Bruss — Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, D-40225 Düsseldorf, Germany

Physical Unclonable Functions [1] (PUFs) are physical systems with a challenge-response behaviour intended to be hard to clone or simulate. This emerging technology has been proposed in several cryptographic protocols, with particular emphasis on authentication protocols [1]. Later on, extensions of such systems to quantum protocols, the so-called Quantum Readout of PUFS (QR-PUF) [2], were suggested. A major issue of the research on PUFs is the lack of a well-defined agreement about theoretical assumptions and main properties behind the intuitive ideas of QR-PUFs, which limits our ability to characterise the security of cryptographic protocols. We develop a theoretical framework in which we define and quantify the security properties of QR-PUFs. As a first implementation of this framework, we design a program to simulate the behaviour of QR-PUFs in order to study their properties and to test their efficiency under the requirements of secure cryptographic protocols. The program will be also a basis for a comparison between the performances of different QR-PUFs, and between QR-PUFs and classical PUFs.

[1] R. Pappu, B. Recht, J. Taylor, N. Gershenfeld, *Physical one-way functions*, Science 297, 2026 (2002)
[2] B. Škorić, *Quantum Readout of Physical Unclonable Functions*, Progress in Cryptology-AFRICACRYPT 2010, 369-386 (2010)

Q 41.34 Wed 16:15 S Fobau Physik

A new apparatus for experiments with single atoms in crossed fiber cavities — •Manuel Brekenfeld, Dominik Niemietz, Joseph Christesen, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Garching

Single atoms coupled to a quantized mode of the electromagnetic field confined in an optical resonator have proven to be a very clean and fruitful experimental platform for the study of fundamental quantum mechanical effects and have in recent years been tremendously successful with applications in the context of quantum information processing.

Current experimental advancement in the field comprises two directions of development: A further reduction of the mode volumes of the resonators, as with the development of fiber-based Fabry-Perot cavities (FFPCs) [1], and an increase in the number of well-controlled modes the atoms can couple to, either spatial [2] or frequency modes [3].

We have set up a new experiment which combines these two advancements in a single platform with single neutral atoms trapped at the center of two crossed FFPCs. We will present details on the apparatus, on trapping, cooling and manipulating atoms coupled to the cavities, as well as first results of a quantum storage experiment in this new experimental configuration.

[1] Hunger et al., New J. Phys. **12**, 065038 (2010)
[2] Leonard et al., Nature **543**, 87-90 (2017)
[3] Hamsen et al., Nat. Phys. **14**, 885-889 (2018)

Q 41.35 Wed 16:15 S Fobau Physik

Integrating a fiber cavity along the axis of a linear ion trap — •Viktor Messerer[1], Markus Teller[1], Klemens Schüppert[1], Dario A. Fioretto[1], Konstantin Friebe[1], Maria Galli[1], Yunfei Pu[1], Yueyang Zou[1], Jakob Reichel[2], Reiner Blatt[1,3], and Tracy E. Northup[1] — [1]Institute of Experimental Physics, University Innsbruck, Austria — [2]Laboratoire Kastler Brossel ENS / UPMC-Paris 6 / CNRS, Paris, France — [3]Institute of Quantum Optics and Quantum Information, Innsbruck

Interfaces between stationary and traveling qubits are fundamental building blocks for quantum networks. Cavities are an established approach for an efficient interface; here, we use a fiber cavity to couple trapped ions to photons. Fiber cavities allow access to the strong coupling regime, due to their small effective mode volume, allowing quantum communication to be carried out over long distances with high fidelity and efficiency. Our design requirements for this fiber-based ion-cavity interface include the ability to trap ion crystals, to compensate for surface charges on the dielectric cavity mirrors, and to align the fiber cavity with respect to the ion. To address these challenges, we have designed and constructed an ion-cavity system in which the mirrors of a fiber cavity are integrated in the electrodes of a linear Paul trap. We have simulated the trap potential for various configurations of surface charges, trap voltages and electrode positions in order to confirm that our requirements are met. We are currently testing and characterizing the trap in the absence of the fiber cavity. Furthermore, we will report on parallel work on the assembly of the fiber cavity.

Q 41.36 Wed 16:15 S Fobau Physik

Cavity-enhanced spectroscopy of a few-ion ensemble in Eu^{3+}:Y_2O_3 — Bernardo Casabone[1,2], Julia Benedikter[2,3,4], Thomas Hümmer[2,3], Franziska Oehl[3], Karmel de Oliveira Lima[5], Theodor W. Hänsch[2,3], Alban Ferrier[5,6], Philippe Goldner[5,6], Hughes de Riedmatten[1,7], •Timon Eichhorn[4], Kelvin Chung[4], and David Hunger[4] — [1]ICFO-Institut de Ciencies Fotoniques — [2]Max-Planck-Institut für Quantenoptik — [3]Fakultät für Physik, Ludwig-Maximilians-Universität — [4]Karlsruher Institut für Technologie — [5]Université PSL, Chimie ParisTech, CNRS — [6]Sorbonne Université — [7]ICREA-Institució Catalana de Recerca i Estudis Avançats

We present cavity-enhanced spectroscopy measurements of a few ions in europium-doped yttria (Eu^{3+}:Y_2O_3) nanoparticles (NPs) as recently published in *New J. Phys.* **20** (2018) 095006. In particular, we focus on the coherent transition $^5D_0$ - $^7F_0$ of Eu^{3+} that has been shown to have narrow optical linewidth in the order of kHz. This transition was coupled to a high-finesse fiber-based Fabry-Pérot microcavity to allow for the determination of number of ions, and observation of increased fluorescence count rate, which is agreeable with Purcell enhancement. The inhomogenous linewidth of the $^5D_0$ - $^7F_0$ transition was found to be 22 GHz, which is close to bulk value, indicative of high crystal quality of the NPs. The results represent an important step towards the efficient readout of single rare earth ions with excellent optical and spin coherence properties, which is promising for applications in quantum communication and distributed quantum computation.

Q 41.37 Wed 16:15 S Fobau Physik

Dynamical decoupling of Erbium spins in Yttrium Orthosilicate — •Pablo Cova Fariña, Bejamin Merkel, Natalia Herrera Valencia, Kutlu Kutluer, and Andreas Reiserer — Max Planck Institute of Quantum Optics, Garching, Germany

Rare-earth doped crystals can offer coherent optical transitions and long spin coherence times and are therefore an interesting candidate for quantum repeater protocols. Among the rare-earths, Erbium stands out as it exhibits optical transitions at a telecom wavelength, offering unique potential for constructing global quantum networks using optical fibers. Unfortunately, the strong effective g-factor of Erbium spins makes them sensitive to interactions with the environment and with one another, which leads to a reduction of the electronic spin coherence time down to a few microseconds. This challenge can be overcome by applying tailored sequences of microwave pulses to achieve dynamical decoupling. Building on such techniques, we will present simulations and the current status of an experiment that aims at achieving long coherence times of the electronic spins in Er:YSO.

Q 41.38 Wed 16:15 S Fobau Physik

Time - Optimal Control of Qubit Purification — •Jonas Fischer[1,2], Dominique Sugny[1,3], and Christiane Koch[2,3] — [1]Laboratoire Interdisciplinaire Carnot de Bourgogne, University of Bourgogne-Franche-Comte, Dijon, France — [2]Laboratoire Interdisciplinaire Carnot de Bourgogne, UniversInstitute of Physics, University of Kassel, Kassel, Germany — [3]Institute for Advanced Study, Technical University of Munich, Garching, Germany

The purification of a qubit is a common task in quantum control and necessary for quantum technology. We follow the idea of arithmetic cooling and couple the qubit to a structured environment made of a two-level quantum system (TLS) and a Markovian bath. It is possible to deduce analytic formulas and a simple geometric description for the minimal time needed to reach the state of maximum purity. We can further show that the purity can be further increased while the necessary time decreases by adding initial correlations between the qubit and the TLS. The results also show the transition between the Markovian and Non-Markovian dynamics and how Non-Markovianity is beneficial for this task.

Q 41.39 Wed 16:15 S Fobau Physik

Spectroscopy of the tin-vacancy centre in diamond — •Dennis Herrmann[1], Johannes Görlitz[1], Morgane Gandil[1], Philipp Fuchs[1], Takayuki Iwasaki[2], Takashi Taniguchi[3], Mutsuko Hatano[2], and Christoph Becher[1] — [1]Fachrichtung 7.2, (Experimentalphysik), Universität des Saarlandes, Campus E2.6, 66123 Saarbrücken — [2]Department of Electrical and Electronic Engineering, Tokyo Institute of Technology, Meguro, Tokyo 152-8552, Japan — [3]Advanced Materials Laboratory, National Institute for Material Science, 1-1 Namiki, Tsukuba, 305-0044, Japan

Colour centres in diamond are promising candidates for quantum information processing applications. The nitrogen-vacancy centre exhibits milliseconds coherence times for the electron spin at room temperature while the silicon-vacancy (SiV) centre excels with negligible spectral diffusion and emission of the majority of photons into its zero phonon line. A potential candidate combining long coherence times with outstanding optical properties is the tin-vacancy (SnV) centre. The fine structure ground state splitting is about a factor 20 larger than for the SiV thereby potentially suppressing phonon mediated decoherence processes already at liquid helium temperatures. We here present spectroscopy on SnV centres determining the lifetime and polarization as well as the temperature dependence of linewidth and line shifts. Furthermore, a precise determination of Debye-Waller factor and single photon emission properties are presented, enabling further investigations of spin coherence times assessing the suitability of the SnV centre as spin qubit.

Q 41.40 Wed 16:15 S Fobau Physik

Probing the modal structure of squeezed pulses via homodyne detection — •Thomas Dirmeier[1,2], Johannes Tiedau[3], Vahid Ansari[3], Christine Silberhorn[3], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institut für die Physik des Lichts, Staudstr. 2, 91058 Erlangen — [2]Institut für Optik, Information und Photonik, FAU Erlangen-Nürnberg, Staudstr. 7, 91058 Erlangen — [3]Integrierte Quantenoptik, Angewandte Physik, Universität Paderborn, Warburgerstr. 100, 33098 Paderborn

Squeezed states are valuable resource states for quantum technologies stretching from metrology to information processing applications. In parametric down-conversion, they are often generated as states multimode in the time-frequency domain which makes separating and detecting them by ordinary optical techniques a challenge.

Optical homodyne detection, the method typically used to detect changes in the quadrature variances, is by its nature a mode-selective measurement procedure that only selects those parts of the modal spectrum that overlap with the signal field while being blind to all other modes. In our experiment, we use this feature to probe the time-frequency Schmidt mode distributions of squeezed fs pulses generated in a PPKTP waveguide down-conversion source at telecommunication frequencies. We use the unique tuning features of this source to generate pulses with varying Schmidt mode distributions and compare our homodyne results with the distributions retrieved from $g^{(2)}$-measurements.

Q 41.41 Wed 16:15 S Fobau Physik

Harnessing path and polarization encoding in integrated photonic chips — •Leonardo Ruscio[1,2], Eric Meyer[3], Jan Dziewior[1,2], Lukas Knips[1,2], Jasmin Meinecke[1,2], Alexander Szameit[3], and Harald Weinfurter[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Department für Physik, Ludwig-Maximilians-Universität, 80797 München, Germany — [3]Institut für Physik, Universität Rostock, Albert-Einstein-Straße 23, 18059 Rostock, Germany

Thanks to the low decoherence properties and the short times needed to transmit through optical circuits and channels, photons represent a promising physical system to be used in future quantum technologies. In this context, integrated photonic chips are important for miniaturizing and scaling up photonic quantum circuits. They already allowed observation of fundamental quantum interference phenomena such as quantum random walks and boson sampling. Modern quantum technologies require systems with a growing number of dimensions and complexity. Thus, the combined use of different degrees of freedom in integrated circuits will take full advantage of the photonic platform.

In this work, we experimentally harness polarization as well as path degrees of freedom of single photons. Laser written waveguides in fused silica are well suited for handling these simultaneously. We explore the use of entanglement and multi-photon quantum interference in an integrated quantum photonic chip, the feasibility of experimentally simulating dynamics in open quantum systems, and the effect of entanglement in boson sampling.

Q 41.42 Wed 16:15 S Fobau Physik

coupled spatiotemporal coherence for parametric down-conversion under negative group velocity dispersion. — •Paula Cutipa[1,2] and Maria V. Chekhova[1,2,3] — [1]Max Planck Institute for the Science of Light, Staudtstr. 2, 9108 Erlangen, Germany. — [2]University of Erlangen-Nuremberg, Staudtstr.7/B2, 91058 Erlangen, Germany — [3]Department of Physics, M. V. Lomonosov Moscow State University, Leninskie Gory, 119991 Moscow, Russia

Parametric down-conversion (PDC) is one of the sources to generate entangled photon pairs and twin beams, which have many applications in quantum metrology and quantum information. It is well known that type-I PDC usually has a specific X-shape wavelength-angle spectra. Meanwhile, it has been shown that in the negative group velocity dispersion range PDC has a ring-shaped wavelength-angle spectrum, which is restricted in both variables [1]. This means that the first-order correlation function of PDC has coupled spatiotemporal dependence (is not just a function on time or space, or a product of two functions). In this work, we measure the first-order correlation function of this unusual PDC showing that a temporal delay can be compensated by a spatial displacement.

[1] K. Yu. Spasibko, D. A. Kopylov, T. V. Murzina, G. Leuchs, and M. V. Chekhova, Ring-shaped spectra of parametric downconversion and entangled photons that never meet. Optics Letters 41, 2627 (2016)

Q 41.43 Wed 16:15 S Fobau Physik

Investigation of color centers formed by IV Group impurity-vacancy conjunctions — •Michael Kern[1], Katharina Senkalla[1], Mathias Metsch[1], Petr Siyushev[1], Igor Kupriyanov[2,3], Takayuki Iwasaki[4], and Fedor Jelezko[1,5] — [1]Institute for Quantum Optics Ulm University, Ulm, Germany — [2]Magirushof — [3]49 — [4]Department of Electrical and Electronic Engineering Tokyo Institute of Technology, Tokyo, Japan — [5]Center for Integrated Quantum Science and Technology (IQst), Ulm University, Germany

Recently, color centers formed by IV Group impurity-vacancy conjunctions gain increasing interest in the community.

Due to their inversion symmetry (D_{3d}) they show good optical properties, and possess a high Debye-Waller factor.

In combination with the inherent 1/2 spin these color centers provide good candidates for light matter applications.

For the SiV^- the main drawback is its limited coherence time due to phonoic coupling of its two branches of the ground state even at liquid helium temperatures.

Other color centers from the same family, as GeV^- and SnV^-, can povide better coherence properties of the electron spin at these temperatures due to significantly larger spin-orbit coupling of the ground state. We investigate these using techniques established for SiV^-.