Q 23: Poster 2: Intersectional Session

Time: Tuesday 18:00–21:00 Location: P1

Q 23.1 Tue 18:00 P1

Entanglement dynamics of multi-qubit states in single- and many-sided noisy channels — •Michael Siomau[1,2] and Stephan Fritzsche[3,4] — [1]Max-Planck-Institut fuer Kernphysik, Postfach 103980, D-69029 Heidelberg, Germany — [2]Physikalisches Institut, Heidelberg Universitaet, D-69120 Heidelberg, Germany — [3]Department of Physical Sciences, P.O.Box 3000, Fin-90014 University of Oulu, Finland — [4]GSI Helmholtzzentrum fuer Schwerionenforschung, D-64291 Darmstadt, Germany

We study the entanglement dynamics of a multi-qubit system which is initially prepared in a GHZ or a W state and undergoes the action of some noisy channel. We discuss both cases of single- and many-sided noisy channels, i.e. when just one or several qubits simultaneously being subject to local noise. As noise models for the influence of the environment we use the Pauli channels σ_x, σ_y and σ_z. The entanglement of the (mixed) states is quantified with a lower bound for multi-qubit concurrence as suggested recently by Li et al. [J. Phys. A **42**, 012312 (2009)]. We show that for a single-side channel, the loss of the entanglement of the multi-qubit system is independent on the initial state and the type of acting noise. For many-sided channels, however, there is a difference in the “speed of disentanglement” between the GHZ and the W states which, moreover, depends on the type of coupling noise.

Q 23.2 Tue 18:00 P1

Entanglement Dynamics in Harmonic Oscillator Chains — •Razmik Unanyan and Michael Fleischhauer — Fachbereich Physik und Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, D-67663 Kaiserslautern, Germany

We study the long-time evolution of the bipartite entanglement in translationally invariant gapped harmonic lattice systems with finite-range interactions. A lower bound for the von Neumann entropy is derived in terms of the purity of the reduced density matrix. It is shown that starting from an initially Gaussian state the entanglement entropy increases at least linearly in time. This implies that the dynamics of gapped (non-critical) harmonic lattice systems cannot be efficiently simulated by algorithms based on matrix-product decompositions of the quantum state.

Q 23.3 Tue 18:00 P1

Entanglement and Thouless time from coincidence measurements across disordered media — •Nicolas Cherroret and Andreas Buchleitner — Institute of Physics, Albert-Ludwigs University of Freiburg, Hermann-Herder-Str. 3, D-79104 Freiburg, Germany

When light propagates in a disordered medium, it generally experiences a diffusion process. In some cases however, when the disorder strength is increased, interference between multiple scattering paths may build up, which lead to non-vanishing intensity correlations between different points of the scattering sample. If this picture is today well understood in situations where the light is in a classical state, less is known about multiple scattering of non-classical light. We will investigate the propagation of a photon-pair, a strongly nonclassical state of light, in a disordered medium. We will show that interference contributions to the coincidence counting rate of the two transmitted photons contain information about the spectral entanglement of the pair, and about the dynamical properties of the medium. A possible experimental technique for accessing this information will be proposed.

Q 23.4 Tue 18:00 P1

Scalable quantum computation via local control of only two qubits — •Daniel Burgarth[1], Koji Maruyama[2], Michael Murphy[3], Simone Montangero[3], Tommaso Calarco[3], Franco Nori[2], and Martin Plenio[4] — [1]IMS and QOLS, Imperial College, London, United Kingdom — [2]Advanced Science Institute, The Institute of Physical and Chemical Research (RIKEN), Wako-shi, Japan — [3]Institut für Quanteninformationsverarbeitung, Universität Ulm — [4]Institut für Theoretische Physik, Universität Ulm

Recent experiments on solid state qubits have focused on the implementation of high-fidelity operations on two qubits. It may seem that scaling these experiments to say 30 qubits requires a further big step in controlling the qubits. We show that this is not the case: the control implemented today is enough to indirectly control the remaining qubits, which can therefore remain passive. The control we have on the two qubits is mediated by the system Hamiltonian in a scalable way. This is shown by quantum control. In order to compute the required control pulses in a scalable fashion, we had to find a trick to separate the complexity of the dynamics (required for universal quantum computation) from its simulability (required for quantum control).

Q 23.5 Tue 18:00 P1

Estimating mixed qudits: hedging and adaption — •Christof Happ, Florian Nägele, and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm

Reconstruction of a completely unknown quantum state from limited resources, i. e. when only a small number of identically prepared states are available, is an important challenge in the field of quantum information. We present Monte-Carlo simulations of estimation processes for mixed qubits and qu*d*its (d-level states), that compare different estimation methods, namely standard maximum likelihood estimation and a modification of it, the so called hedged maximum likelihood estimation. The latter promises better estimation quality for mixed states. Additionally, we discuss adaptive methods to further improve estimation quality for this estimation schemes.

Q 23.6 Tue 18:00 P1

Cyclic Mutually Unbiased Bases and the Fibonacci Sequence — •Ulrich Seyfarth[1], Kedar Ranade[2], and Gernot Alber[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, 64289 Darmstadt, Germany — [2]Institut für Quantenphysik, Universität Ulm, Albert-Einstein-Allee 11, 89069 Ulm, Germany

The construction of mutually unbiased bases (MUBs) is of high interest in quantum information science. MUBs are called cyclic if they can be constructed by repeated applications of a single unitary operator. To get a deeper notion of how to contruct complete sets of cyclic MUBs in arbitrary dimensions it is important to explore their mathematical structure. Based on recent work [1] a connection between cyclic MUBs and the Fibonacci sequence is established. This connection enables one to find complete sets of cyclic MUBs in arbitrary even prime-power dimensions. Thereby, known properties of the Fibonacci sequence yield a simplified construction method conveying a better notion of complete sets of cyclic MUBs.

[1] O. Kern, K. S. Ranade and U. Seyfarth, J. Phys. A, 43, 275305 (2010)

Q 23.7 Tue 18:00 P1

Designing Ideal Hamiltonian Qubit Dynamics by Dynamical Recoupling — •Holger Frydrych and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Darmstadt

Dynamical recoupling is a powerful method for suppressing unwanted parts of an active Hamiltonian on a qubit network, provided one is able to control all relevant qubits appropriately. A general construction principle is presented for dynamical recoupling schemes which are capable of transforming a given qubit Hamiltonian into a desired ideal form. The necessary and sufficient conditions which have to be fulfilled by the Hamiltonian are discussed.

As an example it is demonstrated how a particular perfect-state-transfer Hamiltonian [1][2] can be designed by a dynamical recoupling scheme in a linear qubit chain governed by nearest-neighbour interactions.

References:
[1] G. M. Nikolopoulos et al. Eur. Phys. Lett. 65, 297 (2004)
[2] M. Christandl et al. Phys. Rev. Lett. 92, 187902 (2004)

Q 23.8 Tue 18:00 P1

Local Entropy Flow in Qubit Networks Under Random Controlled Unitary Transformations — •Jaroslav Novotny[1,2], Gernot Alber[1], and Igor Jex[2] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Darmstadt, Germany — [2]Department of Physics, FNSPE CTU in Prague, Czech Republic

The asymptotic dynamics of many-qubit quantum systems is investigated under iteratively applied random unitary transformations [1]. For a one-parameter family of controlled unitary transformations two main theorems are proved which characterize completely the dependence of this asymptotic dynamics on the topology of the interaction graph which encodes all possible qubit couplings. On the basis of these theorems the local entropy transport between an open quantum system and its environment are explored for strong non-Markovian couplings and for different sizes of the environment and different interaction topologies. In particular, the processes of thermalization and cooling of an open subsystem are investigated in detail. It is shown that both processes are possible if couplings between the subsystem and its environment act in both directions. If this condition is violated a successful realization of both processes is not possible.

References:
[1] J. Novotny, G. Alber, I. Jex, Cent. Eur. J. Phys. **8**, 1001 (2010).

Q 23.9 Tue 18:00 P1

Noise Spectrum Analysis at the NV center in diamond — •Konstantin Schukraft, Florian Rempp, Fedor Jelezko, and Jörg Wrachtrup — 3. Physikalisches Institut, Uni Stuttgart

Being able to extend the coherence time of quantum systems is very important not only for quantum computers, but also for high precision metrology applications. To efficiently decouple a system from its environment one needs to know that environment, characterised by the noise spectrum it generates. Since the noise spectrum isn't accessible directly in our case, we retrieve it via echo measurements. These are conducted with the NV centers electron spin; not only already an important measurement tool for the aforementioned high precision measurements, but also a candidate for high/room temperature quantum computers.

Q 23.10 Tue 18:00 P1

Illustrating the Geometry of Quantum Channels — •Corey O'Meara[1], Gunther Dirr[2], and Thomas Schulte-Herbrüggen[1] — [1]Dept. Chem., TU-Munich, Germany — [2]Math. Inst., University of Würzburg, Germany

Standard Markovian quantum channels are elucidated geometrically in terms of (Lie)semigroups. We specify the respective tangent cones, i.e. Lie wedges, for a variety of open quantum system evolutions undergoing well known types of dissipative interactions with the environment.

In practice, such dissipative dynamics are inherent in many experimental implementations. The corresponding tangent cones which characterize the channels' time evolution subject to external controls in fact give illustrative insight into the differential geometry of open-system dynamics under Hamiltonian controls. Furthermore, this insight may subsequently be exploited to approximate the reachable sets of given initial quantum states.

Q 23.11 Tue 18:00 P1

Quantum information transfer with trapped-ion antennae — •Regina Lechner[1], Maximilian Harlander[1], Michael Brownnutt[1], Rainer Blatt[1,2], and Wolfgang Hänsel[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstraße 25, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaften, Technikerstraße 21a, 6020 Innsbruck, Austria

To make trapped-ion quantum computing useful, scaling to many ions is imperative. One method of achieving this is to use miniaturized, segmented ion traps and by coupling ions trapped in separate wells[1]. A major obstacle to be overcome in implementing such techniques is to achieve gate operations that are much faster than the ion-heating rate which scales as d^{-4}, where d is the distance between the ions and the electrodes. As traps are miniaturized the gate speed increases, but so do the heating rates. We solve this problem by using multiple ions in each well as antennae to increase the dipole-dipole interaction. By using three ions in each of two wells, a 7-fold increase in interaction speed is observed compared with the case of a single pair of ions[2]. The experimental setup used to implement the double-well potential is described, focusing on the generation of the low-noise voltages required to achieve suitable ion stability, and for the reduction of technical-noise-induced ion heating. References [1] Cirac, J. I. & Zoller, P.; Nature 404, 579 (2000). [2] Harlander, M., Lechner, R., Brownnutt, M., Blatt, R. & Hänsel, W.; arXiv:1011.3639v2.

Q 23.12 Tue 18:00 P1

Measurement Based Quantum Computing with Optical Superlattices — •Alexander Kegeles[1], Mathis Friesdorf[1], Jonas Hörsch[1], Matthias Ohliger[1], David Gross[2], and Jens Eisert[1] — [1]Universität Potsdam, Institut für Physik und Astronomie, Karl-Liebknecht-Strasse 24/25, 14476 Potsdam, Germany — [2]ETH Zürich, Theoretische Physik, Wolfgang-Pauli-Strasse 27, 8093 Zürich, Switzerland

Measurement Based Quantum Computing (MBQC) is a very promising paradigm for the realization of a quantum computer, as it allows to separate the computation in the creation of an universal (independent of the performed algorithm) resource and the actual computing which is done by local measurements only. Possible resource states for single-qubit processing (quantum wires) and their couplings have already be classified using the formalism of Matrix Product States (MPS).

Cold atoms in optical super-lattices allow for controlled translationally invariant nearest-neighbor interaction between qubits, which can be described with the Margolus model of Quantum Cellular Automata (QCA). We explore the possibilities to create quantum wires with experimentally accessibly operations and discuss possible two-dimensional couplings.

Q 23.13 Tue 18:00 P1

Entanglement-Enhanced Classical Communication over a Noisy Classical Channel — •Robert Prevedel, Yang Lu, Will Matthews, Rainer Kaltenbaek, and Kevin Resch — Institute for Quantum Computing, University of Waterloo, Waterloo, N2L 3G1, ON, Canada

We present and experimentally demonstrate a communication protocol that employs shared entanglement to reduce errors when sending a bit over a particular noisy classical channel. Specifically, it is shown that, given a single use of this channel, one can transmit a bit with higher success probability when sender and receiver share entanglement compared to the best possible strategy when they do not. The experiment is realized using polarization-entangled photon pairs, whose quantum correlations play a critical role in both the encoding and decoding of the classical message. Experimentally, we find that a bit can be successfully transmitted with probability 0.891 ± 0.002, which is close to the theoretical maximum of $(2 + 2^{-1/2})/3 \approx 0.902$ and is significantly above the optimal classical strategy, which yields $5/6 \approx 0.833$.

Q 23.14 Tue 18:00 P1

Aufbau eines QKD-Setups mit passiver Zustandspräparation — •Tobias Diehl, Sabine Euler, Jan Hendrik Abel, Mathias Sinther und Thomas Walther — IAP, TU Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

Die Quantenkryptografie bietet eine Möglichkeit, einen zur Verwendung als One-Time-Pad geeigneten Schlüssel sicher zwischen den Übertragungspartnern auszutauschen. Das BB84-Protokoll bietet eine mögliche Realisierung, basierend auf der Präparation der Polarisation einzelner Photonen in zwei verschiedenen Basen. Zur Bereitstellung der einzelnen Photonen verwenden wir einen Typ-II SPDC-Prozess in einem PPKTP mit Wellenleiterstruktur. Ein Photon des erzeugten Paares dient dabei als Herald für das zweite, zur Übertragung verwendete, Photon. Um die beiden erforderlichen Basen zu realisieren, wird der Pumplaser bei 404 nm (cw) von beiden Seiten in den Kristall eingekoppelt. Eine geeignete Detektionseinheit aus einer Kombination aus Strahlteilerwürfeln und Photodioden macht es möglich, einzelne Photonen in verschiedenen Polarisationszuständen zu präparieren und angekündigt zu verschicken, ohne auf aktive Präparationseinheiten wie beispielsweise akusto-optische Modulatoren zurückzugreifen. Die klassische Kommunikationsstrecke, basierend auf einem gepulsten Laser, dient gleichzeitig der Strahlverfolgung und Justage des Empfängermoduls. Der aktuelle Stand des Projekts wird diskutiert.

Q 23.15 Tue 18:00 P1

Quantum Key Distribution on Hanover Campus — •Vitus Händchen[1], Tobias Eberle[1,3], Jörg Duhme[2,3], Torsten Franz[2], Roman Schnabel[1], and Reinhard Werner[2] — [1]Institut für Gravitationsphysik, Leibniz Universität Hannover und Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) — [2]Institut für Theoretische Physik, Leibniz Universität Hannover — [3]QUEST Centre for Quantum Engineering and Space-Time Research, Leibniz Universität Hannover

We report on the planned experimental implementation of quantum key distribution on the campus of the Leibniz Universität Hannover. A fiber based continuous variable quantum cryptographic link will be established between the Albert-Einstein-Institute and the Institute of Quantum Optics, which are about 1 km apart. The link will be build with two-mode squeezed states at 1550 nm and standard telecommunication fibers. We present first experimental results concerning the generation of two-mode squeezing at 1550 nm. Furthermore the security of our scheme will be discussed and the expected secure key rates will be presented.

Q 23.16 Tue 18:00 P1

Efficient entanglement purification protocol using chains of atoms and optical cavities — •Denis Gonta and Peter van Loock — Optical Quantum Information Theory Group, Max Planck Institute for the Science of Light, Günther-Scharowsky-Str. 1, Bau 26, D-91058 Erlangen

In the framework of cavity QED, we propose an efficient scheme to purify bipartite entanglement by using short chains of atoms coupled to high-finesse optical cavities. In contrast to the conventional entanglement purification scheme [1], we avoid CNOT gates and reduce, therefore, complicated pulse sequences and superfluous qubit operations. Our interaction scheme works in a deterministic way, and together with entanglement distribution and swapping, yields an efficient quantum repeater protocol for long-distance quantum communication.

[1] C. H. Bennett et al., Phys. Rev. Lett. 76, 722 (1996);
C. H. Bennett et al., Phys. Rev. A 54, 3824 (1996).

Q 23.17 Tue 18:00 P1

Aufbau einer Zwei-Photonen-Quelle — •Sabine Euler, Mathias Sinther und Thomas Walther — TU Darmstadt, Institut für angewandte Physik, Schlossgartenstraße 7, 64289 Darmstadt

Durch einen Typ II SPDC-Prozess in PPKTP bei 404 nm werden zunächst zwei frequenzgleiche Photonen erzeugt, die sich nur in ihrer Polarisation unterscheiden. In einem zweiten Schritt wird eines dieser Photonen um 90° in seiner Polarisation gedreht und erneut in den Kristall eingekoppelt. Durch einen DFG-Prozess zwischen diesem rückgekoppelten Photon und einem Pumpphoton entstehen zwei identische Photonen, die an einem polarisierenden Strahlteiler ausgekoppelt und nach einem weiteren 50-50 Strahlteiler als koinzidente Ereignisse detektiert werden können. Ein weiteres, zu den beiden ersten Photonen senkrecht polarisiertes Photon kann erneut zur Rückkopplung verwendet werden. Der aktuelle Status des Experimentes wird diskutiert.

Q 23.18 Tue 18:00 P1

Quantum key distribution on Hanover Campus: Theory — •Jörg Duhme[1], Torsten Franz[1], Reinhard F. Werner[1], Vitus Händchen[2], Tobias Eberle[2], and Roman Schnabel[2] — [1]Leibniz Universität Hannover, Institut für Theoretische Physik, AG Quanteninformation — [2]Albert Einstein Institut, Quantum Interferometry

We report on the implementation of an entanglement-based quantum cryptograph on Hanover campus using squeezed gaussian states (continuous variables). This poster focuses on the theoretical aspects of this project. First available experimental data has been compared with the theoretical simulation of the experimental setup. We discuss the different sources of noise in the setup focusing especially on their impact on the key rate and the EPR-criterion. Furthermore we discuss the possible origins of memory effects in the experiment.

Q 23.19 Tue 18:00 P1

Laser-Assisted Bell Measurements and Spontaneous Decay Processes — •Jozsef Zsolt Bernad and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Darmstadt

Following the original suggestion of Briegel et al. [1] recently also alternative theoretical proposals of quantum repeaters have been developed in which the Bell-measurements required are implemented by different physical processes. The recent proposal for a quantum repeater based on continuous variables by van Loock et al. [2,3], for example, is based on Bell measurements which are performed with the help of off-resonant laser-induced couplings in the relevant material qubits. In this contribution the resulting realistic effects of spontaneous decay of the excited qubits are investigated and their influence on the quality of Bell measurements is explored. It constitutes a first step towards the development of appropriate error suppression methods which counteract the entanglement breaking tendencies of spontaneous decay processes.

[1] H. J. Briegel, W. Dür, J. I. Cirac, P. Zoller, Phys. Rev. Lett. 81, 5932 (1998).
[2]P. van Loock, T. D. Ladd, K. Sanaka, F. Yamaguchi, K. Nemoto, W. J. Munro, and Y. Yamamoto, Phys. Rev. Lett. 96, 240501 (2006).
[3]P. van Loock, N. Lütkenhaus, W. J. Munro, and K. Nemoto, Phys. Rev. A 78, 062319 (2008).

Q 23.20 Tue 18:00 P1

Fabrication and characterisation of tailored waveguide PDC sources in RPE:PPLN for quantum communication — •Stephan Krapick, Hubertus Suche, Harald Herrmann, Raimund Ricken, Viktor Quiring, Christine Silberhorn, and Wolfgang Sohler — Universität Paderborn - Department Physik - AG "Integrierte Quantenoptik", Warburger Str. 100, D-33098 Paderborn

Parametric down conversion (PDC) is a well established process for the generation of photon pairs. Due to their high brightness, the spatial mode confinement and most importantly the flexibility in wavelength of the generated photon pairs, PDC devices can be utilized as ideal sources to address various ionic quantum memories in quantum repeaters. We present the results of the preparation and characterisation of waveguides in periodically poled z-cut Lithium Niobate (PPLN). In order to exploit the large second order nonlinearity of Lithium Niobate, Type I quasi-phasematching is employed to enable photon pair generation. In the fabrication process of the waveguides the promising approach of reversed proton exchange (RPE) is used. This provides us with low-loss and high-efficiency waveguides of symmetrical mode intensity distributions, which allow extraordinary fiber coupling. Various parameters have been tested to tailor the fluorescence of a 532 nm pump at will, yielding the addressability of Nd(3+)- and Tm(3+)-Ions to be used in quantum memories.

Q 23.21 Tue 18:00 P1

Improving entanglement based quantum key distribution through turbulent atmosphere — •Bettina Heim[1,2,3], Chris Erven[3], Raymond Laflamme[3,4], Gregor Weihs[3,5], and Thomas Jennewein[3] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Institute of Optics, Information und Photonics, University of Erlangen-Nuremberg, Erlangen, Germany — [3]Institute for Quantum Computing, University of Waterloo, Waterloo, ON, Canada — [4]Perimeter Institute, Waterloo, Canada — [5]Institute for Experimental Physics, University of Innsbruck, Innsbruck, Austria

Within the framework of our free-space quantum key distribution system, we study influences of the turbulent atmosphere on entangled photons sent over a 1.3 km free-space link, and explore the possibility of optimizing the quantum transmisson in this situation. Entangled photons are created in a Sagnac configuration [1], using a periodically poled KTP non-linear optical crystal that is placed in an interferometer loop and pumped bi-directionally. One photon of each pair is detected locally, the other one is sent through the free-space channel. We specifically studied the effects of the atmospheric channel on the entanglement properties and the performance of our system under various losses and pump rates with a view to improving the signal-to-noise ratio of the system in order to increase the secret key rate. In the future, we intend to perform the same study with two independent free-space links. [2].

[1] C. Erven et al., QuantumCom2009, LNICST 36, 108-116, 2010.
[2] C. Erven et al., Opt. Exp. 16, 16840-16853 (2008).

Q 23.22 Tue 18:00 P1

Quantifying effective entanglement in a continuous-variables QKD system — •Imran Khan[1,2], Christoffer Wittmann[1,2], Nitin Jain[1,2], Josef Fürst[1,2], Nathan Killoran[3], Norbert Lütkenhaus[3], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max-Planck-Institute für die Physik des Lichts, Günther-Scharowsky-Str. 1, 91058 Erlangen — [2]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, Staudtstraße 7/B2, 91058 Erlangen — [3]Institute for Quantum Computing, 200 University Ave. W.,Waterloo, ON N2L 3G1

We discuss a continuous-variables QKD system, where non-orthogonal coherent states are sent through a fiber-based quantum channel. The phase modulated signal is detected using simultaneous homodyne detection of conjugate quadratures. Evidence of quantum correlations in this raw data are a prerequisite for the production of a secure key. The quantum correlations can be modeled by effective entanglement. We have witnessed these correlations for a 2 km link. Our aim is to increase the channel length and quantify the effective entanglement.

Q 23.23 Tue 18:00 P1

Coherent Rydberg Excitation in Thermal Microcells — •Renate Daschner[1], Harald Kübler[1], Bernhard Huber[1], Thomas Baluktsian[1], Andreas Kölle[1], James P. Shaffer[2], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Germany — [2]Homer L. Dodge Department of Physics and Astronomy, The University of Oklahoma, USA

In order to create quantum devices based on the Rydberg blockade mechanism, it is necessary to have a confinement of the excitation volume to less than the blockade radius in a frozen gas of atoms; i.e. the excitation times need to be shorter than the timescales of the respective dephasing mechanisms.
While ultracold gases seem to be the obvious choice, our approach utilizes thermal atomic vapor in small glass cells [1] which offer multiple advantages like good optical access and scalability. Such a system can be realized by confining the atoms to geometries in the μm regime.
Decoherence effects like resonant interactions of the Rydberg atoms with polaritonic excitations in the glass have been studied and can be minimized by the appropriate choice of Rydberg states [2].
Using a bandwidth-limited pulsed laser system for the Rydberg excitation we observe coherent Rabi oscillations on the nanosecond timescale. We discuss future perspectives for Quantum information processing.

[1] Baluktsian, T., et. al. *Opt. Lett.* **35**, 1950 (2010)
[2] Kübler, H., et. al. *Nature Photon.* **4**, 112-116 (2010)

Q 23.24 Tue 18:00 P1

Towards an efficient quantum memory using atomic vapour — •Tobias Latka, Andreas Neuzner, Eden Figueroa, and Gerhard Rempe — Max-Planck-Institute of Quantum Optics, Hans-Kopfermann-Str. 1, 85748 Garching

One of the main challenges in the implementation of quantum memories is achievement of high retrieval efficiency. State of the art experiments report efficiencies as high as 45% [1]. Nonetheless, higher values are required e.g. for the implementation of an efficient quantum repeater. A new approach based on off-resonant photon echoes in three-level atoms has paved the way for higher storage efficiencies [2]. We present our current results towards the implementation of such a device in Rubidium vapor. We discuss our simulations regarding the design of coils capable of producing the essential switchable linear field gradient required for the photon echoes generation, experimentally achievable efficiencies, and the future use of the system in combination with a cavity QED based source of single photons [3].

[1] I. Novikova, et al., Phys. Rev. A 78, 021802 (2008)
[2]M. Hosseini, et al., arXiv: 1009.0567v1 (2010).
[3] M. Hijlkema, et al., Nature Physics 3, 253 (2007).

Q 23.25 Tue 18:00 P1

A Bose-Einstein Condensate as Quantum Memory for Optical Polarisation Qubits — •Christoph Vo, Matthias Lettner, Martin Mücke, Stefan Riedl, Carolin Hahn, Simon Baur, Jörg Bochmann, Stephan Ritter, Stephan Dürr, and Gerhard Rempe — Max-Planck-Institute of Quantum Optics, Hans-Kopfermann-Str. 1, 85748 Garching

We present the experimental characterization of a quantum memory for optical polarisation qubits using electromagnetically induced transparency (EIT) in a Bose-Einstein condensate of ^{87}Rb atoms. Our system operates 70 MHz detuned from the D_1-line in a moderately-detuned Raman regime rather than the on-resonance EIT regime. Photonic polarisation qubits are mapped onto Zeeman qubits in the atomic system. Using classical light pulses, we performed a full quantum process tomography to determine the Müller matrix of the system.

To demonstrate the performance of our memory in the quantum regime, we stored a single photon of a polarisation-entangled Einstein-Podolsky-Rosen pair. After retrieving the stored photon from the memory we performed a quantum state tomography to determine the density matrix of the bi-partite system and found close resemblance with the original state. The fidelity of the retrieved state with respect to the maximally-entangled $|\Psi^-\rangle$ Bell state is found to be well above the classical limit of 0.5, showing the memory's suitability as building block of a quantum repeater for long-distance quantum communication.

Q 23.26 Tue 18:00 P1

Non-linear optics using single-atom cavity Electromagnetically Induced Transparency — •Eden Figueroa[1], Celso J. Villas-Boas[2], Stephan Ritter[1], and Gerhard Rempe[1] — [1]Max-Planck-Institute of Quantum Optics, Hans-Kopfermann-Str. 1, 85748 Garching — [2]Departamento de Fisica, Universidade Federal de São Carlos, 13565-905 São Carlos, SP, Brazil

A fundamental challenge for quantum optics is the realization of non-linear systems capable of mediating strong interactions between light fields at the few- photon level. A promising avenue to achieve this goal is the combination of cavity Quantum Electrodynamics (cQED) and Electromagnetically Induced Transparency (EIT). Along these lines, a breakthrough has been achieved recently, as a new generation of experiments has reached the necessary conditions to observe EIT with single atoms [1]. Here we study this new phenomenon theoretically and explore possible realistic applications based upon the non-classical behaviour of the system, ranging from the coherent control of the photon statistics of incident beams, to its use as a photonic gate for quantum information purposes [2]. We will highlight future perspectives and possible strategies to implement these ideas with existing cQED setups.

[1] M. Mücke, et al., Nature 465, 755 (2010).
[2] Rebic et al., J. Opt. B: Quantum Semiclass. Opt. 1, 490 (1999).

Q 23.27 Tue 18:00 P1

Optical nanofibers in ion-traps — •Jan Petersen[1], Benjamin Ames[2], Michael Brownnutt[2], Rainer Blatt[2], and Arno Rauschenbeutel[1] — [1]Technische Universität Wien - Atominstitut, 1020 Wien, Austria — [2]Institut für Experimentalphysik, Universität Innsbruck, 6020 Innsbruck, Austria

Atoms and molecules can be efficiently coupled to the intense evanescent light field around optical nanofibers. Such nanofibers are realised from standard optical fibers in a heat and pull process to produce a waist with a diameter of several 100 nm. Ion traps, on the other hand, are one of the most successful systems for manipulating single particles. Trapped ions can be confined for long durations and by tuning the electric trapping potentials one can adjust their position with a precision of a few nanometers.

We are planning to profit from the advantageous properties of both systems and set up an experiment, in which an optical nanofiber is integrated in an ion trap. With this setup one could probe the evanescent light field with an ion and also use the optical nanofiber to efficiently excite the ions and to collect their fluorescence. As the ion will have to be placed in close vicinity of the nanofiber surface (around 100 nm), charging effects of the fiber surface have to be minimized. We present results and discuss possibilities of coating the fibers to tackle this problem.

Financial support by ERA-Net Research Network “Nanofibre Optical Interfaces, (NOIs)”, the Volkswagen Foundation (Lichtenberg Professorship) and the ESF (EURYI Award) is gratefully acknowledged.

Q 23.28 Tue 18:00 P1

Implementation of quantum error correction protocols in a small quantum register — •Matthias Nitsche, Matthias Steiner, Gerald Waldherr, Philipp Neumann, Fedor Jelezko, and Joerg Wrachtrup — 3. Physikalisches Institut, Universitaet Stuttgart, Pfaffenwaldring 57, D-70550, Germany

Electron spins associated with the nitrogen-vacancy (NV) defect in diamond are promising candidates for quantum information processing at room temperature. For practical applications, however, the quantum information stored in a spin qubit has to be protected from phase and bit-flip errors. Techniques like the encoding of quantum state in decoherence free subspaces or the application of error correction protocols involving proximal nuclear spins are discussed.

Q 23.29 Tue 18:00 P1

Quantum information processing with atoms in arrays of dipole potentials — •Sascha Tichelmann, Malte Schlosser, Jens Kruse, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

Neutral atoms confined in two-dimensional multi-site potential geometries represent an important experimental approach towards quantum information processing. By using well separated optical micro-potentials created by micro-fabricated lens arrays, we obtain highly controllable and scalable quantum systems with single-site addressability and long coherence times. Our microtrap array accesses the regime of collisional blockade, which allows us to prepare atom distributions with sub-Poissonian statistics.
We achieve a direct control of each trap by implementing a spatial light modulator to create arbitrary trap configurations as well as flexible, site-specific, but also parallelized initialization and coherent manipulation of small ensembles or single ^{85}Rb atoms. Towards the entanglement of qubits, we demonstrate the coherent transport of atomic quantum states in a shift register architecture. The shift sequence is based on loading, moving and reloading of two independently controllable microtrap arrays.
We also report on an experimental scheme compensating for the differential lightshift induced by the dipole traps. This "magic-wavelength"

behavior results in a strong suppression of dephasing. The scheme is extendable to all alkali elements.

Q 23.30 Tue 18:00 P1

Spin-Spin interaction in impurity doped ion crystal — •Peter Ivanov, Amado Bautista-Salvador, Jens Welzel, Niels Kurz, Frank Ziesel, Max Hettrich, Ulrich Poschinger, and Ferdinand Schmidt-Kaler — Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany

For the simulation of magnetic quantum phase transitions, we consider the behavior of the effective spin-spin couplings in an ion crystal of $^{40}Ca^{+}$ S = 1/2 ions doped with high magnetic moment ions, such as Mn^{+}, which possess spin S = 3 in the electronic-ground state. Spin-spin interactions are tailored by employing an oscillating magnetic field with a strong gradient. The presence of ion species with S > 1/2 increases the strength of the effective spin-spin interaction which allows for observation of Schrodinger cat states of large size. Moreover, we discuss how the impurity doped ion crystal is suited for the investigation of quantum phase transitions and frustration effects in spin systems. First experimental steps in a specialized planar ion trap have been realized. We will report about the experimental and theoretical progress

Q 23.31 Tue 18:00 P1

Towards a universal, single-atom based quantum interconnect — •Andreas Reiserer, Holger Specht, Christian Nölleke, Manuel Uphoff, Eden Figueroa, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

A prerequisite for the realization of quantum networks is a coherent interface between flying and stationary qubits. A promising candidate for such a device is a single atom that interacts with single photons via a high-finesse optical cavity. It has been shown that atom-cavity systems can be used for efficient and controlled single photon production via vacuum stimulated Raman transitions (vSTIRAP) between two atomic ground states. Here, we report on the reverse process - coherent absorption of single photons by a single atom. In our setup, we quasi-permanently trap a single Rb atom in a resonator in the intermediate coupling regime of cavity QED. We prepare the atom in the lower atomic hyperfine state (F=1). By adiabatically ramping down the power of a strong control laser pulse, we cause the atom to absorb a single photon out of a weak coherent probe pulse impinging on the cavity. In this process, the atom is transferred to the upper atomic ground state (F=2). After a finite storage time, a vSTIRAP is used to read out the stored excitation by producing a single photon. The current status towards the implementation of a quantum memory will be presented.

Q 23.32 Tue 18:00 P1

State manipulation of single atoms in a high-finesse optical cavity — •Manuel Uphoff, Christian Nölleke, Andreas Reiserer, Holger Specht, Eden Figueroa, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching

Single atoms trapped in a high-finesse optical cavity are an ideal candidate for the distribution of quantum information over a quantum network. Coherent manipulation of the atomic state allows single qubit rotations on the atom and the mapping of qubits to decoherence-free subspaces. Efficient state transfer by microwave radiation is prohibited in our atom-cavity system as the cavity assembly largely shields the long-wavelength radiation. Therefore stimulated Raman transitions with their sub-natural linewidth are best suited to drive transitions between hyper-fine states of atoms trapped in a high-finesse cavity. We report on near unity transfer of the population using π-pulses in 1 μs, which is much shorter than the lifetime of the atomic state. The effects of the geometry and polarisation of the Raman beams and their interplay with different Zeeman substates are investigated and future applications in detecting and manipulating the motional state of the atom will be discussed.

Q 23.33 Tue 18:00 P1

Qubit-Auslese mit einer EMCCD-Kamera — •Alex Wiens, Ulrich Poschinger, Andreas Walther, Frank Ziesel, Kilian Singer und Ferdinand Schmidt-Kaler — QUANTUM, Universität Mainz, Staudingerweg 7, 55128 Mainz

Die Auslese von atomaren Quantenbits erfolgt experimentell durch die Detektion von Resonanzfluoreszenz. Dabei wird der Zustand durch die Anzahl der detektierten Photonen in "hellöder "dunkel"klassifiziert, so dass die Güte dieser Zustandsdiskriminierung fundamental durch Schrotrauschen und Hintergrundlicht limitiert ist[1]. Wir benutzen eine EMCCD-Kamera, um mithilfe der Ortsauflösung festzustellen, inwieweit es möglich ist die optimale Güte der Diskriminierung zu erreichen [2]. Es werden Fluoreszenzmessungen an einem $^{40}Ca^{+}$ Ion benutzt, um den Ausleseprozess präzise zu modellieren. Auf dieser Basis werden verschiedene Zustandsklassifikationsalgorithmen in Simulationen verglichen.

[1] A.H. Myerson et al., Phys. Rev. Lett. 100, 200502 (2008).
[2] A.H. Burrell et al., Phys. Rev. A 81, 040302 (2010).

Q 23.34 Tue 18:00 P1

Interfacing Ions with Nanofibres — •Benjamin Ames[1], Michael Brownnutt[1], Jan Petersen[2], Arno Rauschenbeutel[2], and Rainer Blatt[1,3] — [1]Institut für Experimentalphysik, Uni. Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria — [2]Atominstitut, Technische Universität Wien, Stadionallee 2, 1020 Wien, Austria — [3]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, 6020 Innsbruck, Austria

Given the advances made in trapped-ion quantum information processing, ions make a natural choice of physical qubit in a register. By contrast, the ability to reliably transmit light over long distances makes photons a natural choice for flying qubits to connect the registers. It may be possible to couple these two systems by trapping ions in the evanescent field of a nanofibre.

Implementation of such an ion-fibre system is not without technical and physical challenges, particularly with regard to positional stability, and ion heating close to nanostructures. We describe an ion-trap/nanofibre system used to investigate such effects, and propose methods of observing coupling between ions and evanescent waves, even in the presence of such perturbations.

Q 23.35 Tue 18:00 P1

Aufbau zur Erzeugung von Mikrowellensignalen mit phasenkohärenter Frequenzumschaltung — •T. F. Gloger, M. Johanning, A. Khromova, Chr. Piltz, B. Scharfenberger, A. Varón und Chr. Wunderlich — Fachbereich Physik, Universität Siegen

In einer linearen Paul-Falle gespeicherte Ytterbium-Ionen lassen sich als Systeme zur Quantensimulation und -informationsverarbeitung nutzen. Geeignete Qubits werden in den langlebigen Hyperfeinzuständen $|S_{1/2}, F=0\rangle \leftrightarrow |S_{1/2}, F=1\rangle$ des $^{171}Yb^{+}$ Ion realisiert. Zur direkten Manipulation dieser Qubits wird ein Mikrowellenfeld mit einer Frequenz von etwa 12.6 GHz benötigt. Durch einen Magnetfeldgradienten entlang der Fallenachse werden Qubits in den zeemanaufgespaltenen Übergängen $|F=0\rangle \leftrightarrow |F=1, m_F=\pm 1\rangle$ einzeln im Frequenzraum adressierbar. Zur Quantenzustandsmanipulation mehrerer Ionen ist es notwendig, die Frequenz des elektromagnetischen Feldes phasenkohärent schalten zu können.

Wir erzeugen das benötigte Mikrowellensignal durch Mischen eines schmalbandigen Signals mit 12.568 GHz mit den Signalen zweier phasenkohärent schaltbarer Signalgeneratoren mit Frequenzen von 1-150 MHz in IQ-Konfiguration. Dies ermöglicht einen Adressierungsraum der Qubits von 300 MHz.

Der experimentelle Aufbau wird vorgestellt und hinsichtlich Frequenzstabilität, Amplitudenstabilität und Phasenrauschen charakterisiert. Darüber hinaus werden die Addressierung und Manipulation mehrerer $^{171}Yb^{+}$ Ionen in einer linearen Paul-Falle mit Magnetfeldgradient demonstriert.

Q 23.36 Tue 18:00 P1

Direct Characterization of Quantum Dynamics in a system of $^{40}Ca^{+}$ - ions — •Daniel Nigg[1], Julio T. Barreiro[1], Philipp Schindler[1], Thomas Monz[1], Michael Chwalla[1,2], Stefan Quint[1], Markus Hennrich[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Technikerstr. 21A, 6020 Innsbruck, Austria

Quantum process tomography (QPT) is an essential tool for characterizing a process in quantum information processing. Standard QPT requires a large number of measurements for various input states and measurement bases of the respective quantum system. Direct characterization of quantum dynamics (DCQD) can significantly reduce the number of measurements [1]. The process acting on a single qubit is characterized by entangling it initially with an auxiliary qubit and performing Bell-state measurements on the joint final state. An experimental realization of DCQD is reported in a system of $^{40}Ca^{+}$ ions confined in a linear Paul trap. The unitary processes $\sigma_{X,Y,Z}$ as well as phase and amplitude damping are characterized on a single qubit. DCQD allows determining the longitudinal and transversal relaxation times T_1 and T_2 of one or two qubits in a single measurement. Thus the system's spontaneous decay time (T_1) and dephasing time (T_2) are quantitatively analysed with a single experimental setting.

[1] M. Mosheni and D. A. Lidar, *Phys. Rev. Lett.*, 97:1-4, (2006).

Q 23.37 Tue 18:00 P1

Entangled photons at 780 nm and 795 nm from a single atom — •Joerg Bochmann, Martin Mücke, Carolin Hahn, Andreas Neuzner, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Neutral atoms embedded in high-finesse optical cavities are well suited for applications in quantum information science. A prime example is entanglement of a single intra-cavity atom with a single emitted photon by means of a deterministic scheme [1]: A vacuum stimulated Raman adiabatic passage generates a photon whose polarization is entangled with the atomic spin state. After a chosen delay time, the atomic state can be mapped onto the polarization state of a second emitted photon. Crucial for applications of this scheme in quantum network experiments are achievable success rates, fidelities and coherence times.

Here, we report on significant improvements of these key parameters in our experiment and compare its performance on the D1 (795 nm) and D2 (780 nm) lines of Rubidium. We show that the fidelity with the desired Bell state is markedly increased when using the D1 line. Moreover, we are able to extend the coherence time of the atomic qubit by more than an order of magnitude, beyond 100 us. Further optimization strategies will be discussed.

[1] B. Weber et al., Phys. Rev. Lett. 102, 100 (2009).

Q 23.38 Tue 18:00 P1

Efficient single-mode fiber coupling of photons from a single ion — •Christoph Kurz[1], Jan Huwer[1,2], Michael Schug[1], José Brito[1], Philipp Müller[1], Joyee Ghosh[1,2], and Jürgen Eschner[1,2] — [1]Universität des Saarlandes, Experimentalphysik, Campus E2.6, 66123 Saarbrücken — [2]Institut de Ciències Fotòniques, Mediterranean Technology Park, 08860 Castelldefels (Barcelona)

We operate two independent linear Paul traps with single $^{40}Ca^{+}$ ions, which provides a highly modular setup for implementing quantum information processing and communication tools [1, 2]. In one application, a trapped ion is used to efficiently generate single photons, which are then coupled to a single-mode fiber. Here we present a significant improvement over previous measurements [1] by optimising the fiber coupling and making use of constructive interference of light from the ion and its mirror image.

[1] M. Almendros et al., PRL **103**, 213601 (2009)
[2] N. Piro et al., DOI: 10.1038/NPHYS1805

Q 23.39 Tue 18:00 P1

Fast and stable laser pulses using EOM for quantum information — •Stephan Quint[1], Daniel Nigg[1], Philipp Schindler[1], Markus Hennrich[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Technikerstr. 21A, 6020 Innsbruck, Austria

Technical developments in the field of quantum computing with trapped ions have made significant progress and allow one to perform single- and two-qubit quantum gates with fidelities of up to 99%. Further technological improvements are necessary to reduce the operational errors below the fault-tolerant threshold of 10^{-3} - 10^{-4}. One important source of errors are intensity fluctuations of the laser pulses used to manipulate the electrical and vibrational states of the ions. For quantum computer experiments with ions, acousto-optical modulators (AOM) are used to shape and tune these pulses. Unfortunately, thermal effects within the AOM crystal lead to intensity fluctuations of the laser intensity. This problem is overcome by using an electro-optical modulator (EOM) to shape the amplitude of the applied pulses. Besides better thermal stability, EOMs enable faster switching speeds than AOMs. An EOM, however, requires sophisticated control electronics to drive laser pulses and to compensate for drifts. In this presentation, the control electronics for generating laser pulses with an EOM is discussed and the use of this device for quantum information processing with trapped ions is reviewed.

Q 23.40 Tue 18:00 P1

Phase transitions in ion chains — •Luis Rico Pérez and James R. Anglin — Technische Universität Kaiserslautern, Germany

The interest in the understanding of the behavior of low dimensional cooled ion structures has recently grown due to the suggested possibility of using them to implement quantum information processors and simulators [1]. We identify and classify the different possible phase transitions of an ion chain depending on strength and asymmetry of the trapping potential. Our results for the regime where the line and zig-zag configurations are stable agrees with previous studies for homogeneous traps [2] and we extend this by considering also transitions to 3D structures as well.

[1] J. I. Cirac, P. Zoller, PRL 74, 4091 (1995); D. Leibfried et al, Nature 422, 412 (2003); D. Porras, J. I. Cirac, PRL 92, 207901 (2004)
[2] S. Fishman, G. De Chiara, T. Calarco, G. Morigi, PRB 77, 064111 (2008)

Q 23.41 Tue 18:00 P1

Entanglement between two remotely trapped atoms — •N. Ortegel[1], J. Hofmann[1], M. Krug[1], F. Henkel[1], W. Rosenfeld[1], M. Weber[1], and H. Weinfurter[1,2] — [1]Fakultät für Physik der LMU München, Schellingstr. 4/III, 80799 München — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Entangled atom-atom pairs can serve as basic elements in quantum communication schemes such as quantum repeaters. They can also be used to carry out fundamental tests of quantum mechanics such as tests of Bell's inequality.

In our experiment we generate an entangled pair of single atoms that are located in two independent optical dipole traps by using the entanglement-swapping protocol.

Here we present details of the main building blocks of this experiment: Creation of entanglement between the electronic spin state of an atom and the polarization state of a photon [1], distribution of atom-photon entanglement over a distance of 300 m via an actively stabilized optical fiber link [2], a Bell-state measurement of the two photons by two-photon interference at a fiber beam-splitter and finally a sub-microsecond readout scheme of the atomic state by state-selective ionization [3]. The latter promises to be fast and efficient enough to allow for a loophole-free test of Bell's inequality [4].

[1] J. Volz et al., PRL 96 (2006)
[2] W. Rosenfeld et al., PRL 101 (2008)
[3] F. Henkel et al., arXiv:1008.1910v2 (2010)
[4] W. Rosenfeld et al., Adv. Sci. Lett. 2, 469 (2009)

Q 23.42 Tue 18:00 P1

Towards quantum simulations in a two-dimensional lattice of ions — •Christian Schneider, Johannes Stroehle, Martin Enderlein, Thomas Huber, Stephan Duewel, and Tobias Schaetz — Max-Planck-Institut für Quantenoptik

Linear Paul traps have demonstrated to be a well-suited tool for quantum simulations [1,2]. General 2D interactions or large-scale systems can hardly be simulated in conventional Paul traps. Surface-electrode traps are a promising candidate to overcome some of these limitations and allow to design arbitrary trapping geometries [3].

We started a collaboration with Roman Schmied (Uni Basel), Didi Leibfried (NIST, Boulder) and Dave Moehring (Sandia National Labs) to investigate the feasibility of a surface-electrode trap providing a lattice of RF traps. We want to report on our progress in setting up a new experiment and visions for quantum simulations. A linear surface-electrode trap from Sandia National Labs has been successfully assembled into a vacuum system to test the integral parts of a new setup. Afterwards, we plan to substitute it by a first lattice trap with three trapping zones arranged in a triangle. The zones will have mutual distances of 40 μm and a height above the surface of 40 μm, which could already allow to achieve a sufficient coupling strength between the ions for first quantum simulation experiments in two dimensions.

[1] A. Friedenauer et al., Nat. Phys. 4, 757-761 (2008)
[2] H. Schmitz et al., PRL 103, 090504 (2009) and
F. Zähringer et al., PRL 104, 100503 (2010)
[3] R. Schmied et al., PRL 102, 233002 (2009)

Q 23.43 Tue 18:00 P1

Microstructured ion traps for microwave-based quantum information — •Muhammad Tanveer Baig, Thomas Collath, Michael Johanning, Delia Kaufmann, and Christof Wunderlich — Fachbereich Physik, Universität Siegen, 57068 Siegen

Ion trap based quantum computing has proven its prominent position for a future quantum computer and laser cooled ions held in microstructured segmented linear Paul traps (micro-traps) are particularly promising candidates. A large number of DC electrodes in micro-traps are very useful for shuttling and separating the trapped ions as well as for controlling the range and magnitude of the spin-spin coupling between the ions. We will use Magnetic Gradient Induced Coupling (MAGIC) to address individual trapped (Yb+) ion and do laser-less quantum information with microwave pulses controlling the qubits. Our recent setup provides a ceramic chip carrier; this acts as the mechanic base for the micro-structured trap chip and as a vacuum interconnect using thick film technology; furthermore it permits very short distances to low pass filtering circuits. A glass cap allows good optical and microwave access. The recent results will be presented.

Q 23.44 Tue 18:00 P1

Opical Trapping of an Ion - Results and Perspectives — •Thomas Huber, Martin Enderlein, Christian Schneider, Stephan Duewel, Johannes Stroehle, and Tobias Schaetz — MPI für Quantenoptik

The simulation of large quantum systems on conventional computers is impossible, since quantum behavior is not efficiently translatable in classical language. However, one could gain deeper insight into complex quantum dynamics via experimentally simulating the quantum behaviour of interest in quantum system, where some relevant parameters can be controlled and robust effects detected sufficiently well. One example is simulating quantum-spin systems with trapped ions and one approach among others to reach scalability might be to combine the advantages of trapped ions with optical lattices. As a first experimental step, we were able to trap an ion in an optical dipole trap. The measured lifetime of milliseconds allows for hundreds of oscillations within the optical potential. It is limited by heating due to photon scattering. In the near future, we plan to realize cooling to increase the lifetime and to investigate the limitations on the coherence times. Next to quantum simulations with several ions interacting via phonons like the simulation of the Ising Hamiltonian, a new class of quantum simulations might become accessible, based on the potentially intriguing interplay between neutral and charged particles in common optical lattices. Furthermore, confining an ion and atoms in one common optical dipole trap might allow to investigate ultra cold collisions without the limitations set by radio-frequency driven micro-motion.

Q 23.45 Tue 18:00 P1

Spin and spin-lattice relaxation in isotopically pure diamond — •Jan Honert[1], Helmut Fedder[1], Michael Klas[1], Junichi Isoya[3], Matthew Markham[2], Daniel Twitchen[2], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]Universität Stuttgart, 70550 Stuttgart, Germany — [2]Element Six Ltd, King's Ride Park, Ascot SL5 8BP, UK — [3]Graduate School of Library, Information and Media Studies, University of Tsukuba, 1-2 Kasuga, Tsukuba, Ibaraki 305-8550, Japan

The Nitrogen-Vacancy defect in diamond is a promising solid-state spin qubit, that allows optical readout and coherent spin manipulation even at room temperature. One of the crucial properties with respect to spin based quantum applications is a long spin coherence time T2. In diamond, T2 is typically limited by coupling to 13C nuclear spins. Record T2 times reaching several ms were recently demonstrated using isotopically enriched (99.7% 12C) diamond. Under ideal conditions, the limit for T2 is set by spin-lattice relaxations that can reach tens of ms in typical samples. We study the spin and spin-lattice relaxation time in ultra pure isotopically enriched (up to 99.99%) diamonds. In addition to results from our magnetically shielded setup an overview of the current understanding of the contributing factors to the spin decoherence are presented.

Q 23.46 Tue 18:00 P1

Trapping of ions in a deep parabolic mirror — •Robert Maiwald[1,2], Andrea Golla[1,2], Benoît Chalopin[2], Martin Fischer[1,2], Alessandro S. Villar[2], Markus Sondermann[1,2], and Gerd Leuchs[1,2] — [1]Institut für Optik, Information und Photonik (IOIP), Universität Erlangen-Nürnberg, Staudtstr. 7/B2, 91058 Erlangen — [2]Max-Planck-Institut für die Physik des Lichts (MPL), Günther-Scharowsky-Str. 1/Bau 24, 91058 Erlangen

Due to its fundamental significance as well as its applicability to, e.g., quantum networks, a wide variety of investigations exists dealing with the efficient coupling of photons and matter. Whether it is atoms in a cavity, in or close to a fiber or a waveguide, all these methods employ some sort of coupling tool to match the profile of the electromagnetic field to the atomic transition. The aim of our research is to couple the light field to an atomic ion directly, i.e. in free space. This requires excitation from the full solid angle for optimal field-transition overlap.

Our solution to this problem is to trap an ion with a single tip ion trap with wide optical access, which is placed inside the focus of a deep parabolic mirror. We examine experimental issues like loading and cooling in such a geometry, micro-motion compensation, optimization of the focal position and detection schemes.

Q 23.47 Tue 18:00 P1

Towards Continuous Variable Quantum Information with trapped Ions — •Felix Just[1,2], Alessandro S. Villar[2], and Gerd Leuchs[1,2] — [1]Institut für Optik, Information und Photonik (IOIP), Universität Erlangen-Nürnberg, Staudtstr. 7/B2, 91058 Erlangen — [2]Max-Planck-Institut für die Physik des Lichts (MPL), Günther-Scharowsky-Str. 1/Bau 24, 91058 Erlangen

One approach to quantum information and quantum computation relies on physical systems with continuous degrees of freedom, or 'continuous variables'. In this context, one usually employs the quadratures of the light field as the physical implementation of quantum information. In this project, we investigate the preparation and manipulation of non-classical states using the vibrational modes (i.e. the position and momentum degrees of freedom) of a trapped Yb ion, which are formally identical to the quadratures of the electromagnetic field. The ionic internal degrees of freedom are utilised both for the readout of the motional state and for mediating interaction between different vibrational modes. We aim at preparing useful quantum states to demonstrate coherent control over a continuous variables system.

Q 23.48 Tue 18:00 P1

Generation of a light mode that couples efficiently to a dipole transition — •Andrea Golla[1,2], Benoît Chalopin[2], Robert Maiwald[1,2], Irina Harder[1], Markus Sondermann[1,2], and Gerd Leuchs[1,2] — [1]Institut für Optik, Information und Photonik (IOIP), Universität Erlangen-Nürnberg, Staudtstr. 7/B2, 91058 Erlangen — [2]Max-Planck-Institut für die Physik des Lichts (MPL), Günther-Scharowsky-Str. 1/Bau 24, 91058 Erlangen

For perfect coupling of light with an atomic transition the light field must be mode matched to the atomic radiation pattern. Localizing an atom with a linear dipole transition inside a deep parabolic mirror enables efficient absorption of a single-photon wave packet in free space. A linear dipole field radiated by the atom is transformed after reflecting off the parabolic mirror into a transverse mode very close to a radially polarized doughnut mode. We demonstrate the generation of such a mode at the transition wavelength with the optimum size for our focusing geometry, envisioning 98% overlap with the atomic dipole radiation.

Imperfections of the mirror surface induce errors on the phase front. We show that by inserting a phase plate fabricated to fit to the specific mirror these aberrations are corrected such that the focal intensity reaches more than 90% of the diffraction limited case.

For the perfect absorption of photons, also the temporal shape of the wave packet must be tailored to the transition, requiring an exponentially increasing envelope. This is achieved with the modulation of highly attenuated continuous wave laser beams.

Q 23.49 Tue 18:00 P1

Coherent spin dynamics in isotopically pure diamond — •Helmut Fedder[1], Jan Honert[1], Michael Klas[1], Florian Dolde[1], Junichi Isoya[3], Matthew Markham[2], Daniel Twitchen[2], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]Universität Stuttgart, 70550 Stuttgart, Germany — [2]Element Six Ltd, Ascot, UK — [3]Graduate School of Library, Information and Media Studies, University of Tsukuba, 1-2 Kasuga, Tsukuba, Japan

Nitrogen-Vacancy (NV) centers in diamond are promising solid-state spin system for applications in quantum information and communication, that allow optical readout and coherent spin manipulation even at room temperature. Of pivotal importance for scalable NV based quantum architectures is a long spin coherence time in the diamond host material. In diamond, spin coherence is typically limited by coupling of the NV centers to adjacent 13C nuclear spins, that occurr with a natural abundance of 1.1%. Here we present our recent results towards ultralong coherent spin dynamics in isotopically pure diamond, and their application to magnetic-dipole type spin-spin entanglement. We find that spin coherence times get close to the limit set by spin-lattice relaxation. Complementary, we study the decoupling of the electron spin from magnetic fluctuations through |+> and |-> type excitations in 'dirty' diamond host material under zero magnetic field conditions. We give an account of the resulting perspectives for quantum gate operations using bias field switching.

Q 23.50 Tue 18:00 P1

Trapped ions as quantum bits: Essential numerical tools — •Kilian Singer[1], Ulrich G. Poschinger[1], Michael Murphy[2], Frank Ziesel[1], Tommaso Callarco[2], and Ferdinand Schmidt-Kaler[1] — [1]Universität Mainz, Staudingerweg 7, 55128 Mainz — [2]Universität Ulm, Albert-Einstein-Allee 11, 89069 Ulm

We present powerful numerical tools for the optimization of the external control of the motional and internal states of trapped neutral atoms, explicitly applied to the case of trapped laser-cooled ions in a segmented ion-trap [1]. We then solve inverse problems, when optimizing trapping potentials for ions. Optimizing a quantum gate is realized by the application of quantum optimal control techniques. The numerical methods presented can also be used to gain an intuitive understanding of quantum experiments with trapped ions by performing virtual simulated experiments on a personal computer [2].

[1] K. Singer, U. G. Poschinger, M. Murphy, P. Ivanov, F. Ziesel, T. Calarco, F. Schmidt-Kaler, Rev. Mod. Phys. 82, 2609 (2010). [2] http://kilian-singer.de/ent

Q 23.51 Tue 18:00 P1

Ultra-bright and compact fibre coupled single photon source based on a defect centre in diamond using a solid immersion lens — •Friedemann Gädeke, Tim Schröder, and Oliver Benson — AG Nano Optics, Institut für Physik, Humboldt Universität zu Berlin, Newtonstr. 15, 12489 Berlin

Single photons are fundamental elements for quantum information technologies such as quantum cryptography, quantum information storage and optical quantum computing. Colour centres in diamond have proven to be stable single photon sources and thus essential components for reliable and integrated quantum information technology. A key requirement for such applications is a large photon flux and a high efficiency. We present an ultra bright and very compact single photon source based on nitrogen-vacancy defect centres in nanodiamonds. To increase the photon flux we used a hemispheric solid immersion lens made of ZrO_2. The nanodiamonds were spin-coated on the flat surface of the solid immersion lens. We found stable count rates of up to 853 kcts/s and have access to more than 100 defect centres with count rates between 400 kcts/s and 500 kcts/s. We also found a blinking defect centre with a count rate of 2.4 Mcts/s for time intervals of several ten seconds at saturation intensity. At pulsed excitation with 10 MHz we got count rates of up to 221 kcts/s indicating a detection efficiency of 2.2 %. For flexible operation we intend to integrate excitation, collection and fibre coupling into a very compact device with a size of about 30 cm x 11 cm x 5 cm.

Q 23.52 Tue 18:00 P1

Quantum interference and non-locality of independent photons from disparate sources — •Ralph Wiegner[1], Joachim von Zanthier[1], and Girish Agarwal[2] — [1]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, Erlangen, Germany — [2]Department of Physics, Oklahoma State University, Stillwater, OK, USA

We quantitatively investigate the non-classicality and non-locality of a whole new class of mixed disparate quantum and semiquantum photon sources at the quantum-classical boundary (arXiv:1005.4176v1). The key quantity in our investigations is the visibility of the corresponding photon-photon correlation function. We present explicit results on the violations of the Cauchy-Schwarz inequality - which is a measure of nonclassicality - as well as of Bell-type inequalities for path correlations rather than for polarization correlations.

Q 23.53 Tue 18:00 P1

Interaction of two-level atoms with circularly polarized light — •Armen Hayrapetyan[1] and Stephan Fritzsche[2,3] — [1]Max-Planck-Institut für Kernphysik, Postfach 103980, D-69029 Heidelberg, Germany — [2]Department of Physics, P.O. Box 3000, Fin-90014 University of Oulu, Finland — [3]GSI Helmholtzzentrum für Schwerionenforschung, D-64291 Darmstadt, Germany

The interaction of two-level atoms with circular-polarized light is examined to explore how the polarization properties of the light affect the population dynamics of the atoms. Equations are presented and discussed for the probability amplitudes of the atomic levels. It is shown that the inversion in the population in two-level atoms depends on both, the space and time coordinates, and can be expressed in terms of the invariant phase of the light.

Q 23.54 Tue 18:00 P1

How well can photons change their colour - about the efficiency of single photon frequency down-conversion — •Susanne Blum[1], Georgina Olivares-Rentería[2,3], Carlo Ottaviani[3], Sebastian Zaske[1], Christoph Becher[1], and Giovanna Morigi[1,3] — [1]Universität des Saarlandes, Germany — [2]Universidad de Concepción, Chile — [3]Universitat Autònoma de Barcelona, Spain

Efficient single photon transmission in future quantum networks requires wavelengths in the low loss band of optical fibres. Currently most single photon sources do not emit in this spectral region, but rather in the red or near-infrared. We analyse theoretically the conversion efficiency of single photons into the low-loss band at 1550nm, when using difference frequency generation in a $\chi^{(2)}$ material. For this purpose we use Heisenberg-Langevin equations for the signal, idler, and pump fields, in the limit of a strong classical signal field. We consider the effects of quantum noise sources, e.g. photon loss in pump and idler modes, and photon generation at 1550nm due to optical parametric fluorescence. From this model we study the efficiency of the single photon down-conversion process by determining the value of intensity-intensity correlations at zero delay and the influence of quantum noise sources on photon correlation funtions.

Q 23.55 Tue 18:00 P1

Towards coupling of a single N-V center in diamond to a fiber based micro- cavity — •Roland Albrecht[1], Christian Deutsch[2], Jakob Reichel[2], Tim Schröder[3], Rico Henze[3], Oliver Benson[3], and Christoph Becher[1] — [1]Fachrichtung 7.2, (Experimentalphysik), Universität des Saarlandes, Campus E2.6, 66123 Saarbrücken — [2]Laboratoire Kastler Brossel, ENS/UPMC-Paris 6/CNRS, 24 rue Lhomond, 75005 Paris, France — [3]Institut für Physik, AG Nanooptik, Humboldt-Universität zu Berlin, Newtonstraße 15, 12489 Berlin

Coupling a single N-V center in diamond to a micro-cavity is a crucial step towards sucessful implementation of many quantum information protocols.[1] We here investigate fiber based Fabry Perot cavities which consist of a flat dielectric mirror and an optical fiber. N-V centers in diamond nanocrystals are deposited onto the flat mirror by spin coating. This cavity design has several advantages: it is tunable, can be scanned transversally and is automatically fiber-coupled with very good efficiency. To achieve stable cavities, a concave impression has been produced on the fiber facet by laser machining prior to deposition of a dielectric coating. As a second approach for fabrication of the concave mirror we investigate focused ion beam milling of tapered fibers, allowing for enhanced design flexibility. Cavities using mirrors with radii of curvature of about 50 μm, with a finesse of up to 3000 and a length of 5 μm have been realized. We observe emission of a single N-V center into the fiber cavity.

[1] S. Prawer and A.D. Greentree, Science 320, 1601 (2008)

Q 23.56 Tue 18:00 P1

Optimal pulse shaping for excitation of single atoms in free-space. — •Dao Hoang Lan, Syed Abdullah Aljunid, Brenda Chng, Gleb Maslennikov, and Christian Kurtsiefer — Centre for Quantum Technologies / Dept. of Physics, National University of Singapore

Recent theoretical works suggest that an optimal excitation of single atoms can be performed by optical pulses that are time reversed replica of spontaneously emitted light [1,2]. In the time domain this would constitute a pulse with an envelope given by rising exponential function, followed by a fast drop. The time constant τ_c of such exponential pulse should correspond to the lifetime of atomic excited state. We present an experimental implementation based on an electronic circuit that allows to generate electrical pulses with $\tau_c = 27$ ns which is compatible to the D2 transition in ^{87}Rb. The output of the circuit is multiplied with an RF carrier at 1.5 GHz and the resulting product sent to a fast Electro-Optical Modulator to change the phase of a cw laser beam. One of the corresponding optical sidebands is selected by a filter cavity, effectively preparing an optical pulse with the desired exponential envelope and the corresponding Lorentzian spectrum. The scheme has a high on/off ratio for the optical pulses, since all the switching can be done by toggling the RF oscillator. We discuss the implementation of this scheme in free-space atom-photon interfaces.

[1] M. Stobinska, G. Alber and G. Leuchs, Euro. Phys. Lett **86**, 14007 (2009)
[2] Y. Wang, L. Sheridan and V. Scarani, arXiv:1010:4661v1 (2010)

Q 23.57 Tue 18:00 P1

Probing the Wigner function of pulsed single photons point-by-point — Kaisa Laiho[1], •Georg Harder[2], Katiuscia N. Cassemiro[1], David Gross[3], and Christine Silberhorn[1,2] — [1]MPI for the Science of Light, Erlangen, Germany — [2]Applied Physics, University of Paderborn, Germany — [3]Institute for Theoretical Physics, ETH Zürich, Switzerland

Quantum tomography is essential in different quantum optical applications. The standard technique, homodyne detection, allows the characterization of quantum states and processes in terms of the Wigner function. However, the determination of the properties at a single point in phase space with homodyne detection requires tomographical reconstruction, since the Heisenberg's uncertainty principle precludes the simultaneous measurement of non-commuting field quadratures.

Nevertheless, the evaluation of the Wigner function point-by-point is possible by measuring the mean value of parity operator. An all optical implementation of this *direct probing* scheme requires a realization of displacement operator and photon counter. We have implemented this scheme and measured the phase-averaged Wigner function of spectrally broadband, pulsed single photons at individual points in phase space [1]. Our results verify the non-classicality of the prepared single-photon state. Since the measurement is sensitive to all signal modes, it can uncover the single-mode properties of the signal in spatiotemporal degrees of freedom. Furthermore, it allows us to directly investigate the statistics of displaced states.

[1] K. Laiho, *et al.*, Arxiv:1010.1208 (2010)

Q 23.58 Tue 18:00 P1

An optimized 1560nm polarization squeezer for quantum information protocols — •Christian Gabriel[1,2], Joel F. Corney[3], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Insitute for the Science of Light, Günther-Scharowsky-Strasse 1, D-91058 Erlangen, Germany — [2]Institute for Optics, Information and Photonics, University Erlangen-Nuremberg, Staudtstrasse 7/B2, D-91058 Erlangen, Germany — [3]ARC Centre of Excellence for Quantum-Atom Optics, School of Physical Sciences, The University of Queensland, Brisbane, QLD 4072, Australia

We investigate polarization squeezing with ultrashort pulses in optical fibers over a wide range of input energies, pulse lengths and fibre lengths. We present first experimental results of how an optimization of all these parameters gives rise to highly efficient polarization squeezing. The optimization is based on quantum mechanical simulations which reveal the influence of phase noise and Raman effects on the squeezing. This squeezing source can be used for quantum information protocols, ranging from squeezing and entanglement distillation to actual quantum communication with squeezed and entangled states over a realistic freespace link.

Q 23.59 Tue 18:00 P1

Einfluss der Photonenstatistik auf die Kalibrierung von Einzelphotonendetektoren — •Waldemar Schmunk, Silke Peters, Mark Rodenberger, Helmuth Hofer und Stefan Kück — Physikalisch-Technische Bundesanstalt, 38116 Braunschweig

In den sich rasch entwickelnden Anwendungsgebieten der Einzelphotonentechnik, wie z.B. der Quantenoptik und -kryptographie gewinnen radiometrische Fragestellungen zunehmend an Bedeutung. Dabei gehört die Detektionsseffizienz von Einzelphotonendetektoren zu den wichtigen Kenngrössen, welche unter anderem durch die Photonenstatistik des eingestrahlten Lichts beeinflusst wird. Denn im Gegensatz zu analogen registrieren digitale Detektoren das gleichzeitige Eintreffen mehrerer Photonen als ein Einphoton-Ereignis, was zu Fehleinschätzungen der gemessenen Detektionseffizienzen bei der Kalibrierung führen kann. Die Kalibrierung erfolgt hier mittels einer radiometrischen Methode aus dem Bereich der fasergekoppelten Detektoren. Untersucht wird der Einfluss der Photonenstatistik auf die Bestimmung der relativen Detektionseffizienz von SPADs. Eine Lampe, ein Laser sowie eine Einzelphotonenquelle ($g^{(2)}(0) = 0,15$) erzeugen die benötigte Strahlung. Übereinstimmend mit den Vorhersagen einer Modellierung zeigt sich, dass sich die mit Laser und Lampe gemessenen relativen Detektionseffizienzen von $0,165 \pm 0,002$ sowie $0,161 \pm 0,001$ signifikant von denen der nicht-klassischen Einzelphotonenquelle von $0,122 \pm 0,001$ unterscheiden. Die vorliegende Arbeit diskutiert in wie weit die Photonenstatistik für die gemessenen Abweichungen verantwortlich ist und gibt einen Ausblick auf die Realisierung einer absoluten Rückführung.

Q 23.60 Tue 18:00 P1

Correlation measurements on optical fields from a Whispering Gallery Mode Optical Parametric Oscillator — •Gerhard Schunk[1,2], Josef Fürst[1], Dmitry Strekalov[1,3], Michael Förtsch[1], Ulrik L. Anderson[1,4], Andrea Aiello[1], Christoph Marquardt[1], and Gerd Leuchs[1] — [1]Max Planck Institute for the Science of Light, Institute for Optics, Information and Photonics, University Erlangen-Nuremberg, Erlangen, Germany, — [2]Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany — [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA — [4]Department of Physics, Technical University of Denmark, Kgs. Lyngby, Denmark

The second order optical nonlinear process of parametric down conversion (PDC) has successfully been demonstrated in a z-cut Lithium Niobate whispering gallery mode (WGM) resonator. Inherently, PDC affects the quantum properties of the interacting fields, where squeezing and entanglement can be observed. PDC becomes very efficient, in particular as our WGM resonator provides a high Q-factor and small optical mode volume. This makes WGM resonators attractive for applications like Quantum Information Processing and quantum sensing.

Our present focus is to study and optimize the quantum properties of the signal and idler beams in our above threshold WGM optical parametric oscillator. For this goal we work on the improvement of the detector design and aim for further investigations of the parameter space accessible in our WGM setup. We will report on the latest results of the project.