Q 35: Poster 2

Time: Wednesday 16:30–19:00 Location: Poster.I+II

Q 35.1 Wed 16:30 Poster.I+II

Propagation effects of pulsed Rydberg excitations in thermal vapor — •Fabian Ripka, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart

We present numerical simulations of three-level Maxwell-Bloch equations and examine propagation effects of a pulsed two-photon Rydberg excitation in thermal atoms. This work is related to the recent observation of Rabi oscillations to Rydberg states in thermal vapor [1]. While the latter could be reproduced neglecting spatial dependency, we show that for high optical densities and/or low Rabi frequencies effects of light propagation have to be taken into account. Finally we compare our simulations to corresponding experimental results.

[1] B. Huber et al., *Phys. Rev. Lett.* **107**, 243001 (2011)

Q 35.2 Wed 16:30 Poster.I+II

Experimental quantum measurement reversal using quantum error correction — Philipp Schindler[1], Julio Barreiro[1], •Daniel Nigg[1], Michael Chwalla[1,2], and Rainer Blatt[1,2] — [1]Institut fuer Experimentalphysik, Universitaet Innsbruck, Technikerstrasse 25, A-6020 Innsbruck — [2]Institut fuer Quantenoptik und Quanteninformation der Oesterreichischen Akademie der Wissenschaften, Technikerstrasse 21a, A-6020 Innsbruck

We report on the reversal of a quantum measurement using a 3-qubit phase flip quantum error correction algorithm. This algorithm is capable of correcting phase flips and therefore also dephasing on a single qubit. A measurement in the computational basis (I_z) of a single qubit is described by a projection onto the corresponding axis of the Bloch sphere, which can also be interpreted as complete phase damping. This means that the measurement of a single qubit can be undone with a three qubit error correction code protecting against phase-flips. We use the algorithm presented in [1] and adapt it to be able to measure a single qubit once the information is encoded into the protected state. As measurements in ion trap quantum computers heat the motional state of the system it is necessary to re-cool the system before performing the correction step. This cooling has to be performed without affecting the quantum state of the qubits. We use the Raman cooling technique to re-cool the ion string within the sequence. We assess the fidelityof this measurement reversal using quantum process tomography.

[1] P. Schindler, et. al., Science **332**, 1059(2011)

Q 35.3 Wed 16:30 Poster.I+II

Extension of Landau-Khalatnikov Two-Fluid Model for Anisotropic Quantum Gases — •Carolin Wille[1] and Axel Pelster[2] — [1]Fachbereich Physik, Freie Universität Berlin, Germany — [2]Hanse-Wissenschatskolleg, Delmenhorst, Germany

Dipolar Bose-Einstein condensates (BEC) at zero temperature with weak disorder [1] as well as at finite temperature without disorder [2] possess anisotropic superfluid properties which are not described by the standard hydrodynamic Landau-Khalatnikov (LK) theory. In order to cope with a tensorial superfluid density, we extend the LK equations by working out and comparing two different methods – first by Hamilton's principle of least action and second by a conservation law approach analog to the initial work of Landau and Khalatnikov. Finally, a linearization of the extended LK equations yields the first and second sound with a characteristic direction dependence which can be further specialized for a dipolar BEC.

[1] C. Krumnow and A. Pelster, Phys. Rev. A **84**, 021608(R) (2011).
[2] T. Checinski and A. Pelster, to be published.

Q 35.4 Wed 16:30 Poster.I+II

Long-distance entanglement between two defects embedded in a linear chain of ions — •Endre Kajari[1], Thomas Fogarty[2], Bruno Taketani[1], Alexander Wolf[3], Thomas Busch[2], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66041 Saarbrücken, Germany — [2]Physics Department, University College Cork, Cork, Ireland — [3]Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

Decoherence is generally considered as major obstacle for the observation of quantum effects in the macroscopic world and its description within the framework of open quantum systems has attracted a lot of attention. However, there exist scenarios in which the coupling of a small system to a quantum reservoir supports the occurrence of quantum effects. Along these lines, it has been recently shown that it is possible to generate long-distance entanglement between two remote oscillators that couple indirectly via a harmonic chain [1]. In this talk, we present an experimentally feasible setup to test the creation of long-distance entanglement. For this purpose, we consider an ion chain in a linear Paul trap with two embedded impurities, whose transverse modes are the two degrees of freedom that we aim to entangle via the rest of the chain. With the help of appropriately designed laser fields, the dynamics of [1] can be recovered. The resulting entanglement between the transverse modes of the impurities is analyzed by means of the logarithmic negativity.

[1] A. Wolf, G. de Chiara, E. Kajari, E. Lutz and G. Morigi, EPL **95**, 60008 (2011).

Q 35.5 Wed 16:30 Poster.I+II

Fractional photon-assisted tunnelling of ultra-cold atoms — Martin Esmann[1,2], Jonathan D. Pritchard[3], Niklas Teichmann[2], and •Christoph Weiss[2,4] — [1]Physics Department, Harvard University, Cambridge, MA 02138, USA — [2]Institut für Physik, Carl von Ossietzky Universität, D-26111 Oldenburg, Germany — [3]Department of Physics, University of Strathclyde, Glasgow, G4 0NG, United Kingdom — [4]Department of Physics, Durham University, Durham DH1 3LE, United Kingdom

Fractional photon-assisted tunnelling is investigated both numerically and analytically in a periodically shaken double-well lattice [1,2]. While integer photon-assisted tunnelling is a single-particle effect, fractional photon-assisted tunnelling is an interaction-induced manybody effect. Far from being the small effect reported previously, we predicted [1] that the one-half-photon resonance is a large effect. This has subsequently been observed experimentally [3].

Fractional photon-assisted tunnelling provides a physically relevant model for which N-th order time-dependent perturbation theory can be large although all previous orders are small [2]. All predicted effects will be observable with an existing experimental setup [3].

[1] M. Esmann, N. Teichmann and C. Weiss, Phys. Rev. A **83**, 063634 (2011).
[2] M. Esmann, J. Pritchard and C.Weiss, Laser Phys. Lett., in press, arXiv:1109.2735 (2011).
[3] Y.-A. Chen *et al.*, Phys. Rev. Lett. **107**, 210405, (2011).

Q 35.6 Wed 16:30 Poster.I+II

Dynamics of Atoms in a Hamiltonian Quantum Ratchet — •Martin Leder, Tobias Burgermeister, Tobias Salger, Sebastian Kling, Christopher Grossert, and Martin Weitz — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn, Germany

Ratchets are devices that are able to generate a directed motion of particles in a fluctuating environment without any gradients or net forces. In order to observe the ratchet effect, one has to break the spatiotemporal symmetry of the system [1]. We have experimentally realized a Hamiltonian Quantum Ratchet [2]. Directed motion of a ^{87}Rb Bose-Einstein condensate is achieved by asymmetrically modulating the ampltitude of the ratchet potential.

Furthermore Absolute Negative Mobility (ANM), a counterintuitive motion against an external bias force, is presented. This effect has also been investigated with ac-driven systems in general.

[1] S. Denisov et al., Phys. Rev. A **75**, 063424 (2007)
[2] T. Salger et al., Science **326**, 1241 (2009)

Q 35.7 Wed 16:30 Poster.I+II

Quasi-particle Theory of strongly correlated Lattice Bosons - Application to the Bose-Hubbard Model — •Michael Buchhold, Ulf Bissbort, and Walter Hofstetter — Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, D-60438 Frankfurt/Main, Germany

We present a quasi-particle theory for strongly interacting lattice bosons, which, in contrast to Bogoliubov theory, is also valid for strong depletion of the condensate and in the Mott insulating phase. The derivation is based on the linearization of the equations of motion for a Gutzwiller variational state and a quantization of the classical amplitudes of the resultant excitations.

Within this theory of non-interacting quasi-particles, we calculate

the single-particle spectral function of the single-band Bose-Hubbard model. In addition to the gapless Bogoliubov mode, we also clearly resolve the amplitude mode, which becomes particularly relevant in the strongly correlated regime, in the vicinity of the superfluid-Mott transition. Subsequently we express physical operators in terms of quasi-particles, which directly reveals the coupling to the system's eigenmodes. In particular, we demonstrate this for the Bragg operator in lattice representation.
Our first application beyond theories of non-interacting quasi-particles is to take higher order terms into account which we initially neglected in the derivation. We determine the quasi-particle lifetimes as well as the induced broadening of the spectral function.

Q 35.8 Wed 16:30 Poster.I+II

Perfect conducting channel in two-dimensional random lattices with XY-disorder and engineered hopping amplitudes — •Alberto Rodriguez[1], Arunava Chakrabarti[2], and Rudolf A. Römer[3] — [1]Phisikalisches Institut, Albert-Ludwigs Universität Freiburg, Hermann-Herder Strasse 3, D-79104, Freiburg, Germany — [2]Department of Physics, University of Kalyani, Kalyani, West Bengal-741 235, India — [3]Department of Physics and Centre for Scientific Computing, University of Warwick, Coventry, CV4 7AL, United Kingdom

We study the spectral and transport properties of two-dimensional lattices with random on-site energies $\epsilon_{x,y}$, and random vertical hopping amplitudes $\gamma_{(x,y)\to(x,y+1)}$. The disorder in the system is defined by three independent random sequences $\{\alpha_x\}, \{\beta_y\}, \{\xi_y\}$, in the following way: $\epsilon_{x,y} = \alpha_x\beta_y$, and $\gamma_{(x,y)\to(x,y+1)} = \alpha_x\xi_y$. By engineering the random distribution ξ_y, a full band of Bloch states emerges in the spectrum, and a perfect conducting channel in the x direction is induced in the system. We describe how to create the conductance channel in finite systems, and we study its robustness against deviations from the ideal requested values for ξ_y. Remarkably, we demonstrate that the channel persists in the thermodynamic limit —for the infinite two-dimensional system—. Furthermore, we also discuss how to modify the localization of the eigenstates almost at will in the x and y directions. Our results are constructed analytically and supported by extensive numerical calculations of localization lengths, conductance and density of states.

Q 35.9 Wed 16:30 Poster.I+II

Orbital Physics with Ultracold Atoms in Higher Bands of an Optical Lattice — •Thorge Kock, Matthias Ölschläger, Georg Wirth, and Andreas Hemmerich — Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Atoms trapped in optical lattices have been used successfully to study many-body phenomena. But the positive definite ground-state wavefunction of bosons limits their usefulness for simulating many-body systems of interest. Such limitations, however, do not apply to excited states of bosons.

Using a two-dimensional optical square lattice with adjustable time phase difference, we can selectively excite a large fraction of atoms into higher bands by means of a population swapping technique, where a collision-aided condensation to the band minima reestablishes coherence. Depending on the involved band and the lattice configuration, we can realize real-valued striped superfluid order parameters, or complex-valued order parameters which break time reversal symmetry.

Lifetimes of higher bands of up to 150 ms allow us to study the nature of the order parameter in the second band and phenomena like a topologically induced avoided band crossing between the 3rd and 4th band of our chequerboard lattice.

Q 35.10 Wed 16:30 Poster.I+II

Renormalization of Hubbard models for optical lattices — •Ole Jürgensen, Dirk-Sören Lühmann, and Klaus Sengstock — Institut für Laser-Physik, Universität Hamburg

Ultracold atoms in optical lattices are often described by means of single-band Hubbard models that are restricted to on-site interactions. Off-site interactions lead to an additional tunneling process, so-called bond-charge interactions that can be identified with an effective tunneling potential.

We apply a fully correlated treatment to derive an extended model that includes off-site interactions, as well as higher-orbital processes [1,2]. The effective tunneling in optical lattices is found to deviate significantly from the commonly applied Hubbard models.

Using this model, we analyse the superfluid to Mott-insulator transition for a purely bosonic system as well as for Bose-Fermi mixtures. The corresponding phase diagrams are strongly influenced by the above extensions, which corresponds to a considerable shift of the critical lattice depth of the transition.

The presented results cast new light on the importance of higher bands and off-site interactions for ultracold atoms in optical lattices.

[1] D.-S. Lühmann et al., arxiv: 1108.3013
[2] U. Bissbort et al., arxiv: 1108.6047

Q 35.11 Wed 16:30 Poster.I+II

Quantum magnetism of bosons in hexagonal optical lattices — •Eva-Maria Richter[1], Dirk-Sören Lühmann[2], and Daniela Pfannkuche[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Germany — [2]Institut für Laser-Physik, Universität Hamburg, Germany

Ultracold quantum gases in optical lattices open many new perspectives for the investigation of quantum behaviour in condensed-matter physics under ideal circumstances. Our concern is directed to the effects of finite-size systems. Starting from the Bose-Hubbard-Hamiltonian and within the framework of exact diagonalization for finite systems with periodic boundary conditions we investigate the magnetic phases in a hexagonal optical lattice with triangular sublattice structure. We study the finite-size effects of different sized unit cells in the case of a two-component Bose mixture in the deep Mott phase. For our model an effective spin-Hamiltonian can be derived in second order pertubation theory by a Schrieffer-Wolff-transformation in the limit of U>>J. The investigation of next-neighbour correlation functions within our two-component system therefore unravels ferro- or antiferromagnetic ordering in the according isospin hamiltonian. A ferro-antiferromagnetic transitions is investigated for different parameters and different unit cells, exhibiting the influence of finite sample sizes. We also implement an additional rotating magnetic field in the plane of the lattice to investigate spin transport.

Q 35.12 Wed 16:30 Poster.I+II

An optical lattice of tunable topology for ultracold fermions — •Thomas Uehlinger, Leticia Tarruell, Daniel Greif, Gregor Jotzu, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

Ultracold Fermi gases have emerged as a versatile tool to simulate condensed matter phenomena. For example, the control of interactions in optical lattices has lead to the observation of Mott insulating phases. However, the topology of the lattice is equally important for the properties of a solid. A prime example is the honeycomb lattice of graphene, where the presence of topological defects in momentum space - the Dirac points - leads to extraordinary transport properties.

We report on the observation of Dirac points of a quantum degenerate Fermi gas of ^{40}K atoms confined in the honeycomb structure of an optical lattice with tunable topology. The lattice is created by superimposing a square lattice with an interfering superlattice, which can be continuously adjusted to create square, triangular, dimer und honeycomb structures. We change the effective mass of the fermions by breaking the lattice inversion symmetry. As we adjust the lattice anisotropy we move the Dirac points in the Brillouin zone and observe the topological transition to a lattice structure without Dirac points. We also report on recent progress on the investigation of this novel lattice.

Q 35.13 Wed 16:30 Poster.I+II

Dynamics of bosons with tunable interactions in optical lattices — •Jens Philipp Ronzheimer[1,2], Simon Braun[1,2], Michael Schreiber[1,2], Sean Hodgman[1,2], Tim Rom[1,2], Ulrich Schneider[1,2], and Immanuel Bloch[1,2] — [1]LMU München — [2]MPQ Garching

We prepare a Bose-Einstein Condensate of K^{39} and load it into a blue detuned optical lattice. Employing a broad Feshbach resonance in combination with confining potentials from red detuned dipole traps and anti-confining potentials from the lattice beams, we are able to control all parameters of the Bose-Hubbard Hamiltonian describing the system. In addition to presenting equilibrium states of the system, i.e. mapping out the SF-to-MI transition for different interaction strengths, we will show our latest results on the dynamics of out-of-equilibrium states and compare them to previous results on the dynamics of fermions.

Q 35.14 Wed 16:30 Poster.I+II

Shaking Optical Lattices: From Frustrated Magnetism to

Synthetic Gauge Fields — •Christoph Ölschläger[1], Julian Struck[1], Malte Weinberg[1], Juliette Simonet[1], André Eckardt[2], Patrick Windpassinger[1], and Klaus Sengstock[1] — [1]Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Max-Planck-Institut für Physik komplexer Systeme, Noethnitzer Strasse 38, 01187 Dresden, Germany

Ultracold quantum gases in optical lattices are well suited to investigate and simulate systems known from solid state physics.

Here we report on the experimental realization of frustrated classical magnetism in triangular optical lattices as well as tuneable artificial gauge fields in one-dimensional optical lattices with ultracold atoms. First, by applying a time-reversible, periodic force to spinless bosons, it is possible to change the order and sign of the tunneling matrix elements between adjacent lattice sites in a wide range. In a triangular optical lattice we observe different non-ferromagnetic phases that can be described in analogy to classical magnetism.

Second, by inducing a time-irreversible, periodic force, we present the possibility to create complex-valued tunneling matrix elements, where the resulting Peierls phase can be tuned between zero and two pi. With this we are able to realize a synthetic gauge field in a one dimensional optical lattice, which leads to the observation and analysis of ground state superfluids at arbitrary, finite quasi momentum. Extending these methods to triangular optical lattices, it is possible to create staggered magnetic fields with large fluxes per plaquette.

Q 35.15 Wed 16:30 Poster.I+II

Equilibration versus thermalization in the Bose- and Fermi-Hubbard model — •Friedemann Queisser[1], Patrick Navez[2], Konstantin Krutitsky[1], and Ralf Schützhold[1] — [1]Fakultät für Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47057 Duisburg, Germany — [2]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

The question of whether and how strongly interacting many-body quantum systems equilibrate and thermalize is still not well understood. To gain some insight, we study the Bose-Hubbard model after a quantum quench within the Mott phase. Via an $1/Z$-expansion into inverse powers of the coordination number Z, we calculate the time-dependence of the on-site density matrix and the two-point-correlations. It turns out that these observables settle down to some quasi-stationary state, but this state is not thermal. Thus, thermalization (if it occurs) takes much longer than this equilibration process. Analogous results are obtained for the Fermi-Hubbard model when the system is initially in its ground state at half filling.

References: Phys. Rev. A **82**, 063603 (2010)

Q 35.16 Wed 16:30 Poster.I+II

Exploring cavity-mediated long-range interactions in a dilute quantum gas — •Rafael Mottl, Kristian Baumann, Renate Landig, Ferdinand Brennecke, Tobias Donner, and Tilman Esslinger — Quantum Optics Group, ETH Zurich, Switzerland

We create a Bose-Einstein condensate with long-range atom-atom interactions which are mediated by the vacuum field of an optical cavity. These long-range interactions lead to a phase transition (equivalent to the Dicke quantum phase transition) between a normal and a supersolid phase, where the atoms arrange on a checkerboard lattice. We report on the observation of a characteristic change in the excitation spectrum and increased density fluctuations due to the long-range interactions. The openness of the cavity allows for time-resolved information about the density fluctuations.

Q 35.17 Wed 16:30 Poster.I+II

An experiment for the study of artificial gauge fields with ultracold ytterbium atoms — •Matthias Scholl, Alexandre Dareau, Daniel Döring, Jérôme Beugnon, Jean Dalibard, and Fabrice Gerbier — Laboratoire Kastler Brossel, Ecole Normale Supérieure, Paris, France

I will present an experiment aiming at realizing artificial gauge fields for ultracold neutral atoms in an optical lattice. Combining intense gauge fields with strong on-site interactions should allow to explore atomic analogs of fractional quantum Hall systems [1]. Moreover, the scheme can be extended to realize non-Abelian gauge fields [2].

We have chosen Ytterbium (Yb) as the atomic species for our experiment. The metastable state 3P0 (lifetime 16s) allows the implementation of a two-dimensional optical lattice, where the ground and excited states arrange in spatially separated sublattices. Optical coupling of the two states enables tunneling between the sublattices, imprinting the laser phase on the atomic wavefunction. The resulting geometrical phase felt by the atoms is equivalent to the Aharonov-Bohm phase of a charged particle in a magnetic field. The availability of fermionic and bosonic isotopes makes Yb a well-suited choice.

I will present the first results of an apparatus to produce degenerate Ytterbium quantum gases and describe the experimental techniques to implement laser-induced vector potentials.

[1] Sorensen et al.,Phys. Rev. Lett. 94, 086803 (2005)
[2] Osterloh et al., Phys. Rev. Lett. 95, 010403 (2005)
[3] Jaksch and Zoller, New J. Phys. 5 56 (2003)

Q 35.18 Wed 16:30 Poster.I+II

Position-dependent spin-orbit coupling for ultracold atoms — •Simonas Grubinskas[1], Ian Spielman[2], and Gediminas Juzeliunas[1] — [1]Institute of Theoretical Physics and Astronomy, Vilnius University, A. Goštauto 12, LT-01108 Vilnius, Lithuania — [2]Joint Quantum Institute, National Institute of Standards and Technology, and University of Maryland, Gaithersburg, Maryland, 20899, USA

Recently several schemes have been proposed to create the spin-orbit coupling (SOC) of the Rashba-Dresselhaus (RD) type for ultracold atoms illuminated by several laser beams [1]. This leads to numerous interesting phenomena such as a non-conventional atomic Bose-Einstein condensation for ultracold atoms affected by the SOC. Here we explore effects due to the position-dependence of the spatial profiles of the laser fields inducing the SOC. We show that the spatial-dependent laser beams can provide the Lorentz force in additional to the SOC. Subsequently we analyze a combined action of the contributions due to the Lorentz force and the SOC. [1] J. Dalibard, F. Gerbier, G.Juzeliunas, and P.Ohberg. Artificial gauge potentials for neutral atoms. Rev. Mod. Phys. 83 1523 (2011).

Q 35.19 Wed 16:30 Poster.I+II

2D discrete quantum simulators — •Stefan Brakhane, Anna Hambitzer, Andrea Alberti, Wolfgang Alt, and Dieter Meschede — Institut für Angewandte Physik der Universität Bonn,Wegelerstr. 8,53115 Bonn

In recent years atoms in 2D optical lattices have gained much interest for simulating complex physical phenomena from solid state physics. The detection and coherent manipulation of atoms have advanced to the point that individual atoms can be addressed with single lattice site resolution. By controlling the polarization of the laser beams forming a 1D optical lattice, spin-dependent transport has been utilized to realize discrete quantum walks [1].

We report on a novel set-up featuring state-dependent transport in a 2D optical lattice with single side detection and addressing. This will be used as a discrete quantum simulator to investigate new physics, such as Dirac points in the dispersion relation of 2D quantum walks, artificial gauge potentials, and quantum information processing based on a "one-way" quantum computer.

[1] Karski et al. *Quantum Walk in Position Space with Single Optically Trapped Atoms*, Science **325**, 174 (2009)

Q 35.20 Wed 16:30 Poster.I+II

Optimization of Imaging Systems for Cold Quantum Gases — •Cristina Gherasim and Reinhold Walser — Institute for Applied Physics, TU Darmstadt, Germany

Optimizing the quality of imaging systems is of crucial importance for any precision measurement for cold quantum gas experiments. In the context of the QUANTUS experiment, a free falling atomic cloud is prepared in the drop tower of the Center of Applied Space Technology and Microgravity (ZARM) in Bremen [1]. We present a detailed analysis of the imaging system by performing geometrical ray-tracing as well as physical optics considering diffraction effects based on commercial software. Various examples of the simulation and optimization results are presented in analysis diagrams.

[1] T. van Zoest *et al*, Science, **328**, 1540 (2010).

Acknowledgments: This project is supported by the Deutsche Luft und Raumfahrt Agentur (DLR Grant: 50 WM 1137)

Q 35.21 Wed 16:30 Poster.I+II

Fast Feedback on a Single Neutral Atom — •Christian Sames, Markus Koch, Haytham Chibani, Tatjana Wilk, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany

We extend our feedback scheme, which was successfully implemented to cool the slow radial motion of an atom strongly coupled to a high-finesse optical cavity [1], to the atom's fast axial motion. The atom is caught in an intra-cavity optical dipole trap where the radial and axial trap frequencies differ by about two orders of magnitude. The interaction strength between the atom and the resonator depends on the atomic position and hence governs the intensity of a probe beam transmitted through the resonator. This leads to a modulation of the photon stream emitted from the cavity at two distinct frequencies, about 5 kHz for the radial and 500 kHz for the axial motion. The large difference enables to distinguish between these two frequencies. Despite of having less than one photon impinging on the detector per oscillation period we have first indication that with fast FPGA electronics it is possible to manipulate the fast axial motion. Furthermore, we report on first results obtained by performing a continuous heterodyne detection of the field instead of measuring the number of transmitted photons.

[1] M. Koch et al., Phys. Rev. Lett. 105, 173003 (2010).

Q 35.22 Wed 16:30 Poster.I+II

Feedback control of atomic spin states in an optical cavity — •Miguel Martinez-Dorantes[1], Stefan Brakhane[1], Wolfgang Alt[1], Tobias Kampschulte[1], Rene Reimann[1], Artur Widera[1,2], and Dieter Meschede[1] — [1]Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn — [2]Fachbereich Physik der TU Kaiserslautern, Erwin-Schrödinger-Str., 67663 Kaiserslautern

Detection and manipulation of atomic spin states is essential for many experimental realizations of quantum gates. Feedback schemes to stabilize the states and their superpositions can counteract perturbations caused by the environment.

In our experiment we deduce the atomic spin states of one and two Caesium atoms by measuring the transmission of a probe laser through a high-finesse cavity. A digital signal processor calculates time-dependent probabilities for the spin states in real-time utilizing a Bayesian update formalism [1]. Furthermore, we can use these probabilities for a feedback loop which allows us to experimentally create and stabilize any arbitrary mixture of atomic spin states inside the cavity.

[1] S. Reick, K. Mølmer *et al.*, J. Opt. Soc. Am. B **27**, A152 (2010)

Q 35.23 Wed 16:30 Poster.I+II

Towards coherent interaction between single neutral atoms and a BEC — •Michael Bauer, Shrabana Chakrabarti, Philipp Franzreb, Benjamin Gänger, Farina Kindermann, Nicolas Spethmann, and Artur Widera — Technische Universität Kaiserslautern

Combining a single neutral atom with a quantum many body system, such as a Bose-Einstein condensate (BEC) poses a challenge, not only due to the different temperatures of both systems realized in experiments so far, but also because of the different measurement statistics and typical sequence durations. Studying the interaction of a single atom with a BEC requires many repetitions of the experimental cycle to obtain sufficient statistics. Thus it is essential to achieve short measuring times and therefore a high production rate of the BEC. Here we present a concept for a new setup capable of breeding an all optical BEC in less than 10 seconds and immersing single atoms into the ultracold quantum system.

Our setup will feature mechanisms for independently manipulating and detecting both single atoms and the BEC, thereby providing an unrivaled level of control over impurities in a quantum gas. Possible research directions include the investigation of coherent impurity physics and the creation and characterization of polarons in a BEC.

Q 35.24 Wed 16:30 Poster.I+II

Trion and Dimer Formation of three Fermions in an optical lattice — •Jan Pohlmann[1], Antonio Privitera[1,2], Irakli Titvinidze[1,3], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, 60438 Frankfurt am Main, Germany — [2]Democritos National Simulation Center, Consiglio Nazionale delle Ricerche Istituto Officina dei Materiali (IOM) and Scuola Internazionale Superiore di Studi Avanzati (SISSA), 34136 Trieste, Italy — [3]Institut für Theoretische Physik, Universität Hamburg, 20355 Hamburg, Germany

We study the problem of three fermions with different hyperfine states in a lattice for $D = 1, 2$, considering the case of $SU(3)$ attractive interactions and also including a three-body constraint, which mimics the effect of strong three-body losses. We combine an exact diagonalization approach with the Lanczos method, and evaluate both eigenvalues and eigenstates of the problem.

In $D = 1$, we observe that the ground state is always a three-body bound state (trion), while in $D = 2$, due to the stronger influence of finite-size effects, we are not able to identify the existence of a finite threshold for trion formation. Our data are however compatible with a threshold value which vanishes logarithmically with the system size. Moreover we are able to identify the presence of a fine structure inside the spectrum, which we associate with off-site trionic states. Finally, the inclusion of a three-body constraint due to losses stabilizes these off-site trions in the ground state, at least in strong-coupling.

Q 35.25 Wed 16:30 Poster.I+II

Towards Photons storage in a small atomic ensemble — •Sutapa Ghosh, Miguel Martinez-Dorantes, Jose Gallego, Natalie Thau, Seokchan Yoon, Marcel Spurny, Wolfgang Alt, and Dieter Meschede — Institut für Angewandte Physik, Universität Bonn, Bonn, Deutschland

Single photons can be collectively absorbed by large ensembles of atoms creating spin-wave states. Stokes and anti-Stokes photons can be used to write and read quantum information even if some atoms have decohered. Thus we can transform photonic information into stationary qubits. To achieve the required strong coupling of light with an atom we can introduce it in an ultra high finesse optical resonator. To avoid losses and stabilization issues, one can use small atomic ensembles in medium finesse cavities. Recently a novel type of optical fiber based Fabry-Perot cavities with high finesse has been realized [1]. These cavities allow miniaturization (improving stability) and reduce coupling losses. In this work we present our first design for an experimental setup involving optical fiber based Fabry-Perot cavities. A small atomic ensemble can be loaded in a 3D lattice inside the cavity creating a strong atomic localization and avoiding motional dephasing. This lattice will be implemented using two crossed standing wave dipole traps, together with an intra-cavity lock laser standing wave. Short focal length aspheric lenses will be used for focusing these dipole traps and a large numerical aperture lens will allow an efficient fluorescence collection.

[1] D Hunger, T Steinmetz , Y Colombe , C Deutsch , T W Hänsch and J Reichel, 2010 New J. Phys. 12 065038

Q 35.26 Wed 16:30 Poster.I+II

Cold-Atom Scanning Probe Microscopy of Carbon Nanotubes — •P. Federsel, P. Schneeweiss, M. Gierling, S. Bell, T.E. Judd, A. Günther, and J. Fortágh — CQ Center for Collective Quantum Phenomena and their Applications, Eberhard-Karls-Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen, Germany

We demonstrate a novel cold-atom scanning probe microscope, which employs cold atom clouds as ultrasoft probe tips. The microscope can be operated in either contact or dynamic mode and allows for non-destructive measurements of nano-structures and forces in the yN (10^{-24} N) regime.

Using this cold-atom scanning probe microscope we measure the Casimir-Polder force between Rubidium atoms and a single carbon nanotube. We spatially overlap ultracold thermal clouds and Bose-Einstein condensates with a free-standing nanotube and record the corresponding atom losses. From the loss rates we deduce the strength of the Casimir-Polder interaction and the inelastic scattering cross section of the nanotube.

Q 35.27 Wed 16:30 Poster.I+II

From Anderson to Anomalous Localization in Cold Atomic Gases with Effective Spin-Orbit Coupling — •Johannes Otterbach[1], Matthew J. Edmonds[2], Mikhail Titov[2,3], Patrick Öhberg[2], Razmik G. Unanyan[4], and Michael Fleischhauer[4] — [1]Physics Department, Harvard University — [2]SUPA, Department of Physics, Heriot-Watt University — [3]Institut für Nanotechnologie, Karlsruhe Institute of Technology — [4]Fachbereich Physik, TU Kaiserslautern

The advanced techniques in coherently controlling and manipulating cold atomic gases allow for the formation of, e.g., artificial magnetic fields or the creation of effective Spin-Orbit coupling for neutral atoms. Confining such spin-orbit coupled particles to one dimension gives rise to an effective relativistic Dirac-like dynamics in the limit of small particle momenta. The addition of disorder potentials drastically changes the properties of these systems giving rise to phenomena as, e.g., exponential Anderson localization. Here we study the dynamics of ultracold atoms with an effective Spin-Orbit coupling moving in a one-dimensional random potential. We show that tuning the ratio between spin-orbit coupling and disorder strength leads to a crossover from exponential Anderson-like localization of massive particles to an anomalous power-law behavior. Its origin can be traced back to the emergence of a Dyson-like singularity in the density of states around the zero-energy (mid-gap) state, reminiscent of the so-called Random Mass Dirac model.

Q 35.28 Wed 16:30 Poster.I+II

Ion crystals in multipole traps — •Florian Cartarius, Cecilia Cormick, and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes, 66041, Saarbrücken, Deutschland

Doppler cooled ions in linear radiofrequency multipole traps can organize in ordered structures. For a sufficiently large number of ions, tubes of various sizes have been reported [1]. In this work, we theoretically analyse the equilibrium configurations of dozens of ions in anisotropic traps for different orders of the multipolar potential. We identify the parameter regimes where the tubes are stable, and derive the dispersion relation and the normal modes of these structures. These results are applied to calculate the thermodynamic properties of the ion tubes.

[1] K. Okada, K. Yasuda, T. Takayanagi, M. Wada, H. Schuessler, and S. Ohtani, Phys. Rev. A, **75** 033409 (2007)

Q 35.29 Wed 16:30 Poster.I+II

Collective photon interaction with three-level Rydberg gases — •Fabio Cinti and Thomas Pohl — Max Planck Institute for the Physics of Complex Systems, Dresden

The interaction of light with highly excited Rydberg atoms has recently become the focus of several investigations. Interest stems from intriguing possibilities to generate non-classical photon states by exploiting the strong interactions between Rydberg atoms.

Here, we study the dynamics of three-level atoms, driven in a ladder-configuration that exhibits electromagnetically-induced transparency. We present simple mean field models and numerical Monte-Carlo simulations of the underlying many-body master equation and investigate the effects of the correlated atomic dynamics on the properties of the emitted light. Prospects for generating non-classical light are also discussed.

Q 35.30 Wed 16:30 Poster.I+II

Electromagnetically induced transparency in cold Rydberg Gases — •Sevilay Sevinçli[1,2], Nils Henkel[2], Cenap Ates[3], and Thomas Pohl[2] — [1]Aarhus University — [2]Max Planck Institute for the Physics of Complex Systems, Dresden — [3]University of Nottingham

We study the optical response of cold three-state atoms under conditions of electromagnetically induced transparency, where one atomic level corresponds to a Rydberg state that exhibits very strong van-der-Waals interactions. Using different numerical and analytical approaches we show that this leads to a non-linear and highly non-local optical response of the EIT medium, which, moreover, exhibits universal behavior [1]. Good agreement with recent measurements of the nonlinear absorption in Rb-Rydberg gases is demonstrated. Furthermore, we show that the resulting non-local photon-photon interactions can give rise to interesting nonlinear wave phenomena [2], such as stable bright solitons and modulational instabilities.

[1] C. Ates, S. Sevinçli and T. Pohl, Phys. Rev. A **83** 041802(R)
[2] S. Sevinçli et al., Phys. Rev. Lett. **107** 153001

Q 35.31 Wed 16:30 Poster.I+II

Introduction to the Lie-Semigroup Picture of Markovian Open Quantum Systems — •Corey O'Meara[1], Gunther Dirr[2], and Thomas Schulte-Herbrüggen[1] — [1]TU-Munich, Dept. Chem. — [2]University of Würzburg, Inst. Math.

In practical quantum control, a fundamental question is into which states can one coherently steer a given initial state subject to relaxation.

Before determining such *reachable sets* for coherently controlled channels, we step back and analyse the set of all directions along which a given dissipative system can be steered coherently. To this end, we build on the established fact that Markovian quantum channels form *Lie (sub)semigroups* [1]. So here we analyse their tangent cones. Such cones (Lie wedges) are key to understanding the dynamics of controlled unital and non-unital channels. They can be parametrized and constructed explicitly for many types of qubit and multi-qubit systems [2].

Finally, the cones provide valuable tools to approximate reachable sets, where the advantage over current estimates even increases with system size.

References:

[1] G. Dirr, U. Helmke, I. Kurniawan, and T. Schulte-Herbrüggen, Rep. Math. Phys. 64 (2009) 93–121, [doi:10.1016/S0034-4877(09)90022-2]

[2] C. O'Meara, G. Dirr, and T. Schulte-Herbrüggen, IEEE Trans. Control, in press (2011), [see: http://arxiv.org/abs/1103.2703v2]

Q 35.32 Wed 16:30 Poster.I+II

A universal integrator for sparse qubit Hamiltonians: Probing Adiabatic Quantum Computation for an NP-hard problem — •Michael Hofmann, Gernot Schaller, and Tobias Brandes — Institut für Theoretische Physik, Technische Universität Berlin, Berlin

The adiabatic paradigm of quantum computation allows to solve problems via adiabatically preparing a sought-after ground state of a problem Hamiltonian by slow deformations starting from a simple initial Hamiltonian. Simulating a quantum system with n qubits classically requires exponential (2^n) resources and is even further hindered if the time-dependent Hamiltonian is not stored efficiently. We relax this second constraint by introducing a size-scalable universal decomposition of the Hamiltonian into tensor products of Pauli matrices, which allows for an efficient storage and matrix-vector multiplication for k-local Hamiltonians. At the example of the NP-complete problem Exact Cover 3, we study the efficiency of the quantum algorithm for different adiabatic preparation schemes on a hard subset of problem instances that has not been considered before. Even though the worst-case scaling of the algorithm is probably exponential, we find significant performance differences between the different schemes on the average problem.

Q 35.33 Wed 16:30 Poster.I+II

Designing Ideal Hamiltonian Interactions on Networks of Qudits by Dynamical Recoupling — •Holger Frydrych and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Darmstadt

Dynamical recoupling is a method which uses local unitary control operations at fixed time intervals to modify the strength of selected Hamiltonian couplings in a quantum system. It can be applied to suppress errors or to implement desired Hamiltonian dynamics. We describe a method to find suitable control sequences on arbitrary qudit networks to transform an acting Hamiltonian into an arbitrary desired Hamiltonian to first order. The required control operations are the generalised spin operators applied to each qudit individually. The only restriction of this method is that any desired coupling must already be present in the acting Hamiltonian. An example of how to apply this method in practice is presented.

Q 35.34 Wed 16:30 Poster.I+II

Bounding Ground State Energies From Below — •Tillmann Baumgratz and Martin B. Plenio — Institut für Theoretische Physik, Albert-Einstein-Allee 11, Universität Ulm, D-89069 Ulm, Germany

In contrast to standard variational methods this talk presents a technique that determines lower bounds on the ground state energy of condensed matter systems. This is achieved by relaxing the positivity constraint on the density matrix of the system thus yielding an optimization problem scaling polynomially in the system size. We discuss how symmetries, especially translational invariance, can help to reduce the number of variables in the programme [1]. Further, a novel numerical approach, principally a combination of a projected gradient algorithm with Dykstra's algorithm, for solving the optimization problem is presented.

[1] T. Baumgratz and M.B. Plenio, arXiv:1106.5275.

Q 35.35 Wed 16:30 Poster.I+II

The Problem of Compatibility in Experimental Tests of Quantum Contextuality — •Jochen Szangolies, Matthias Kleinmann, and Otfried Gühne — Naturwissenschaftlich-Technische Fakultät, Walter-Flex-Str. 3, Universität Siegen

The Kochen-Specker theorem is a famous result in the foundations of quantum mechanics that rules out non-contextual hidden variable models. In such models, individual experimental outcomes are assumed to be independent of jointly performed compatible measurements. It can be expressed in the form of inequalities, which are obeyed by non-contextual models, but violated by quantum mechanics. Recently, several experiments have indeed observed such a violation. However, the interpretation of these tests remains controversial. One of the main reasons for this is that perfect compatibility between measurements is difficult to achieve in any real experiment. We approach this issue by modelling the typical effects of experiment-induced noise on measurement compatibility. Furthermore, we investigate the possibility of improving the bounds for non-contextuality, taking these effects into account.

Q 35.36 Wed 16:30 Poster.I+II

Optimized witnesses for Dicke- and W-states — •Marcel Bergmann[1], Bastian Jungnitsch[2], and Otfried Gühne[1] — [1]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Straße 3, D-57068 Siegen — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Technikerstraße 21A, A-6020 Innsbruck

Multiparticle entanglement is an important subject in quantum information theory. Recently, the number of particles that can be entangled experimentally using polarized photons or ion traps has been significantly enlarged. Due to this fact, criteria to decide the question whether a given multiparticle state is entangled or not have to be improved.

Our approach to this problem uses the notion of PPT mixtures [1] which form an approximation to the set of biseparable states. With this method, entanglement witnesses can be obtained in a natural manner via linear semidefinite programming. In our contribution, we will present analytical results for witnesses for W-states and Dicke states. This allows to overcome the limitations of convex optimization.

[1] B. Jungnitsch et al., Phys. Rev. Lett. 106, 190502 (2011).

Q 35.37 Wed 16:30 Poster.I+II

Pointer State Optimization — •Raoul Heese and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

Arthurs and Kelly's simultaneous measurements in the spirit of von Neumann involve two pointer systems which are coupled to a quantum system to be measured. It seems natural to ask which pointers are optimal for a given system state at hand. This, however, requires to define optimality, which can on the one hand be approached with the help of traditional uncertainty relations, or, on the other hand, by means of entropic measures. Both concepts can lead to totally different directions of optimization. Similarly, the question arises whether there even exist such optimal pointer states for all possible system states to be measured.

Q 35.38 Wed 16:30 Poster.I+II

Postselection in simultaneous and weak measurements — •Joachim Fischbach and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

We examine the role of postselection in simultaneous measurements of conjugate variables. Postselection in general is an important element of weak measurements in which the interaction between system and measuring device is weak. In our contribution we present the differences between postselected and non-postselected measurements. In particular, we analyze the corresponding uncertainties. As our setup involves Gaussian states and therefore is analytically solvable for an arbitrary interaction strength, we can explicitly study the transition between ordinary and weak measurements.

Q 35.39 Wed 16:30 Poster.I+II

Entanglement of motion with optimal control — •Thomas Stefan Häberle and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, 89069 Ulm

We discuss two atoms in a harmonic trap which interact via point-like collisions. The interaction can be modelled by a δ-potential in the relative coordinate of the atomic positions. Each collision will dynamically entangle the motion of the atoms by a certain amount. Therefore, the time evolution of entanglement, measured by a von-Neumann entropy, will show a step-like behaviour with local minima and maxima. Our aim is to improve the von-Neumann entropy at the time, where the first local minimum appears, by dynamically varying the trap frequency. Hence we apply an iterative algorithm based on optimal control theory which allows us to calculate the optimal trap frequency under restrictions and which guarantees monotone convergence even for non-linear functionals.

Q 35.40 Wed 16:30 Poster.I+II

Generation of squeezing in higher-order spatial modes with a spatial light modulator — •Marion Semmler[1,2], Christian Gabriel[1,2], Peter Banzer[1,2], Andrea Aiello[1,2], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Guenther-Scharowsky-Str. 1, D-91058 Erlangen, Germany — [2]Institute of Optics, Information and Photonics, University Erlangen-Nuremberg, Staudtstr. 7/B2, D-91058 Erlangen, Germany

We report on our investigations of generating amplitude squeezing in higher-order spatial modes. To achieve this, we use a spatial light modulator which can mode convert squeezed Gaussian modes into the desired higher-order spatial mode. The modulator is capable of transforming Gaussian modes not only into Laguerre-Gaussian and Hermite-Gaussian modes of different order but also into cylindrically polarized modes [1]. These have the intriguing feature that they display entanglement between the polarization and spatial degree of freedom when quadrature squeezed [2]. An efficient generation of these modes is desirable in order to investigate their unique quantum-mechanical properties. In our study we examine the properties of the spatial light modulator and especially focus on its ability to maintain the nonclassicality of the quantum state during the mode conversion process.

[1] C. Maurer et al., New J. Phys. 9, 78(2007).
[2] C. Gabriel et al., Phys. Rev. Lett. 106, 060502(2011).

Q 35.41 Wed 16:30 Poster.I+II

Lower Bounds on a Genuine Multipartite Entanglement Measure — •Junyi Wu[1], Marcus Huber[2], Hermann Kampermann[1], and Dagmar Bruss[1] — [1]Institute for Theoretical Physics III, Heinrich-Heine-University Düsseldorf, Germany — [2]Faculty of Physics, University of Vienna

In [1] a genuine multipartite entanglement measure based on the definition of concurrence was introduced. A lower bound of this measure was calculated via a relation to a nonlinear entanglement witness [2]. This bound depends therefore on the type of state that one considers. By using the witnesses introduced in [3], we provide new lower bounds and extend the approach of [1] to a wide range of states (in particular, Dicke states).

[1] Z.Ma, Z.Chen, Z.Chen, C.Spengler, A.Gabriel, and M.Huber, Phys. Rev. A 83, 062325 (2011).
[2] M.Huber, F.Mintert, A.Gabriel, and B.C.Hiesmayr, Phys. Rev. Lett. 104, 210501 (2010).
[3] M.Huber, P.Erker, H.Schimpf, A.Gabriel, and B.C.Hiesmayr, Phys. Rev. A 83, 040301(R) (2011)

Q 35.42 Wed 16:30 Poster.I+II

Comparison of methods for quantum state tomography — •Phuc Thanh Luu, Hermann Kampermann, and Dagmar Bruss — Heinrich-Heine-Universität, Institut für theoretische Physik III, Universitätstr. 1, 40225 Düsseldorf

Estimation of quantum states is a basic task in quantum information science. The major problem is that the number of measurements scales exponentially with respect to the number of particles. Several methods can be used to extract information about the quantum state with a limited number of measurements, e.g. Maximum Likelihood Estimation (1), Hedged Maximum Likelihood Estimation (2), Compressed Sensing (3), and Bayesian Mean Estimation (4). Here we do a comparison between these methods and show advantages/disadvantages as well as open problems.

References:
(1) J. Řeháček, Z. Hradil, and M. Ježek. Phys. Rev. A 63, 040303 (2001).
(2) R. Blume-Kohout, Phys. Rev Lett 105, 200504 (2010).
(3) D. Gross et al., Phys. Rev. Lett. 105, 150401 (2010).
(4) R. Blume-Kohout, New J. Phys. 12, 043034 (2010).

Q 35.43 Wed 16:30 Poster.I+II

Efficient and long-lived quantum memory with cold atoms inside a ring cavity — Xiao-Hui Bao[1,2], •Andreas Reingruber[1], Peter Dietrich[1], Jun Rui[2], Alexander Dück[1], Thorsten Strassel[1], Bo Zhao[3], and Jian-Wei Pan[1,2] — [1]Physikalisches Institut der Universitaet Heidelberg, Philosophenweg 12, Heidelberg

69120, Germany — [2]Hefei National Laboratory for Physical Sciences at Microscale and Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China — [3]Institute for Theoretical Physics, University of Innsbruck, A-6020 Innsbruck, Austria

Quantum memories for photons are regarded as one of the fundamental building blocks of linear-optical quantum computation and long-distance quantum communication. A long standing goal in scalable quantum information processing is to build a long-lived and efficient quantum memory. There have been significant efforts distributed towards this direction. So far, efficient but short-lived or long-lived but inefficient quantum memories have been demonstrated. However, either a low efficiency or a short lifetime severely limits the scalability of any quantum information protocols. Here we report a high-performance quantum memory in which long lifetime and high retrieval efficiency meet for the first time. We present the realization of a quantum memory with an intrinsic spin wave to photon conversion efficiency of 73(2)% together with a storage lifetime of 3.2(1) ms. This realization provides an essential tool towards realistic scalable linear-optical quantum information processing.

Q 35.44 Wed 16:30 Poster.I+II

Progress in Operating 2 Dimensional Arrays of Adressable Ion Traps — •Muir Kumph[1], Michael Brownnutt[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Uni. Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, 6020 Innsbruck, Austria

Controlling interactions between ions in a segmented linear ion trap is becoming standard technology. Extending these methods to two dimensions, however, is not trivial. The trapping and control of 40Ca+ ions in a 4 by 4 array of addressable planar-electrode ion traps is shown. Progress in adjustable radio-frequency control of the electrodes is demonstrated, allowing the addressing and tuning of the Coulomb interaction between nearest-neighbours in the 2D array.

Q 35.45 Wed 16:30 Poster.I+II

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 35.46 Wed 16:30 Poster.I+II

Ultralong coherence times of single electron — •Alexander Gerstmayr, Kay Jahnke, and Rainer Pfeiffer — Institut für Quantenoptik, Universität Ulm

During the last decade, on the search for a solid state quantum bit system, scientists have put a lot of effort into the Nitrogen Vacancy centers (NVs) of diamond. In the need of long coherence times, for performing quantum operations, they try to avoid many obstacles, that cause decoherence, like fluctuating spins of uncoupled nitrogen atoms or C13 impurities in the crystall lattice. The latter ones lead with a natural abundance of 1.1 percent to strong spin coupling between NVs and the C13 spins. A solution of this problem is the usage of highly C12 enriched diamond samples with a C12 concentration of 99.999%. Our work shows, that there is no big difference in coherence times regarding mono- or polycrystalline diamond samples. What really counts, are low nitrogen and C13 concentrations.

Q 35.47 Wed 16:30 Poster.I+II

Reconfigurable addressing and efficient single-atom loading in 2D dipole trap arrays — Malte Schlosser, Sascha Tichelmann, •Moritz Hambach, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany

Optical dipole potentials such as arrays of focused laser beams provide flexible geometries for the synchronous investigation of multiple atomic quantum systems, as studied e.g. in the fields of quantum degenerate gases, quantum information processing, and quantum simulation with neutral atoms. In our work, we focus on the implementation of trapping geometries based on microfabricated optical elements. This approach allows us to develop flexible and integrable configurations for quantum state storage and manipulation, simultaneously targeting the important issues of single-site addressing and scalability. We report on the investigation of ^{85}Rb atoms in two-dimensional arrays of individually addressable dipole traps featuring trap sizes and a tuneable site-separation in the single micrometer regime. The direct control of each trap is provided by a spatial light modulator, thus enabling arbitrary trap configurations as well as the initialization and manipulation of qubits in a flexible, site-specific, and parallelized fashion. Advanced schemes for atom number resolved detection with high efficiency and reliability allow us to probe small ensembles and even single atoms stored in the microtrap array. For single atom preparation we utilize light assisted collisions to improve one atom loading efficiencies beyond Poissonian statistics while eliminating multi-atom events.

Q 35.48 Wed 16:30 Poster.I+II

Synchronization and coherent transport of atomic qubits for quantum information processing — •Sascha Tichelmann, Malte Schlosser, Moritz Hambach, Felix Schmaltz, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany

The coherent control of the internal and external quantum states of ultra-cold neutral atoms represents an important approach towards quantum information processing. We present an experimental implementation of physically independent qubits arranged in a scalable quantum register. Key elements of our approach are two-dimensional registers of optical micro-potentials with pitch in the micrometer regime created by microfabricated lens arrays which inherently provide single-site addressability. This architecture is complemented by the implementation of a scalable quantum shift register that offers precise control of the position and transport of trapped neutral-atom qubits and can serve as a 2D quantum state register to store and sequentially shuffle quantum information in complex architectures. We show the scalability of the transport process by performing the repeated hand-over of atoms from trap to trap on a millisecond timescale and demonstrate the conservation of coherence during transport. We also present an experimental scheme for the cancellation of the differential light shift that is extendable to all alkali elements and arbitrary trapping wavelengths. The resulting "magic-wavelength" behaviour leads to a strong suppression of dephasing and ensures scalability by synchronizing the coherent evolution of qubits at all register sites.

Q 35.49 Wed 16:30 Poster.I+II

Two photon interference for quantum networking between independent atom-cavity systems — •Andreas Neuzner, Christian Nölleke, Carolin Hahn, Andreas Reiserer, Eden Figueroa, Stephan Ritter, and Gerhard Rempe — MPI für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

We experimentally demonstrate quantum interference of two photons generated by two atom-cavity systems 21m apart. The photons are generated via a vacuum-stimulated Raman adiabatic passage (vSTIRAP) on two trapped single atoms. The temporal length of the generated photon wave packet exceeds the duration of a single-photon detection event by several orders of magnitude. Therefore we are able to resolve the arrival time of each individual photon within the distribution given by the wave packet envelope. This allows us to gain detailed insight into the interference process.

Polarization-sensitive detection of the photons in combination with our ability to create atom-photon entanglement can be used to exploit two-photon interference for quantum teleportation. We will discuss our progress towards quantum teleportation from one atom onto the other.

Q 35.50 Wed 16:30 Poster.I+II

Coherent Rydberg Excitation in Thermal Vapor Cells — •Bernhard Huber, Thomas Baluktsian, Andreas Kölle, Georg Epple, Harald Kübler, Robert Löw, and Tilman Pfau —

5. Physikalisches Institut, Universität Stuttgart

Highly excited Rydberg atoms are the heart of many proposals regarding the realization of quantum devices that make use of the long-range character of the Rydberg-Rydberg interaction to impose correlations between different quantum states. While various experiments in cold gases have already shown beautiful results, the basic principles are also valid for a thermal gas. We show that the coherent control of Rydberg atoms is feasible in thermal vapor.

In our case the Rydberg state is addressed by a two-photon-excitation using a bandwidth-limited pulsed laser system. With this system we can achieve very fast excitation dynamics such that the atoms can be considered frozen on the relevant timescales. We present Rabi oscillations to a Rydberg state in Rb in the GHz range showing that despite the limited coherence time in a thermal gas it is possible to do fully coherent excitation [1].

We also discuss the status of our search for Rydberg-Rydberg interaction effects on the Rabi oscillations.

[1] B. Huber, T. Baluktsian, M. Schlagmüller, A. Kölle, H. Kübler, R. Löw, and T. Pfau
GHz Rabi Flopping to Rydberg States in Hot Atomic Vapor Cells, *Phys. Rev. Lett.* **107**, 243001 (2011)

Q 35.51 Wed 16:30 Poster.I+II

Advancements in the fabrication of high finesse fibre Fabry-Pérot cavities — •Leander Hohmann, Natalie Thau, Christian Deutsch, Jérôme Estève, and Jakob Reichel — ENS - Ecole Normale Supérieure

We present the recent progress in realisation of fibre-based Fabry-Pérot cavities. These cavities are formed by concave, ultra-low roughness mirror surfaces fabricated with CO_2 laser pulses directly on the end facets of optical fibres and coated with a high-performance dielectric coating. These fibre Fabry-Pérot cavities (FFPCs) combine very small size, high finesse F > 130 000, small waist and mode volume, and good mode matching between the fibre and cavity modes. Due to this attractive combination of features, FFPCs are used in an increasing number of experiments in cavity quantum electrodynamics as well as in a wide range of other applications where they provide coupling to single atoms, molecules and ions. We present our current progress in FFPC fabrication which is aimed at further reducing absorption and scattering loss, improving precision and reproducibility of the laser machining process, and enhanced control of the cavity birefringence caused by the dielectric mirror coating.

Q 35.52 Wed 16:30 Poster.I+II

Magnetfeldgradienten in planare Ionenfallen zur Simulation von Spinmodellen — •Amado Bautista-Salvador, Niels Kurz, Jens Welzel und Ferdinand Schmidt-Kaler — QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz

Planare Mikro-Ionenfallen mit komplexen Strukturen sind mit lithographischen Techniken vergleichsweise einfach herzustellen. Insbesondere können stromführende Leitungen in das Chiplayout integriert werden und so magnetische Felder und Gradienten erzeugt werden, deren Quelle sich lediglich um die 100 μm entfernt von den gefangenen Ionen befindet. Stromführende Mikrostrukturen in planaren Ionenfallen sind daher vielversprechend [1] um magnetische Spin-Spin Wechselwirkung mit hohen Kopplungsstärken zu induzieren, was die Quantensimulation unterschiedlicher magnetische Spin-Modelle [2] erlaubt.

Unsere Falle besitzt eine kleine Schlaufe unterhalb der Position der gefangenen Ionen, welche einzelnen Strompulse von bis zu 6 A über 100 ms und fortwährenden Pulsen von 2 A standhält. Da ihre Induktivität gering ist, können wir Wechselstrom im Bereich von 10^5 Hz verwenden. Simulationen des erzeugten Magnetfeldes versprechen Gradienten im Bereich von 5-20 T/m, was wir überprüfen wollen, indem wir ein einzelnes Ion als Sonde verwenden und die Verschiebung atomarer Übergänge aufgrund der Zeemanaufspaltung messen. [1] J. Welzel et al., Eur. Phys. J. D 65, 285-297 (2011) [2] P. A. Ivanov et al., New J. Phys. 13, 125008 (2011)

Q 35.53 Wed 16:30 Poster.I+II

Fast and Coherent Manipulation of Trapped Ion Qubits — •Samuel T. Dawkins, Konstantin Ott, Andreas Walther, Alex Wiens, Ulrich Poschinger, Kilian Singer, and Ferdinand Schmidt-Kaler — QUANTUM, Institut für Phyzik, Johannes-Gutenberg Universität Mainz

We present details on the manipulation of $^{40}Ca^+$ ions in a segmented Paul trap with the purpose of realizing scalable quantum information experiments. On the one hand, fast shuttling of a trapped ion within 10 μs is required for the scalability of this approach, while near-perfect control over the ion motion has to be realized [1]. We present experimental results on such shuttling of laser-cooled ions on the timescale of the trap oscillation period, where vibrational excitations are minimized and the ion remains close to the ground state. The voltages appearing on the DC segments of the trap are generated by a custom-built FPGA-based digital arbitrary waveform generator, designed to provide 48 analog signals with update times as short as 400 ns. We furthermore give details for the combination of gate operations, shuttling operations and laser-cooling protocols, which will constitute the basic ingredients for future scalable quantum information experiments.

[1] G. Huber et al., *Applied Physics B: Lasers and Optics*, **100**, 725-730 (2010).

Q 35.54 Wed 16:30 Poster.I+II

Towards quantum simulations in a triangular surface trap — •Miriam Bujak[1,2], Manuel Mielenz[1,2], Christian Schneider[1,2], Magnus Albert[1,2], and Tobias Schaetz[1,2] — [1]Physikalisches Institut, Albert-Ludwigs Universität Freiburg — [2]Max-Planck-Institut für Quantenoptik, Garching

Ions confined in linear Paul traps have proven to be well suited for analogue quantum simulations. While in proof-of-principle experiments the adiabatic evolution of quantum magnets has been simulated with linear chains of two [1] and later with up to nine ions [2], scalability of ion based quantum simulators remains a major issue.

To overcome the limitations of one-dimensional linear Paul traps, novel two-dimensional surface traps for triangular arrays of ions have been proposed [3] and optimized [4]. While the ions will be stored in individual potential minima, the mutual distances should be small enough to provide a sufficient coupling strength for quantum simulation experiments in two dimensional lattices [5]. We will report on the current status of the experimental setup and will present first proposals for quantum simulations that could be envisioned [6].

[1] A. Friedenauer *et al.*, Nature Phys. **4**, 757-761 (2008)
[2] R. Islam *et al.*, Nature Comm. **2**, 377 (2011)
[3] T. Schaetz *et al.*, J. Mod. Optic. **54**, 16-17 (2007)
[4] R. Schmied *et al.*, PRL **102**, 233002 (2009)
[5] C. Schneider *et al.*, arXiv:1106.2597v1, to be published in Rep. Prog. Phys.
[6] A. Bermudez *et al.*, RL **107**, 150501 (2011)

Q 35.55 Wed 16:30 Poster.I+II

An Ion Trapped in an Optical Lattice — •Martin Enderlein[1,2], Thomas Huber[1,2], Christian Schneider[1,2], Magnus Albert[1,2], Michael Zugenmaier[1,2], and Tobias Schaetz[1,2] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching — [2]Albert-Ludwigs-Universität Freiburg, 79104 Freiburg

In 2010 we trapped an ion in an optical dipole trap for the first time [1]. Optically trapped ions are promising in several ways: For example to study ultra-cold atom-ion collisions not suffering from micromotion-induced heating and as potentially scalable systems with long-range interaction for quantum simulations.

The motivation for a quantum simulator is to gain insight into complex quantum dynamics (e.g. of a solid-state system) via experimentally simulating the quantum behaviour of interest in another quantum system (e.g. trapped ions). In order to gain genuinely new insights one has to scale these simulations to particle numbers that cannot be handled efficiently on a classical computer. One promising approach to reach scalability is based on micro-arrays of radio-frequency surface traps [2]. An alternative approach might be to combine the advantages of trapped ions with those of (atoms in) optical lattices [2]. Here we report on trapping of an ion in an optical lattice, an important step towards larger systems, e.g. combining atoms and ions. Furthermore, we present a new setup dedicated to optical ion trapping which will allow us to make further progress towards the above-stated goals.

[1] Schneider et al., Nat. Photonics 4 (2010)
[2] Schneider et al., arXiv:1106.2597 (2011)

Q 35.56 Wed 16:30 Poster.I+II

Towards simultaneous optical trapping of Ba^+ ions and Rb atoms — •Michael Zugenmaier, Thomas Huber, Martin Enderlein, Christian Schneider, Magnus Albert, and Tobias Schätz — Albert-Ludwigs Universität Freiburg

In 2010 our group demonstrated the trapping of an Mg^+ ion in an optical dipole trap [1]. The lifetime in the optical potential was limited by heating due to photon recoils out of the optical field.

We are designing a new setup to trap Ba^+ ions and Rb atoms simultaneously in a far off-resonance dipole trap. The Rb atoms will be trapped in a MOT with a temperature in the μK regime. The Ba^+ ions will be prepared in a RF trap. Then Ba^+ and Rb will be transferred into the optical dipole trap. Using far detuned trapping lasers minimizes the photon scattering rate and will result in longer trapping durations. We expect that the Ba^+ ions will be sympathetically cooled by the Rb atoms to low temperatures avoiding residual heating by RF-micromotion.

Trapping the ions and atoms in one common optical trap might allow to enter the regime of ultracold chemistry, where quantum phenomena are predicted to dominate.

[1] Ch. Schneider et al., Nat. Phot. 4, 772-775 (2010)

Q 35.57 Wed 16:30 Poster.I+II

Bloch oscillations in discrete quantum walks — •Maximilian Genske, Andreas Steffen, Noomen Belmechri, Andrea Alberti, Wolfgang Alt, and Dieter Meschede — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn

The question of quantum simulation and processing has become very interesting in recent years. Particularly in the context of ultra cold atoms, experimental proposals have been made and realizations of these achieved. The concept of a quantum random walk is a candidate for realizing quantum algorithms. Our group has accomplished such a walk with neutral atoms in an optical lattice [Karski et al. Science 2009]. Due to the characteristics of the walk operations, this time and space discrete system is expected to show quantum transport phenomena which are typical for arrangements of a periodic potential. One of those are the well known Bloch oscillations. Prospectively, by using additional walk levels one should be able to resemble the effect of a magnetic field on Bloch electrons, which gives rise to the fractal structure described by Hofstadter's butterfly.

Q 35.58 Wed 16:30 Poster.I+II

Rydberg EIT in thermal caesium vapour — •Alban Urvoy, Lara Bauer, Harald Kübler, Tilman Pfau, and Robert Löw — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart Germany

Rydberg atoms are promising candidates for the realization of quantum devices, making use of the long-range atom-atom interactions. Results towards the control of Rydberg excitations in time domain have recently been obtained with thermal rubidium vapour [1]. In caesium, the excitation scheme $6S_{1/2} \rightarrow 7P_{3/2} \rightarrow nS, nD$ has the advantage that the upper transition is driven at a wavelength of approx. 1064 nm. It is possible at this wavelength to reach high powers in a continuous wave regime and we therefore hope to continue the work of [1] in a more flexible way.

We present spectroscopic results for this three level ladder system. The data exhibits transitions from EIT to enhanced absorption. We show that this is a consequence of the optical pumping out of the three level model of EIT.

[1] B. Huber, et al., *Phys. Rev. Lett.* **107**, 243001 (2011)

Q 35.59 Wed 16:30 Poster.I+II

Fabrication processes of a segmented surface trap — •Peter Kunert, Daniel Georgen, Michael Johanning, and Christof Wunderlich — Universität Siegen, Naturwissenschaftlich-Technische Fakultät, Dept. Physik, 57068 Siegen, Deutschland

Small dimensions of ion traps are advantageous to build up complex trap-structures and trap-arrays. A promising approach for this is the development of a surface trap. This type of trap consists of an electrode structure reduced to a 2D plane. An important advantage of the surface trap is the possibility to use micro-system technology for its production. We present a possible fabrication procedure of such a trap-chip using clean room technology such as optical lithography, electroplating and etching. For this purpose a gold-electroplating device was constructed and integrated into an inexpensive small, self-made clean room. 100 to 200 micrometer wide gold-electrode structures with a height of 8.5 micrometer and an inner electrode distance of 10 micrometer are produced onto a sapphire wafer. Also, the integration of the trap-chip into an ultra-high-vacuum-system via a self-made chip-carrier is shown. This carrier is produced using thick-film technology especially and includes electrical low-pass filters directly on the carrier.

Q 35.60 Wed 16:30 Poster.I+II

Development of a segmented ion trap for quantum control of multi-species ion chains — •Hsiang-Yu Lo, Daniel Kienzler, Ben Keitch, Joseba Alonso, Florian Leupold, Ludwig de Clercq, Frieder Lindenfelser, Roland Habluetzel, Martin Sepiol, and Jonathan Home — Institute for Quantum Electronics, ETH Zürich, Zürich, Switzerland

We are developing a new experimental setup for quantum information processing, simulation and state engineering with trapped atomic ions. The system is designed to simultaneously trap both beryllium and calcium ions using a segmented linear Paul trap. We have designed and optimized a trap with three zones for quantum control and two zones for separation of ion strings; each step of trap fabrication has now been run independently. Preparation, cooling and quantum control of both ion species will require a wide range of laser light sources, many of which are not commercially available. For beryllium we have developed a 6W source of 626nm light using sum-frequency generation of two commercial high-power fibre lasers - further frequency doubling of the light will use BBO crystals in resonant cavities. The laser sources required for the calcium ion are commercial systems, which we have stabilized to home-built optical cavities. In order to detect fluorescence emitted from both ion species simultaneously, we have designed a high numerical-aperture imaging system consisting of in-vacuum objective lenses plus dual-channel optics outside the vacuum. This work presents a number of key experimental steps towards precision control of trapped ions.

Q 35.61 Wed 16:30 Poster.I+II

Deterministische Einzelionenquelle — •Stefan Ulm, Georg Jacob, Stefan Weidlich, Johannes Rossnagel, Henning Kaufmann, Sebastian Wolf, Andreas Kehlberger, Ferdinand Schmidt-Kaler und Kilian Singer — QUANTUM , Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Die deterministische nanometergenaue Implantation von Stickstoff in Diamant ist eine der wesentlichen Anforderungen, um einen skalierbaren Festkörperquantencomputer basierend auf NV-Zentren zu entwickeln. Aus diesem Grund haben wir eine deterministische Einzelionenquelle auf der Grundlage einer linearen segmentierten Ionenfalle realisiert [1,2]. Um den Anforderungen an die Emittanz und die Geschwindigkeitsverteilung gerecht zu werden, haben wir eine neuartige mikrostrukturierte Ionenfalle gebaut, die dank der höheren Fallenfrequenzen ein Grundzustandskühlen der Ionen ermöglicht. Durch das symmetrische Endkappendesign welches mit Hilfe nummerischer Methoden [3] optimiert wurde, können bis zu 5 keV Extraktionsspannung bei gleichzeitig nanometergenauer lateraler Auflösung erreicht werden. Dies wird es uns erlauben deterministisch Ionen in Substrate zu implantieren und dabei die Erzeugungseffizienz optisch aktiver Farbzentren mit Hilfe eines konfokalen Mikroskops insitu zu überwachen. Wir haben bereits gezeigt, das dieser Aufbau in der Lage ist, einzelne NV's bei Normaldruck wie auch unter Vakuumbedingungen zu messen.

[1] J. Meijer et al., Appl. Phys. A 91, 567 (2008) [2] W. Schnitzler et al., Phys. Rev. Lett. 102, 070501 (2009) [3] K.Singer et al., RMP 82, 2609 (2010)

Q 35.62 Wed 16:30 Poster.I+II

Experimentelle und theoretische Untersuchung von Zick-Zack Ionenkristallen — •Henning Kaufmann, Stefan Ulm, Georg Jacob, Sam Dawkins, Thomas Feldker, Ferdinand Schmidt-Kaler und Kilian Singer — QUANTUM, Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Gefangene Ionen kristallisieren in einem harmonischen Fallenpotential wenn sie mit Laserlicht gekühlt werden[1]. Zick-Zack Ionenkristalle [2] sind dabei für die Quanteninformation und Quantensimulation [3,4] von großem Interesse. Wir präsentieren Ergebnisse an planaren Zick-Zack Ionenkristallen, welche in einer linearen Paulfalle erzeugt werden, indem Ionen in einem Potential mit zwei sehr unterschiedlichen radialen Fallenfrequenzen gefangen werden. Wir haben die Positionen von 3 bis 19 Ionen in einer Zick-Zack Konfiguration bei radialen Fallenfrequenzen von 160 bis 330 kHz mit submikrometer Genauigkeit gemessen. Dabei konnten wir direkt unsere Messungen mit Simulationen der Zick-Zack Übergänge vergleichen. Desweiteren wurden die kritischen Anisotropieparameter $\alpha_{1,2}$ ebenso wie die Eigenmoden und Frequenzen der Zick-Zack Moden berechnet und gemessen. Von speziellem Interesse wird das Vermessen und die Beobachtung von Zick-Zack Ionenkristallen aus unterschiedlichen atomaren Spezies sein.

[1] D. F. V. James, Appl. Phys. B 66, 181 (1998). [2] D. G. Enzer, et. al., Phys. Rev. Lett. 85, 2466 (2000). [3] A. Bermudez, et. al, Phys. Rev. Lett 107, 207209 (2011). [4] J. Welzel, et. al., EPJD 65, 285

(2011).

Q 35.63 Wed 16:30 Poster.I+II

Manipulation of Yb+ ions in a micro-structured segmented Paul trap using a versatile electric field generator — •Muhammad Tanveer Baig, Thomas Collath, Delia Kaufmann, Peter Kaufmann, Timm F. Gloger, Andreas Wiese, Michael Ziolkowski, Michael Johanning, and Christof Wunderlich — Faculty of Science and Technology, Department of Physics, University of Siegen, Walter Flex Str. 3, 57072 Siegen, Germany

Ions held in micro-structured segmented electrodynamic traps (microtrap) are promising candidates for a future quantum computer. A large number of DC electrodes are required for shuttling and separation of trapped ions as well as for controlling the range and magnitude of coupling between ions.

We have developed a versatile electric field generator (EFG) [1] to provide arbitrary DC potentials up to 24 DC electrodes of the microtrap experimental setup [2]. The microtrap has mainly two (loading and processing) regions. In both regions we have performed trapping, shuttling, splitting and recombination of Yb+ ion strings. We will present recent results on the manipulation of ion strings.

[1] Electric field generator, german patent application de 10 2011 001 399.7, filed on march 18, 2011.

[2] D. Kaufmann, T. Collath, M. T. Baig, P. Kaufmann, E. Asenwar,M. Johanning,

Q 35.64 Wed 16:30 Poster.I+II

Eine kryogene, mikrostrukturierte Ionenfalle zur Untersuchung von Heizeffekten in der Quanteninformationsverarbeitung — •Max Hettrich, Frank Ziesel, Tim Lindner und Ferdinand Schmidt-Kaler — QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz

Um die Verarbeitung von Quanteninformation mit kalten Ionen in Paulfallen zu skalieren, können segmentierte, mikrostrukturierte Fallen verwendet werden. Deren kleinere geometrische Abmessungen bedingen allerdings ein erhöhtes, inkohärentes Aufheizen des Bewegungszustandes der Ionen. In dem auf diesem Poster präsentierten Aufbau bekämpfen wir diesen Effekt, indem wir eine Mikrofalle an einem Durchflusskryostaten montiert haben, was uns die Möglichkeit gibt, diese nachteiligen Effekte zu reduzieren, und damit die Entkopplung des Ions von der Fallenstruktur zu verbessern. Das System erlaubt es, die Oberflächentemperatur der Falle zwischen 4K und 300K zu variieren, und damit die Abhängigkeit zwischen Fallentemperatur und Heizrate des Ions zu untersuchen, eine Frage, die bis heute nicht abschließend beantwortet ist. Die experimentellen Werkzeuge für diese Untersuchungen wurden bereits realisiert: Das Arbeiten mit einzelnen Ionen bei unterschiedlichen Fallentemperaturen ist möglich, wir beobachten Trägerrabioszillationen mit Frequenzen von ca. $2\pi \cdot 100$ kHz sowie die dazugehörigen Seitenbänder.

Q 35.65 Wed 16:30 Poster.I+II

A nanofiber optical interfacing for trapped ions — •Jan Petersen[1], Benjamin Ames[2], Michael Brownnutt[2], Rainer Blatt[2,3], and Arno Rauschenbeutel[1] — [1]VCQ, TU Wien – Atominstitut, Stadionallee 2, A-1020 Wien — [2]Institut für Experimentalphysik, Unversität Innsbruck, Technikerstr. 25, A-6020 Innsbruck — [3]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, A-6020 Innsbruck

Optical nanofiber have proven to be a versatile tool for the efficient coupling of light and matter. As an example, atoms and molecules have recently been coupled to the intense evanescent light field around such nanofibers. We plan to extend this method to interfacing trapped ions with optical nanofibers in order combine the advantageous properties of the respective systems. For this purpose, we integrate an optical nanofiber into a Paul trap which allows one to position the ions with a precision of a few nanometers by tuning the trapping potentials. Given that the ion has to be placed in close vicinity ($\sim$ 100 nm) of the nanofiber surface, stray charges on the fiber surface have to be avoided. We discuss possibilities and present results towards coating the fibers to tackle this problem. In an alternative trapping scheme, we aim to employ nonlinearities using the intense light field on the nanofiber surface. The resulting electromagnetic difference frequency fields might be suitable for realizing a trapping potential for ions.

Financial support by ERA-Net Research Network "Nanofibre Optical Interfaces", the Volkswagen Foundation and the ESF is gratefully acknowledged.

Q 35.66 Wed 16:30 Poster.I+II

Vibrational ground state cooling of a neutral atom in a tightly focused optical dipole trap — Syed Abdullah Aljunid, Victor Xu Heng Leong, •Kadir Durak, Gleb Maslennikov, and Christian Kurtsiefer — Centre for Quantum Technologies / Dept. of Physics, National University of Singapore

We have shown that a substantial interaction between light and single trapped atom can be achieved by strongly fosucing the light into the position of the atom[1-3]. However, for optimal interaction the atom has to be well localized at the field maximum. The position uncertainty due to residual kinetic energy of the atom in the dipole trap (depth $\sim$ 1mK) is still significant after molasses cooling (few 100 nm)[2]. To address this problem we implement a Raman Sideband cooling technique, similar to the one commonly used in ion traps [4], to cool a single ^{87}Rb atom to the ground state of the trap. We have cooled the along the transverse trap axis (trap frequency $\nu_\tau = 81\,\text{kHz}$), to a mean vibratonal state $\bar{n_\tau} = 0.55$ and investigate the impact on atom-light interfaces.

[1] M. K. Tey, et al., Nature Physics **4** 924 (2008) [2] M. K. Tey et. al., New J. Phys. **11**, 043011 (2009) [3] S.A. Aljunid et al., Phys. Rev. Lett. **103**, 153601 (2009) [4] C. Monroe et al., Phys. Rev. Lett. **75**, 4011 (1995)

Q 35.67 Wed 16:30 Poster.I+II

Development of a cryogenic surface-electrode ion trap — •Florian Leupold, Ludwig de Clercq, Joseba Alonso, Roland Hablützel, Ben Keitch, Daniel Kienzler, Frieder Lindenfelser, Hsiang-Yu Lo, Martin Sepiol, and Jonathan Home — ETH Zürich, Switzerland

We are developing a cryogenic ion-trap setup for investigating quantum control of trapped ions in microfabricated traps. The experiments we will perform involve quantum control of both beryllium and calcium ions, which presents a challenge for trap design due to the different ion masses, and also requires achromatic imaging.

We have built a prototype surface trap using photolithography, and have designed a reflective single-piece objective for imaging of the ions with minimal chromatic aberrations (currently under fabrication).

The experiments we wish to perform demand a high level of computer control. As a first step we are developing a home-built FPGA based servo-controller with an embedded microprocessor which can run without interruption and be updated by a computer interface. This incorporates a number of features which will be required for fast control of both the electrode potentials and the laser pulses with which the actual quantum-control experiments will be performed.

Q 35.68 Wed 16:30 Poster.I+II

Towards the realization of an optical quantum switch — •Jürgen Volz[1], Danny O'Shea[1], Christian Junge[1], Konstantin Friebe[1,2], and Arno Rauschenbeutel[1] — [1]Vienna Center for Quantum Science and Technology, TU Wien – Atominstitut, Vienna, Austria — [2]Johannes Gutenberg-Universität Mainz, AG QUANTUM, Mainz, Germany

We experimentally investigate the realization of a fiber-based optical quantum switch, a crucial element of future quantum communication applications. Whereas classical optical switches allow the rerouting of optical signals between different ports, a quantum switch can also be prepared in coherent superposition states.

In order to realize such a device, we strongly couple single rubidium atoms to a novel type of high-Q whispering-gallery-mode resonator – a so-called bottle microresonator. In our experiment, this resonator is simultaneously interfaced by two independent coupling fibers, thereby realizing a true four-port device with extremely low coupling and transmission losses. We analyze the transit of single atoms through the microresonator mode in the four-port configuration. Measuring the correlation functions between the different output ports in the presence of an atom coupled to the resonator mode allows us to observe "classical" switching behavior and to gain insight in the atom–cavity interaction.

We gratefully acknowledge financial support by the DFG, the Volkswagen Foundation, and the ESF.

Q 35.69 Wed 16:30 Poster.I+II

Strong coupling of single atoms to a high-Q whispering-gallery-mode bottle microresonator — •Christian Junge[1], Danny O'Shea[1], Konstantin Friebe[1,2], Jürgen Volz[1], and Arno Rauschenbeutel[1] — [1]Vienna Center for Quantum Science and Technology, TU Wien – Atominstitut, Stadionallee 2, 1020 Vienna, Austria

— [2]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany

We report on the observation of strong coupling between single atoms and a high-Q whispering-gallery-mode (Q = 50 million) of a bottle microresonator. Light is coupled evanescently into the resonator using a tapered optical fiber with an actively stabilized fiber–resonator gap. Cold rubidium atoms with an average temperature of 5 μK are delivered to the resonator by means of an atomic fountain. We observe single atom transit events in the resonator transmission spectrum which last several microseconds. In order to study the atom–resonator coupling in more detail, we have implemented a realtime detection scheme based on fast digital FPGA logic. This allows us to react to the arrival of atoms and to adopt the frequency and power of the light probing the bottle mode with a response time of less than 150 ns. We present our experimental results characterizing the strongly coupled atom–resonator system.

Financial support by the DFG, the Volkswagen Foundation, and the ESF is gratefully acknowledged.

Q 35.70 Wed 16:30 Poster.I+II

Rydberg excitation of $^{40}Ca^{+}$ by VUV radiation at 123 nm — •Matthias Stappel[1,2], Daniel Kolbe[1,2], Thomas Feldker[1], Julian Naber[1], Ferdinand Schmidt-Kaler[1], and Jochen Walz[1,2] — [1]Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz, Deutschland — [2]Helmholtz-Institut Mainz, Johannes Gutenberg-Universität, 55099 Mainz, Deutschland

Lasercooled ions in paul traps are one of the most promising candidates for future applications in quantum information. At the same time Rydberg states and the related dipole blockade are a rapidly growing field of atom physics in the past years. By exciting $^{40}Ca^{+}$ trapped ions to Rydberg states with VUV (vacuum ultraviolet) laser radiation at 123 nm, we combine these two approaches. First the $^{40}Ca^{+}$ ions are trapped and lasercooled in a linear paul trap. In a next step the ions are transferred to the $^{3}D_{5/2}$ state and finally excited by radiation at 123 nm to a Rydberg state. Goals of our experiment are the spectroscopy of generated Rydberg states, investigation of Rydberg blockade and entanglement of $^{40}Ca^{+}$ ions in an ion crystal. We present the setup of our experiment, the generation of VUV radiation at 123 nm and report on the current status of the experiment.

Q 35.71 Wed 16:30 Poster.I+II

Experimental quantum spin-flip error-correction using single nitrogen-vacancy defect centers in diamond. — •Sebastian Zaiser[1], Mathias Nietsche[1], Gerald Waldherr[1], Philipp Neumann[1], Jason Twamley[2], Fedor Jelezko[3], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Uni Stuttgart — [2]Centre for Engineered Quantum Systems, Departement of Physics and Astronomy, Faculty of Science, Macquarie University, Sydney, Australia — [3]Institut für Quantenoptik, Universität Ulm

The Nitrogen-Vacancy color center in diamond and its associated spin system is a promising candidate for the technical realization of a quantum computer and can be used as nanoscale electric and magnetic field sensor at room temperature. Manipulation and readout of the spin states is done by optical and microwave techniques. At high magnetic fields the spin system consisting of ^{14}N and weakly coupled ^{13}C nuclear spins can be used for improved readout and for information storage [1]. Further improvement can be achieved by error correction schemes. Here we experimentally demonstrate a code which corrects spin-flip errors of single nuclear spins.

[1] P.Neumann, *et al. Science* **329,** 542 (2010)

Q 35.72 Wed 16:30 Poster.I+II

Trapped single ion in the focus of a deep parabolic mirror — •Andrea Golla[1,2], Robert Maiwald[1,2], Martin Fischer[1,2], Marianne Bader[1,2], Benoît Chalopin[3], Markus Sondermann[1,2], and Gerd Leuchs[1,2] — [1]Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg, 91058 Erlangen, Germany — [2]Max Planck Institute for the Science of Light, 91058 Erlangen, Germany — [3]Laboratoire Collisions Agrégats Réactivité , Université Paul Sabatier, 31062 Toulouse, France

Trapping a single ion in the focal spot of a deep parabolic mirror provides a setup for efficient free space coupling of single ions with a suitable shaped incident light field [1]. High coupling arises from the ability of this system to illuminate the atom from nearly the complete solid angle. For this purpose we duplicated an ion trap with high optical access, a so-called stylus trap [2], and combined it with a metallic parabolic mirror.

We report the trapping of single Ytterbium ions in this trap. Especially we discuss the trap setup and show technical details of different methods of micromotion compensation and fluorescence light imaging. This setup not only promises high absorption efficiencies of light incident onto the ion but also allows for high collection efficiencies of the fluorescence light emitted by the ion. Thus, in addition we show experimental details of measuring the collection efficiency of the light emitted by a single ion.

[1] M. Sondermann et. al., Applied Physics B, 89, 489 (2007)
[2] R. Maiwald et. al., Nature Physics 5, 551 (2009)

Q 35.73 Wed 16:30 Poster.I+II

Optical Studies and Charge State Detection of single Nitrogen-Vacancy Centers in Diamond — •Nabeel Ahmad Aslam[1], Gerald Waldherr[1], Philipp Neumann[1], Fedor Jelezko[2], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart, Stuttgart, Germany — [2]Institut für Quantenoptik, Universität Ulm, Germany

When Gruber et al. [1] first studied optical and spin properties of *single* Nitrogen-Vacancy centers (NV) in diamond they hardly imagined that NV centers will be widely applied in nanoscale magnetometry, single photon sources and many more fields in future such as quantum computation. The negatively charged NV center has the properties to fulfill the requirements of each of these fields. But since Waldherr et al. [2] showed that the negatively charged NV center is for 30 % of time in a different charge state, the NV^0, further studies were necessary. We have explored the excitation wavelength- and power- dependence of the NV fluorescence emission. Furthermore we were able to measure the ionization rates into the NV^0 state (Waldherr et al. [2]) for varying excitation wavelengths. Additionally, a new method is introduced that enables us to detect the charge state. These studies help to understand the photodynamics of the NV center. [1] A. Gruber et al. Scanning confocal optical microscopy and magnetic resonance on single defect centers. Science, 276:2012, 1997. [2] G. Waldherr et al. Dark States of Single Nitrogen-Vacancy Centers in Diamond Unraveled by Single Shot NMR. Physical Review Letters 106(15), 157601 (Apr 2011)

Q 35.74 Wed 16:30 Poster.I+II

Microwave control of N-V centres coupled to structures nanofabricated on demand — •Florian Striebel, Luca Marseglia, Andreas Häussler, and Fedor Jelezko — Institut für Quantenoptik, Universität Ulm, Albert-Einstein-Allee 11, 89081 Ulm - Germany

The negatively charged Nitrogen Vacancy color center (NV) a spin active defect in diamond with a long spin lifetime at room temperature. It is a three level system whose value of the spin of the ground state can be driven by applying a small microwave field (2.88 GHz) giving a great promise for the implementation of qubits for quantum computing. Here we aim to couple microwave structures, made of metal, lithographically deposited on the diamond, in order to apply high intensity microwave field to the NV, to address its spin and to drive Rabi oscillation of it. We have performed simulations of the microwave structures in order to study the quality of the field and to check the feasibility of its fabrication regarding to conventional evaporative deposition technique. We are able to locate a single NV centre and etch Solid Immersion Lens (SIL) with Focused Ion Beam (FIB) directly onto it, coupling the SIL to the colour centre. We will create a microwave structure, formerly characterised, placed precisely on the nanofabricated SIL coupled to the colour centre. These integrated structures will allow us to handle the spin of the NV centre with very high precision and microwave field intensity.

Q 35.75 Wed 16:30 Poster.I+II

Narrowband Source of Correlated Photon Pairs via Four-Wave Mixing in Atomic Vapour — Bharath Srivathsan[1], Gurpreet Kaur Gulati[1], Mei Yuen Brenda Chng[1], Gleb Maslennikov[1], Dzmitry Matsukevich[1,2], and •Christian Kurtsiefer[1,2] — [1]Centre for Quantum Technologies, National University of Singapore, Singapore 117543 — [2]Department of Physics, National University of Singapore, Singapore 117542

Many quantum communication protocols require entangled states of distant qubits which can be implemented using photons. To efficently transfer entanglement from photons to stationary qubits such as atoms, one requires entangled photons with a frequency bandwidth matching the absorption profile of the atoms. In our setup, a cold Rb^{87} atomic ensemble is pumped by two laser beams (780nm and 776nm) resonant with the $5S_{1/2} \rightarrow 5P_{3/2} \rightarrow 5D_{3/2}$ transition. This generates time-correlated photon pairs (776nm and 795nm) by nondegenerate four-wave mixing via the decay path $5D_{3/2} \rightarrow 5P_{1/2} \rightarrow 5S_{1/2}$. Coupling the photon pairs into single mode fibres and using silicon APDs, we observe $g^{(2)}$ of about 2000 and pairs to singles ratio of 11.2% (2800 photon pairs per second) with an optical bandwidth $< 30/(2\pi)$ MHz.

References: Willis, R. T. et al. Phys. Rev. A 79, 033814 (2009) Du, S-W. et al. Phys. Rev. Lett. 100, 183603 (2008) Chaneliere, T et al. Phys. Rev. Lett. 96, 093604 (2006)

Q 35.76 Wed 16:30 Poster.I+II

Generation of mesoscopic entangled states in a cavity coupled to an atomic ensemble — •Gor Nikoghosyan[1], Michael Hartmann[2], and Martin Plenio[1] — [1]Institut für Theoretische Physik, Albert-Einstein Allee 11, Universität Ulm, 89069 Ulm — [2]Technische Universität München, Physik Department, James-Franck-Strasse, 85748 Garching

The creation of mesoscopic entangled states is one of the fundamental challenges in quantum optics since they are very useful as resources for optical quantum information, quantum metrology, and super-precision lithography. In the present work (arXiv:1111.6047v1) we propose a novel system for the efficient production of optical NOON states based on the resonant interaction of a pair of quantized cavity modes with an ensemble of atoms. We show that in the strong-coupling regime the adiabatic evolution of the system tends to a limiting state that describes mesoscopic entanglement between photons and atoms which can easily be converted to a purely photonic or atomic NOON state. We also demonstrate the remarkable property that the efficiency of our scheme increases exponentially well with the cavity cooperativity factor, which gives efficient access to high number NOON states. The experimental feasibility of the scheme is discussed and its efficiency is demonstrated numerically.

Q 35.77 Wed 16:30 Poster.I+II

Realization and prospects of highly efficient up-conversion from 1550 nm to 532 nm — •Christina E. Vollmer[1], Christoph Baune[1], Aiko Samblowski[1], Jaromír Fiurášek[2], and Roman Schnabel[1] — [1]Institut für Gravitationsphysik, Leibniz Universität Hannover and Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstr. 38, 30167 Hannover, Germany — [2]Department of Optics, Palacký University, 17. listopadu 50, 77200 Olomouc, Czech Republic

Highly efficient up-conversion processes allow the generation of continuous wave squeezed vacuum states into the visible wavelength range. Here, we report on an experiment where a weak (2 mW) coherent signal field at 1550 nm is converted into a 532 nm field. We use the sum frequency generation process in a doubly resonant optical parametric oscillator which is pumped with an 810 nm field. An optimum set of parameters yielded to a conversion efficiency of (84.4 ± 1.5) %. This high value allows the transfer of the quantum state of the 1550 nm field into the 532 nm field [1], so that the experiment seems applicable to generate continuous wave squeezed vacuum states in the visible wavelength range. For that purpose the coherent 1550 nm field will be replaced by a squeezed vacuum field at 1550 nm generated in an independent experiment. This field is converted into a 532 nm squeezed vacuum field which will further increase the sensitivities of quantum metrology applications and opens possibilities in quantum information.

[1] P. Kumar. Quantum frequency conversion. Optics letters, 15(24):1476-8, December 1990.

Q 35.78 Wed 16:30 Poster.I+II

Pulsed Sagnac Source of Polarisation-Entangled Photon Pairs — Ana Predojević[1], •Stephanie Grabher[1], and Gregor Weihs[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Austria — [2]Institute for Quantum Computing, University of Waterloo, Canada

Entangled photon pairs are used in several important quantum information applications including quantum networks and quantum computing. Moreover, they are a crucial component for multi-photon experiments like entanglement swapping. In addition, photonic quantum information experiments demand bright and highly entangled photon pair sources.

We demonstrate a picosecond-pulsed laser pumped system for the generation of entangled photon pairs. The down-conversion source is realized in a Sagnac-interferometer based geometry. The characteristics of this type of polarisation-entangled photon source are wavelength tunability and intrinsic phase stability. The combination of periodic poling and collinear excitation allows the use of long crystals. We characterized the Sagnac source by measuring the entanglement visibility and performing quantum state tomography. The measurements yielded visibilities of 99.88(3)% and 98.70(9)% in the rectilinear and diagonal linear bases, respectively, a tangle of 96.50(83)% and a fidelity of 98.20(70)% with the $|\Psi^+\rangle$-Bell state. Furthermore, we measured the influence of the Gouy phase shift onto the phase of the output state.

This research was funded in part by the European Research Council (ERC) and the Austrian Science Fund (FWF).

Q 35.79 Wed 16:30 Poster.I+II

Continuous-wave light with a GHz squeezing bandwidth — •Stefan Ast, Aiko Samblowski, Moritz Mehmet, Sebastian Steinlechner, Tobias Eberle, Henning Vahlbruch, and Roman Schnabel — Institut für Gravitationsphysik, Hannover

Two-mode squeezed states can be used for entanglement-based continuous-variable quantum key distribution. The secure key rate is proportional to the bandwidth of the squeezing. We produced a continuous-wave squeezed state at the telecommunication wavelength of 1550 nm with a squeezing bandwidth of more than 2 GHz. The experimental setup used optical parametric down conversion (PDC) via a periodically poled potassium titanyl phosphate crystal (PPKTP) inside an optical cavity. To enhance the intra-cavity pump for the PDC process the resonator had a high Finesse for the harmonic wavelength at 775 nm. For the fundamental wavelength of 1550 nm there was no resonant enhancement, which should allow to produce the squeezed light within the phase-matching bandwidth of 3.22 nm. The squeezing was measured to be up to 0.3 dB below the vacuum noise from 50-2000 MHz. The squeezing strength was possibly limited by high thermal effects inside the non-linear crystal due to a high intra cavity pump power.

Q 35.80 Wed 16:30 Poster.I+II

Optical studies on individual transitions in GaN:Zn,Si/AlGaN heterostructures — •Matin Mohajerani[1], Arne Behrends[1], Silke Peters[2], Helmut Hofer[2], Waldemar Schmunk[2], Stefan Kück[2], Andrey Bakin[1], and Andreas Waag[1] — [1]Institute for Semiconductor Technology, Hans-Smmer-Straße 66, 38106 Braunschweig, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

During the past few years many methods have been developed to generate single-photon sources including atoms, ions, molecules or impurities in semiconductors and quantum dots. In this work, we have investigated Si and Zn co-doped GaN/AlGaN heterostructures. This approach could potentially allow room temperature electrically driven single photon emission. The samples studied were fabricated by metal-organic chemical vapor deposition and were patterned by photolithography and plasma etching processes in 3D pillar structures in order to confine individual emitters. Photoluminescence (PL) images were obtained by a confocal fluorescence microscope with a spatial resolution of 0.3μm and focal resolution of 0.5μm demonstrating well separated pillars. PL spectra measured under 325 nm He-Cd laser excitation show a broad emission around 2.9 eV (blue luminescence band) which is attributed to transition between the shallow donor band and the Zn deep acceptor. In addition, time-resolved PL was utilized to study the recombination lifetime of the BL transitions by 375 nm pulsed laser excitation. The potential of the GaN:Zn system for single photon emission will be discussed in detail.

Q 35.81 Wed 16:30 Poster.I+II

Single Photon Source with Diamond Nanocrystals on Tapered Optical Fibers — •Lars Liebermeister[1], Daniel Burchardt[1], Juliane Hermelbracht[1], Toshiyuki Tashima[1], Markus Weber[1], Ariane Stiebeiner[3], Arno Rauschenbeutel[3], and Harald Weinfurter[1,2] — [1]Ludwig-Maximilians-Universität, München — [2]Max-Planck-Institut für Quantenoptik, Garching — [3]Technische Universität Wien - Atominstitut, Wien, Austria

The development of high yield single photon sources is crucial for applications in quantum information as well as for experiments on the foundations quantum optics. The NV-center in diamond is a promising solid state candidate, however, in bulk diamond the collection efficiency is limited due to total internal reflection. To overcome this problem the use of nanodiamonds has become an auspicious approach, additionally providing the possibility for coupling to intregrated nano-optical elements as well as plasmonic[1] and nanocavity structures[2].

We follow the approach of coupling the single photon emission of an NV-center in a nanodiamond to the evanescent field of the guided mode in a tapered optical fiber. Theory[3] predicts up to 28% coupling efficiency under ideal conditions. With nanodiamonds on the tapered region and their excitation perpendicular to the fiber axis we observed the NV-emission in the guided mode of the fiber. Our new AFM-Setup will provide a more deterministic handling of the nanodiamonds and allows the positioning of selected nanocrystals on the taper region. [1] Huck et al.: Phys. Rev. Lett. 106, 2011; [2] Dumeige et al.: New J. Phys. 13(2), 2011; [3] Kien et al.: Phys. Rev. A 72(3), 2005

Q 35.82 Wed 16:30 Poster.I+II

Studying Photon Antibunching of Bunched Emitters — •Silke Peters, Johannes Dühn, Helmuth Hofer, Waldemar Schmunk, and Stefan Kück — Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

We report on the emission characteristics of bunched NV-centers in nano-diamonds by focusing on different spatial areas of the emission spot. The results show that the common expression $g^{(2)}(0) < 0.5$ does not sufficiently prove single center emission. In our setup, the emitted fluorescence is detected by a scanning confocal microscope setup and spectral filtering at (697 ± 37) nm. Due to the spot size of the 532 nm pulsed excitation laser, which is orders of magnitude larger than the dimensions of the NV-centers, the observed light might be emitted by more than one NV-center being present. To study this possibility the $g^{(2)}$-function is measured for various scan positions of two emitting centers 1 and 2 by a fiber coupled Hanbury-Brown-Twiss interferometer. For center 1, a $g^{(2)}(0) = 0.16$ is found independent from the laser focal position within the region around this center. For center 2, a $g^{(2)}(0) = 0.4$ is observed at the local count rate maximum of the center. In contrast, a significantly lower value of 0.196 is determined at the boundary of the center. These variations cannot be induced only by the influence of the detector dark count rate, the remaining background light, or an electronic timing jitter. A possible explanation is that the spot actually contains more than one NV-centers, yet, by shifting the focus to the side, fewer centers are being excited and therefore less simultaneous photon coincidences occur.

Q 35.83 Wed 16:30 Poster.I+II

Towards interconversion between UV- and telecom wavelengths — •Helge Rütz, Stephan Krapick, Raimund Ricken, Viktor Quiring, Hubertus Suche, and Christine Silberhorn — Universität Paderborn, Integrierte Quantenoptik, Warburger Str. 100, D-33098 Paderborn

While trapped ions and other promising candidates for stationary qubit systems in future quantum networks can only be addressed in the UV- and visible spectral region, efficient long distance photonic state transfer is only possible at telecommunication wavelengths. This spectral gap can however be bridged by Frequency Conversion.

Here, we present our conceptual work on a frequency conversion interface for quantum states of light between trapped ions at 369.5 nm and telecommunication wavelengths, based on second order nonlinear interactions ($\chi^{(2)}$) in tailored integrated optics.

Different material systems that are considered for this interface are Ti:PPLN, RPE:PPLN and Rb:PPKTP and we report on the respective challenges in waveguide fabrication and periodic poling techniques as well as current progress in our first frequency upconversion experiment.

Q 35.84 Wed 16:30 Poster.I+II

Statistics of single-mode bright squeezed vacuum — Timur Iskhakov[1], •Angela Perez[1], Kirill Spasibko[2], Maria Chekhova[1,2], and Gerd Leuchs[1] — [1]Max-Planck Institute for the Science of Light, Guenther-Scharowsky-Str. 1 / Bau 24, Erlangen D-91058, Germany — [2]Physics Department, Moscow State University, Leninskiye Gory 1-2, Moscow 119991, Russia

We study the statistics of single-mode (SM) bright squeezed vacuum produced at the output of a type I collinear optical parametric amplifier by the measurement of its second-order correlation function $g^{(2)}$. We implement special detection conditions which require the detection volume to be much smaller than the coherence volume in order to observe photon bunching in the nondegenerate regime and photon superbunching in the degenerate regime. These effects are ideally manifested by reaching a value of $g^{(2)} = 2$ and $g^{(2)} = 3$ respectively, given that the mean photon number per mode (N) is large. Observation of SM statistics of the states considered is a difficult experimental problem because they are essentially multimode and should remain macroscopic after SM selection. In our experiment we have measured values of $g^{(2)} = 1.84$ and $g^{(2)} = 2.58$ due to the fact that the detection volume is restricted from below by the spectral bandpass of the monochromator, only twice as narrow as the estimated spectral mode size. On the contrary, the detected angle was much smaller than the angular mode size which results in an effective number of detected spatio-temporal modes ($m = 1.25$) small enough to observe SM statistics. After SM selection, $N \approx 8 \times 10^3$ photons per pulse which is remarkably high.

Q 35.85 Wed 16:30 Poster.I+II

Characterization of continuous variable entangled states with photon counting — •Georg Harder[1], Kaisa Laiho[2], and Christine Silberhorn[1] — [1]Integrated Quantum Optics, Applied Physics, University of Paderborn, D-33098 Paderborn — [2]MPI for the Science of Light, Erlangen, Germany

Quantum state characterization is essential for applications in quantum optics and quantum communication. The standard technique, homodyne detection, measures field quadratures and relies on tomographic reconstruction of the Wigner function to yield complete information about the state. Hereby, the Heisenberg uncertainty principle precludes simultaneous measurement of non commuting variables. An alternative approach, photon counting, measures photon number probabilities from which the value of the Wigner function at single points in phase space can be deduced. Utilizing photon counting, we propose and implement a scheme that allows for the characterization of entanglement between CV entangled states without phase reference. Omitting phase stabilization in an experimental setup significantly simplifies its realization.

Q 35.86 Wed 16:30 Poster.I+II

Efficient generation of squeezing by waveguided parametric downconversion — •Thomas Dirmeier[1,2], Andreas Eckstein[3], Nitin Jain[1], Georg Harder[3], Christoffer Wittmann[1], Gerd Leuchs[1], Christoph Marquardt[1], and Christine Silberhorn[3] — [1]Max Planck Institute for the Science of Light, Guenther-Scharowsky-Str. 1, 91058 Erlangen, Germany — [2]Institute for Optics Photonics and Information, University Erlangen-Nuremberg, Germany — [3]Applied Physics, University of Paderborn, Warburgerstrasse 100, 33098 Paderborn, Germany

Biphoton sources based on parametric downconversion can be utilized as a reliable source of two-mode squeezed states with high brightness featuring reasonable squeezing values [1]. Modern continuous variable experiments, e.g. the generation of Schrödinger kitten states rely on such sources of the highest quality. Using a single-mode potassium-titanyl-phosphate waveguide in single-pass configuration, we provide a compact and robust source of two-mode squeezed states. To quantify the quality of the squeezed states, we study the spectral and quantum properties of frequency-degenerate signal and idler photons. Matching the temporal and spectral modes of the signal and idler photons with those of a coherent local oscillator, we seek to measure the resulting squeezing with a homodyne detection scheme.

[1] A.Eckstein, et al., Phys. Rev. Lett. **106**, 013603 (2011)

Q 35.87 Wed 16:30 Poster.I+II

Interferometry and Multiparticle Entanglement — •Philipp Hyllus[1,2], Luca Pezzé[3,4], Augusto Smerzi[1,4], Wieslaw Laskowski[5], Roland Krischek[6], Christian Schwemmer[6], Witlef Wieczorek[6,7], and Harald Weinfurter[6] — [1]INO-CNR BEC Center and Dipartimento di Fisica, Università di Trento, I-38050 Povo, Italy — [2]Department of Theoretical Physics, The University of the Basque Country, E-48080 Bilbao, Spain — [3]Laboratoire Charles Fabry, Institut d'Optique, 91127 Palaiseau, France — [4]INO-CNR and LENS, 50125 Firenze, Italy — [5]Fakultät für Physik, LMU Munich, D-80799 Munich, and Max-Planck Institut für Quantenoptik, D-85748 Garching, Germany — [6]Institute of Theoretical Physics and Astrophysics, University of Gdańsk, PL-80-952 Gdańsk, Poland — [7]Faculty of Physics, University of Vienna, A-1090 Vienna, Austria

Entangled quantum states allow for sub shot-noise sensitivity with linear interferometers, with applications in various fields such as quantum frequency standards, quantum lithography, quantum positioning and clock synchronization, and quantum imaging. This contribution discusses further the structure of entanglement needed for reaching the smallest phase uncertainties. In particular, we investigate the relation between entanglement of at most k particles in the probe state and the corresponding phase uncertainty both theoretically [1] and experimentally [2], using a Dicke state of 4 photons.

[1] P. Hyllus *et al.*, arXiv/1006.4366; see also G. Tóth, arXiv/1006.4368. [2] R. Krischek *et al.*, Phys. Rev. Lett. **107**, 080504 (2011).