Q 35: Poster I

Time: Tuesday 16:00–18:30 Location: Empore Lichthof

Q 35.1 Tue 16:00 Empore Lichthof

Geometric measure of entanglement of mixed three-qubit-GHZ-symmetric states — •Lars Erik Buchholz, Tobias Moroder, and Otfried Gühne — Theoretische Quantenoptik, Universität Siegen, Department Physik, Emmy-Noether-Campus, Walter-Flex-Strasse 3, 57068 Siegen

Quantifying entanglement is one of the challenging tasks in quantum information theory. The simplest case containing entanglement is the two-qubit system. This was intensively studied and significant results were distilled out of it. Progressive achievements on the experimental sector makes a consideration of multipartite entanglement essential. This problem is not a trivial extension of the bipartite entanglement due to different types of entanglement classes. Consequently, there exists not just one measure but a variety of possible quantifiers.

To improve our understanding about this quantum phenomenon, one has started to investigate special cases, like the mixed GHZ-symmetric-three-qubit states of Ref. [1]. This set of states exposed to be interesting due to the fact that the GHZ-Class is a nontrivial class of genuine tripartite entanglement and because of its high symmetric properties. Partial results were already obtained in Ref. [2] like the “three-tangle” as a measure for the three particle entanglement. To complete our understanding of these states we give an explicit expression of the geometric measure of entanglement with respect to fully separable states as well as for the concurrence for this class of states.

[1] C. Eltschka and J. Siewert, PRL **108**, 020502 (2012)
[2] J. Siewert and C. Eltschka, PRL **108**, 230502 (2012)

Q 35.2 Tue 16:00 Empore Lichthof

Scaling of genuine multi particle entanglement close to a quantum phase transition — •Martin Hofmann[1], Andreas Osterloh[2], and Otfried Gühne[1] — [1]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Straße 3, 57068 Siegen, Germany — [2]Institut für Theoretische Physik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg, Germany

Quantum phase transitions (QPT), which occur at zero temperature as some physical parameter reaches its critical value, are caused by abrupt changes in the ground state of a many body system. These transitions have been investigated and predicted in many different systems one of which was the one dimensional Ising model in a transverse field [1]. In this work the authors discuss the effects of the QPT on the two-particle entanglement using a finite size scaling ansatz. They also reveal that contrary to the correlation length, which diverges at the QPT, the two particle entanglement stays short ranged.

We extend their work from the investigation of two-particle entanglement to genuine multiparticle entanglement in three and four particles reduced states using the computable entanglement monotone for multi particle entanglement arising from the approach of PPT mixtures [2]. Our results show that also multi particle entanglement stays short ranged and follows a scaling behavior as the number of particles in the spin chain is varied.

[1] A. Osterloh *et al.*, Nature **416**, 608-610 (2002).
[2] B. Jungnitsch *et al.*, Phys. Rev. Lett. **106**, 190502 (2011)

Q 35.3 Tue 16:00 Empore Lichthof

A universal measure for genuine multipartite entanglement — •Florian Sokoli and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt

In addition to the standard concept of multipartite entanglement so called genuine multipartite entanglement has become an interesting and challenging field of reaserch. We provide a measure for quantifying genuine multipartite entanglement and several other types of entanglement based on Arvesons entanglement measure [1]. This measure is given by a norm and applies to all types of multipartite quantum states on finitely many finite dimensional Hilbert spaces. Furthermore, we propose an intuitive partial order relation on the set of all entanglement types and show that our measure is monotonous with respect to that order yielding a natural system of mutual estimations between the measures for different kinds of entanglement. Finally, we demonstrate how to reduce the computation of our measure for an arbitrary mixed state to its computation for a corresponding pure state on an enlarged system. This work is financially supported by the Center of Advanced Security Darmstadt.

[1] W. Arveson, Maximal vectors in Hilbert space and quantum entanglement, J. Funct. Analysis 256, 1476-1510 (2009) arXiv:0804.1140[math.OA]

Q 35.4 Tue 16:00 Empore Lichthof

Fixpoint Engineering for Markovian Open Quantum Systems — •Corey O’Meara[1], Gunther Dirr[2], and Thomas Schulte-Hebrüggen[1] — [1]Dept. Chem., TU-München — [2]Inst. Math., University of Würzburg

In quantum memories and practical quantum control, recent focus has been on steering the open quantum system into desired fixed points.

Here we give a complete picture of fixpoint sets arising under Markovian relaxation. For n-qubit systems, we parameterise *all* Lindblad generators sharing a desired fixed point. We also give a constructive overview how to make this fixed point unique. Building upon our classification thus facilitates to choose the simplest Markovian experimental implementation to arrive at any desired fixed point.

Q 35.5 Tue 16:00 Empore Lichthof

Adiabatic interaction representation and Floquet Theory: quantum state dynamics under periodic Hamiltonians with different energy scales — •Hermann Kampermann[1], Dagmar Bruss[1], Alex Bain[2], and Randall Dumont[2] — [1]Institut für theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf — [2]Department of Chemistry, McMaster University, Ontario, Canada

We consider a quantum system which evolves under a time-dependent periodic Hamiltonian. We focus on the situation that the Hamiltonian contains terms which have large energy splittings in comparison to the periodic frequency of the Hamiltonian. An adiabatic interaction basis in Floquet space is used which allows to calculate accurate frequency spectra for an observable of a given quantum state. We exemplify the power of this framework by calculating the magic-angle-spinning nuclear magnetic resonance spectra of a spin-$\frac{1}{2}$ nucleus dipolar coupled to spin-1 or spin-$\frac{3}{2}$ nuclei.

Q 35.6 Tue 16:00 Empore Lichthof

Pointer-based measurements of conjugate observables in a thermal environment — •Raoul Heese and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

Arthurs and Kelly’s simultaneous measurements of conjugate observables involve two pointer systems which are coupled to a quantum system to be measured. This coupling leads to generalized versions of uncertainty relations. A more realistic treatment of this model has to take environmental effects into consideration which further disturb the measurement process. We therefore treat the pointer systems as particles under Brownian motion in a thermal bath. This approach will allow us to discuss damping and decoherence of quantum measurements.

Q 35.7 Tue 16:00 Empore Lichthof

Distilling N00N-like Components of Two-Mode Quantum States of Light — •Falk Töppel[1,2], Kirill Yu. Spasibko[3], Timur Sh. Iskhakov[1], Magdalena Stobińska[4,5], Maria V. Chekohva[1,2,3], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Günther-Scharowsky-Straße 1/Bldg. 24, 91058 Erlangen, Germany — [2]Institute for Optics, Information and Photonics, Universität Erlangen-Nürnberg, Staudtstraße 7/B2, 91058 Erlangen, Germany — [3]Department of Physics, M. V. Lomonosov Moscow State University, Leninskie Gory, 119991 Moscow, Russia — [4]Institute of Physics, Polish Academy of Sciences, Al. Lotników 32/46, 02-668 Warsaw, Poland — [5]Institute of Theoretical Physics and Astrophysics, University of Gdańsk, 80-952 Gdańsk, Poland

The set of efficiently produced quantum states of light is limited. Particularly difficult to produce are non-classical non-Gaussian superpositions. Nevertheless, with quantum state engineering certain properties of accessible states can be modified. We propose a filter that diminishes the contributions of components with approximately equal population to a two-mode quantum state of light. In return, N00N-like contributions to the quantum state are enhanced. The main feature of our method is that it works symmetrically on components with different mode occupation and thus does preserve superpositions. Furthermore, the filter is especially suitable for macroscopic states of light and can be implemented easily with beam splitters and photon detectors only. We discuss its applications to several quantum states and present first experimental results on the filters working principle.

Q 35.8 Tue 16:00 Empore Lichthof

Single calcium-40 ions as quantum memories for single-photon polarization — •Philipp Müller, Joyee Ghosh, and Jürgen Eschner — Quantenphotonik, Universität des Saarlandes, Campus E 2.6, 66123 Saarbrücken, Germany

The controlled transfer of quantum states from one system to another is a cornerstone in the realization of quantum networks.

Here we present an overview of several schemes of storing polarization states of single photons in single $^{40}Ca^{+}$ ions. We compare the requirements, efficiencies and possible applications of these schemes with respect to the preparation of the absorber state, the absorption process and its analysis. These schemes can be used to create and herald entanglement of two (distant) ions through entanglement swapping from photon pairs onto the ions [1].

[1] S. Lloyd *et al.*, PRL **87**, 167903 (2001)

Q 35.9 Tue 16:00 Empore Lichthof

Effects of stochastic noise on dynamical decoupling procedures — Jozsef Zsolt Bernad, •Holger Frydrych, and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Darmstadt

Dynamical decoupling is a well-established technique to protect quantum systems from unwanted influences of their environment by exercising active control. It has been used experimentally to drastically increase the lifetime of qubit states in various implementations. The efficiency of different dynamical decoupling schemes defines the lifetime. However, errors in control operations always limit this efficiency. We propose a stochastic model as a possible description of imperfect control pulses and discuss the impact of this kind of error on different decoupling schemes. In the limit of continuous control, i.e. if the number of pulses $N \to \infty$, we derive a stochastic differential equation for the evolution of the density operator of the controlled system and its environment. In the context of this modified time evolution we discuss possibilities of protecting qubit states against environmental noise.

Q 35.10 Tue 16:00 Empore Lichthof

Optimal control of entanglement under restrictions — •Thomas Stefan Häberle and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm

We present a novel iterative algorithm with a special presearching step that can optimize the entanglement of a coupled quantum system while fulfilling restrictions of the control function. As an example we regard two atoms in a harmonic trap which interact via pointlike collisions. Our aim is to improve the entanglement at a fixed time by dynamically varying the trap frequency within a fixed interval. In order to get rid of the restrictions for the trap frequency, we use a suitable parametrization that transforms the optimization problem from a restricted to an unrestricted one. By applying the presearching step we get a reasonable initial guess for the optimal trap frequency. Finally, we use a standard method based on optimal control theory to further increase the entanglement.

Q 35.11 Tue 16:00 Empore Lichthof

Effects of entanglement on the measurement of phase shifts — •Simon Laibacher and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

It has recently been shown that a two-mode squeezed vacuum has the capability to yield phase uncertainties at, or even slightly below, the Heisenberg limit, when applied in conjunction with a parity measurement [1]. We show that this can also be achieved using a different measurement scheme that is based on homodyne detection in an eight port interferometer. In particular, we look at the effect of entanglement on the phase uncertainty by comparing our results for a displaced two-mode squeezed vacuum with the case where two separable single-mode squeezed states are used.

[1] P. M. Anisimov et al., Phys. Rev. Lett. **104**, 103602 (2010).

Q 35.12 Tue 16:00 Empore Lichthof

Quantum State Reconstruction with Weak Measurement — •Phuc Thanh Luu, Hermann Kampermann, and Dagmar Bruss — Heinrich-Heine-Universität, Institut für Theoretische Physik III, Universitätstr. 1, 40225 Düsseldorf

The estimation of quantum states has become a basic task in quantum information. Here, we propose an alternative scheme: quantum state reconstruction with weak measurement. By tuning the interaction strength between the system and the ancilla to the weak regime, we can obtain a small amount of information about the state and cause a slight disturbance on it. Thus, the scheme can be found useful for experiments that requires the measuring of quantum states as an intermediate stage in a process.

Q 35.13 Tue 16:00 Empore Lichthof

Influence of initial correlations on the dynamics of open quantum systems — •Simon Milz — Institut für theoretische Physik TU Dresden, Deutschland

We investigate the effects of initial system-bath correlations on the dynamics of open quantum systems. While the dynamics of a system initially uncorrelated with its environment is well-known to be completely positive, the reduced time evolution arising from a general system-bath initial state does not necessarily display this feature [1,2].

By investigating the open dynamics of low-dimensional systems, we aim to shed light on the crucial differences between the dynamics of correlated and uncorrelated initial states. Moreover a detailed examination of the general reduced dynamics and the subset of states it can be applied to is carried out.

[1] P. Pechukas, Phys. Rev. Lett. 73 (8) (1994) 1060.

[2] T.F. Jordan, A. Shaji, E.C.G. Sudarshan, Phys. Rev A. 70 (5) (2004) 052110.

Q 35.14 Tue 16:00 Empore Lichthof

Multi-mode cooling in anharmonic ion traps — •Regina Lechner[1], Philip Holz[1], Maximilian Harlander[1], Thomas Monz[1], Michael Brownnutt[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstraße 25, A-6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaften, Technikerstraße 21a, A-6020 Innsbruck, Austria

The ultimate usefulness of quantum computation is strongly bound to scalability. One standard route towards scalable architectures is by miniaturizing and segmenting traps. With such traps being used in various groups throughout the community, longer ion chains came into the focus of interest. With increasing ion numbers within a chain the number of motional modes increases too. However, in order to make use of ions and the ions' motion as information carrier, a way to cool unwanted modes is required to circumvent decoherence and information loss.

We investigate EIT cooling for multi-mode cooling of ion chains, both in harmonic and anharmonic trapping potentials. Segmented traps allow the application of anharmonic potentials and thus the possibility to arrange ions within a chain equidistantly. This property is of particular interest for quantum simulations, where equidistant spacing would more closely resemble the natural structure of - for example - solids.

Q 35.15 Tue 16:00 Empore Lichthof

A scanning probe quantum processor using NV centres — •Andreas Brunner, Friedemann Reinhard, and Jörg Wrachtrup — 3. Physikalisches Institut und Forschungszentrum SCoPE, Universität Stuttgart, Germany

The nitrogen-vacancy (NV) colour centre in diamond has shown to be a promising candidate for applications in spin sensing [1] and quantum information [2]. This is due to its electron spin structure featuring long coherence times and allowing optical state readout.

We pursue the realisation of a scanning-probe quantum processor by combining a mobile NV read-write-head with a stationary array of solid state quits. The scanning probe consists of an NV placed in the tip of microfabricated diamond pillar. This structure equally acts as a photonic waveguide and enables highly efficient fluorescence readout.

Our planned setup for these experiments is presented including our progress on the fabrication of such scanning NV sensors.

[1] N. Zhao et al., Nature Nanotechnology **7**, 657-662 (2012)

[2] N. Mizuochi et al., Nature Photonics **6**, 299-303 (2012)

Q 35.16 Tue 16:00 Empore Lichthof

A two-dimensional quantum register of single-atom qubits

in optical microtraps — •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 give an overview on the investigation of ^{85}Rb atoms in two-dimensional arrays of well over 100 individually addressable dipole traps featuring trap sizes and a tuneable site-separation in the single micrometer regime. 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 loading efficiencies while eliminating multi-atom events. We present single-site resolved addressing of single spins in a reconfigurable fashion and discuss the feasibility of Rydberg based two-qubit gates in our setup.

Q 35.17 Tue 16:00 Empore Lichthof

Coherent Rydberg Excitation in Thermal Caesium Vapour — •Alban Urvoy, Fabian Ripka, Christian Veit, Tilman Pfau, and Robert Löw — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart Germany

Rydberg atoms are promising candidates for the realisation of quantum devices, making use of their long-range atom-atom interaction. The presence of van der Waals-type interaction among Rydberg states has recently been demonstrated in thermal Rubidium vapour using a pulsed amplifier [1]. In Caesium, the excitation scheme $6S_{1/2} \rightarrow 7P_{3/2} \rightarrow nS, nD$ has the advantage, compared to that in Rubidium, that the upper transition may be driven at a wavelength of approx. 1064 nm. At this wavelength it is possible to reach high laser powers with CW fibre amplifiers and we therefore can expand the work of [1] to longer time scales with the use of a Pockels cell. However due to the strong Doppler effect present in thermal vapours, the wavelength ratio between the two driving laser fields plays a crucial role in the system and has to be considered carefully.
In this three level ladder system in Cs, we present our results on the coherence properties for the steady-state EIT spectroscopy as well as for the pulsed nanosecond regime.

[1] T. Baluktsian, B. Huber, et al., arXiv:1212.0690 [physics.atom-ph]

Q 35.18 Tue 16:00 Empore Lichthof

Towards quantum simulation of spin-ice dynamics — •Henning Kalis, Miriam Bujak, Manuel Mielenz, Ulrich Warring, and Tobias Schaetz — Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, Hermann-Herder-Strasse 3, 79104 Freiburg, Germany

Geometrically frustrated systems exhibit a residual entropy due to their exponentially large number of degenerate classical groundstates. In analogy to the proton-disorder in commom water ice they are called *spin-ice*-systems, e.g. the triangular Ising-Model with nearest neighbor antiferromeagnetic exchange interactions. Although spin-ice systems are of interest for many years [1] little is known about the microscopic mechanisms governing their physics.
High fidelity quantum control of multiple spin systems have been implemented [2] with ions in linear Paul traps (e.g. quantum simulation of Ising-Models [3]). A novel type of surface electrode trap [4] may extend this degree of control to two dimensional trap arrays (lattices) and therefore we may gain insight of the microscopic dynamics of spin-ice systems.
We introduce the surface trap geometry and report on the current status of the experiment.

[1] G.H. Wannier, Phys. Rev. **79**, 357 (1950)
[2] Ch Schneider *et al.*, Rep. Prog. Phys. **75** 024401 (2012)
[3] A. Friedenauer *et al.*, Nature Physics **4**, 757 - 761 (2008)
[4] R. Schmied *et al.*, PRL **102**, 233002 (2009)

Q 35.19 Tue 16:00 Empore Lichthof

Wärmekraftmaschine mit einzelnen Ionen — •Johannes Rossnagel[1], Georg Jacob[1], Charlotte Degünther[1], Obinna Abah[2], Ferdinand Schmidt-Kaler[1], Eric Lutz[2,3] und Kilian Singer[1] — [1]QUANTUM, Institut für Physik, Universtität Mainz, Staudingerweg 7, 55128 Mainz, Germany — [2]Institut für Physik, Universität Augsburg, D-86135 Augsburg, Germany — [3]Dahlem Center für komplexe Quantensysteme, Freie Universtiät Berlin, Arnimallee 14, D-14195 Berlin-Dahlem, Germany

Wir präsentieren einen realistischen Vorschlag für eine Nano-Wärmekraftmaschine mit einem einzelnen Ion als aktives Medium [1]. Um einen Otto-Kreisprozess zu realisieren, wird ein einzelnes Ion in einer linearen Paulfalle mit speziell geformten Elektroden gefangen und an Wärmebäder gekoppelt. Diese Wärmebäder können durch verstimmte Laserstrahlung oder elektronisches Rauschen erzeugt werden und heizen und kühlen die radiale Komponente des thermischen Zustands des Ions im Wechsel. Die zugeführte Wärme wird umgesetzt in eine kohärente Bewegung des Ions entlang der Fallenachse, aus der die erzeugte Leistung bestimmt werden kann. Mit Monte-Carlo Simulationen unter realistischen Bedingungen zeigen wir, dass Effizienzen von 30% bei maximaler Leistung erreicht werden können.

[1] O.Abah, J.Roßnagel, G.Jacob et. al, PRL 109, 203006 (2012).

Q 35.20 Tue 16:00 Empore Lichthof

Near-field Microwave Quantum Logic with Trapped Ions — •Martina Carsjens[1,2], Matthias Kohnen[1,2], Timko Dubielzig[1], Anna-Greta Paschke[1], Malte Niemann[1], and Christian Ospelkaus[1,2] — [1]QUEST, Institut für Quantenoptik, Leibniz Universität Hannover — [2]QUEST, PTB Braunschweig

Multi-qubit interactions for quantum information processing with trapped ions require a coupling between individual ion-qubits and a shared motional degree of freedom as a quantum bus. Recent experiments have shown how such interactions can be realized using microwave near-fields rather than the widely used laser fields. The near-field approach holds great promise for integration, simplification and operation fidelities. To achieve these goals, the structure supplying the microwave fields needs to be well understood and optimized. We report on efficient and accurate numerical simulations of microwave guiding structures. Furthermore, near-field manipulation requires close proximity of ion-qubits to conductors, where anomalous motional heating can be a significant source of decoherence. To suppress these detrimental effects in our experiments, we have developed a low-vibration closed-cycle cryogenic setup.

Q 35.21 Tue 16:00 Empore Lichthof

Heralded photonic interaction between distant single ions — •Christoph Kurz[1], Jan Huwer[1,2], Michael Schug[1], Philipp Müller[1], and Jürgen Eschner[1] — [1]Experimentalphysik, Universität des Saarlandes, Saarbrücken, Germany — [2]ICFO – The Institute of Photonic Sciences, Castelldefels (Barcelona), Spain

Single trapped atoms and ions offer a high level of control over their internal and external quantum state and are therefore ideal systems for implementations of quantum information processing. They also allow for the controlled emission and absorption of single photons as a resource in quantum communication and quantum networking.

We operate two independent linear Paul traps with single $^{40}Ca^{+}$ ions, which provides a highly modular setup for implementing quantum processing and communication tools. The ions interact over 1 m distance through emission and absorption of single resonant photons. Single-photon emission in the sender ion is continuous or triggered; absorption in the receiver is signaled by a quantum jump. Frequency, polarization, and temporal shape of the single photons are controlled by appropriate laser pulses [1].

[1] C. Kurz et al., arXiv:1211.5922

Q 35.22 Tue 16:00 Empore Lichthof

Towards a Loophole Free Bell Test with a Pair of Remotely Entangeld 87Rb-Atoms — •Kai Redeker[1], Daniel Burchardt[1], Norbert Ortegel[1], Julian Hofmann[1], Michael Krug[1], Markus Weber[1], Wenjamin Rosenfeld[2], and Harald Weinfurter[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität München, D-80799 München, Germany — [2]Max-Planck Institut für Quantenoptik, D-85748 Garching, Germany

Bell's inequality allows to test the validity of local hidden variables theories. To perform a conclusive Bell test, one has to fulfill two major requirements: The state measurements of the entangled particles need to be highly efficient and space like separated.

We present progress towards an experiment which can fulfill both requirements. We use entanglement between single trapped atoms and single photons to create heralded entanglement between separated atoms [1]. The measurement including choosing a random setting and efficiently reading out the atomic state, will take less then one microsecond. This is achieved by state dependent ionization and subsequent detection of the ionization fragments [2]. We plan extending the distance between the atoms from now 20m to 400m to enable the space like separation of the measurements on the atoms. Together, this will enable to finally close the locality and the efficiency loophole in one experiment.

[1]J.Hofmann et al. Science 337, 72 (2012)
[2]F.Henkel et al. Phys. Rev. Lett 105 253001 (2010)

Q 35.23 Tue 16:00 Empore Lichthof

Effective Interaction between Light Pulses based on Storage in a Bose-Einstein Condensate — •Simon Baur, Christoph Vo, Stephan Riedl, Dominik Fauser, Daniel Tiarks, Gerhard Rempe, and Stephan Dürr — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany

Creating an interaction between single photons is a key step towards realizing a photonic quantum gate. In conventional optical materials nonlinearities are so weak that they become negligible on the single photon level. However, light pulses can be stored in cold atomic ensembles as atomic spin waves with high efficiency and converted back to light on demand [1]. Coherent interaction between spin waves can be introduced by collisions between ground-state atoms or by excitation to Rydberg states with a long-range interaction. We experimentally demonstrate that in a Bose-Einstein condensate of ^{87}Rb s-wave scattering betweeen ground-state atoms is sufficiently strong to realize a classical AND gate for classical light pulses [2]. We show that the gate operation is phase coherent, an essential prerequisite for extensions to a quantum logic gate. We further report on experimental progress towards implementing interactions between single photons by using the long-range dipole-dipole interaction between Rydberg atoms.

[1] M. Lettner et al. *Phys. Rev. Lett.* **106**, 210503 (2011)
[2] C. Vo et al. arXiv:1211.7240

Q 35.24 Tue 16:00 Empore Lichthof

Rydberganregung von lasergekühlten ^{40}Ca$^+$ Ionen — •Lennart Pelzer, Thomas Feldker, Ferdinand Schmidt-Kaler, Daniel Kolbe, Matthias Stappel und Jochen Walz — Institut für Physik, Johannes Gutenberg Universität, Mainz

In Paulfallen gefangen, lasergekühlte Ionen gehören zu den vielversprechendsten Kandidaten für die Quanteninformationsverarbeitung. Eine Kombination dieser Technologie mit quantenlogischen Operationen durch Rydberganregung und der damit verbundenen Dipol-Blockade verspricht eine erweiterte Skalierbarkeit.

In unserem Experiment werden die ^{40}Ca$^+$ Ionen in einer Paulfalle gefangen und gekühlt bevor sie in den metastabilen $3D_{5/2}$ Zustand gebracht werden, von wo sie mittels Laserlicht bei einer Wellenlänge von 122nm in den Rydbergzustand 67P angeregt und spektroskopisch untersucht werden sollen[1]. Weitergehende Ziele sind die Modifikation der Modenstruktur des Ionenkristalles durch Rydberganregung einzelner Ionen sowie die Erzeugung von Vielteilchen-Verschränkung in Ionenkristallen mittels Dipolblockade.

Wir präsentieren die experimentellen Fortschritte der letzten Zeit, insbesondere die Ionisation von ^{40}Ca$^+$ durch den VUV-Laser und damit den ersten Nachweis einer Interaktion des VUV-Lasers mit den Ionen.

[1] F. Schmidt-Kaler, T. Feldker, D. Kolbe, J. Walz, M. Müller, P. Zoller, W. Li and I. Lesanovsky,"Rydberg excitation of trapped cold ions: a detailed case study", New J. Phys., 2011

Q 35.25 Tue 16:00 Empore Lichthof

Automatisierte Messverfahren für einen zukünftigen Ionenfallen-Quantencomputer — •Thomas Ruster[1], Henning Kaufmann[1], Andreas Walther[2], Claudia Warschburger[1], Max Hettrich[1], Kilian Singer[1], Ferdinand Schmidt-Kaler[1] und Ulrich Poschinger[1] — [1]QUANTUM, Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz — [2]Department of Physics, Lund University, Box 118, SE-221 00 Lund

Der Betrieb einer Ionenfalle zur Quanteninformationsverarbeitung ist mit erheblichem Kalibrationsaufwand verbunden. Darunter fallen die Präparation und Detektion von Ionen, die Spektroskopie kohärenter Übergänge sowie die Kalibration von Pulsflächen und Gatterparametern. Gerade im Hinblick auf die Skalierbarkeit des Systems ist es unverzichtbar, diese Messungen effizient und automatisiert durchzuführen.

Zur effizienten fluoreszenzbasierten Zustandserkennung eines Ionenkristalls wurde ein Algorithmus nach dem Prinzip der Support Vector Machine implementiert. Ein Verfahren zur Korrektur von Auslesefehlern erlaubt die Umwandlung systematischer Fehler in der Präparation, beim Electron Shelving und in der Fluoreszenzauslese in statistische Fehler. Es wird gezeigt, wie die Anwendung des Verfahrens die gemessene Fidelität einer Gatteroperation zur Verschränkung zweier Ionen verbessert.

Darüber hinaus werden automatisierte Verfahren zur Bestimmung und Vorhersage von Laserfrequenzen und zur präzisen Kalibration von Pulsflächen vorgestellt.

Q 35.26 Tue 16:00 Empore Lichthof

Ein mikrostrukturiertes Resonator-Ionenfallensystem für CQED-Experimente — •Max Hettrich, Andreas Pfister, Marcel Salz und Ferdinand Schmidt-Kaler — Institut für Physik, Universität Mainz

Die starke Kopplung von Atomen und Photonen in CQED-Experimenten ist mit ultrakalten, neutralen Atomen und Rydbergatomen schon seit einiger Zeit Stand der Technik, mit Ionen in Paulfallen konnten Experimente in diesem Regime bisher jedoch noch nicht realisiert werden. Das Hauptproblem stellt hierbei die Nähe der Ionen zu den dielektrischen Spiegeloberflächen dar, welche sich durch das Streulicht der verwendeten Laser aufladen können, und so das Fallenpotential unkontrolliert ändern. In unserem Design, welches wir auf diesem Poster vorstellen, umgehen wir diesen Effekt, indem wir den Bereich, in dem das Ion mit Laserlicht von außen interagiert von dem Bereich räumlich trennen, in welchem das Ion mit dem optischen Resonator wechselwirkt. Zwischen beiden Bereichen kann das Ion schnell hin- und hertransportiert werden. Wir benutzen hierfür eine segmentierte, mikrostrukturierte Paulfalle und integrieren darin einen Faserresonator. Wir untersuchen die Formung der Faserendflächen mit einem FIB, um eine für unseren Aufbau optimierte Resonatorgeometrie zu realisieren. Die so entstehende Schnittstelle ermöglicht den Austausch von Quanteninformation zwischen Photonen und Ionen. Dies ist unter anderem ein entscheidender Baustein eines Quantenrepeaters zur Vergrößerung der maximalen Übertragungsstrecke von Quantenzuständen.

Q 35.27 Tue 16:00 Empore Lichthof

Tools for single-ion quantum state preparation and analysis — •Pascal Eich[1], Jan Huwer[1,2], Christoph Kurz[1], Philipp Müller[1], Michael Schug[1], and Jürgen Eschner[1] — [1]Universität des Saarlandes, Experimentalphysik, Campus E2 6, 66123 Saarbrücken, Germany — [2]ICFO – Institut de Ciències Fotòniques, Mediterranean Technology Park, 08860 Castelldefels (Barcelona), Spain

Reliable preparation and analysis of quantum states is essential for quantum information applications. Here we demonstrate the required tools for the manipulation of electronic states of a single ^{40}Ca$^+$ ion in the context of quantum repeaters. In the $S_{1/2}$ ground state, we prepare one of the two Zeeman sublevels by optical pumping and create a coherent superposition using radio frequency pulses. The population in the $S_{1/2}$ Zeeman sublevels is coherently transferred to one of the Zeeman sublevels of the metastable $D_{5/2}$ state using a narrowband laser at 729 nm, either via the rapid adiabatic passage technique or by a Rabi pulse.

Q 35.28 Tue 16:00 Empore Lichthof

Präzise experimentelle Untersuchung planarer Ionenkristalle für Quantensimulationen — •Henning Kaufmann[1], Stefan Ulm[1], Georg Jacob[1], Ulrich Poschinger[1], Haggai Landa[2], Alex Retker[3], Martin Plenio[4] und Ferdinand Schmidt-Kaler[1] — [1]QUANTUM, Institut für Physik, Universität Mainz — [2]Tel-Aviv University — [3]The Hebrew University of Jerusalem — [4]Universität Ulm

Das Verständnis von Eigenmoden und Eigenfrequenzen großer zweidimensionaler Ionenkristalle bildet die Basis für die weitere Verwendung solcher Strukturen zur Quantensimulation [1]. Wir untersuchen gefangene planare Ionenkristalle experimentell [2]. Die theoretische Vorhersage der Ionenpositionen konnte mit einer relativen Genauigkeit von $4 \cdot 10^{-5}$ bestätigt werden. Durch Veränderung der an die Falle angelegten Spannungen kann der Anisotropieparameter verändert werden, welcher das Verhältnis von axialem zu radialem Einschluss angibt. Wir beobachten mehrere Strukturübergänge und bestimmen kritische Anisotropiewerte für diese Übergänge. Mit Hilfe von Seitenband-Spektroskopie werden die gemeinsamen Schwingungsmoden in der Zickzack-Konfiguration untersucht. Hierbei stimmen die

Messdaten jedoch nicht mit gängigen Pseudopotential Berechnungen überein, erst die komplette Zeitentwicklung der Mathieu Gleichungen zeigt gute Übereinstimmung mit den experimentellen Daten. [1] A. Bermudez et al., NJP,**14**, 9, (2012). [2] H. Kaufmann et al., accepted for publication in PRL, arxiv:1208.4040

Q 35.29 Tue 16:00 Empore Lichthof

Simulating the spin-boson model in a Paul trap — •Govinda Clos, Martin Enderlein, Ulrich Warring, and Tobias Schaetz — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany

Employing a linear chain of several Mg-25 ions stored in a Paul trap, we aim to experimentally simulate the dynamics of the spin-boson model. Using different lasers and control protocols we can, e.g., cool the ions to the motional ground state ($\bar{n} < 0.03$) and manipulate their internal and external degrees of freedom. Two-photon stimulated Raman transitions enable coherent couplings between the hyperfine states of one ion (the simulated spin) and the set of axial vibrational modes of all ions in the chain. These modes represent a finite number of harmonic oscillators (the bosons).

Following a proposal by Porras *et al.* [1] and based on the simulations realized by Friedenauer *et al.* [2], our setup based on trapped ions and of finite size will permit to explore the different regimes of the model depending on the spectral density of the environment: *(i)* revivals of excitation and entanglement, *(ii)* the overdamped regime, and finally, *(iii)* localization, i.e., inhibition of spin/energy transfer due to the Quantum Zeno effect.

[1] Porras, D., Marquardt, F., von Delft, J. and Cirac, J. I., Phys. Rev. A **78**, 010101 (2008).

[2] A. Friedenauer, H. Schmitz, J. Glueckert, D. Porras and T. Schaetz, Nat. Phys. **4**, 757-761 (2008).

Q 35.30 Tue 16:00 Empore Lichthof

Nanofibers as light-matter interfaces for quantum networks — •Dominik Maxein, Baptiste Gouraud, Adrien Nicolas, Elisabeth Giacobino, and Julien Laurat — Laboratoire Kastler Brossel, Université P. et M. Curie, École Normale Supérieure, and CNRS, 4 place Jussieu, 75252 Paris Cedex 05, France

An interesting and emerging system for light-matter interfacing is the optical nanofiber, where light is guided by a “glass wire” with sub-wavelength diameter. The strong evanescent field can yield strong interactions between guided light modes and matter in the surroundings of the nanofiber. To hold an ensemble of atoms in the vicinity of the fiber, two-color optical dipole traps have been recently realized [Vetsch et al., PRL **104**, 203603 (2010) and Goban et al., PRL **109**, 033603 (2012))].

Our group focuses on the development of quantum memories in cold, neutral atom clouds. We are currently building a work bench for the production of nanofibers using the brushing flame technique, heating a small portion of the fiber and pulling in a well-controlled way. We will present the technological background and characterization for our system and the first obtained tapered fibers. Future applications will be discussed.

Q 35.31 Tue 16:00 Empore Lichthof

Toward quantum simulations in a triangular surface trap — •Miriam Bujak, Manuel Mielenz, Henning Kalis, Ulrich Warring, and Tobias Schaetz — Physikalisches Institut, Albert-Ludwigs Universität Freiburg

Ions confined in linear Paul traps have proven to be well suited for quantum information processing and quantum simulations [1-2]. While many proof-of-principle experiments have been realized in these traps with up to tens of ions [2], scalability of ion based quantum processors and 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 in this new approach the ions will be stored in individual minima of the potential, the mutual distances are kept small enough to provide sufficient coupling strength for quantum simulation experiments in two-dimensional lattices [5]. We report on the current status of the experimental setup.

[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. Optics **54**, 16-17 (2007)
[4] R. Schmied *et al.*, PRL **102**, 233002 (2009)
[5] Ch. Schneider *et al.*, Rep. Prog. Phys. **75**, 024401 (2012)

Q 35.32 Tue 16:00 Empore Lichthof

Radiofrequency Spectroscopy of a single ^{40}Ca^{+} Qubit — •Jens Welzel, Amado Bautista-Salvador, Niels Kurz, Rene Gerritsma, and Ferdinand Schmidt-Kaler — QUANTUM, Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Miniaturized ion traps may offer a route towards scalable quantum computation and simulation. Such devices also allow the manipulation of ions via magnetic field gradients in the radiofrequency domain, thus avoiding the technological overhead of lasers [1]. Here, we report on experimental work on a planar ion trap designed to coherently manipulate ^{40}Ca^{+} ions via magnetic field gradients [2]. We performed radiofrequency spectroscopy [1] of a single ^{40}Ca^{+} ion in the presence of static currents. Additionally, by moving the ion 600 μm along the trap axis we measured the total static magnetic field which yields a gradient of 1.11 ± 0.18 T/m per Ampere along the trap axis. Oscillating currents may be employed to couple the spin of the ions to their motion. We anticipate gradients of 10 T/m per Ampere perpendicular to the trap axis. These fields may be used to engineer spin-spin interactions in an ion crystal [2]. The presented experiments also pave the way for the implementation of a laser-less sideband cooling and robust quantum gates based on oscillating magnetic field gradients in the radiofrequency regime.

[1] Johanning, M. et. al. Phys. Rev. Lett. **102**, 073004 (2009).
[2] Welzel, J. et. al. Eur. Phys. J. D **65**, 285−297 (2011).

Q 35.33 Tue 16:00 Empore Lichthof

Single ion saturation as efficiency measurement for light-matter interaction — •Robert Maiwald[1,2], Andrea Golla[1,2], Martin Fischer[1,2], Marianne Bader[1,2], Markus Sondermann[1,2], and Gerd Leuchs[1,2] — [1]Institut für Optik, Information und Photonik (IOIP), Universität Erlangen-Nürnberg, Erlangen — [2]Max-Planck-Institut für die Physik des Lichts (MPL), Erlangen

The characteristic answer of a two-level system to a resonantly exciting laser field can be used as a measurement for the efficiency of light-matter interaction, aiming at applications such as quantum memories and quantum networks. We follow a free space approach where the incoming light field is mode-matched to a linear dipole transition of a single atomic ion. For this purpose we prepare a spatially and temporally formed light mode that has – after focusing – an almost perfect overlap with the emission of a linear dipole [1]. With a specialized ion trap we place a single ^{174}Yb^{+} ion in the focus of a parabolic mirror covering 81 % of the solid angle surrounding the ion [2]. This set-up allows one to directly interface the tailored light mode with the single ion. We use the saturation of the ion's cooling transition as a measure for the light-matter interaction efficiency to characterize the quality of the incoming light mode and the spread of the parabolic mirror's focal spot. Additionally, imaging the ion's fluorescence via the parabolic mirror yields the highest resolution achieved so far with single ions.

[1] A. Golla *et al.*, Eur. Phys. J. D **66**, 190 (2012)
[2] R. Maiwald *et al.*, Phys. Rev. A **86**, 043431 (2012)

Q 35.34 Tue 16:00 Empore Lichthof

Trapping Yb+ ions in a segmented surface trap with integrated magnetic field gradient — •Peter Kunert, Daniel Georgen, Michael Johanning, and Christof Wunderlich — Universität Siegen, Naturwissenschaftlich-Technische Fakultät, Dept. Physik, 57068 Siegen, Deutschland

A promising approach for realizing complex ion trap-structures and -arrays are planar ion traps where all electrodes and current carrying elements are arranged in a quasi-2-dimensional structure. We demonstrate trapping of 172Yb+ ions in a surface ion trap in ultra high vacuum at 5*10^-11 mbar. Long storage times of several hours are achieved. We characterize the trap in terms of its secular frequencies and demonstrate deterministic transport of ions above the plane. A 60 um thin glass plate is mounted at 2.5 mm above and parallel to the trap surface. It is coated with a 100 nm thin indium tin oxide layer allowing for the application of a static electric potential. This serves to protect the trapped ion from stray fields possibly induced by particles at the chip surface and the detection viewport, to change the trapping height of the ion and increase the trap depth by applying a suitable voltage. The ITO layer transmits 68% of resonance fluorescence light near 369 nm. We present briefly the production process using different lithography and electroplating steps. The trap design includes current carrying electrodes to produce magnetic field gradients with different tuneable shapes at the ion position. The magnetic field gradients will permit addressing of ions in the frequency domain and allows to couple internal and external motion with an effective Lamb-Dicke parameter.

Q 35.35 Tue 16:00 Empore Lichthof

Time-resolved Bell-state measurement between photons from remote single atoms — •Andreas Neuzner, Christian Nölleke, Andreas Reiserer, Carolin Hahn, Gerhard Rempe, and Stephan Ritter — Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

Detecting the Bell-state of two particles via a combined measurement is the key technique for the implementation of quantum teleportation protocols that allow for the heralded transfer of quantum information over large distances. We investigate Bell-state measurement of the polarization state of two photons originating from cavity-based neutral-atom quantum memories in separate laboratories. Two-photon interference and polarization-sensitive detection allow us to unambigously detect two of the four Bell states. The photons are generated via a vacuum-stimulated Raman adiabatic passage (vSTIRAP). By adjusting parameters of this process, we can tailor properties of the photons like temporal envelope and center frequency. We choose a width of the photons' envelope that exceeds the temporal resolution of the detection setup by more than two orders of magnitude. We can thus distinguish the arrival-time difference of the two temporal envelopes from the detection time difference of two individual photon events. A technique to herald events with increased interference contrast is demonstrated. Combining the Bell-state measurement with the creation of atom-photon entanglement enables us to implement teleportation of atomic states over a distance of 21m.

Q 35.36 Tue 16:00 Empore Lichthof

Hyperfine Qubit in a Microstructured Ion Trap with Integrated Solenoids — •Timm F. Gloger, M. Tanveer Baig, Thomas Collath, Delia Kaufmann, Peter Kaufmann, Michael Johanning, and Christof Wunderlich — Universität Siegen, NT Fakultät, Department Physik, 57068 Siegen, Germany

We characterize a micro-structured segmented ion trap with integrated solenoids. Using the segmented DC electrode structure of the trap we shuttle and split strings of laser cooled ions along the trap axis and are able to design various trapping potentials.

The trap is operated with ions of two Ytterbium isotopes, $^{172}\mathrm{Yb}^+$ and $^{171}\mathrm{Yb}^+$. We coherently manipulate a qubit implemented in the $\left|S_{1/2}, F=0\right\rangle \leftrightarrow \left|S_{1/2}, F=1\right\rangle$ hyperfine transistions of $^{171}\mathrm{Yb}^+$ and use the qubit as a sensor to characterized the magnetic field along the trap axis.

The solenoids are used to create switchable magnetic field gradients that in turn allow for addressing trapped ions in frequency space and coupling the ions' motional and spin states. Furthermore, long range spin-spin coupling of the ions' internal states is induced by the gradient. These mechanisms are called **Ma**gnetic **G**radient **I**nduced **C**oupling, MAGIC.

Switchable gradients and the ability to shape the trapping potentials enable the custom design of spin-spin coupling constants useful for a variety of experiments in quantum information science.

Q 35.37 Tue 16:00 Empore Lichthof

Towards laser-machined optical cavities — •Manuel Uphoff, Manuel Brekenfeld, Johannes Lang, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany

Single atoms strongly coupled to fiber-based, high-finesse optical cavities are a promising system for applications in quantum information processing. Fiber-based cavities allow for small mode volumes and a small system size thereby improving the scalability compared to conventional Fabry-Pérot resonators. The Bragg mirrors are directly coated onto the end facets of the fibers. This requires concave structures on the end facets. Their surface has to be spherical over a large area with the surface roughness as low as possible. We report on the fabrication of such fiber ends, machined with a $\mathrm{CO_2}$-laser at a wavelength of 9.3 μm. This new wavelength enables unprecedented structure sizes approaching the diameter of the fiber. We achieve a residual surface roughness well below 0.3 nm rms and investigate effects of the laser polarization on the eccentricity of the surface. We plan to fabricate cavities from these fibers that will enable strong atom-cavity coupling. The progress towards this goal will be discussed.

Q 35.38 Tue 16:00 Empore Lichthof

Charakterisierung einer deterministischen Einzelionenquelle — •Georg Jacob, Sebastian Wolf, Stefan Ulm, Johannes Rossnagel, Charlotte Degünther, Ferdinand Schmidt-Kaler und Kilian Singer — QUANTUM, Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Ionenquellen, wie sie in Ionenmikroskopen und Focused Ion Beams Verbreitung finden, emittieren in ein sehr kleines Phasenraumvolumen, was eine Fokussierung bis auf wenige Nanometer ermöglicht. Aufgrund ihrer inhärent statistischen Natur ist es diesen nicht möglich deterministisch einzelne Ionen zu extrahieren, was jedoch für eine Reihe von Anwendungen, wie z.B. das deterministische Erzeugen von NV-Farbzentren, unabdingbar ist. Zu diesem Zweck wurde eine deterministische Einzelionenquelle auf der Grundlage einer linearen Paul-Falle entwickelt [1]. Mit einer verbesserten Version dieser Einzelionen-Quelle erreichen wir mit einer Einzelschuss Folge von 3 Ionen/s eine Strahldivergenz 30 μrad bei einer Energie von $(1352,6 \pm 0,3)$ eV, was einer Geschwindigkeitsverteilung von ungefähr 8 m/s entspricht. Um diese Messergebnisse zu stützen und realistische Startparameter für ein anschließendes Fokussieren des Strahls mittels einer elektrostatischen Einzellinse zu erzeugen, wurden zusätzlich nummerische Simulationen durchgeführt [2]. Eine entsprechende Modellierung lässt sogar Fokussradien im Sub-Nanometerbereich erwarten.

[1] W. Schnitzler *et al.*, Phys. Rev. Lett. **102**, 070501 (2009)
[2] K. Singer *et al.*, RMP **82**, 2609 (2010)

Q 35.39 Tue 16:00 Empore Lichthof

A novel ion trap design: the fibre cane trap — •Andrea Golla[1,2], Alexander L. Chekhov[3], Robert Maiwald[1,2], Patrick Uebel[2], Markus Schmidt[2,4], Markus Sondermann[1,2], Philip Russell[1,2], and Gerd Leuchs[1,2] — [1]Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg, Staudtstr. 7 B2, 91058 Erlangen — [2]Max Planck Institute for the Science of Light, Guenther-Scharowsky-Str. 1 Bldg. 24, 91058 Erlangen — [3]Department of Physics, M. V. Lomonosov Moscow State University, 119991 Moscow, Russia — [4]The Institute of Photonic Technology, Friedrich Schiller University Jena, Albert-Einstein-Str. 9, 07745 Jena

We present a novel ion trap design enabling large optical access. The design is a further development of the stylus trap [1] allowing for down scaling of the trap size. The new trap is realized using a fibre cane as mounting base enabling a simplified, highly precise installation of the trap electrodes while offering large mechanical stability. The manufacturing process of this fibre cane trap will be described and the constructed trap will be presented. Furthermore, results of simulations of the trap structure and future applications will be discussed.

[1] R. Maiwald et al., Nature Physics 5, 551 (2009)

Q 35.40 Tue 16:00 Empore Lichthof

Trapping of Topological-Structural Defects in Coulomb Crystals — •Manuel Mielenz[1], Jonathan Brox[1], Haggai Landa[2], Steffen Kahra[1], Guenther Leschhorn[1], Magnus Albert[1], Benni Reznik[2], and Tobias Schaetz[1] — [1]Physikalisches Institut, Albert-Ludwigs Universität Freiburg — [2]School of Physics and Astronomy, Tel-Aviv University

We study experimentally and theoretically structural defects which are formed during the transition from a laser cooled cloud to a Coulomb crystal, consisting of tens of ions in a linear radiofrequency trap. We demonstrate the creation of predicted topological defects ('kinks') [1, 2, 3] in purely two-dimensional crystals, and also find kinks which show novel dynamical features in a regime of parameters not considered before. The kinks are always observed at the centre of the trap, showing a large nonlinear localized excitation, and the probability of their occurrence surprisingly saturates at ~ 0.5. Simulations reveal a strong anharmonicity of the kink's internal mode of vibration, due to the kink's extension into three dimensions. As a consequence, the periodic Peierls-Nabarro potential experienced by a discrete kink becomes a globally confining potential, capable of trapping one cooled defect at the center of the crystal.

[1] H. Landa *et al.*, PRL **104**, 043004 (2010)
[2] Ch. Schneider *et al.*, Rep. Prog. Phys. **75**, 024401 (2012)
[3] M. Mielenz *et al.*, submitted to PRL

Q 35.41 Tue 16:00 Empore Lichthof

Controlled interactions of two ions with an optical cavity — •Konstantin Friebe[1], Bernardo Casabone[1], Andreas Stute[1], Birgit Brandstätter[1], Klemens Schüppert[1], Tracy Northup[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstraße 25, 6020 Innsbruck, Österreich —

[2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, 6020 Innsbruck, Österreich

We explore the integration of optical resonators and ion traps in the context of quantum networks. We have recently demonstrated entanglement between a single trapped ion and a cavity photon as well as state mapping from the ion to the polarization state of the photon. Here we present results with two trapped ions coupled to the same cavity mode. By changing the position of the ions in the cavity standing wave, the ions' respective coupling to the mode can be accurately controlled.

By encoding a single qubit across both ions, the coupling of the qubit to the cavity mode can be increased by a factor of $\sqrt{2}$, which enables higher fidelities for state mapping from the stationary qubit to a photon. We present our plans in this direction as well as a scheme for generation of photonic cluster states as resources for measurement-based quantum computation in our setup.

Q 35.42 Tue 16:00 Empore Lichthof

Dynamical quantum teleportation — •Christine Muschik[1], Eugene Polzik[2], and Ignacio Cirac[3] — [1]ICFO-Institut de Ciencies Fotoniques, Spain — [2]Niels Bohr Institute, Denmark — [3]Max-Planck-Institute, Germany

We introduce two protocols for inducing non-local dynamics between two separate parties. The first scheme allows for the engineering of an interaction between the two remote systems, while the second protocol induces a dynamics in one of the parties, which is controlled by the other one. Both schemes apply to continuous variable systems, run continuously in time and are based on instantaneous feedback.

Q 35.43 Tue 16:00 Empore Lichthof

Quantum sensing using vacuum forces — •Christine Muschik[1], Simon Moulieras[1], Kanupriya Sinha[2], Frank Koppens[1], Maciej Lewenstein[1], and Darrick Chang[1] — [1]ICFO-Institut de Ciencies Fotoniques, Spain — [2]University of Maryland, US

We propose a scheme, which harnesses quantum vacuum forces for practical applications. Casimir Forces become extremely strong at very short distances. We use this mechanism to coupling a quantum emitter to a suspended graphene membrane. This setup allows for an instantaneous and highly sensitive read-out the position of the graphene sheet, which has important applications for mass and force sensing. Since the coupling via the Casimir force is very strong, it is also a very valuable tool for engineering the quantum state of the membrane and for investigating the damping mechanisms of moving graphene in a hitherto inaccessible regime of precision.

Q 35.44 Tue 16:00 Empore Lichthof

Single atom cavity quantum electrodynamics with non-transversally polarized light fields — •Christian Junge, Danny O'Shea, Jürgen Volz, and Arno Rauschenbeutel — Vienna Center for Quantum Science and Technology, TU Wien, Atominstitut, Stadionallee 2, A-1020 Wien, Austria

Whispering-gallery-mode (WGM) microresonators are versatile devices for enhancing light–matter interaction. They combine ultra high quality factors and small mode volumes with near lossless in- and out-coupling of light via tapered fiber couplers. Here, we report on a cavity quantum electrodynamics (CQED) experiment in which single ^{85}Rb atoms interact in the strong coupling regime with a WGM in an ultra high-Q bottle microresonator. We present optical transmission spectra of our system that fundamentally deviate from the predictions of the established theoretical model for CQED in ring resonators. We identify the non-transversal character of the field of WGMs as the origin of this discrepancy. Excellent agreement is found between our data and the predictions of an extended theoretical model that accounts for the full vectorial description of the WGMs. Our studies demonstrate that the non-transversal character of WGMs allows one to realize a paradigmatic quantum system that is ideally suited for basic studies as well as for technological applications.

Q 35.45 Tue 16:00 Empore Lichthof

Weakening of superradiance due to dipole-dipole interactions — •François Damanet and John Martin — Institut de Physique Nucléaire, Atomique et de Spectroscopie, Université de Liège, Bât. B15, B - 4000 Liège, Belgium

Superradiance, known as the cooperative spontaneous emission of a directional light pulse by excited atoms placed in vacuum, has recently regained attention in the context of photon localization [1] and single photon cooperative emission [2]. The dissipative dynamics of the atoms is known to depend dramatically on the ratio between the typical inter-atomic distance and the atomic transition wavelength, notably because of dipole-dipole interactions [3]. In this work, we study the effects of these interactions on superradiance as in [4] by solving numerically the corresponding master equation. In particular, by averaging over many realizations of the randomly distributed atomic positions, we show that the decay of the radiated energy pulse height with the intensity of the dipolar coupling follows a power law.

[1] E. Ackermans, A. Gero & R. Kaiser, Phys. Rev. Lett. 101, 103602 (2008).

[2] R. Friedberg & J. T. Manassah, J. Phys. B 43, 035501 (2010).

[3] M. Gross & S. Haroche, Physics reports 93, 301-396 (1982).

[4] B. Coffey & R. Friedberg, Phys. Rev. A 17, 1033 (1978).

Q 35.46 Tue 16:00 Empore Lichthof

Decoherence of the Orientation state — •Timo Fischer and Klaus Hornberger — Universität Duisburg-Essen

We introduce a Lindblad master equation describing the decoherence of the orientation state of extended quantum objects, such as molecules. Using the Monte Carlo unravelling the master equation is analyzed numerically. We further determine the pointer states of the master equation, i.e. the pure states which are minimally affected by the environment. They result from the competition of two opposing effects, the dispersion caused by the coherent part of the dynamics and the localization induced by the interaction with the environment [1]. To this end, we solve an associated nonlinear equation for pointer states.

[1] Pointer basis induced by collisional decoherence, M. Busse and K. Hornberger, J. Phys. A **43** (2010)

Q 35.47 Tue 16:00 Empore Lichthof

Control and manipulation of the nuclear spin bath via continuous measurement and feedback — •Julia Michl[1], Christian Burk[1], Philipp Neumann[1], Jason Twamley[2], and Jörg Wrachtrup[1] — [1]3. Institute of Physics, University Stuttgart, D-70550 Stuttgart — [2]MQ Research Center for Quantum Science and Technology, Maquarie University, NSW 2109, Australia

The detailed control of the electron and surrounding nuclear spins of the nitrogen vacancy (NV) defect in diamond is of interest both for sensing applications as well as for quantum information processing. Detailed control of these spins is hampered by decoherence from the extended surrounding nuclear spin bath consisting of ^{13}C nuclear spins. Researchers have previously shown that it is possible to control quantum systems via pulsed measurements and feedback in optomechanics. We theoretically describe how a similar protocol can be implemented in the solid-state spin to allow the NV to manipulate the surrounding nuclear spin bath to achieve a complete purification of the bath, to prepare the bath in a fully polarized state or to prepare highly spin squeezed states of the bath. By achieving detail control over the surrounding nuclear spins allows for greatly extended spin dephasing times for the electron spin of the NV and the potential use of the spin squeezed bath for improved sensing.

Q 35.48 Tue 16:00 Empore Lichthof

Electron spin decoherence of divacancy defect center in silicon carbide nuclear spin baths — •Christian Burk[1], Julia Michl[1], Nan Zhao[2], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart, 70550 Stuttgart, Germany — [2]Beijing Computational Science Research Center, Beijing 100084, China

The neutral divacancy in silicon carbide is a defect center which can be controlled coherently. It is very similar to the well-known nitrogen-vacancy center in diamond, as it is also a paramagnetic defect center in a solid with a spin $S = 1$ ground state, and can be polarized via excitation into an excited state and an alternate decay path over a metastable singlet state, which also allows for optical readout. Thus it is a promising system for quantum information processing or as a magnetic probe for sensing. Since the defect center is embedded in a lattice consisting of carbon and silicon atoms, there can be stable spin bearing isotopes of these atoms. Those isotopes (^{13}C and ^{29}Si, both with spin $S = 1/2$) act as a source of decoherence. Since there are too many relevant interactions between the divacancy and the nuclear spins and the nuclear spins with each other to completely include them all in calculations, the nuclear spins are generally treated as an environment or more specifically as a nuclear spin bath for the central electron spin. To effectively manipulate a defect center, the effects that occur due to the interaction with its environment have to be understood. To overcome the limitation, that prevents a purely quantum mechanical treatment of the bath due to its size, a cluster correlation expansion for this system was applied.

Q 35.49 Tue 16:00 Empore Lichthof

König-digraph Interaction Model of Decoherence and Quantum Darwinism — •Nenad Balaneskovic[1], Gernot Alber[1], and Jaroslav Novotny[1,2] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Darmstadt, Germany — [2]Department of Physics, FNSPE, Czech Technical University in Prague, 115 19 Praha 1 - Stare Mesto, Czech Republic

We discuss characteristic properties of pure decoherence and Quantum Darwinism based on qubit-models of open systems interacting with their respective environment by iterated and randomly applied controlled-NOT-type operations. From the analytically determined asymptotic dynamics of the resulting quantum Markov chain the Quantum Darwinistic appearance of Classicality and its connection to König-digraph interaction models of pure decoherence can be investigated.

König-digraph interactions comprise environmental qubits which do not interact among themselves by unitary quantum operations and are thus suitable to physically describe objective quantum measurements performed on an open system by autonomous observers (environmental qubits). König-digraph interactions also account for the most efficient storage of the classical information about a system of interest into its environment. Since the efficiency of the mentioned information storage is also connected with the concept of Quantum Darwinism, we therefore address possible limits of Quantum Darwinism as a valid physical mechanism leading to the appearance of objective reality.

Q 35.50 Tue 16:00 Empore Lichthof

Pointer states of a marker particle in an ideal gas environment — •Lutz Sörgel and Klaus Hornberger — Fakultät für Physik, Universität Duisburg-Essen

We study a quantum test particle interacting with an ideal gas environment via collisions, an important system for understanding the quantum-to-classical transition of particle motion. We consider first the case of collisional decoherence (i.e. the limit of a very massive test particle) and then the general effect of collisions. The latter is described by the quantum linear Boltzmann equation [1], which accounts also for the friction and thermalization experienced by the test particle. An orthogonal unraveling of collisional decoherence shows that the emerging pointer states follow classical trajectories in phase space [2]. Based on that we aim at characterizing the pointer states of the quantum linear Boltzmann equation and finding their equations of motion.

[1] B. Vacchini, K. Hornberger, Phys. Rep. 478 (2009)
[2] M. Busse, K. Hornberger, J. Phys. A 43 (2010)

Q 35.51 Tue 16:00 Empore Lichthof

Non-equilibrium states of two oscillators coupled to separate baths — Giuseppe Cammarata[1], •Carsten Henkel[2], Benjamin Schäfer[3], and Illarion Dorofeyev[4] — [1]Institute of Mathematics, Universität Potsdam, Germany — [2]Institute of Physics and Astronomy, Universität Potsdam, Germany — [3]Universität Göttingen, Germany — [4]Russian Academy of Sciences, Nizhny Novgororod, Russia

Oscillators coupled to heat baths have a long tradition as models for dissipative systems in statistical and quantum mechanics [1]. We apply quantum Langevin equations to a system of two oscillators with a bilinear coupling [2]. Spectral representations for the mean energy of interaction and the covariance matrix of the canonical coordinates are derived and discussed [3]. Of particular interest are shifts in the eigenfrequencies as the coupling is increased, the thermal equilibrium situation and the quantum correlations between the oscillators if the attached baths have different temperatures. In addition, we provide a survey of quantization schemes starting from a classification of couplings between classical oscillators.

[1] P. Ullersma, Physica 32 (1966) 27-96; R. J. Rubin, Phys. Rev. 131 (1963) 964.
[2] J. P. Paz and A. J. Roncaglia, Phys. Rev. Lett. 100 (2008) 220401
[3] I. Dorofeyev, arXiv:1207.3881

Q 35.52 Tue 16:00 Empore Lichthof

Spatial decoherence of ions near surfaces — •Kristine Karstens and Stefan Scheel — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

Decoherence is a fundamental mechanism that destroys quantum mechanical superpositions of quantum states. It provides a limiting factor in the ability to coherently manipulate quantum systems such as atoms or ions. One particular example is path decoherence of coherently split particle beams [1].

Here we derive an expression for the spatial decoherence rate of coherently split beams of ions near metallic and superconducting surfaces. Our investigation is based on the formalism of macroscopic quantum electrodynamics [2] and the decoherence functional [3]. We evaluate the contributions of the possible charge-charge, charge-dipole and dipole-dipole interactions between the particles and their mirror images [4].

[1] P. Sonnentag and F. Hasselbach, Phys. Rev. Lett. **98**, 200402 (2007).
[2] S. Scheel and S. Y. Buhmann, Acta Phys. Slov. **58**, 675 (2008).
[3] H.-P. Breuer and F. Petruccione, *The Theory of Open Quantum Systems*, Oxford University Press, Oxford (2002).
[4] S. Scheel and S. Y. Buhmann, Phys. Rev. A **85**, 030101 (2012).

Q 35.53 Tue 16:00 Empore Lichthof

Decoherence of driven quantum systems — Walter Strunz and •Nina Megier — Institut für Theoretische Physik, TU Dresden

Based on exactly solvable models we investigate qubit decoherence under influence of time depending driving. We compare our findings to the usual quantum optical master equations approaches and discuss implications for nonequilibrium thermodynamics.

Q 35.54 Tue 16:00 Empore Lichthof

Spectral diffusion measurements on the zero phonon line of single nitrogen-vacancy centers diamond — •Niko Nikolay, Max Strauss, Nikola Sadzak, Janik Wolters, and Oliver Benson — Humboldt Universität zu Berlin, Nano-optics, Berlin, Germany

Nitrogen-vacancy (NV) centers in diamond have proven to be a promising resource for quantum technology. In particular, the NV center in bulk diamond is attractive as a source of indistinguishable single photons, as it provides a narrow zero phonon line (ZPL) at the optical 3A * 3E transition at 638 nm [1]. Furthermore the ZPL can be used for spin measurements and entanglement experiments [2]. However, fast fluctuations of the transition line, known as spectral diffusion are a major problem. Performing photon-correlation interferometry measurements [3] we determine the time-scale of the spectral diffusion and gain further knowledge about the underlying processes in bulk diamond, as well as in nano diamonds. In the future, our results will help to tackle the problem of spectral diffusion of NV centers in diamond.

[1] Two-Photon Quantum Interference from Separate Nitrogen Vacancy Centers in Diamond, H. Bernien et al., Physical Review Letters 108, 1*5 (2012).
[2] Quantum entanglement between an optical photon and a solid-state spin qubit, E. Togan et al., Nature 466, 730*4 (2010).
[3] Measurement of the ultrafast spectral diffusion of the optical transition of nitrogen vacancy centers in nano- size diamond using correlation interferometry, J. Wolters et al., Physical Review Letters, in press, arXiv:1206.0852.

Q 35.55 Tue 16:00 Empore Lichthof

Implementation of a waveguide based source of polarization entangled photon pairs — •Xu Yang, Harald Herrmann, Abu Thomas, Wolfgang Sohler, and Christine Silberhorn — Universität Paderborn, Integrierte Quantenoptik, Warburger Str. 100, D-33098 Paderborn

We designed and demonstrate an integrated source of entangled photon pairs based on spontaneous parametric downconversion (PDC) in a periodically poled Ti:LiNbO3 waveguide with Type-II quasi-phase-matching. The waveguide consists of two specially tailored interlaced periodicities to allow for two different phase-matched PDC processes exhibiting identical non-degenerate frequencies, but interchanged polarizations for the signal and idler photons. Thus the direct generation of polarization entangled state can be obtained at the output of the waveguide. Using standard polarization maintaining fibers we compensated the temporal walk-off caused by the birefringence of the crystal. Subsequent wavelength dependent splitting of the photon pairs was implemented by using a fiber based coarse wavelength division multiplexer. We characterized the polarization entangled photon pair by performing the two-photon interference and observe a visibility as high as of 95%, and a measured value of 2.57*0.06 of the Bell's inequality, with a violation of more than 9 standard deviations.

Q 35.56 Tue 16:00 Empore Lichthof

Stabilizing entanglement against local dissipation — Simeon Sauer, •Clemens Gneiting, and Andreas Buchleitner — Albert-Ludwigs-Universität, Freiburg, Germany

Natural dissipative processes in multipartite quantum systems are mostly of local nature and therefore affect entanglement adversely. In their presence, initially highly entangled states generically evolve into at most weakly entangled states. We investigate by what means this detrimental process can be counteracted. It is shown that a suitable, dissipator-adapted static system Hamiltonian can preserve entanglement in the stationary state to a significant but limited extend. We then extend our analysis to the general class of periodically driven Hamiltonians and show that they are subject to similar limitations. Finally, we develop incoherent but local control strategies which overcome these limits.

Q 35.57 Tue 16:00 Empore Lichthof

Stochastic approach to thermal states in the reduced system space — •Richard Hartmann — Institut für theoretische Physik, TU Dresden, Germany

We investigate a stochastic method to calculate the reduced density operator of a system for a total thermal state of a coupled system + bath model. We use that a coherent state representation of the bath allows for a stochastic interpretation of the dynamic equation. This technique was developed by Diosi, Strunz et al. [1] to efficiently calculate the reduced system dynamics in a stochastic manner. The numerical solutions of the stochastic equation are examined for soluble systems and compared to their known analytical solutions. We investigate the connection between such thermal states and time evolved reduced system states which have been in long time interaction with the bath.

[1] L. Diosi, W. T. Strunz, Physics Letters A 235, 569*573 (1997).

Q 35.58 Tue 16:00 Empore Lichthof

Finite Temperature Simulations of Exciton Dynamics in Biological Structures — •Robert Rosenbach[1], Alex W. Chin[2], Javier Prior[3], Felipe Caycedo-Soler[1], Susana F. Huelga[1], and Martin B. Plenio[1] — [1]Institut für Theoretische Physik, Universität Ulm — [2]Theory of Condensed Matter Group, Cavendish Laboratory, University of Cambridge — [3]Departamento de Física Aplicada, Universidad Politécnica de Cartagena

The Time Evolving Density Matrix with Orthogonal Polynomial Algorithm (TEDOPA) is a numerically exact technique to simulate open quantum systems interacting with arbitrarily structured environments. The algorithm has been developed in order to analyse excitonically coupled systems in structures of biological relevance at physiological temperatures, though there is a wide range of applications in solid state physics as well.

These technical developments are illustrated, based upon its successful application to reproduce the experimental observation of long-lived coherences in the Fenna-Matthews-Olson complex. Further applications regarding similar harvesting pigment protein structures are also considered.

Q 35.59 Tue 16:00 Empore Lichthof

Energy transfer dynamics in structured environments — •Daniel Süss and Walter T. Strunz — Institut für Theoretische Physik, TU Dresden

We determine energy transfer dynamics in molecular aggregates influenced by a structured quantum environment using a stochastic Schrödinger equation approach to open quantum systems [1]. A solution is presented in terms of a hierarchy of pure-state equations motivated by the corresponding framework for density operators [2].

[1] J. Roden, A. Eisfeld, W. Wolff and W.T. Strunz, Phys. Rev. Lett. 103, 058301 (2009) [2] Y. Tanimura, J. Phys. Soc. Jpn. 75, 082001 (2006)

Q 35.60 Tue 16:00 Empore Lichthof

MAIUS - a Bose-Einstein-Condensate in a sounding rocket — •André Kubelka[1], Sven Herrmann[1], and the QUANTUS-TEAM[1,2,3,4,5,6,7,8,9] — [1]ZARM, Universität Bremen — [2]Institut für Quantenoptik, LU Hannover — [3]Institut für Physik, HU Berlin — [4]Institut für Laserphysik, Universität Hamburg — [5]Institut für Quantenphysik, Universität Ulm — [6]Institut für angewandte Physik, TU Darmstadt — [7]MUARC, University of Birmingham, UK — [8]FBH, Berlin — [9]DLR RY, Bremen

MAIUS will be an atom-optical experiment that will show the feasibility of experiments with ultra-cold quantum gases in microgravity in a sounding rocket. The MAIUS setup will be able to produce a sample of ultra-cold atoms on-board a sounding rocket of the type VSB-30 launched at Esrange, Sweden. It is designed to create a Bose-Einstein-Condensate of 10^5 ^{87}Rb-atoms in less than 5 s and to observe its evolution over periods on the order of a few seconds. In addition, the properties of the sample shall be probed using atom interferometric techniques. The laser fields and magnetic fields used for trapping and manipulating the atoms will be created by hardware specifically designed to meet the requirements of a rocket mission. Special attention is thereby also spent on the appropriate magnetic shielding. A three layer magnetic shield provides a high shielding factor for an undisturbed operation of the experiment.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50 WM 1135.

Q 35.61 Tue 16:00 Empore Lichthof

Compact electronics for laser system in microgravity — •Thijs Wendrich, Wolfgang Ertmer, and Ernst Maria Rasel — Leibniz Universität Hannover, Institut für Quantenoptik

Microgravity experiments with ultra cold degenerate quantum gases require very compact and robust apparatuses. The LASUS project develops miniaturized and robust diode lasers, optical modules and electronics for use in the drop tower in Bremen and in space. In this poster we present the FPGA-based electronics for a complete experiment, fitting in a volume of less than a few liters. These electronics allow for a fully automated laser locking system to enable long term operation without manual intervention outside the lab. The LASUS project is a collaboration of FBH Berlin, HU Berlin, U Hamburg and LU Hannover supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number 50WM1239.

Q 35.62 Tue 16:00 Empore Lichthof

A miniaturized, high flux BEC source for precision interferometry — •Jan Rudolph[1], Ernst Maria Rasel[1], and The QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]ZARM, Universität Bremen — [3]Institut für Physik, HU Berlin — [4]Institut für Laser-Physik, Universität Hamburg — [5]Institut für Quantenphysik, Universität Ulm — [6]Institut für angewandte Physik, TU Darmstadt — [7]MUARC, University of Birmingham — [8]FBH, Berlin — [9]MPQ, Garching

Atom chips have proven to be excellent sources for the fast production of ultra-cold gases due to their outstanding performance in evaporative cooling. However, the total number of atoms has previously been limited by the small volume of their magnetic traps. To overcome this restriction, we have developed a novel loading scheme that allows us to produce Bose-Einstein condensates of a few 10^5 ^{87}Rb atoms every two seconds. The apparatus is designed to be operated in microgravity at the drop tower in Bremen, where even higher numbers of atoms can be achieved in the absence of any gravitational sag.

Using the drop tower's catapult mode, our setup will perform atom interferometry during nine seconds in free fall. Thus, the fast loading scheme allows for interferometer sequences of up to seven seconds – interrogation times which are inaccessible for ground based devices.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50WM1131.

Q 35.63 Tue 16:00 Empore Lichthof

Analysis of electron-wave decoherence near a semiconducting surface — Regine Frank, •Thimo Böhl, Henrike Prochel, Alexander Rembold, and Alexander Stibor — Physikalisches Institut, Tübingen, Deutschland

Dissipation and localization effects lead to decoherence. Novel quantum devices, such as hybrid quantum systems, exist in the transition region between a pure quantum state and a classical object. Understanding the strength of distinct decoherence mechanisms is still a challenge, which needs to be solved to realize new technical applications in the quantum regime. Here we describe an experiment were electron wave decoherence is observed in a biprism interferometer in the vicinity of a semiconducting plate [1]. An electron beam is separated by a fine biprism wire and guided a few micrometers above a silicon waver where interference and naturally decoherence occurs. The separated electron states gain 'which-path' information, when the electron wave suffers dissipation or it is weakly localized at the surface of the silicon waver. It can be clearly observed, that the interference contrast decreases with smaller beam distances towards the surface. We compare the results to an 'ab inito' theoretical description of electronic interaction and decoherence above a semiconductor surface. Decoherence is perfectly suited for investigations of material properties, so it might be possible to distinguish surface effects from bulk influences by fine-tuning the distance of flight above the surface.

[1] P. Sonnentag and F. Hasselbach, PRL **98**, 200402 (2007)

Q 35.64 Tue 16:00 Empore Lichthof

Quantum optical experiments with charged matter-waves — •Annika Bräuer, Georg Schütz, Alexander Rembold, Andreas Pooch, Henrike Prochel, and Alexander Stibor — Physikalisches Institut, Tübingen, Germany

In the history of quantum optics most experiments have been performed with neutral particles or pointlike electrons. The advantage of neutral atoms and molecules is the possibility to manipulate their inner structure, e.g. with lasers or by thermic excitation. The benefit of electrons is their easy manipulation. Both characteristics can be combined by performing interferometry experiments with ions and charged molecules. We present the setup and current status of the first stable ion biprism-interferometer based on [1] and propose novel quantum optical experiments in connection with the ion structure dependency in the magnetic and electrostatic Aharonov-Bohm effects. Helium ions are thereby field emitted from a novel single atom tip. They are separated and combined by an electrostatic biprism. Such interferometers have interesting technical prospects as highly sensitive detectors for rotation and acceleration. We additionally propose an experiment, where a charged particle biprism-interferometer can be used to measure the energy distribution of coherent field emitted electrons from a fine superconducting niobium tip. These sources could potentially create extremely monochromatic and coherent electron beams.

[1] F. Hasselbach and U. Maier, 1999 Quantum Coherence and Decoherence, ISQM, Tokyo, p. 299

Q 35.65 Tue 16:00 Empore Lichthof

Ray tracing for matter-waves — •Mathias Schneider and Reinhold Walser — Institut für Angewandte Physik, TU Darmstadt

The development of quantum limited acceleration and rotation devices is a key research direction. In the context of ultra-cold matter-waves, whether thermal clouds or Bose-Einstein condensates, this is usually realized with interferometers. The design of high precision optical devices, in particular optical interferometers, does not rely on the full Maxwell's equations but only on efficient semi-classical ray tracing methods. In the same spirit, we approximate the dynamics interacting thermal clouds or Bose-Einstein condensates with a ray tracing formalism that is very suited for realistic experimental setups. We employ the effective single-particle Wigner function as a phase-space representation of the atom cloud. A major virtue of this formulation is that, once the distribution is known for the initial state, it can be calculated at arbitrary times by merely propagating its values along the phase-space flow. The trajectories comprising this flow can be considered the matter-wave rays. In addition to this ray aspect, the phase-space formulation leads to a simple approximation scheme for the interacting stationary state at finite temperature. This Lambert-approximation interpolates between the Thomas-Fermi approximation of strongly interacting gases and the Maxwell-Boltzmann distribution for ideal gases.

Q 35.66 Tue 16:00 Empore Lichthof

A low-noise optical dipole trap as a source for matter wave interferometry — •Jonas Matthias, Jonas Hartwig, Dennis Schlippert, Ulrich Velte, Henning Albers, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik and Centre for Quantum Engineering and Space-Time Research - QUEST, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

We present our intensity stabilization design for an optical dipole trap (ODT) at a wavelength of $2\,\mu$m using a Pockels cell and a digital feedback loop. Since the response of a Pockels cell and an analyzer is non-linear we implement a linear feedback and a linearization of the response function in a field programmable gate array (FPGA). This enables high feedback loop performance independent of the nonlinear response.

The low-noise ODT allows for control of the initial position of the cold atomic cloud with high repeatability as a source for matter wave interferometry. Applications include loading the ODT from a single species magneto-optical (MOT) trap as well as from a ^{87}Rb/^{39}K dual-species MOT.

Q 35.67 Tue 16:00 Empore Lichthof

Towards an inertial sensitive ^{39}K matter wave interferometer — •Henning Albers, Jonas Hartwig, Dennis Schlippert, Ulrich Velte, Jonas Matthias, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik and Centre for Quantum Engineering and Space-Time Research - QUEST, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

We report on our work directed towards a space-time enclosing ^{39}K matter-wave interferometer.

Due its relatively low atomic mass and the small excited state hyperfine splitting on the order of only few linewidths ^{39}K is rather hard to cool. Therefore we investigate methods for efficient sub-Doppler cooling, e.g. dark optical molasses techniques, UV-cooling and prospects of evaporative and/or sympathetic cooling in an optical dipole trap.

We employ a three-dimensional magneto-optical trap (3D-MOT) loaded from a 2D-MOT. Our laser system is based on lasers phase-locked to a spectroscopy-locked reference laser. Frequencies for cooling, repumping and detection, as well as the light for driving stimulated Raman-transitions are then generated using double-pass acousto-optical modulators yielding both simplicity and stability. Also, cooling and repumping light are amplified in the same tapered amplifiers with only low losses into sidebands due to four-wave mixing. The laser system provides a total of 3W output power. We discuss performing a differential measurement of the acceleration of free falling ^{87}Rb and ^{39}K atoms to test Einstein's equivalence principle (universality of free fall).

Q 35.68 Tue 16:00 Empore Lichthof

Tidal Corrections for Free Falling Relativistic Bose-Einstein Condensates — •Oliver Gabel and Reinhold Walser — Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstr. 4a, 64289 Darmstadt

On Earth, the release of trapped Bose-Einstein condensates is usually an auxiliary tool for exploring the properties of matter waves. However, in the QUANTUS experiment [1] the exploration of free-fall physics in microgravity and the Einstein equivalence principle are at the centre of attention.

In a recent article [2], we have formulated a relativistic mean field theory for Bose-Einstein condensates in a given background metric. In this contribution we explore the dominant corrections of the field equation in the non-relativistic limit, i. e., the local tidal corrections, which constitute additional harmonic potentials around the centre of mass [3]. In particular, we evaluate the magnitude of the interferometric phase shift originating from this tidal potential.

[1] T. van Zoest et. Al., *Bose-Einstein Condensation in Microgravity*, Science, **328**, 1540 (2010).
[2] O. Gabel, and R. Walser, *Relativistic corrections to free falling Bose-Einstein condensates in micro-gravity*, submitted (2013)
[3] G. Nandi, R. Walser, E. Kajari, and W. P. Schleich, *Dropping cold quantum gases on Earth over long times and large distances*, Phys. Rev. A **76**, 63617 (2007).

Q 35.69 Tue 16:00 Empore Lichthof

Atom interferometry with Bose-Einstein condensates in microgravity — •André Wenzlawski[1], Patrick Windpassinger[1], Klaus Sengstock[1], and the Quantus team[1,2,3,4,5,6,7,8,9] — [1]Institut für Laser-Physik, Universität Hamburg — [2]Institut für Quantenoptik, Universität Hannover — [3]Institut für Physik, HU Berlin — [4]ZARM, Universität Bremen — [5]Institut für angewandte Physik, TU Darmstadt — [6]Institut für Quantenphysik, Universität Ulm — [7]MUARC, University of Birmingham, UK — [8]FBH, Berlin — [9]MPQ, Garching

Atom interferometers have emerged as a standard tool for highly precise inertial measurements. The achievable precision strongly depends on the interrogation time which is why a BEC with its narrow momentum distribution serves as an ideal source for these type of sensors. Since the first realization of a Bose-Einstein condensate in microgravity in the Bremen drop tower [1] we were able to observe the free expansion of ultra-cold atoms for up to 2s, which allows for the realization of matter wave interferometers of unprecedented sensitivities. Furhtermore we could demostrate a matter wave interferometer based on stimulated Bragg scattering with which we will show the feasibility of bringing BEC-based atom interferometry into microgravity.

The QUANTUS Project is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50WM1131-1137.

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

Q 35.70 Tue 16:00 Empore Lichthof

Laser stabilization to a frequency comb for an optical clock — •Nils Scharnhorst, Jannes B. Wübbena, Sana Amairi, and Piet O. Schmidt — QUEST Institute of Experimental Quantum Metrology, Physikalisch-Technische Bundesanstalt and Leibniz Universität Hannover, Bundesallee 100, D-38116 Braunschweig, Germany

The goal of our project is to build a transportable optical clock based on a single aluminium ion using quantum logic spectroscopy with a co-trapped calcium ion [1]. We give an overview of our clock and the required lasers for laser cooling and clock interrogation. Laser frequency stabilisation is performed by phase-locking all lasers to an optical frequency comb. The repetition rate of the frequency comb can either be locked to a maser, which is referenced to the caesium fountain at PTB, or to a cavity-stabilized laser. The beat signal between the frequency comb and each laser contains the noise of the offset beat, which is fundamentally limited by the feedback bandwidth to the frequency comb. In our scheme the offset beat is electronically subtracted from the beat signals, thus eliminating its noise contribution [2]. The repetition rate can be tightly locked to the reference signal through an intra-cavity electro-optical modulator in the frequency comb's oscillator.

For the stabilization of a laser to the frequency comb a combination of a phase-frequency comparator for slow frequencies and a PI-controller for fast frequencies improves the long-term stability of our laser-lock.

[1] P. O. Schmidt et al., Science 309, 749-752 (2005).
[2] J. Stenger et al., Phys. Rev. Lett. 88, 073601 (2002).

Q 35.71 Tue 16:00 Empore Lichthof

Laser system technology for quantum gas experiments on a sounding rocket — •Markus Krutzik[1], The LASUS Team[1,2,3,4], and The QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Physik, HU Berlin — [2]Ferdinand-Braun-Insitut, Leibniz Institut für Höchstfrequenztechnik, Berlin — [3]Institut für Quantenoptik, LU Hannover — [4]Institut für Laserphysik, U Hamburg — [5]ZARM, U Bremen — [6]Institut für Quantenphysik, U Ulm — [7]MPQ, Garchin — [8]Institut für angewandte Physik, TU Darmstadt — [9]Midlands Ultracold Atom Research Centre, University of Birmingham, UK

Autonomous experiments with ultra cold quantum gases on microgravity platforms can place fundamental physics in a unique position to adress some of the most significant questions of modern science, such as testing the weak equivalence principle. As an important next stepping stone with regard to space qualification, MAIUS aims at realizing Bose-Einstein condensates and investigating its coherence properties onboard a double-stage sounding rocket. In this poster, we present the current status of our laser system in detail. Special challenges in the construction are posed by the extreme environment, putting stringent requirements in terms of robustness, miniaturization and redundancy. All critical subsystems successfully passed mechanical vibration tests, that simulate the mechanical loads of a sounding rocket launch.

The QUANTUS and LASUS project are supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant numbers DLR 50 WM 1131-1137 and 1237-1240.

Q 35.72 Tue 16:00 Empore Lichthof

A compact laser system for dual species atom interferometry — Christoph Grzeschik[1], •Kai Lampmann[1,2], Max Schiemangk[1,2], Markus Krutzik[1], Achim Peters[1,2], and The QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Physik, HU Berlin — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin — [3]Institut für Quantenoptik, LU Hannover — [4]Institut für Laserphysik, U Hamburg — [5]ZARM, U Bremen — [6]Institut für Quantenphysik, U Ulm — [7]MPQ, München — [8]Institut für angewandte Physik, TU Darmstadt — [9]Midlands Ultracold Atom Research Centre, University of Birmingham, UK

We present a compact and integrated laser system for dual-species interferometry being capable of testing the universality of free fall with rubidium and potassium atoms in microgravity. The setup is built around a set of hybrid-integrated master-oscillator power-amplifier modules consisting of a distributed feedback laser diode, coupled into a tapered amplifier, providing output power in the Watt range and an intrinsic linewidth below 200 kHz. Results from several catapult launches at the droptower in Bremen with acceleration loads up to 50 g demonstrate the stability and ruggedness of the complete system. We discuss the electro-optical properties in detail, including the implementation and performance of compact laser electronics and FPGA-based digital frequency locking circuits.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant numbers DLR 50WM 1131-1137.

Q 35.73 Tue 16:00 Empore Lichthof

Zerodur based laser systems for precision measurements in micro-gravity — •Mona Rafipoor[1], Hannes Duncker[1], and the LASUS Team[1,2,3,4] — [1]Institut für Laser-Physik, U Hamburg — [2]Institut für Physik, HU Berlin — [3]Ferdinand-Braun-Institut, Berlin — [4]Institut für Quantenoptik, LU Hannover

Ballistic rockets provide several minutes of micro-gravity and thereby promise to improve the precision of interferometric measurements with matter waves. However, a rocket launch poses stringent requirements on the employed components in terms of thermal and mechanical stress yet to be met by commercial products. To pave the way for the next generation of quantum precision experiments in micro-gravity, e.g. on sounding rockets, we developed laser system technology based on Zerodur within the project Lasus. The components and integrated systems benefit from the vanishing thermal expansion of Zerodur and its mechanical robustness.

The LASUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number 50WM1238.

Q 35.74 Tue 16:00 Empore Lichthof

CASI Cold Atom Gyroscope Experiment — •Sven Abend, Peter Berg, Gunnar Tackmann, Katja Baxmann, Teresa Feld, Paul Kaebert, Christian Schubert, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover

We report on recent progress of the Cold Atom Sagnac Interferometer (CASI) experiment at Leibniz Universtity of Hannover. This experiment demonstrates the use of cold atomic ensembles to measure ultra-slow rotations via the Sagnac effect with a sensitivity of 5.3 10^{-7}rad/s. Atomic superposition states enclose areas as large as 19 mm^2 on a rather short baseline of 13.7 cm. We present several methods of modulating the interferometric phase via the reference mirrors and therefore a precise tool to compensate drift behaviours of the sensor. A careful analysis should allow to overcome our current limitation of 3 10^{-8}rad/s and to measure Earth's rotation rate at the 10^{-9} rad/s level. This work is supported by the DFG, the cluster of excellence QUEST, and IQS.

Q 35.75 Tue 16:00 Empore Lichthof

Projekt FOKUS (Faserlaserbasierter Optischer Kammgenerator unter Schwerelosigkeit) — •Tobias Wilken[1,2], Matthias Lezius[2], Theodor W. Hänsch[1], Ronald Holzwarth[1,2], Anja Kohfeldt[3], Andreas Wicht[3], Hannes Duncker[4], Ortwin Hellmig[4], Patrick Windpassinger[4], Klaus Sengstock[4], Vladimir Schkolnik[5], Markus Krutzik[5] und Achim Peters[3,5] — [1]MPQ, Garching — [2]Menlosystems GmbH, Martinsried — [3]FBH, Berlin — [4]UHH, Hamburg — [5]HUB, Berlin

Im April 2013 wird im Rahmen des Projektes FOKUS die Technologiereife eines Frequenzkammes auf der Höhenforschungsrakete TEXUS 51 demonstriert und ein Test zur Universalität der gravitativen Rotverschiebung durchgeführt. Dieses Prinzip besagt, dass zwei Uhren in einem veränderlichen Gravitationspotential synchron gehen, unabhängig von ihrem inneren Aufbau. Das Experiment besteht aus einem Frequenzkamm, der auf einen Radiofrequenzübergang in Rubidium stabilisiert ist und einem mikrointegrierten DFB-Diodenlaser, welcher auf einen optischen Übergang in Rubidium stabilisiert ist. Während des Raketenflugs werden beide Uhren bei ihrem gemeinsamen Flug durch das Schwerefeld der Erde durch eine Schwebungsmessung von Kamm und Diodenlaser verglichen. Der raketentaugliche Frequenzkamm wurde gemeinsam vom MPQ und Menlosystems GmbH entwickelt. Der Diodenlaser und die Spektroskopie wurden von FBH, UHH und HUB im Rahmen des DLR-Projekts LASUS entwickelt.

Gefördert von DLR und BMWi (50WM0934 und 50WM1237-1240)

Q 35.76 Tue 16:00 Empore Lichthof

Compact apparatus for an Ytterbium lattice clock — •Gregor Mura, Charbel Abou Jaoudeh, Tobias Franzen, and Axel Görlitz — Institut für Experimentalphysik, HHU Düsseldorf, Universitätsstr. 1, 40225 Düsseldorf

Optical clocks using neutral atoms hold the promise to eventually reach an inaccuracy at a level of 10^{-18}. So far stationary optical lattice clocks have been demonstrated for Yb, Sr and Hg. In the framework of the Space Optical Clocks 2 project we are developing a transportable Yb lattice clock demonstrator. Here we present current developments of subsystems which are intended to improve the transportability. These include basically all laser systems in particular the cooling lasers at 399 nm and 556 nm.

Q 35.77 Tue 16:00 Empore Lichthof

Towards a test of the Universality of Free Fall of atoms in microgravity — •Christian Vogt, Sascha Kulas, Andreas Resch, and Sven Herrmann — ZARM, Universität Bremen, Am Fallturm, 28259 Bremen

Matter wave interferometry today is an established tool to perform precision measurements in fundamental physics. One of the main limiting factors in such experiments is the finite free evolution time available to matter waves in a laboratory setup. Thus, the extended free fall time which can be achieved in a microgravity environment is expected to be of great benefit to future matter wave precision measurements. First promising results towards this have been achieved by the QUANTUS collaboration in recent years [1]. Within the PRIMUS project (Präzisions-Interferometrie unter Schwerelosigkeit) we aim to further explore this potential in a dedicated drop tower experiment. Therefore, we are currently setting up a dual species interferometer to compare the free fall of 87Rb and 39K atoms. Here, we present the current status of this experiment and discuss the perspectives and attainable sensitivity of such a free fall test in the Bremen Drop Tower. The PRIMUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50 WM 1142.

[1] T. van Zoest et al., "Bose-Einstein condensation in microgravity", Science, vol 328, no. 5985, p. 1540, 2010

Q 35.78 Tue 16:00 Empore Lichthof

An iodine frequency reference with 10^{-15} stability for space applications — •Klaus Döringshoff[1], Julia Pahl[1], Christian Marciniak[1], Moritz Nagel[1], Evgeny V. Kovalchuk[1], Johannes Stühler[2], Thilo Schuldt[2,3,4], Claus Braxmaier[3,4], and Achim Peters[1] — [1]Humboldt-Universität zu Berlin, Institutfür Physik — [2]University of Applied Sciences Konstanz(HTWG), Institute of Optical Systems — [3]University Bremen, Center for Applied Space Technology and Microgravity (ZARM) — [4]DLR Institute for Space Systems (Bremen)

Future space missions related to fundamental science, earth observation, and navigation and ranging require ultra-stable optical frequency references. Iodine references for laser stabilization have the potential to be developed space compatible on a relatively short time scale, while featuring frequency stabilities superior to other references like hydrogen masers.

We present a semi-monolithic, glass ceramic setup realized with an adhesive bonding technology, featuring a frequency stability of $8 \cdot 10^{-15}$ at 1 s averaging down to $2 \cdot 10^{-15}$ at 100 s.

Further, we report on the development of an engineering model utilizing a compact multi-pass gas cell. This setup will undergo environmental testing, including vibration tests and thermal cycling.

This work is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant numbers 50 QT 1102 and 50 QT 1201.

Q 35.79 Tue 16:00 Empore Lichthof

Magnetic sensing using nitrogen-vacancy centres in diamond nanocrystals — •Helena Knowles, Dhiren Kara, and Mete Atature — University of Cambridge, United Kingdom

Nitrogen-vacancy (NV) centres in diamond are point defects in the diamond lattice that form an electronic spin state $S = 1$ with sublevels $m_s = 0$ and ± 1 that are Zeeman shifted in a magnetic field. This spin can be initialised and read out optically, and driven coherently with a microwave field. Ramsey type interferometry then enables the detection of magnetic fields at the site of the NV defect.

Compared to NV centres in ultra-pure bulk diamond, nanodiamonds have a higher concentration of spins surrounding the defect reducing the coherence time of the NV spin and its sensitivity as a magnetometer. However, due to their small spatial extent and the possibility of precise positioning of the crystal on the nanometre scale, NV centres in nanocrystals provide the ideal system for high precision spatially resolved magnetometry. We demonstrate the ability to move 15 nm diameter nanocrystals containing single NV defects using an atomic force microscope. We then perform multi-pulse decoupling sequences and extract magnetic field sensitivities of 0.5 μT $/\sqrt{\text{Hz}}$ in the shot noise limit.

Q 35.80 Tue 16:00 Empore Lichthof

Optical traps for a magnesium frequency standard — •Klaus Zipfel, André Kulosa, Steffen Rühmann, Dominika Fim, Temmo Wübbena, André Pape, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Optical atomic clocks offer a significantly higher accuracy and stability compared to microwave atomic clocks and thus will allow more precise frequency measurements. As alkaline earth element magnesium features narrow transitions suitable for an optical atomic clock.

State-of-the-art optical clocks with neutral atoms rely on atoms trapped in an optical lattice at the magic wavelength. For magnesium, loading the optical lattice directly from a magneto optical trap (MOT) is not possible because of high temperatures and ionization losses from the upper $^3\text{D}_j$ MOT-states induced by the lattice light. This requires an optical dipole trap at 1064 nm as intermediate step, which is continuously loaded. The technical setup and performance of both optical traps will be presented in detail.

Q 35.81 Tue 16:00 Empore Lichthof

The mobile atom interferometer GAIN: towards low noise absolute gravity measurements — •Christian Freier, Matthias Hauth, Vladimir Schkolnik, Alexander Senger, Malte Schmidt, and Achim Peters — Humboldt-Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Newtonstr. 15, 12489 Berlin

GAIN (Gravimetric Atom Interferometer) is a mobile atom gravimeter, based on interfering ensembles of laser cooled 87Rb atoms in an atomic fountain configuration. It is specifically designed to show the potential of atom interferometry for mobile gravity measurements in the context of geodesy and geophysics.

In order to compete or surpass current state-of-the-art absolute gravimeters, measurement noise caused by environmental vibrations has to be carefully removed. Furthermore, various systematic effects have to be taken into account to come to a reliable absolute value for g.

This contribution will focus on an active vibration isolation which increased the sensitivity of the atom gravimeter to about $2\times10^{-8}\text{g}/\sqrt{\text{Hz}}$, and the implementation of a tip/tilt mirror system to eliminate Coriolis effect offsets and actively stabilize the measurement axis of the instrument within a few μrad.

Q 35.82 Tue 16:00 Empore Lichthof

Ein hochstabiler Lokaloszillator mit einer Instabilität von 10^{*16} in 1s für eine optische Neutralatomuhr basierend auf Magnesium — •Steffen Rühmann, André Kulosa, Dominika Fim, Klaus Zipfel, Temmo Wübbena, André Pape, Wolfgang Ertmer und Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Essentiell für die Abfrage eines schmalbandigen atomaren Übergangs für eine optische Atomuhr ist ein hochstabiler optischer Lokaloszillator. Kernstück eines solchen Oszillators ist gewöhnlich ein gegen akustische und thermische Störfaktoren isolierter Resonator hoher Längenstabilität. Am Institut für Quantenoptik (IQ) wurde ein derartiger Oszillator mit einer Stabilität von $5 \cdot 10^{-16}$ in 1s entwickelt und aufgebaut. Sein Licht wird nach Frequenzverdopplung zur Spektroskopie des stark verbotenen Übergangs $^1\text{S}_0 \rightarrow {}^3\text{P}_0$ von neutralem Magnesium-24 genutzt. Wir untersuchten inwieweit die Rauscheigenschaften bei der fundamentalen Wellenlänge durch Einsatz der resonanten Frequenzverdopplung modifiziert werden. Eine weitere Erhöhung der Stabilität ist im Prinzip mit längeren Resonatoren vorstellbar. Wir diskutieren den extremen Fall, die exzellente Kurzzeitstabilität eines Gravitationswellendetektors zu nutzen.

Q 35.83 Tue 16:00 Empore Lichthof

Performance of a cooling method by quadratic coupling at

high temperatures — •Zhijiao Deng[1,2,3], Yong Li[2], Ming Gao[1], and Chunwang Wu[1] — [1]Department of Physics, College of Science, National University of Defense Technology, Changsha 410073, People's Republic of China — [2]Beijing Computational Science Research Center, Beijing 100084, People's Republic of China — [3]Institute for Theoretical Physics, Universität Erlangen-Nürnberg, Staudtstraße 7, 91058 Erlangen, Germany

Cooling mechanical resonators to a quantum regime at high temperatures is important in terms of exploring and applying their quantum effects unrestricted by low environmental temperatures. It has been suggested by M. Bhattacharya et al. [Phys. Rev. A 77, 033819 (2008)] that quadratic coupling could be used to help cool a membrane in membrane-in-the-middle optomechanical systems (MMOSs) at room temperature to a state with a mean phonon number smaller than 1. We found that its cooling effect is actually overestimated because of the unconsidered factor that it is limited by the small frequency difference between the quadratically coupled cavity mode and its neighboring mode, which imposes an upper bound on the input trapping laser power. Here we have concretely investigated the performance of this cooling method by a more rigorous calculation. Our calculation shows that the cooling effect is indeed ultimately limited by the input trapping laser power, but one can still cool a membrane close to a quantum regime at 77 K with parameters approaching experimental values.

Q 35.84 Tue 16:00 Empore Lichthof

A new setup for interfacing ultracold atoms with micromechanical oscillators — •Aline Faber, Maria Korppi, Andreas Jöckel, Tobias Kampschulte, Matthew Rakher, and Philipp Treutlein — Departement Physik, Klingelbergstrasse 82, 4056 Basel, Schweiz

Ultracold atomic ensembles and mechanical oscillators have recently-attracted much interest as candidates for a hybrid quantum system. We aim to couple the motion of laser-cooled atoms to the vibrations of a micromechanical membrane in a single-sided cavity. The coupling is mediated over a long distance by a laser beam, which is reflected off the cavity and creates an optical lattice for the atoms. It is enhanced by the cavity finesse as well as the square root of the number of atoms. Such a coupling can e.g. be used to sympathetically cool the membrane by laser cooling the atoms.

Here we present a new experimental setup, with which we want to enhance the bidirectional coupling observed in an earlier experiment without a cavity [1]. Besides placing the membrane in a cavity, the new setup allows to create larger ultracold atomic clouds at higher loading rates. Furthermore, a transverse lattice will suppress light-assisted collisions between atoms in the presence of the coupling laser light. With these improvements we expect to increase the coupling rate by several orders of magnitude and to observe substantial cooling of the membrane's thermal motion.

[1] S. Camerer, M. Korppi et al., PRL 107, 223001 (2011)

Q 35.85 Tue 16:00 Empore Lichthof

Nonlinear response of an optomechanical system studied via the noise power spectrum — •Gotthold Fläschner[1,2], Kai Ruschmeier[1], Mohammad Reza Bakhtiari[2], Alexander Schwarz[1], Roland Wiesendanger[1], and Michael Thorwart[2] — [1]Institute of Applied Physics and Center of Microstructure Research, University of Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany — [2]I. Institute of Theoretical Physics, University of Hamburg, Jungiusstrasse 9, 20355 Hamburg, Germany

Utilizing a fiber optical Fabry-Perot interferometer is one way to detect the cantilever deflection in an atomic force microscopy set-up. Cantilever and fiber end form a low finesse cavity. The temperature of such a cantilever, which constitutes a micron sized mechanical oscillator, can be in principle determined by recording the power spectral density.

However, in the current experiment with a metal-coated cantilever, the spectral response function differs from the simple Lorentzian shape. In particular, its line shape is asymmetric and even shows antiresonant behavior due to the coupling of cavity and oscillator. We attribute this effect to a subtle interplay of different noises, which generates a nontrivial response of this nonlinear system. We analyze a tractable theoretical model and compare its predictions with experimental data. Its implications on accurate temperature measurement schemes are discussed.

Q 35.86 Tue 16:00 Empore Lichthof

Towards coupling a BEC to a micromechanical oscillator — •Andreas Bick[1], Christina Staarmann[1], Philipp Christoph[1], Philip Rothfos[1], Patrick Windpassinger[1], Christoph Becker[1], Klaus Sengstock[1], Hai Zhong[2], Gotthold Fläschner[2], Alexander Schwarz[2], and Roland Wiesendanger[2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Deutschland — [2]Institut für Angewandte Physik, Universität Hamburg, Deutschland

The study of quantum hybrid systems is an emergent field of quantum optics with many potential applications in e.g. quantum communication or in the search for quantum behavior of macroscopic objects. In this poster we present our progress towards a new hybrid quantum system experiment, which aims at coupling ultracold atoms to micromechanical oscillators. In a first experiment we will couple a high-Q micromechanical membrane located inside a fiber fabry-perot cavity to a Rubidium BEC via an optical lattice. As a promising starting point to reach the ground state of the oscillator the fiber cavity - membrane setup will be cooled to temperatures around 30mK inside a dilution cryostat. On the long-term also short range (e.g. magnetic) interactions can be realized by creating Rubidium BEC inside the cryostat. This work is supported by the Landesexzellenzinitiative Hamburg, the Joachim Herz Stiftung and the ERC Advanced Grant "FURORE".

Q 35.87 Tue 16:00 Empore Lichthof

Synchronization dynamics in arrays of optomechanical oscillators — •Roland Lauter[1], Max Ludwig[1], Christian Brendel[1], and Florian Marquardt[1,2] — [1]Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 7, D-91058 Erlangen, Germany — [2]Max Planck Institute for the Science of Light, Günther-Scharowsky-Str. 1/Bau 24, D-91058 Erlangen, Germany

We consider 1d and 2d arrays of coupled optomechanical oscillators. Each of those consists of a laser-driven optical mode coupled to a mechanical mode, and it can be driven into a state of self-sustained mechanical oscillations. We analyze the dynamics of the phase field characterizing those oscillations. In the absence of noise, we find that there can be either vortex structures or spatiotemporal chaos in the phase field, depending on the system parameters. In the presence of noise (e.g. thermal or quantum fluctuations), the phase-phase correlator decays as a function of distance. We analyze this behaviour using both numerical simulations and simplified models.

Q 35.88 Tue 16:00 Empore Lichthof

Optomechanical state reconstruction using Kalman filtering — •Jason Hoelscher-Obermaier[1], Sebastian G. Hofer[1], Witlef Wiezcorek[1], Karoline Siquans[1], Ralf Riedinger[1], Garrett D. Cole[1], Klemens Hammerer[2], and Markus Aspelmeyer[1] — [1]Vienna Center for Quantum Science and Technology, Faculty of Physics, University of Vienna, 1090 Vienna, Austria — [2]Institute for Theoretical Physics, Institute for Gravitational Physics, Leibniz University Hannover, 30167 Hannover, Germany

Optomechanics uses light to control the state of a vibrational mode of a massive mechanical object. To verify the success of optomechanical protocols, the joint state of mechanical mode and light field needs to be measured. The mechanical mode can be measured only indirectly, however, by measuring the light which has interacted with it.

Kalman filtering allows for the reconstruction of the joint state of the light field and the mechanical mode from measurements on the light field alone. The Kalman filter relies on a system model and a measurement model to provide an optimal estimate of the full state of the system. We illustrate this method for our cavity-optomechanical setup. To this end, we perform homodyne detection on the driving beam after interaction with the mechanical mode, and postprocess the results using the Kalman filter. Since the Kalman filter is based on the full system dynamics (quantum Langevin equations for the interacting optomechanical system together with a model of the detection setup), no further simplifying assumptions (such as weak optomechanical coupling or adiabaticity) enter.

Q 35.89 Tue 16:00 Empore Lichthof

Laser theory for opotomechanical limit cycles in the quantum regime — •Niels Lörch and Klemens Hammerer — Institute for Theoretical Physics, Leibniz University, 30167 Hannover, Germany

We study the dynamics of an optomechanical system consisting of a driven optical cavity that is coupled to a mechanical oscillator via radiation pressure force. In such systems the classical nonlinear dynamics can give rise to self-induced oscillations. We use laser theory to derive an effective equation of motion to study the quantum properties of these oscillations.

Q 35.90 Tue 16:00 Empore Lichthof

Cavity cooling and trapping of levitated nanospheres — •Florian Blaser, Nikolai Kiesel, Uros Delic, David Grass, Rainer Kaltenbaek, and Markus Aspelmeyer — Vienna Center for Quantum Science and Technology (VCQ), Faculty of Physics, University of Vienna, Boltzmanngasse 5, A-1090 Vienna, Austria

Levitated optomechanical systems have been recently put forward [1] as test systems in fundamental quantum experiments [2]. A necessary ingredient of these experiments is cooling of the center-of-mass motion of the levitated object to the ground state. We report on the first experimental demonstration of cavity cooling of levitated nanospheres. In our experiment, a silica nanosphere of 10^{10} amu is trapped in a Fabry-Perot cavity. The sphere's center-of-mass motion is linearly coupled to one of the modes of the cavity, allowing for sideband-resolved optomechanical cooling. Cooling rates of up to 26 kHz and optomechanical interaction close to the strong coupling regime have been observed. Currently, ultra-high Q operation at low pressures is inhibited by particle loss. We will discuss a transverse feedback cooling that will lift this limitation and pave the way towards ground state cooling.

[1] Romero-Isart, O. et al. NJP 12, 33015 (2010), Chang D. et al. PNAS 107, 0912969107, (2009), Barker P, et al. PRA 81, 023826 (2010).

[2] Romero-Isart, O. et al. PRL 107, 020405 (2011), Romero-Isart, O. PRA 84, 5 (2011), Kaltenbaek, R. et al., MAQRO, Exp. Astro. 1 42 (2012)

Q 35.91 Tue 16:00 Empore Lichthof

A tomography formalism for reconstructing the magnetodielectric properties from quantum interference — •Johannes Fiedler and Stefan Scheel — Uni Rostock, Institut für Physik, Rostock, Germany

Wave properties of particles are known from fundamental experiments, like the double-slit interference of electrons, done by Young and Fresnel. This effects can be described by the wave-particle duality with the de Broglie wavelength of a matter wave, $\lambda = \frac{h}{p}$. Similar experiments with neutral atoms and molecules [1,2] have shown an additional effect, that matter waves are accumulating phases depending on the grating distance. These phases are facilitated by the Casimir-Polder potential between scatterer and particles, which results from the fluctuations of the quantized electromagnetic field [3]. Here we will present a possible route towards reconstructing the electromagnetic response properties of grating material by scattering tomography.

[1] Grisenti, Schoellkopf, Toennies et al. Phys. Rev. Lett. (2000). [2] T. Juffmann et al. Nature Nanotechnology 7, 297 (2012). [3] S. Scheel and S. Y. Buhmann, Acta Phys. Slov. 58, 657 (2008).

Q 35.92 Tue 16:00 Empore Lichthof

Aharonov-Casher effect for dark state polaritons — •Vladimir Djokic, Frank Vewinger, and Martin Weitz — Wegelerstr. 8, D-53115 Bonn, Germany

Dark state polaritons, quasiparticles with a photonic contribution and an atomic spin-wave component, exhibit a nonvanishing effective magnetic moment due to the spin-wave contribution. As has been pointed out by Aharonov and Casher, magnetic moments can lead to a topological phase shift when the particle is moving around a charged wire, the Aharonov-Casher phase.

We report on the status of an ongoing experiment aiming at a measure of the Aharonov-Casher phase in dark state polaritons in Rb 87. This set up allows the measurement of the differential phase shift between two polariton components, making the system robust against perturbations.

Q 35.93 Tue 16:00 Empore Lichthof

Experimental Investigation of Quantum Correlations in Multipartite Systems — •Vanessa Chille[1,2], Christian Peuntinger[1,2], Ladislav Mista[4], Niall Quinn[3], Natalia Korolkova[3], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Günther-Scharowsky-Straße 1, 91058 Erlangen, Germany — [2]Institute of Optics, Information and Photonics, University Erlangen-Nuremberg, Germany — [3]School of Physics and Astronomy, University of St. Andrews, North Haugh, St. Andrews KY16 9SS, United Kingdom — [4]Deparment of Optics, Palacky University, 17. listopadu 50, 772 07 Olomouc, Czech Republic

We study quantum correlations in a dissipative quantum system. A special focus lies on quantum discord and entanglement. A two-mode Gaussian mixed state is prepared by modulating a polarization squeezed state and mixing it with the vacuum mode. We measure the covariance matrix in dependence on the dissipation in one of the modes and examine the amount of quantum discord. The quantum discord changes as a side effect of the changes in local entropy caused by the dissipation which corresponds to a coupling of the system to the environment. These experiments serve also as a preparatory study for the experimental implementation of a distribution of continuous-variable entanglement by separable Gaussian states. The scheme uses quantum discord to distribute entanglement between two distant modes by a third separable auxiliary mode.

Q 35.94 Tue 16:00 Empore Lichthof

Multifractality of quantum wave packets — •John Martin[1], Ignacio Garcia-Mata[2,3], Olivier Giraud[4], and Bertrand Georgeot[5,6] — [1]Institut de Physique Nucléaire, Atomique et de Spectroscopie, Université de Liège, Bât. B15, B - 4000 Liège, Belgium — [2]Instituto de Investigaciones Fisicas de Mar del Plata, CONICET-UNMdP, Funes 3350, B7602AYL Mar del Plata, Argentina — [3]Consejo Nacional de Investigaciones Científicas y Tecnológicas, Buenos Aires, Argentina — [4]LPTMS, CNRS and Université Paris-Sud, UMR 8626, Bât. 100, 91405 Orsay, France — [5]Université de Toulouse, UPS, Laboratoire de Physique Théorique (IRSAMC), F-31062 Toulouse, France — [6]CNRS, LPT (IRSAMC), F-31062 Toulouse, France

We study the multifractality of individual wave packets in a periodically kicked system through a combination of numerical and analytical works. We consider a version of the mathematical Ruijsenaars-Schneider model and reinterpreted it physically in order to describe the spreading with time of quantum wave packets in a system where multifractality can be tuned by varying a parameter [1]. We compare different methods to measure the multifractality of wave packets and identify the best one. We find the multifractality to decrease with time until it reaches an asymptotic limit, which is different from the multifractality of eigenvectors but related to it, as is the rate of the decrease. Our results could guide the study of experimental situations where multifractality is present in quantum systems.

[1] I. Garcia-Mata, J. Martin, O. Giraud, B. Georgeot, Phys. Rev. E 86, 056215 (2012).

Q 35.95 Tue 16:00 Empore Lichthof

Highly non-classical symmetric states of an N-qubit system — •Dorian Baguette and John Martin — Institut de Physique Nucléaire, Atomique et de Spectroscopie, Université de Liège, Bât. B15, B - 4000 Liège, Belgium

A host of applications of quantum phenomena, such as quantum information processing and quantum-enhanced measurements, rely on the non-classical nature of quantum states[1]. In this work, we study two measures of non-classicality for pure symmetric N-qubit states : Wehrl participation ratio and Wehrl entropy. We focus more particularly on the identification of the most non-classical symmetric states with respect to these measures and on their nice geometrical properties in the Majorana representation[2]. The scaling of these measures with the number of qubits is also investigated. We show that the quest for the most non-classical symmetric states is somehow related to J. J. Thomson's century-old problem of the minimum energy configuration of charges on the surface of a sphere.

[1] C. Anastopoulos, Phys. Rev. D 59, 045001 (1998).

[2] I. Bengtsson & K. Zyczkowski, Geometry of Quantum States, Cambridge University Press (2006).

Q 35.96 Tue 16:00 Empore Lichthof

Lasing Without Inversion in Quecksilber — •Benjamin Rein und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, AG Laser und Quantenoptik, Schlossgartenstr. 7, D-64289 Darmstadt

Die Entwicklung von cw-Lasern im Wellenlängenbereich der VUV-Strahlung und darunter ist aufgrund der für die Besetzungsinversion benötigten Pumpleistung, die mit der 4ten Potenz der Frequenz der Laserstrahlung ansteigt, technisch stark eingeschränkt und wird zumeist unter der Ausnutzung nicht-linearer Effekte realisiert.

Lasing Without Inversion ist eine Technik die auf der kohärenten Anregung atomarer Übergänge beruht und einen alternativen Ansatz bietet. Durch destruktive Interferenz zweier Anregungswege wird die

Absorption auf dem Laserübergang unterdrückt und erlaubt Lasertätigkeit mit nur wenigen angeregten Atomen.

Quecksilber besitzt Übergänge bei 253,7 nm und 185 nm mit denen sich LWI gewinnbringend einsetzen lässt. Es wird der aktuelle Stand des LWI Experiments bei 253,7 nm vorgestellt. Die benötigten Wellenlängen von 435,8 nm und 546,1 nm werden durch die effiziente Verdopplung von External Cavity Diode Lasern mittels KNbO3- bzw. LiNbO3-Kristall erzeugt. Ein weiterer ECDL bei 404,7 nm, dessen Linienbreite durch weißes Rauschen künstlich erhöht wird, dient als inkohärente Pumpe. Bei allen Lasersystemen handelt es sich um Eigenentwicklungen.

Q 35.97 Tue 16:00 Empore Lichthof

Lasing without inversion in the ultra violet regime — •Martin Sturm and Reinhold Walser — Institut für angewandte Physik, TU Darmstadt

Lasing without inversion on the basis of atomic coherence effects is a promising approach to continuous wave lasing in the ultra violet regime since the threshold pumping power for population inversion scales with ω^4 to ω^6 [1]. Despite successful proof of principle experiments, no lasing without inversion in the ultra violet regime has been realized until now.

In 1999 Fry et al. [2] proposed a lasing without inversion experiment based on the so called 'double-dark' scheme in a four level system. This setup allows Doppler-free lasing on 253 nm in Hg. We investigate this scheme theoretically: technical noise of pump lasers, the geometry of laser medium, the resonator design. This analysis is in cooperation with an experiment performed by B. Rein in the research group of Th. Walther at the Institute of Applied Physics/TU Darmstadt. The current status of this considerations is presented.

[1] J. Mompart and R. Corbalan, "Lasing without inversion", Journal of Optics B **3**, R7-R24 (2000)
[2] E. Fry, M. Lukin, T. Walther and G. Welch, "Four-level atomic coherence and cw VUV lasers", Optics Communications **179**, 499-504 (1999)

Q 35.98 Tue 16:00 Empore Lichthof

Hybrid coherent light: modeling quantum dot superluminescent diodes — •Franziska Friedrich and Reinhold Walser — Institute for Applied Physics, TU Darmstadt, Germany

Quantum dot superluminescent diodes show unusual light characteristics. On the one hand they are spectrally broad (THz) like a thermal light source, when considering the first order field correlation function. On the other hand, they exhibit a suppressed second order intensity noise spectrum like a coherent laser. This novel state of the electromagnetic field is called hybrid coherent light [1,2,3]. It is a interesting topic for fundamental research and has high potential for applications, e.g. in medical diagnostics.
In collaboration with the experimental group of Prof. W. Elsäßer (IAP/TUD) we developed a basic model of the diode to describe the emitted light and its correlation properties.

References :
[1] M. Blazek et al., Optics Express **17**, 16 (2009)
[2] M. Blazek, W. Elsäßer, Phys. Rev. A **84**, 063840 (2011)
[3] M. Blazek, W. Elsäßer IEEE, J. Quantum Electron. **48**, 12 (2012)

Q 35.99 Tue 16:00 Empore Lichthof

A miniaturized electron gun for microwave electron guiding — •Dominik Ehberger[1], Jakob Hammer[1], Johannes Hoffrogge[1], and Peter Hommelhoff[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching — [2]Friedrich-Alexander-Universität Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen

The realization of microwave guiding structures for electrons on micro-fabricated chips [1] enables new experiments in the context of guided matter-wave interferometry and controlled electron-electron or electron-surface interaction studies.

In addition to the spatial confinement of electrons guided in a planar AC-quadrupole guide (linear Paul trap), temporal control is feasible by implementation of a laser-based electron gun. Short blue laser pulses at 400 nm focused on a sharp tungsten tip drive electron emission with high efficiency. Since the emitted electron pulse length and repetition rate are directly linked to the laser pulse length and repetition rate, this set-up is well suited for synchronization with the microwave field. Here we present our ongoing experimental efforts on the realization and characterization of a fast, laser-triggered electron source. Such a miniaturized electron gun in combination with a microwave guide and suitable electron optics should allow tailoring of matter-waves with defined temporal and spatial properties for injection into the guiding potential.

[1] J. Hoffrogge, R. Fröhlich, M. Kasevich and P. Hommelhoff, *Phys. Rev. Lett.* **106**, 193001 (2011).