Q 56: Poster IV

Zeit: Donnerstag 16:30–19:00 Raum: VMP 9 Poster

Q 56.1 Do 16:30 VMP 9 Poster

Collective modes in a simple many body system with quantum chaos — •Martin P. Strzys and James R. Anglin — Technische Universität Kaiserslautern, Germany

Bose-Einstein condensates in two weakly coupled double well potentials can be described by a four-mode Bose-Hubbard Hamiltonian. This system can also be realized by two weakly coupled two-component spinor condensates. The classical mean-field dynamics of such a system is not integrable and thus in general chaotic. This genuine chaotic behaviour gives rise to signatures of chaos in the full quantum system often called quantum chaos. Our investigations try to illuminate the relation between collective excitations, correlations and quatum chaos in this few-mode quantum system and shall show the way towards the emergence of thermodynamics in mesoscopic systems.

Q 56.2 Do 16:30 VMP 9 Poster

Non-thermal fixed points in an ultracold Bose gas far from equilibrium — •Christian Scheppach and Thomas Gasenzer — Institut für Theoretische Physik, Philosophenweg 16, D-69120 Heidelberg

The dynamics of a relativistic N-component scalar quantum field theory is known to exhibit fixed points far from thermal equilibrium characterised by anomalously large critical exponents. The two-particle-irreducible (2PI) effective action in next-to-leading order of a 1/N expansion, a non-perturbative approximation scheme suitable for far-from-equilibrium dynamics, allows to calculate analytically the critical exponents. We investigate such non-thermal fixed points and the associated critical exponents in a non-relativistic quantum field theory describing an ultracold Bose gas and discuss possibilities to observe them in experiment. Ultracold quantum gases are under very good experimental control and hence provide the possibility to gain access to many-body dynamical phenomena far from equilibrium and to test results from non-perturbative quantum field theory in experiment.

Q 56.3 Do 16:30 VMP 9 Poster

Mott-Insulator to superfluid phase transition for arbitrary dimensionality and filling — •Dennis Hinrichs, Matthias Langemeyer, Niklas Teichmann, and Martin Holthaus — Institut für Physik, Carl von Ossietzky Universität, D-26111 Oldenburg, Germany

We study the transition from a Mott insulator to a superfluid in the Bose-Hubbard model at zero temperature, employing the method of the effective potential. Using Kato's formulation of the perturbation series we implement a diagrammatic process chain approach[1], which enables us to obtain accurate phase boundaries not only for two and three spatial dimensions, but also for higher dimensionalities. This allows us to monitor the convergence to the results predicted by mean-field theory, which is exact for an infinite number of dimensions. We also discuss the peculiar case of one dimension. Compared to many other techniques, an advantage of the method presented here is the possibility to deal with high filling factors[2].

[1] A.Eckardt, arXiv:0811.2353

[2] N.Teichmann, D.Hinrichs, M.Holthaus, A.Eckardt, arXiv:0810.0643

Q 56.4 Do 16:30 VMP 9 Poster

Phase slips as fluctuating dark solitons in a quasi-one-dimensional BEC — •Philip Walczak and James Anglin — Fachbereich Physik, TU Kaiserslautern, D-67663 Kaiserslautern

In interferometry experiments with quasi-one-dimensional Bose-condensed gases one can observe local shifts in the interference pattern which are due to thermal phase fluctuations of the condensates [1]. In the semi-classical limit, large phase slips can occur on healing length scales through the formation of so-called grey solitons. Using a path integral with canonical collective co-ordinates for a grey soliton, we compute probabilities for phase slips as quantum and thermal fluctuations. We include Brownian motion of the soliton due to back reaction on the soliton co-ordinates from the Bogoliubov modes of the quasi-one-dimensional dilute Bose gas.

[1] J. Schmiedmayer *et al.*, Nature **449**, 324-328 (2007)

Q 56.5 Do 16:30 VMP 9 Poster

Fractional photon-assisted tunneling for Bose-Einstein condensates in a double well — Niklas Teichmann, •Martin Esmann, and Christoph Weiss — Institut für Physik, Carl von Ossietzky Universität, D-26111 Oldenburg, Germany

Half-integer photon-resonance in a periodically shaken double well are investigated on the level of the N-particle quantum dynamics. Contrary to non-linear mean-field equations, the linear N-particle Schrödinger equation does not contain any non-linearity which could be the origin of such resonances. Nevertheless, analytic calculations on the N-particle level explain why such resonances can be observed even for particle numbers as low as $N = 2$. These calculations also demonstrate why fractional photon resonances are not restricted to half-integer values.

Q 56.6 Do 16:30 VMP 9 Poster

Non-adiabatic effects for a shaken bosonic Josephson junction — •Stephan Arlinghaus, Bettina Gertjerenken, Christoph Weiss, and Martin Holthaus — Institut für Physik, Carl von Ossietzky Universität Oldenburg, 26111 Oldenburg

We investigate a shaken Bose-Einstein condensate in a double-well potential and juxtapose the many-body and the mean-field (Gross-Pitaevskii) dynamics. Time-dependent potential differences with a gaussian envelope lead to interesting effects such as breakdown of adiabaticity which is shown to be related to the emergence of chaos in the classical counterpart. Our numerical studies focus on the influence of frequency and amplitude of the shaking.

Q 56.7 Do 16:30 VMP 9 Poster

Fermion- and Spin-Counting in Strongly Correlated Systems with Noise — •Sibylle Braungardt[1], Aditi SenDe[1], Ujjwal Sen[1], and Maciej Lewenstein[1,2] — [1]ICFO-Institut de Ciencies Fotoniques, Mediterranean Technology Park, 08860 Castelldefels (Barcelona), Spain — [2]ICREA Institucio Catala de Ricerca i Estudis Avancats, 08010 Barcelona, Spain

The properties of certain strongly correlated Fermi systems and spin models can be studied by applying atom counting theory. In particular, the criticality of systems, that exhibit a quantum phase transition (QPT), is reflected in the moments of the counting distribution. For a class of one dimensional Fermi- and spin systems, we study the effects of temperature and noise due to a coupling to the environment. We establish limits to the noise under which the criticality can still be observed in the moments of the distribution.

Q 56.8 Do 16:30 VMP 9 Poster

Fermionic potassium atoms in a CO_2-laser optical dipole trap — •Alexander Gatto, Christian Bolkart, and Martin Weitz — Insitut für Angewandte Physik, Rheinische Friedrich-Wilhelms-Universität Bonn, Wegelerstraße 8, 53115 Bonn

We will report progress in an experiment directed towards realisation of a fermionic potassium Fermi gas with all-optical techniques. The quantum gas will be used for studies of a supersolid phase transition with fermionic atoms in an optical lattice. In our experiment a cold atomic ^{40}K beam emitted from a two-dimensional MOT is used to load a dark magneto optic trap. The density of the trapped atoms is increased by switching to a compressed MOT where we ramp our magnetic field to higher values and reduce the intensity of our repumping laser. We subsequently transfer 10^6 fermionic potassium atoms into the quasistatic dipole trapping potential realized with a focused CO_2-laser beam with wavelength near 10.6 μm. In the future, we plan to cool the atoms evaporatively to quantum degeneracy.

Q 56.9 Do 16:30 VMP 9 Poster

Interspecies interaction in a strongly imbalanced Bose-Bose mixture — •Claudia Weber, Shincy John, Nicolas Spethmann, Tatjana Weikum, Artur Widera, and Dieter Meschede — Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, D-53115 Bonn, Germany

We magnetically trap a Bose-Bose mixture of Rubidium and few Caesium atoms simultaneously. Cs is sympathetically cooled by evaporatively cooled Rb in a magnetic trap to a temperature below 1 μK. The ultracold mixture is loaded into an optical dipole trap. We will present the latest results on the interspecies interaction in an external homogeneous magnetic field. A sensitive fluorescence detection technique is incorporated into the experiment to be able to observe single or very few Cs atoms.

Q 56.10 Do 16:30 VMP 9 Poster

Resonant spinor dynamics — •Manuel Scherer[1], Oliver Topic[1], Garu Gebreyesus[2], Phillip Hyllus[2], Carsten Klempt[1], Wolfgang Ertmer[1], Luis Santos[2], and Jan Arlt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [2]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany

Spinor Bose-Einstein condensates (BEC) present an ideal system to investigate the fundamental properties of magnetic superfluids with large spin. This allows for an investigation of the magnetic properties of such samples, but also enables a detailed analysis of the formation of spin domains. Moreover, recent experiments have shown that the spin dynamics in a BEC can provide an enormously sensitive probe for effects at very low energy. In particular it can be used to detect the effects of dipolar interaction and of quantum fluctuations.

The dependence of the spin dynamics on the applied magnetic field however remained elusive. We have observed strong resonances in this dependence, and we show that this resonant behavior is caused by finite-size effects induced by the trapping potential. These resonances can be understood quantitatively be analyzing the stability of spin Bogoliubov excitations and very good agreement between a model including the full dynamics of the system and the experiment is obtained.

We show that the resonant behavior in this system provides extreme sensitivity to effects at the very lowest energy and thus presents an important new tool for the analysis of quantum degenerate systems.

Q 56.11 Do 16:30 VMP 9 Poster

Spinor Condensates: Spin Dynamics and Magnetism in Triangular Lattices — •Parvis Soltan-Panahi, Julian Struck, Georg Meineke, Christoph Becker, and Klaus Sengstock — Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

In recent years, spinor Bose-Einstein condensates have received rapidly growing attention in the field of ultra-cold quantum gases. Optical lattices on the other hand provide an experimental environment distinguished by an unprecedented degree of control over the system's interaction reaching from the weakly- to the strongly-correlated regime. However, spinor Bose-Einstein condensates have been studied in optical lattices only marginally.
Here, we present recent experimental data on spin dynamics of ^{87}Rb-atoms in a triangular optical lattice. Our investigations have mainly focused on the intermediate interaction regime, where the tunneling energy of the particles between two neighbouring lattice sites is comparable to their on-site interaction strength.

Q 56.12 Do 16:30 VMP 9 Poster

Thermodynamically unstable phases in the Bose-Fermi-Hubbard model — •Alexander Mering and Michael Fleischhauer — Fachbereich Physik, Technische Universität Kaiserslautern, D-67663 Kaiserslautern

The Bose-Fermi-Hubbard model in the case of ultrafast fermions can be described by an effective bosonic Hubbard Hamiltonian including fermion-induced long-range density-density interactions. The resulting model displays a variety of different phases. Beside the well known charge-density wave phase (CDW), for which the amplitude of the CDW can be determined analytically through a selfconsistent treatment of the effective boson Hamiltonian, thermodynamically unstable phases arise. In the corresponding parameter regimes spatially separated Mott-insulator (MI) and CDW regions coexist. Starting from the derivation of the effective bosonic Hamiltonian and the analytic study of the phase diagramm we discuss the emergence of this unstable phase. The analytic results are complemented by numerical simulations using density-matrix-renormalization-group methods.

Q 56.13 Do 16:30 VMP 9 Poster

Interaction effects in Bose-Fermi mixtures in optical lattices — •Simon Braun[1], Sebastian Will[1], Thorsten Best[1], Ulrich Schneider[1], Lucia Hackermüller[1], Dirk-Sören Lühmann[2], and Immanuel Bloch[1] — [1]Johannes Gutenberg-Universität Mainz — [2]Universität Hamburg

The Bose-Fermi Hubbard model describes a system exhibiting a rich phase diagram depending on the strength of interactions and tunneling, going even beyond conventional condensed-matter physics. Ultracold atoms confined in optical lattices offer a unique tool for a clean realization of this model with adjustable parameters.

In our experiment, we cool bosonic ^{87}Rb and fermionic ^{40}K to simultaneous quantum degeneracy and load them into a blue-detuned optical lattice with a superimposed optical dipole trap. This setup allows for the trapping of various spin state combinations as well as rapid control over their interactions by the use of Feshbach resonances and Raman transitions between different hyperfine states.

A bosonic superfluid in an optical lattice constitutes a macroscopic matter wave with Poissonian occupation number statistics. From the collapse and revival of this wave (Greiner et al., 2002), we are able to extract the bosonic interaction energies with very high precision and observe the influence of a fermionic admixture on both interaction and number statistics. In a many-particle scenario, we find a pronounced asymmetry in the bosonic interference pattern for repulsive and attractive interactions. In the latter case, self-trapping leads to a marked shift in the superfluid to Mott insulator transition. (Best et al., 2008)

Q 56.14 Do 16:30 VMP 9 Poster

Freaky phase from frosty fermions: a geometric phase in BCS-BEC crossover — •Bernhard M. Breid and James R. Anglin — Technische Universität Kaiserslautern, Germany

The formation of a molecular Bose-Einstein condensate (BEC) from a BCS state of fermionic atoms as a result of slow sweeping through a Feshbach resonance is analyzed. We apply a path integral approach using adiabatic approximations to solve for an effective action for the molecules. The non-standard aspects of the resulting effective action and its effect on semiclassical dynamics are discussed. Considering this time-dependent process as an analogue of the cosmological Zurek scenario, we compare the way condensate growth is driven in this rigorous theory with its phenomenological description via time-dependent Ginzburg-Landau theory.

[1] B. M. Breid and J. R. Anglin, *Phil. Trans. R. Soc. A* (2008) **366**, 2813-2820

Q 56.15 Do 16:30 VMP 9 Poster

Electromagnetically induced transparency and light storage in an atomic Mott insulator — •Ute Schnorrberger[1], Jeff Thompson[1], Stefan Trotzky[1], Yuao Chen[1], Rami Pugatch[2], Nir Davidson[2], Stefan Kuhr[1], and Immanuel Bloch[1] — [1]Institut für Physik, Johannes-Gutenberg Universität, 55128 Mainz, Germany — [2]Department of Physics of Complex Systems, Weizmann Institute of Science, Rohovot 76100, Israel

We observed electromagnetically induced transparency (EIT) and light storage in an atomic Mott insulator (MI). An EIT window width of about 80Hz and storage times of about 200ms were achieved.

Our system consists of ultracold ^{87}Rb atoms in a 3D optical lattice. For storage, the atoms are prepared in a superposition of two internal states by the coupling and the probe light field. The restoring is done after the storage time, where both beams are off, by switching on the coupling beam again.

Using the differential light shift of a spatially inhomogeneous far detuned light field during the storage time we imprint a "phase gradient" across the atomic sample, resulting in controlled angular deflection of the restored light pulse.

Preparing the atomic superposition state by a two-photon RF-and MW-pulse and then using the coupling laser to read out light after some time provides us a more convenient method to study coherence times. We show the coherence times as a function of dimensionality and lattice depth and the evolution of the coherence when having singly and doubly occupied sites in the MI.

Q 56.16 Do 16:30 VMP 9 Poster

Coherent tunneling of atoms and dimers in half spaces — •Michael Grupp, Reinhold Walser, and Wolfgang Schleich — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

Feshbach scattering of fermions in an one-dimensional optical lattice is an intensively investigated subject [1,2]. Scattering theory in free space differs significantly from scattering in a lattice. By breaking the continuous translation symmetry the center-of-mass momentum of the two particles becomes a new control parameter of Feshbach scattering. We have reported numerical results of this effect in [3]. In the present contribution we study a simple analytic model of this effect by considering the coherent Feshbach scattering of atoms and dimers in half spaces.

[1] I. Bloch, J. Dalibard, W. Zwerger, Rev. Mod. Phys. 80, 885 (2008)
[2] N. Nygaard, R. Piil, K. Mølmer, Phys. Rev. A 78, 023617 (2008)
[3] M. Grupp, R. Walser, W. Schleich, A. Muramatsu and M. Weitz,

J. Phys. B: At. Mol. Opt. Phys. 40 (2007) 2703-2718

Q 56.17 Do 16:30 VMP 9 Poster

Inter-species tunneling in Bose-Bose mixtures — •Anika Carmen Pflanzer[1], Sascha Zöllner[2], and Peter Schmelcher[1,2] — [1]Universität Heidelberg, Physikalisches Institut, Philosophenweg 12, 69120 Heidelberg — [2]Universität Heidelberg, Theoretische Chemie, Im Neuenheimer Feld 229, 69120 Heidelberg

We study ultracold Bose-Bose mixtures in one-dimensional harmonic traps. The few-body dynamics are investigated based on the numerically exact multiconfiguration time-dependent Hartree method. If the effective mass of one of the species is infinitely large, it becomes completely localized in the center of the trap. In this limit, we can map the problem onto an effective double well for the lighter species. The intra-species interaction of the lighter bosons is varied, covering the full range from weak interactions to the fermionization limit. Starting from Rabi oscillations in the non-interacting case, correlated pair tunneling begins for weak interactions and leads to a dynamical behavior governed by two Rabi-like frequencies in the fermionization limit. Small deviations from the infinite-mass requirement allow the heavier bosons to move and thus affect the tunneling dynamics. In the opposite borderline case of equal masses, a completely different behavior arises and thermalization effects are investigated.

Q 56.18 Do 16:30 VMP 9 Poster

Cold atoms on nanostructures – dynamics of a damped nanotube — •Carsten Weiss[1,2], József Fortágh[2], Wolfgang P. Schleich[1], and Reinhold Walser[1] — [1]Institut für Quantenphysik, Universität Ulm — [2]Physikalisches Institut, Universität Tübingen

A single-wall carbon nanotube mounted on a lithographically fabricated chip defines an almost perfect mechanical nano-oscillator. Exposing it to an ultracold beam of rubidium atoms allows us to study inelastic scattering processes and damping mechanisms. In particular, we present a master equation for a damped carbon nanotube embedded in a beam of ultracold atoms.

Q 56.19 Do 16:30 VMP 9 Poster

Degenerate Bose-Fermi Gases in Micrograviy — •Waldemar Herr for the Quantus Team — Institut für Quantenoptik, Leibniz Universität Hannover

Bose Einstein Condensates (BEC) opened the way for realization of atomic ensembles with Heisenberg limited uncertainty. In microgravity extremely dilute samples of BEC can be obtained and observed after a free evolution on timescales of seconds. Applications range from atom optics to matter wave interferometry. This has led us to realize a BEC of 10000 87Rb atoms in microgravity. The experimental results (to be published) establish the fact, that in a microgravity environment ultra-large condensates (˜1.5 mm) after a free evolution of 1 second can be observed. In particular, microgravity provides mass independent confining potential which is very important for the research on a mixture of quantum gases. We aim to realize a new setup for multi-species experiments, which can be used in catapult mode doubling the time for microgravity to 9 seconds. The experiment is planned to use 87Rb and 40K as degenerate Bose and Fermi gases respectively and can be used to carry out experiments on interferometry, Bose-Fermi mixtures and tests of the weak equivalence principle in quantum domain. Up to date progress and future prospects of this ambitious and technically challenging project will be presented. The Quantus project is a collaboration of MPQ Munich, U Bremen, U Ulm, U Hamburg, HU Berlin, and LU Hanover 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 0346.

Q 56.20 Do 16:30 VMP 9 Poster

Interferometry in Microgravity — •Stephan T. Seidel[1] and Hauke Müntinga for the Quantus Team[2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]ZARM, Universität Bremen

The successful demonstration of Bose-Einstein-Condensation in microgravity in 2007 opens the way to realize an atom interferometer operated in the unique environment of weightlessness. Within the project QUANTUS (Quantum systems under microgravity) we plan to build an atom interferometer based on a BEC of Rubidium 87 which will be operated at the drop tower at ZARM in Bremen. The apparatus can produce a BEC of 10^4 at nK from 10^7 thermal atoms at $20\,\mu K$, which will permit to realize interferometry with a coherent evolution on a timescale up to 1 second. The atom interferometer is designed as a Mach-Zehnder-interferometer with Bragg-scattering as a coherent beam splitter mechanism.

The QUANTUS project is a collaboration of the U Hamburg, U Ulm, HU Berlin, MPQ Munich, ZARM at U Bremen, and the LU Hanover. It 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 0346.

Q 56.21 Do 16:30 VMP 9 Poster

Cavity cooling of cesium atoms: experiments in the bad cavity limit — •Arne Wickenbrock, Piyaphat Phoonthong, Lyubomir Petrov, and Ferruccio Renzoni — Department of Physics and Astronomy, Univerity College London, WC1 5BT London, UK

When an atom is placed in an optical cavity, its scattering properties may be significantly modified [1]. Based on this, new mechanisms of laser cooling were proposed [2-4]. In contrast to the standard laser cooling techniques, cooling by coherent scattering inside an optical resonator does not require a closed optical transition. This might expand the range of ultracold particles to more complex structured atoms and molecules.

We report on a series of experiment exploring cavity cooling in the bad-cavity limit. We prepare a cloud of ultracold cesium atoms in the centre of a leaky, near-confocal cavity. Then we pump the cavity with resonant laser light for a certain time and measure the achieved temperature as a function of atom-cavity detuning and laser intensity. The poster presents the status of our experiment and the experimental apparatus.

[1] E. M. Purcell, Phys. Rev. 69, 681 [2] Horak P., Hechenblaikner G., Gheri K. M., Stecher H., Ritsch H., Phys. Rev. Lett.79, 4974 [3] Vuletic V., Chu S., Phys. Rev. Lett. 84, 3787 [4] P. Domokos and H. Ritsch, J. Opt. Soc. Am. B 20, 1089 (2003)

Q 56.22 Do 16:30 VMP 9 Poster

Blue-detuned evanescent field surface traps for neutral atoms based on mode interference in ultra-thin optical fibres — •Alex Baade, Guillem Sagué, and Arno Rauschenbeutel — Abteilung QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz

We propose a novel concept for blue-detuned evanescent field surface traps for cold neutral atoms based on the interference of two transverse modes in an ultra-thin optical fibre. The resulting light-induced potential can be used to trap laser cooled Cs atoms at the positions of destructive interference in free space outside of the fibre. We discuss the trap created by the interference of the fundamental mode with one of the first higher order modes, yielding trapping sites at 100–200 nm from the fibre surface which, using a few tens of milliwatts of trapping laser power, have a depth on the order of 1 mK for caesium atoms and a trapping lifetime exceeding 100 s [1].

In order to experimentally investigate the mode interference in the evanescent field around an ultra-thin fibre we developed an experimental setup using a second tapered fibre as a near-field probe. The probe fibre is moved towards the tested fibre with a piezo actuator with an accuracy of a few nanometers. First measurements of the evanescent coupling between the two fibres as a function of distance are presented.

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

[1] G. Sagué, A. Baade, and A. Rauschenbeutel, New J. Phys. **10**, 113008 (2008).

Q 56.23 Do 16:30 VMP 9 Poster

Superconducting atom chips: parameters and properties — •Bo Zhang and Carsten Henkel — Universität Potsdam, Institut für Physik und Astronomie, Karl-Liebknecht-Str. 24/25, 14476 Potsdam, Germany

Atom chips provide small and robust traps for ultracold atoms at the microKelvin and below. However, the 'hot' chip surface strongly perturbs the trapped atoms. This can be avoided with superconducting atom chips where thermal magnetic noise and thechnical noise are significantly reduced. Superconducting wires show inhomogeneous current distributions, however, that have to be computed self-consistently, taking into account the screening of external bias fields. We investigate magnetic traps produced by wires in the Meissner and mixed (Shubnikov) state, with arbitrary cross-sections, using boundary integral equations in numerics and conformal mappings. The trap parameters and properties are discussed and compared to metallic atom chips. It is well known that temperature, magnetic field and current density must stay below certain critical values, otherwise the superconductivity breaks down: type I superconductors transit into a normal conductor, while type II SC transit into the mixed state (penetration of vortices). We analyze how this constraint imposes critical transport currents and bias fields for selected atom chip geometries.

Q 56.24 Do 16:30 VMP 9 Poster

Microscopy of a molecular ^{6}Li-BEC — •Jakob Meineke, Bruno Zimmermann, Torben Müller, Henning Moritz, and Tilman Esslinger — Instute for Quantum Electronics, Quantum Optics Group, ETH Zurich, Switzerland

We present first results obtained with our new experimental setup that will allow us to study an ultracold fermionic quantum gas in potentials that can be arbitrarily controlled to less than a micrometer. An ultracold gas of ^{6}Li is prepared by first loading 5×10^7 atoms from a MOT into a high-finesse standing wave resonator. About 3×10^6 atoms are transferred into an single-beam optical dipole trap. By translating the focussing lens, the thermal atoms are transported to a region of high optical access. Direct evaporation close to a Feshbach resonance allows us to create a BEC of up to 2×10^5 molecules. The quantum degenerate gas is sandwiched between two microscope objectives, which will enable us to create arbitrary potentials and to locally probe the strongly interacting system. The current state of the experiment will be presented.

Q 56.25 Do 16:30 VMP 9 Poster

Charge exchange reactions between trapped laser-cooled barium ions and hot neutral alkali atoms — •David Offenberg, Christian Wellers, Tobias Schneider, Bernhard Roth, and Stephan Schiller — Institut für Experimentalyphsik, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany

We have studied charge exchange reactions between laser-cooled Ba^+ ions stored in a linear quadrupole trap and neutral alkali atoms (M) evaporated from alkali metal dispensers. The charge exchange reaction $Ba^+ + M \rightarrow Ba + M^+$ has not been observed for Li and Na. For K, Rb, and Cs it is clearly observed, leading to an accumulation and sympathetic cooling of the produced K^+, Rb^+, and Cs^+ ions in the ion trap and causing characteristic deformations of the Ba^+ ion ensembles' spatial distribution. Via their Coulomb interaction with the laser-cooled Ba^+ ions, the alkali ions are cooled to temperatures of a few ten mK. The accumulation of cold Cs^+ ions has been characterized in terms of numbers and their translational temperatures by comparing experimentally acquired images of the Ba^+/Cs^+ ion ensembles with those from molecular dynamics simulations [1]. The K^+ and Rb^+ ions have been identified via an excitation of their specific motional resonances and making use of a mass-to-charge ratio selective extraction of the ions from the trap [2].

[1] C. B. Zhang et al., Phys. Rev. A **76**, 012719 (2007)
[2] D. Offenberg et al., to appear in J. Phys. B, arXiv:0810.5097v2

Q 56.26 Do 16:30 VMP 9 Poster

Coupling ultracold atoms to micromechanical cantilevers — •David Hunger[1,2], Stephan Camerer[1,2], Theodor W. Hänsch[1,2], Daniel König[2], Jörg P. Kotthaus[2], Jakob Reichel[3], Margareta Wallquist[4], Klemens Hammerer[4], Claudiu Genes[4], Peter Zoller[4], and Philipp Treutlein[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Ludwig-Maximilians-Universität, München — [3]LKB, E.N.S., Paris — [4]Universität Innsbruck, Austria

In our work we investigate different coupling mechanisms between ultracold atoms and mechanical oscillators. The motivation is to create hybrid quantum systems in which the atoms are used to cool, read out, and coherently manipulate the oscillators' state.

In a first experiment we use surface forces to couple the vibrations of a classically driven micromechanical oscillator to the motion of a Bose-Einstein condensate in a magnetic microtrap on a chip. At $\sim 1\,\mu$m atom-surface distance we observe parametric resonances induced by the coupling, corresponding to the excitation of different mechanical modes of the atoms. Such a coupling could be employed to couple atoms to molecular-scale oscillators like carbon nanotubes.

In a second experiment we want to study the coupling via an optical lattice. There, atoms are trapped in a 1D optical lattice that is created by reflecting a laser from a mechanical oscillator. Vibrations of the oscillator shake the lattice and can excite center of mass motion of the atoms. We propose that by applying laser cooling to the trapped atoms, cooling of the oscillator can be achieved. We discuss the feasibility of ground state cooling and show the current status of the experiment.

Q 56.27 Do 16:30 VMP 9 Poster

Interaction-induced dynamics in ultracold Rydberg gases — •Thomas Amthor, Christian Giese, Christoph S. Hofmann, Hanna Schempp, Wendelin Sprenger, Janne Denskat, Markus Reetz-Lamour, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg

We present experimental results and model calculations on coherent and incoherent dynamics of an ultracold interacting ^{87}Rb Rydberg gas. Long-range interactions among Rydberg atoms are shown to cause both suppression and enhancement of excitation. Coherence in the excitation to Rydberg states is demonstrated by direct observation of Rabi cycles [1]. Spectroscopic time-resolved measurements of the ionization dynamics reveal interaction-induced motion of the atoms [2] and different excitation schemes are explored which allow for the manipulation of the pair distance distribution. Furthermore, we discuss the dynamics of resonant energy transfer in unordered and ordered systems of Rydberg atoms, which involves model calculations of many-particle clouds and chains with excitation traps [3].

[1] M. Reetz-Lamour et al., Phys. Rev. Lett. 100, 253001 (2008)
[2] T. Amthor et al., Phys. Rev. Lett. 98, 023004 (2007)
[3] O. Mülken et al., Phys. Rev. Lett. 99, 090601 (2007)

Q 56.28 Do 16:30 VMP 9 Poster

Manipulation of atoms with optical tweezers — Lukas Brandt, Cecilia Muldoon, •Edouard Bains, and Axel Kuhn — Universtiy of Oxdord, Clarendon Laboratory, Parks Road, Oxford OX1 3PU, UK

The controlling and positioning of single atoms [1,2] has been the dream for the past decades. This is of interest for quantum engineering and quantum computation. The ultimate goal is to position single atoms with nanometric precision, for example for positioning single atoms into optical cavities [3]. Furthermore arbitrary potential landscapes can be created, so the dynamics of individual atoms can be controlled and observed. By realising controlled collision collisions entangled cluster states can be realised as a resource for one-way quantum computing [4]. We present a new scheme which allows to arbitrarily and independently manipulate the positions and motional properties of single trapped atoms. Cold atoms are loaded from a magneto optical surface trap [5] into an array of dipole-force traps, which act like optical tweezers. This array of dipole-force traps is generated by imaging the intensity distribution of a spatial light modulator with an isoplanatic optical system [6] into the vacuum chamber and is thus forming the optical tweezers.

[1] Miroshnychenko et al, Nature 442, 151 (2006)
[2] Beugnon et al, Nature Physics 3, 696 (2007)
[3] Nußmann et al, PRL 95, 173602 (2005)
[4] Raussendorf and Briegel, Phys. Rev. Lett. 86, 5188 (2001)
[5] Wildermuth et al, Phys. Rev. A 69, 030901 (2004)
[6] Brainis er al, Opt. Com. accepted

Q 56.29 Do 16:30 VMP 9 Poster

Wheeler's Delayed Choice with metastable Ar-atoms — •Michael Schreiber, Jiří Tomkovič, Joachim Welte, and Markus Oberthaler — Kirchhoff Institut für Physik, University of Heidelberg

J.A. Wheelers delayed choice Gedankenexperiment allows for tests of theories of hidden variables. Although these are almost perfectly excluded by experiment with photons a test for massive particles is still lacking. We report on our progress in the experimental realisation for the atomic case.

The necessary "single atom on demand source" is realised utilising a magneto-optical trap. The interferometer is implemented in Mach-Zender geometry utilising Bragg scattering from standing light waves. Whether wave-like or particle-like properties are considered is randomly decided for each atom after it has entered the interferometer by switching the third standing light wave on or off.

Q 56.30 Do 16:30 VMP 9 Poster

Optische Dipolkräfte in linearen $^{40}Ca^+$ Ionen Ketten — •Georg Schütz, J. F. Eble, F. Schmidt-Kaler und K. Singer — Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, D-89069 Ulm

In einer segmentierten linearen Falle können wir $^{40}Ca^+$ Ionen über elektromagnetisch induzierte Transparenz kühlen [1]. Wir wollen in diesem Experiment dem Ionenkristall starke optische nichtresonante Felder überlagern, um damit die Bose-Hubbard Dynamik und die Entstehung eines Bose Einstein Kondensates aus Phononen in einer Ionenkette zu untersuchen [2]. Dazu werden mittels Laser-induzierten Dipolkräften anharmonische Fallenpotentiale erzeugt, die zu einer Kopplung radialer Schwingungsmoden führen. Weiterhin diskutieren wir die Verwendung eines optischen Raman-Stehwellenfeldes, um zwischen den Ionen eine effektive Spin-Spin-Wechselwirkung zu erzeugen [3]. Mit solch einem Aufbau kann das Ising-Modell realisiert werden. Ebenfalls durch Laser Dipolkräfte zielen wir auf eine Manipulation der Wellenfunktion, z.B. um sie räumlich zu quetschen oder zu verschieben.

[1] F. Schmidt-Kaler, J. Eschner, G. Morigi, C. F. Roos, D. Leibfried, A. Mundt, R. Blatt, Appl. Phys. B **7**3, 807 (2001).

[2] D. Porras, J. I. Cirac, Phys. Rev. **9**3, 263602 (2004).

[3] X.-L. Deng, D. Porras, J. I. Cirac, Phys. Rev. A **7**2, 063407 (2005).

Q 56.31 Do 16:30 VMP 9 Poster

A Two-Dimensional Hamiltonian Ratchet — •Sarah Kajari-Schröder[1], Eric Lutz[2], and Wolfgang P. Schleich[1] — [1]Institut für Quantenphysik, Universität Ulm, D-89069, Germany — [2]Institut für Physik, Universität Augsburg, D-86135, Germany

The ratchet effect is the generation of directed transport in the absence of any biased forces. We present a general example of a two-dimensional time-independent Hamiltonian system describing a charged particle in an external potential and a magnetic field. We show that this system can exhibit chaotic ratchet currents whose magnitude and direction can be controlled by properly selecting the parameters of the Hamiltonian.

Q 56.32 Do 16:30 VMP 9 Poster

Bose-Einstein Condensation of stationary light and relativistic dynamics: Klein tunneling and *Zitterbewegung* — •Razmik Unanyan, Johannes Otterbach, and Michael Fleischhauer — Fachbereich Physik, Technische Universität Kaiserslautern, D-67663 Kaiserslautern

We analyze the behaviour of the Dark-state polaritons (DSP's) in atomic ensemble with electromagnetically induced transparency with two counterpropagating control fields. Since DSPs are bosons, they can undergo a Bose-Einstein condensation at a critical temperature which can be many orders of magnitude larger than that of atoms. We show that thermalization of polaritons can occur via elastic collisions mediated by a resonantly enhanced optical Kerr nonlinearity on a time scale short compared to the decay time. The maximum allowed critical temperature, however, is limited due to the small mass of DSP's. That is, the size of the DSP becomes comparable or smaller than the absorption length of the medium. We show that for such situations, the dynamics of the stationaty light pulses must be described by a two-component vector which obeys the one-dimensional two-component Dirac equation with an effective mass m^* and effective speed of light c^*. As a consequence relativistic effects such as Klein tunneling and *Zitterbewegung* can be observed at rather low energy scales or respectively at rather large length scales.

Q 56.33 Do 16:30 VMP 9 Poster

Matter wave interferometry with K_2 molecules — •Sha Liu[1], Ivan Sherstov[2], Horst Knöckel[1], Christian Lisdat[2], and Eberhard Tiemann[1] — [1]IQO Leibniz Universität Hannover, 30167 Hannover — [2]PTB Bundesallee 100, 38116 Braunschweig

We operate a matter wave interferometer on a beam of K_2 molecules in a Ramsey-Bordé configuration. The two exits of this interferometer, with molecules in either the excited state or the ground state, allow distinct detection schemes for the matter wave interference. Under certain geometric conditions the observed matter wave interferences are composed of two distinct structures, a Ramsey-Bordé interference structure from four laser beams employed as beam splitters for the matter wave, and an additional Ramsey interference structure formed by only two laser beams acting as beam splitters.

For a better understanding of the Ramsey interferences, we detected the ground state exit in two different distances near the beam splitters and further away downstream of the molecular beam. With active stabilization of the relative phases of the laser beams used as beam splitters the Ramsey interference shows a good phase stability.

We introduced between the beam splitters a laser field being near resonant to a molecular transition from either the excited state or the ground state to another state. Such experiment allows to determine the transition matrix element of the corresponding molecular transition. By changing the collision characteristics of the K atoms by exciting them to Rydberg states, the collisions between potassium atoms and molecules will be investigated.

Q 56.34 Do 16:30 VMP 9 Poster

Encoding qubits into quantum noise resistant states — •Dennis Heim, Ferdinand Gleisberg, and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

The intention of the proposed scheme is to protect information of an unknown pure qubit against effects of quantum noise represented by a quantum channel. By applying the proposed scheme before and after the qubit passes the channel the resulting fidelity will be higher than the fidelity without protection. The effect of a phase damping channel, for example, can be reduced by coupling and decoupling an additional qubit to the unknown initial state.

Q 56.35 Do 16:30 VMP 9 Poster

Applications of a symmetric quantum cloning machine producing high-fidelity copies for selected regions of the bloch sphere — •Michael Siomau[1] and Stephan Fritzsche[1,2,3] — [1]Max-Planck-Institut für Kernphysik, Postfach 103980, D-69117 Heidelberg, Germany — [2]Gesellschaft für Schwerionenforschung, D-64291 Darmstadt, Germany — [3]Frankfurt Institute for Advanced Studies, D-60438 Frankfurt am Main, Germany

Quantum cloning transformation is utilized to provide copies (i.e. outputs) of unknown input states. While is impossible to provide perfect cloning [1], one can produce copies with certain fidelity compared with input. A cloning transformation is called symmetric if the output states are equal value. In this work we discuss how a symmetric cloning transformation can be applied in quantum data transmission and quantum cryptography. For this purpose, we examine the universal and state-dependent transformations and discuss advantages. Emphasis is placed on problems to be solved.

[1] W.K. Wooters and W.H. Zurek, Nature London 299, 802 (1982)

Q 56.36 Do 16:30 VMP 9 Poster

Experimental Higher Dimensional Entanglement — •Daniel L. Richart[1,2], Witlef Wieczorek[1,2], and Harald Weinfurter[1,2] — [1]MPI für Quantenoptik, Hans Kopfermannstr. 1, 85748 Garching — [2]Ludwig-Maximilians-Universität, Schellingstr. 4, D-80797 München, Germany

Higher dimensional states (qudits) allow to implement quantum communication schemes of increasing complexity, as e.g. superdense coding. Similarly, qudits allow further research into the fundaments of quantum theory.

Here we report on first steps towards the implementation of states with correlated photon pairs in a 2x8 dimensional Hilbert space. To this end the photon pairs are prepared in the energy-time basis, as initially proposed in [1]: Using unbalanced interferometers, information can be encoded in the different arrival times of the photon pairs, early and late, as was experimentally realized in [2]. Here, we extend this scheme by proposing and characterizing a scalable multiple time delay interferometer. This interferometer system allows an exponential increase in the dimensionality of the entangled state with only a linear increase in the optical components used.

Using the proposed interferometer system, first experimental tests on a two-dimensional state yielded a violation of a Bell inequality by four standard deviations.

[1] J. D. Franson, Phys. Rev. Lett. 62, 2205 (1989); [2] W. Tittel et al., Phys. Rev. A 57, 3229 (1998)

Q 56.37 Do 16:30 VMP 9 Poster

Minimizing the statistical error in measurements of witness operators — •Bastian Jungnitsch, Sönke Niekamp, Matthias Kleinmann, and Otfried Gühne — Institut für Quantenoptik und Quanteninformation, Technikerstraße 21a, 6020 Innsbruck, Austria

Witness operators are a well-established tool for the detection of entanglement in quantum information theory. Commonly, one uses witness operators that are optimal with respect to the set of entangled states they detect.

We consider an experimental situation in which one has some knowledge of the prepared state and aims at proving the entanglement of this state. In particular, we deal with experiments that provide low statistics, i.e. small event rates.

To allow for the detection of entanglement in such a case with high certainty, it is of advantage to decrease the statistical error involved in the measurement of the witness operator. We investigate different models of calculating this error in order to minimize it.

Q 56.38 Do 16:30 VMP 9 Poster

Characterisation and Applications of Segmented Miniature Ion Traps — •Michael Brownnutt[1], Maximilian Harlander[1], Felicity Splatt[1], Wolfgang Hänsel[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Innsbruck, Austria

Segmentation of ion traps is a promising route to allow the major results in trapped-ion quantum computing to be extended beyond individual traps to many-ion-trap systems. Additionally, the ability afforded by segmented traps to tailor the confining potential allows qualitatively new problems to be addressed, such as applications to quantum simulations. The use of tailored trap potentials for simulations of solid-state systems are discussed, and experimental progress to this end is outlined. We also report on the characterisation of a laser-machined, gold-on-alumina segmented trap which has been made according to a standardised "pan-European microtrap design". Operation of this trap is compared to others used by different institutions in Europe.

Q 56.39 Do 16:30 VMP 9 Poster

Optimal Control of N-Level Systems: Techniques and Applications — •Robert Fisher[1], Christof Wunderlich[2], Ferdinand Helmer[3], Florian Marquardt[3], Thomas Schulte-Herbrüggen[1], and Steffen Glaser[1] — [1]Department of Chemistry, TUM, Germany — [2]Department of Physics, Universität Siegen, Germany — [3]Arnold Sommerfeld Center for Theoretical Physics, LMU, Germany

We describe a framework for the design of optimal electromagnetic pulses to implement given operations on N-level quantum systems. The techniques are demonstrated in a variety of concrete examples: (i) the optical manipulation of Pr dopant ions in a $YrSO_4$ crystal, (ii) the preparation of cluster states on coupled spin systems - where both analytical solutions in an idealised case and numerical solutions for an experimental ion trap system are obtained, and (iii) the implementation of quantum computing gates in a superconducting cavity grid architecture.

Q 56.40 Do 16:30 VMP 9 Poster

Coherent state discrimination via a Homodyne-Kennedy Hybrid — •Christian Müller[1], Mario Usuga[1,2], Christoffer Wittmann[1], Masahiro Takeoka[3], Ulrik L. Andersen[1,2], and Gerd Leuchs[1] — [1]Max-Planck-Institut für die Physik des Lichts , Günther-Scharowsky-Str. 1 / Bau 24, 91058 Erlangen, Germany — [2]Department of Physics, Technical University of Denmark, Building 309, 2800 Lyngby, Denmark — [3]National Institute of Information and Communications Technology, 4-2-1 Nukui-Kita, Koganei, Tokyo 184-8795, Japan

We present a novel quantum receiver for the discrimination of a coherent state alphabet consisting of four phase covariant coherent states equally spaced in phase by pi/2. The task of the receiver is to guess the arriving quantum state with minimum error. Our receiver is a hybrid system composed of a homodyne detector and an modified Kennedy detector [1] where the latter one is controlled by the outcome of the former one: The measurement outcome of the homodyne detector reduces the alphabet from four states to two states which are then discriminated with the adapted Kennedy detector. We show that in theory this hybrid receiver surpasses a receiver using heterodyne detection for signal states with average photon numbers larger than about 1.5.

[1] C. Wittmann, M. Takeoka, K.N. Cassemiro, M. Sasaki, G. Leuchs, and U.L. Andersen, Phys. Rev. Lett. 101, 210501 (2008)

Q 56.41 Do 16:30 VMP 9 Poster

Studies of atmospheric conditions for free space quantum key distribution with coherent polarization states — •Dominique Elser[1], Bettina Heim[1], Tim Bartley[1,2], Christoffer Wittmann[1], Denis Sych[1], and Gerd Leuchs[1] — [1]Max-Planck-Institut für die Physik des Lichts, Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, Günther-Scharowsky-Str. 1, Bau 24, 91058 Erlangen, Deutschland — [2]Physics Department, Blackett Laboratory, Imperial College, London SW7 2BZ, United Kingdom

We investigate free space quantum key distribution using continuous variables under real atmospheric conditions. More specifically, we transmit weak coherent polarization states over a 100m free space channel on the roof of our institute's building [1]. The use of a retro-reflector enables us to place Alice's and Bob's station on the same optical table. In our scheme, signal and local oscillator are combined in a single spatial mode auto-compensating atmospheric fluctuations and resulting in excellent interference. Furthermore, the local oscillator acts as a spatial and a spectral filter thus allowing for unrestrained daylight operation. We present investigations of the atmospheric channel with respect to excess noise, spatial beam jitter and transmission statistics. Furthermore we report on the first steps of the implementation of a point-to-point link.

[1] D. Elser et al., arXiv:0811.4756 [quant-ph] (2008).

Q 56.42 Do 16:30 VMP 9 Poster

Witnessing Effective Entanglement over 20km of Optical Fibre — Christoffer Wittmann[1], •Josef Fürst[1], Carlos Wiechers[1,2], Dominique Elser[1], Hauke Häseler[1,3], Norbert Lütkenhaus[1,3], and Gerd Leuchs[1] — [1]Max-Planck-Institut für die Physik des Lichts , Günther-Scharowsky-Str. 1 / Bau 24, 91058 Erlangen, Germany — [2]Instituto de Física de la Universidad de Guanajuato — [3]Institute for Quantum Computing, University of Waterloo

We report first results on the experimental demonstration of effective entanglement in a prepare-and-measure type of quantum key distribution protocol. Following previous experiments [1], we send coherent states over a quantum channel and use heterodyne measurements to characterize the transmitted quantum states, reconstructing directly their Q function. In the new experiment, the quadrature encoded quantum states are sent through a 20km fibre channel. Hereby we increased the length of the quantum channel compared to the previous experiment. Furthermore, we monitor the local oscillator power as demanded in [2].

[1] S. Lorenz, J. Rigas, M. Heid, U.L. Andersen, N. Lütkenhaus and G. Leuchs, Phys. Rev. A 74, 042326 (2006), [2] H. Häseler, T. Moroder and N. Lütkenhaus, Phys. Rev. A 77, 032303 (2008)

Q 56.43 Do 16:30 VMP 9 Poster

Atomic Ensemble in an Optical Dipole Trap as Quantum Memory — •Valentin Hagel[1], Thorsten Strassel[1], Bo Zhao[1], Zhen-Sheng Yuan[1], Shuai Chen[1,2], and Jian-Wei Pan[1,2] — [1]Physikalisches Institut, Universität Heidelberg, Germany — [2]Hefei National Laboratory for Physical Sciences at Microscale, Department of Modern Physics, University of Science and Technology of China, Hefei, China

Quantum memory is a device which allows to store and retrieve quantum information. Realization of a quantum memory with long storage times allows for long distance quantum communication. Current implementations are limited to short storage times due to dephasing in residual magnetic fields and thermal atomic motion. In our setup the atoms are confined in a red-detuned, far-off resonant optical dipole trap during the storage-process: Raman-scattering of a weak, off-resonant write pulse imprints a collective atomic state in the ensemble which can be converted back into a defined photonic mode by a strong read-pulse. We provide a range of experimental results on the use of atomic ensembles as a light-matter interface. Moreover we report on techniques to achieve long storage times and further improvements.

Q 56.44 Do 16:30 VMP 9 Poster

Developing Atom-Photon-Interfaces for Single-Photon Generation and Storage — •Gunnar Langfahl-Klabes, Jerome Dilley, Peter Nisbet, Genko Vasilev, Daniel Ljunggren, and Axel Kuhn — Clarendon Laboratory, Parks Road, Oxford, OX1 3PU, UK

Single atoms coupled to high-finesse cavities provide a unique way to deterministically generate a stream of single photons of MHz bandwidth [1]. *Hot atomic ensembles* enable the generation, delay, storage and retrieval of single photons by precisely manipulating an EIT control field [2].

In our new laboratory we aim to generate single photons in a cavity using vacuum-stimulated Raman scattering, store them in a vapour cell, and check the retrieved photons for the preservation of their coherence properties. Generation and storage will utilise a Λ-type scheme connecting two Zeeman sub-levels of the hyperfine ground state $F = 1$.

We report on the latest status of an atomic fountain as a ^{87}Rb source that will lead to atom-cavity interaction times of up to 5 ms, a cavity for single-photon generation that has parameters close to the strong coupling regime, and a ^{87}Rb vapour cell for photon storage.

Work detailing the theoretical optimisation of the storage and retrieval process is additionally presented.

[1] Hijlkema, M. *et al.* Nature Physics **3**, 253 (2007)
[2] Eisaman, M. *et al.* Nature **438**, 837 (2005)

Q 56.45 Do 16:30 VMP 9 Poster

Construction of a Fast Two-Qubit Gate for Ultracold Atoms Using Optimal Control — •Michael Goerz[1], Christian Schwenke[1], Tommaso Calarco[2], and Christiane P. Koch[1] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Germany — [2]Institut für Quanteninformationsverarbeitung, Universität Ulm, Germany

We study the implementation of a two-qubit gate for ultracold Ca atoms trapped in an optical lattice. The qubits are encoded in the internal electronic states of the atoms. The dynamics of the system are driven by shaped laser pulses. A two-qubit CNOT ($\pi/2$-phasegate) can be obtained by applying an appropriate pulse to two neighboring atoms, shifting their relative phase. An optimized pulse, producing the required unitary transformation, can be generated from an initial guess pulse via the Krotov method of Optimal Control Theory.

The main difficulty is that a laser pulse driving the molecular (two-qubit) phase will aways drive the atomic (single-qubit) phases as well. We present our findings in addressing this problem, depending on constraints such as lattice constants, pulse intensity and complexity. Our goal consists in achieving short, high fidelity pulses performing the target two-qubit $\pi/2$-gate.

Q 56.46 Do 16:30 VMP 9 Poster

Towards Cryogenic Surface Ion Traps — •Michael Niedermayr[1], Muir Kumph[1], Birgit Brandstätter[1], Piet O. Schmidt[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstrasse 25, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, 6020 Innsbruck, Austria

A promising approach for scalable quantum information processing (QIP) architectures is based on miniaturized surface ion traps. These traps with dimensions in the sub-100 μm range can be fabricated by photolithography techniques. Experimental results indicate that the motional heating rate of the ions in the trap increases with decreasing trap dimensions to the fourth power. The mechanism of this anomalous heating is not yet fully understood. However, it can be reduced by several orders of magnitude when the trap electrodes are cooled from room temperature to 4 K. We are currently setting up a new experiment in which we intend to investigate surface traps in a cryogenic environment. These self-made traps will be employed to study quantum simulations, fundamentals of large-scale entanglement and cavity-QED systems with integrated micro-optics.

Q 56.47 Do 16:30 VMP 9 Poster

Towards a loophole-free test of Bell's inequality — •Norbert Ortegel[1], Julian Hofmann[1], Michael Krug[1], Florian Henkel[1], Wenjamin Rosenfeld[1], Markus Weber[1], and Harald Weinfurter[1,2] — [1]Department für Physik der LMU, Schellingstraße 4/III, 80799 München — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching

Tests of Bell's inequality are subject to two loopholes - the detection and the locality loophole. Previous experiments with entangled photons [1] closed the locality loophole whereas experiments with entangled ions [2] closed the detection loophole.

In order to close both loopholes simultaneously, one can combine the high readout efficiency of atomic states with the possibility to distribute entanglement over long distances via photons. For that purpose we are setting up two spatially separated single-atom traps, which allow to create entangled atom-photon pairs [3]. A Bell-state measurement on the two photons allows to swap the entanglement to the atoms.

As a first step towards this goal we achieved to distribute for the first time atom-photon entanglement over a 300m long optical fiber [4]. In order to ultimately close the detection and locality loophole we are developing a sub-μs atomic detection based on state selective ionization. First characterizations revealed detection efficiencies of 93,7%.

[1] G. Weihs et al., PRL 81, 5039 (1998)
[2] D. N. Matsukevich et al., PRL 100, 150404 (2008)
[3] J. Volz, M. Weber et al., PRL 96, 030404(2006)
[4] W. Rosenfeld et al., arXiv:0808.3538v1 accepted for publ. in PRL

Q 56.48 Do 16:30 VMP 9 Poster

Maple tools for the simulation of quantum registers and their application to atomic processes — •Thomas Radtke[1], Stephan Fritzsche[2,3], and Andrey Surzhykov[3,4] — [1]Universität Kassel — [2]Frankfurt Institute for Advanced Studies — [3]GSI Helmholtzzentrum für Schwerionenforschung GmbH — [4]Universität Heidelberg

Entanglement is known as a key resource in many quantum computation protocols. However, despite the successful experimental demonstration of several protocols, there are still many open questions concerning the role of entanglement in quantum algorithms or its protection against noisy environments.

To facilitate the simulation of quantum registers and the investigation of their entanglement properties, we have developed the Feynman package for Maple. It supports frequently used concepts like tensor products, partial traces, etc. Additionally, several popular states, quantum gates and noise models are predefined for convenient access. The program also implements a variety of separability criteria and (entanglement) measures to provide tools for the analysis of entanglement [1].

As application of the Feynman program, here we present two case studies in the field of atomic physics [2]. First we investigate the spin entanglement between photoion and photoelectron in the atomic photoionization. The second study analyzes the polarization entanglement and nonlocality of the photon pairs emitted during the decay of (metastable) hydrogen.

[1] T. Radtke and S. Fritzsche, CPC **179** (2008) 647.
[2] T. Radtke *et al.*, PRA **74** (2006) 043709; **77** (2008) 022507.

Q 56.49 Do 16:30 VMP 9 Poster

Deterministic entanglement of ions in thermal states of motion — •Florian Zähringer[1,2], Gerhard Kirchmair[1,2], René Gerritsma[1,2], Jan Benhelm[1,2], Christian Roos[1,2], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Österreich — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Innsbruck, Österreich

We present an implementation of a Mølmer-Sørensen gate entangling $^{40}Ca^{+}$ ions using a bichromatic laser beam near-resonant with a quadrupole transition [1,2]. By amplitude pulse shaping and compensation of AC-Stark shifts we achieve a fast gate operation without compromising the error rate. In principle, the entangling gate does not require ground state cooling of the ions as long as the Lamb-Dicke criterion is fulfilled. We present the first experimental evidence for this claim and create Bell states with a fidelity of 0.974(1) for ions in a thermal state of motion with a mean phonon number of $\bar{n} = 20(2)$ in the mode coupling to the ions' internal states.

[1] J. Benhelm, G. Kirchmair, C. F. Roos and R. Blatt, Nat. Phys. **4**, 463 (2008)
[2] G. Kirchmair, J. Benhelm, F. Zähringer, R. Gerritsma, C. F. Roos and R. Blatt, arXiv:physics/0810.0670v1

Q 56.50 Do 16:30 VMP 9 Poster

Characterization of noise properties of an air-suspended solid-core PCF — •Michael Förtsch[1], Josip Milanovic[1], Mikael Lassen[2], Christoph Marquardt[1], Christoffer Wittmann[1], Dominique Elser[1], Ulrik L. Andersen[1,2], Gerd Leuchs[1], Andre Brenn[1], Meongsoo Kang[1], Jocelyn Chen[1], Michael Scharrer[1], Tijmen Euser[1], and Philip St. J. Russell[1] — [1]Max-Planck-Institut für die Physik des Lichts, Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, Günther-Scharowsky-Str. 1, Bau 24, 91058 Erlangen, Deutschland — [2]DTU Physics, Department of Physics, Technical University of Denmark, Building 309, 2800 Kgs. Lyngby, Dänemark

Photonic crystal fibers (PCF) are promising for the generation of squeezed states of light with ultrashort pulses, since the dispersion properties can be tailored so that one is able to generate solitons at a chosen wavelength and small core sizes generate a large nonlinearity. We investigate the noise properties of a photonic crystal fiber with an extreme core structure (air-suspended solid-core) that can help to suppress photon-phonon interaction and increase the nonlinearity. We study the dispersion and polarization properties, spatial mode structure, Guided Acoustic Brillouin scattering (GAWBS) noise and quantum noise behavior of these fibers.

Q 56.51 Do 16:30 VMP 9 Poster

Single photon downconversion into the telecom band — •Helge Rütz[1], Sebastian Zaske[1], Georgina A. Olivares-Renteria[2,3], Giovanna Morigi[3], and Christoph Becher[1] — [1]Fachrichtung 7.3 (Technische Physik), Universität des Saarlandes, Campus E2.6, 66123 Saarbrücken — [2]Center for Quantum Optics and Quantum Information, Departamento de Física, Universidad de Concepción, Casilla 160-C, Concepción, Chile — [3]Grup d'Optica, Departament de Fisica, Universitat Autonoma de Barcelona, 08193 Bellaterra, Spain

Efficient single photon transmission in future quantum networks requires wavelengths in the low loss band of optical fibers around 1550 nm. However, the vast majority of single photon sources realized to date have emission wavelengths in the red or near-infrared spectral region ($\sim$ 600-1000 nm). We here propose an experimental scheme for nonlinear downconversion of single photons emitted from an SiV center in diamond (738 nm) into the telecom band around 1550 nm. This is accomplished by difference frequency mixing with a strong cw signal wave at 1410 nm in a Ti-indiffused PPLN waveguide crystal. Theoretical considerations show that this process should allow for efficient and, in principle, noise free conversion between the pump and idler fields [1]. We study the conversion efficiency of the process and its quantum noise properties. To this end we include quantum noise sources using Heisenberg-Langevin equations. Finally we analyze the feasibility of the proposed scheme for realistic experimental parameters.

[1] Z. Y. Ou, Phys. Rev. A **78**, 023819 (2008)