Fachverband Quantenoptik und Photonik (Q)

Matthias Weidemüller
Physikalisches Institut der Universität Freiburg
Hermann-Herder-Str. 3
79104 Freiburg
weidemueller@physik.uni-freiburg.de

Übersicht der Fachsitzungen

(Hörsäle 1A, 1B, 1C, 2B/C, 2D, 2F, 2G, 3C, 3D, 3G und 3H; Poster C1 und Poster C2)

Fachsitzungen

Q 1.1–1.4	Mo	14:00–16:00	1A	**Quantengase I [gemeinsam mit A]**
Q 2.1–2.7	Mo	14:00–16:00	1B	**Quanteninformation (Atome und Ionen I)**
Q 3.1–3.4	Mo	14:00–16:00	3D	**Präzisionsmessungen und Metrologie I**
Q 4.1–4.8	Mo	14:00–16:00	3H	**Laserentwicklung (Festkörperlaser I)**
Q 5.1–5.5	Mo	16:30–19:00	1A	**Quantengase II [gemeinsam mit A]**
Q 6.1–6.10	Mo	16:30–19:00	1B	**Quanteninformation (Atome und Ionen II)**
Q 7.1–7.6	Mo	16:30–18:15	3C	**Ultrakurze Pulse (Attosekundenphysik) [gemeinsam mit A und K]**
Q 8.1–8.6	Mo	16:30–18:00	3D	**Präzisionsmessungen und Metrologie II**
Q 9.1–9.10	Mo	16:30–19:00	3H	**Laserentwicklung (Halbleiterlaser)**
Q 10.1–10.7	Di	8:30–10:30	3G	**Kalte Moleküle I [gemeinsam mit MO]**
Q 11.1–11.8	Di	8:30–10:30	3H	**Laserentwicklung (Festkörperlaser II / Andere Laserquellen)**
Q 12.1–12.8	Di	11:00–13:00	3G	**Kalte Moleküle II [gemeinsam mit MO]**
Q 13.1–13.8	Di	11:00–13:00	3H	**Laserentwicklung (Nichtlineare Effekte und Anwendungen)**
Q 14.1–14.6	Di	14:00–15:45	1B	**Quanteninformation (Quantencomputer I)**
Q 15.1–15.8	Di	14:00–16:00	1C	**Quantengase (Gitter I)**
Q 16.1–16.8	Di	14:00–16:00	2B/C	**Photonik I**
Q 17.1–17.8	Di	14:00–16:00	2F	**Ultrakalte Atome I [gemeinsam mit A]**
Q 18.1–18.7	Di	14:00–15:45	3D	**Präzisionsmessungen und Metrologie III**
Q 19.1–19.8	Di	14:00–16:00	3G	**Kalte Moleküle III [gemeinsam mit MO]**
Q 20.1–20.7	Di	14:00–15:45	3H	**Laseranwendungen (Lebenswissenschaften und Umwelt)**
Q 21.1–21.4	Di	16:30–17:30	1B	**Quanteninformation (Quantencomputer II)**
Q 22.1–22.6	Di	16:30–18:00	1C	**Quantengase (Gitter II)**
Q 23.1–23.6	Di	16:30–18:00	2B/C	**Photonik II**
Q 24.1–24.6	Di	16:30–18:00	3G	**Ultrakalte Moleküle [gemeinsam mit MO]**
Q 25.1–25.9	Di	16:30–18:45	3H	**Laseranwendungen (Spektroskopie)**
Q 26.1–26.12	Di	16:30–19:00	Poster C1	**Poster Ultrakurze Laserpulse**
Q 27.1–27.28	Di	16:30–19:00	Poster C2	**Poster Quantengase**
Q 28.1–28.26	Di	16:30–19:00	Poster C2	**Poster Quanteninformation**
Q 29.1–29.19	Di	16:30–19:00	Poster C2	**Poster Quanteneffekte**
Q 30.1–30.7	Di	16:30–19:00	Poster C2	**Poster Präzisionsmessungen und Metrologie**
Q 31.1–31.8	Do	8:30–10:30	1B	**Quanteninformation (Konzepte und Methoden I)**
Q 32.1–32.7	Do	8:30–10:15	1C	**Quantengase (Gitter III)**
Q 33.1–33.6	Do	8:30–10:00	2F	**Ultrakalte Atome II [gemeinsam mit A]**
Q 34.1–34.6	Do	8:30–10:00	2G	**Ultrakalte Rydberggase [gemeinsam mit A]**
Q 35.1–35.6	Do	8:30–10:00	3H	**Laseranwendungen (Optische Messtechnik)**
Q 36.1–36.8	Do	11:00–13:00	1B	**Quanteninformation (Konzepte und Methoden II)**
Q 37.1–37.9	Do	11:00–13:15	1C	**Quantengase (Wechselwirkungseffekte I)**
Q 38.1–38.8	Do	11:00–13:15	2D	**Quanteneffekte (Verschränkung und Dekohärenz)**
Q 39.1–39.8	Do	11:00–13:00	3H	**Ultrakurze Laserpulse (Erzeugung I)**
Q 40.1–40.8	Do	14:00–16:00	1A	**Quantengase (Bosonen I)**
Q 41.1–41.8	Do	14:00–16:00	1B	**Quanteninformation (Konzepte und Methoden III)**
Q 42.1–42.7	Do	14:00–16:00	1C	**Ultrakalte Atome (Manipulation und Detektion / Quantengase)**
Q 43.1–43.8	Do	14:00–16:00	2B/C	**Photonik III**

Q 44.1–44.9	Do	14:00–16:15	2D	**Quanteneffekte (Interferenz / Sonstige)**
Q 45.1–45.7	Do	14:00–15:45	3G	**Materiewellenoptik**
Q 46.1–46.9	Do	14:00–16:15	3H	**Ultrakurze Laserpulse (Erzeugung II / Anwendungen I)**
Q 47.1–47.9	Do	16:30–18:45	1A	**Quantengase (Bosonen II / Fermionen)**
Q 48.1–48.10	Do	16:30–19:00	1B	**Quanteninformation (Quantenkommunikation)**
Q 49.1–49.11	Do	16:30–19:15	3H	**Ultrakurze Laserpulse (Anwendungen II)**
Q 50.1–50.26	Do	16:30–19:00	Poster C2	**Poster Ultrakalte Atome**
Q 51.1–51.6	Do	16:30–19:00	Poster C2	**Poster Ultrakalte Moleküle**
Q 52.1–52.1	Do	16:30–19:00	Poster C2	**Poster Materiewellenoptik**
Q 53.1–53.11	Do	16:30–19:00	Poster C2	**Poster Photonik**
Q 54.1–54.11	Do	16:30–19:00	Poster C2	**Poster Laserentwicklung**
Q 55.1–55.9	Do	16:30–19:00	Poster C2	**Poster Laseranwendungen**
Q 56.1–56.8	Fr	11:00–13:00	1A	**Quanteninformation (Photonen und nichtklassisches Licht I)**
Q 57.1–57.8	Fr	11:00–13:00	2D	**Quanteneffekte (QED / Lichtstreuung)**
Q 58.1–58.5	Fr	11:00–12:30	3B	**Ultrakalte Atome (Einzelne Atome)**
Q 59.1–59.5	Fr	11:00–12:30	3C	**Transport in ultrakalten Gasen und Plasmen [gemeinsam mit A]**
Q 60.1–60.8	Fr	11:00–13:00	3G/H	**Quantengase (Gemische / Tunneleffekte)**
Q 61.1–61.6	Fr	14:00–15:30	1A	**Quanteninformation (Photonen und nichtklassisches Licht II)**
Q 62.1–62.7	Fr	14:00–15:45	3B	**Ultrakalte Atome (Fallen und Kühlung)**
Q 63.1–63.8	Fr	14:00–16:00	3G/H	**Quantengase (Wechselwirkungseffekte II / Spinorgase)**

Mitgliederversammlung des Fachverbands Quantenoptik und Photonik

Donnerstag 13:10–14:00 Raum 1C

- Bericht des Vorsitzenden
- Bericht der AG Photonik
- Wahl eines neuen Vorsitzenden und Stellvertreters
- Verschiedenes

Q 1: Quantengase I [gemeinsam mit A]

Zeit: Montag 14:00–16:00 Raum: 1A

Hauptvortrag Q 1.1 Mo 14:00 1A

Cavity Optomechanics — •Tobias J. Kippenberg — Max Planck Institut fuer Quantenoptik

Achieving the quantum regime with mechanical objects offers fascinating possibilities for applied and fundamental Physics alike but has yet has been unattained so far. Remarkably, research groups working on mechanical systems ranging in size from nanometer-scale oscillators to centimeter-scale optical cavities to kilometer-scale gravity wave detectors are now all independently approaching a regime in which either the mechanical system or its interaction with the environment must be described quantum mechanically. These experiments will mark the beginning of the new research field of cavity Quantum Optomechanics. In this talk I will review our own efforts at the MPQ in this emerging research field; specifically, we have developed a novel laser cooling method (1,2) with which mechanical oscillators can be cooled - analogous to atomic laser cooling - and achieved unprecedented readout of mechanical motion. This technique provides a route towards ground state cooling of a mechanical oscillator. The mechanical oscillators in our work are provided by monolithic micro-cavities, which inherently combine mechanical and optical degree of freedom. I will describe the various efforts my group made towards achieving this interesting, yet highly challenging regime including the mechanical analog of Resolved Sideband Cooling.

References:

(1) A. Schließer et al. Phys. Rev. Lett. 97, 243905 (2006)

(2) I. Wilson-Rae et al. Phys. Rev. Lett. 99, 093901 (2007)

Gruppenbericht Q 1.2 Mo 14:30 1A

Bose-Einstein condensates coupled to solid state systems on an atom chip — •Philipp Treutlein[1,2], David Hunger[1,2], Stephan Camerer[1,2], Pascal Böhi[1,2], Max Riedel[1,2], Johannes Hoffrogge[1,2], Theodor W. Hänsch[1,2], Daniel König[2], Jörg P. Kotthaus[2], and Jakob Reichel[3] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München — [3]LKB, Ecole Normale Superieure, Paris

We present the status of two experiments which explore the interaction of atoms with micro- and nanofabricated solid state systems on a chip.

The first experiment aims at coupling a BEC to the mechanical oscillations of a nanoscale cantilever with a magnetic tip. Theoretical investigations of the magnetic coupling mechanism show that the atoms can be used as a sensitive probe for the cantilever dynamics. At low temperatures, the backaction of the atoms onto the cantilever is significant and the system represents a mechanical analog of cavity QED in the strong coupling regime [P. Treutlein et al., Phys. Rev. Lett. 99, 140403 (2007)].

In the second experiment, the solid state system is a miniaturized microwave guiding structure, which can be used to manipulate BECs. Through microwave dressing of hyperfine states, state-selective double-well potentials can be created. Such potentials have applications in quantum information processing, the study of Josephson effects, and could be used to entangle atoms via state-selective collisions [P. Treutlein et al., Phys. Rev. A 74, 022312 (2006)].

Gruppenbericht Q 1.3 Mo 15:00 1A

Dissipation Fermionizes a One-Dimensional Gas of Bosonic Molecules — •Dominik M. Bauer, Niels Syassen, Matthias Lettner, Thomas Volz, Daniel Dietze, Juan J. Garcia-Ripoll, Ignacio Cirac, Gerhard Rempe, and Stephan Dürr — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

Many-body systems usually behave differently depending on whether the particles are bosons or fermions. However, bosons are forced to behave much like fermions if the system is one-dimensional (1D) and the interactions dominate the dynamics. This strongly correlated system is called a Tonks-Girardeau gas [1,2] and was observed with atoms in optical lattices [3,4]. All this work dealt with conservative interactions. Here we demonstrate a surprising generalisation, namely that inelastic collisions produce a dissipative analogue of the Tonks-Girardeau gas. We report on an experiment with molecules confined to 1D in an optical lattice. Inelastic collisions between the molecules create strong correlations that suppress the molecule loss rate by a factor of about 10. We dramatically increase this suppression by adding a lattice along the 1D direction. We develop theory which agrees with our experimental observations. Our work offers perspectives to create other, and possible new, strongly correlated states using dissipation.

[1] Tonks, L. *Phys. Rev.* **50**, 955-963 (1936).

[2] Girardeau, M. *J. Math. Phys.* **1**, 516-523 (1960).

[3] Paredes, B. *et al. Nature* **429**, 277-281 (2004).

[4] Kinoshita, T. *et al. Science* **305**, 1125-1128 (2004).

Gruppenbericht Q 1.4 Mo 15:30 1A

Strong dipolar effects in Chromium Bose-Einstein condensates (Gruppenbericht) — •Jonas Metz, Bernd Fröhlich, Tobias Koch, Thierry Lahaye, Axel Griesmaier, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart

The experimental observation of strong dipolar effects in a Bose-Einstein condensate of Chromium are presented. Starting with dipolar interactions which perturb the usual contact interactions, we use a Feshbach resonance to reduce and finally switch off the contact interaction. We investigate the stability diagram of a purely dipolar gas for various trap shapes and find a universal behaviour in the large N case for all dipolar gases. We then induce a dipolar collapse and study the dynamics. Quantitative comparison with theoretical calculations by the Ueda group of Tokyo University are presented. The symmetry of the dipolar interaction is observed in the collapse products.

Q 2: Quanteninformation (Atome und Ionen I)

Zeit: Montag 14:00–16:00 Raum: 1B

Gruppenbericht Q 2.1 Mo 14:00 1B

Entanglement and Quantum Networking with Trapped Atoms — •David Moehring[1,2], Jörg Bochmann[1], Dzmitry Matsukevich[2,3], Peter Maunz[2,3], Martin Mücke[1], Tobias Müller[1], Steven Olmschenk[2,3], Holger Specht[1], Bernhard Weber[1], Christopher Monroe[2,3], and Gerhard Rempe[1] — [1]Max-Planck-Institut für Quantenoptik, D-85748 Garching, Germany — [2]FOCUS Center and Department of Physics, University of Michigan, Ann Arbor, MI 48109-1040, USA — [3]JQI and Department of Physics, University of Maryland, College Park, Maryland 20742, USA

Distant, entangled qubits represent a universal resource for distributed quantum computing. One method to entangle two distant particles involves detecting a single photon from each particle after the photons have interfered. When two atoms each become entangled with an emitted single photon, subsequent interference and detection of these photons can leave the trapped atom qubits in an entangled state. Although this entanglement is probabilistic, it is not post-selective and therefore can be utilized for long-distance quantum communication and large-scale quantum computation.

I will discuss the experimental realization of remote-entanglement of two individually trapped ions separated by one meter [1] as well as current efforts toward deterministic entanglement via atoms trapped within high-finesse optical cavities [2,3].

[1] Moehring *et al.*, Nature **449**, 68 (2007)

[2] Wilk *et al.*, Science **317**, 488 (2007)

[3] Hijlkema *et al.*, Nature Physics **3**, 253 (2007)

Q 2.2 Mo 14:30 1B

Ion trap quantum gates with amplitude-modulated laser beams — •Christian Roos — Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, 6020 Innsbruck, Österreich

In ion traps, entangling gate operations can be realized by a bichromatic pair of laser beams that collectively interact with the ions. A new method of modelling the laser-ion interaction is introduced that turns out to be superior to standard techniques for the description of gate operations on optical qubits. The treatment allows for a comparison of the performance of gates based on $\sigma_z \otimes \sigma_z$ and $\sigma_\phi \otimes \sigma_\phi$ interactions on optical transitions where the bichromatic laser field can be realized by an amplitude-modulated laser resonant with the qubit transition [1]. Shaping the amplitude of the bichromatic laser pulse is shown to make the gates more robust against experimental imperfections. An experimental implementation of the gate using a pair of calcium ions have shown very promising results [2].

[1] C. F. Roos, arXiv:0710.1204, accepted for publication in New. J. Phys.
[2] J. Benhelm, G. Kirchmair, C. F. Roos, R. Blatt, manuscript in preparation.

Q 2.3 Mo 14:45 1B

Towards fault-tolerant quantum computing with trapped ions — •Jan Benhelm[1,2], Gerhard Kirchmair[1,2], Christian F. Roos[1,2], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Innsbruck — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Innsbruck

For fault-tolerant computation, it is commonly believed that error thresholds ranging between 10^{-4} and 10^{-2} will be required depending on the noise model and the computational overhead for realizing the quantum gates. Up to now, all experimental implementations have fallen short of these requirements.

Here, we report on the experimental realization of a Mølmer-Sørensen type entangling gate operation with a fidelity of 99.3% which together with single-qubit operations forms a universal set of quantum gates. The gate operation is performed on a pair of qubits encoded in two trapped calcium ions using a single amplitude-modulated laser beam interacting with both ions at the same time. A robust gate operation, mapping separable states onto maximally entangled states, is achieved by adiabatically switching on and off the laser-ion coupling. We analyse the performance of a single gate and concatenations of up to 21 gate operations.

Q 2.4 Mo 15:00 1B

Deterministic Entanglement Swapping with Trapped Ions — •Mark Riebe[1], Thomas Monz[1], Kihwan Kim[1], Alessandro Villar[2], Philipp Schindler[1], Markus Hennrich[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Austria

Entanglement is a key feature in the field of quantum information processing, as it allows for quantum communication, secret key sharing and quantum computation. Many of these applications require entangled states distributed among distant locations. Distribution of entangled states can be aided by a scheme known as entanglement swapping [1]. We demonstrate this scheme with a string of four trapped ^{40}Ca-ions, which carry quantum information in their internal states $S_{1/2}$ and $D_{5/2}$ [2]. Initially, ion pairs 1,2 and 3,4 are each prepared in the Bell state $\Psi^- = (|DS\rangle - |SD\rangle)/\sqrt{2}$. Then, ion 1 and 4 are measured in the Bell basis. The result of this measurement is perfectly correlated with the Bell state into which the previously unentangled ions 2 and 3 are projected. We make use of this fact and apply further rotations to ion 3 conditioned by the Bell measurement result, such that ions 2 and 3 are deterministically mapped to the state Ψ^-. This is confirmed by determining the final state of ions 2,3 by state tomography, which proves that we prepare the state Ψ^- with a fidelity of 79%.

[1] J. W. Pan et al., Phys. Rev. Lett. 80, 3891 (1998).
[2] F. Schmidt-Kaler et al., Appl. Phys. B 77, 789 (2003).

Q 2.5 Mo 15:15 1B

Three-qubit Toffoli gate with trapped ions — •Thomas Monz[1], Kihwan Kim[1], Wolfgang Hänsel[1], Alessandro Villar[2], Philipp Schindler[1], Mark Riebe[1], Markus Hennrich[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Austria

Quantum algorithms are usually decomposed into a sequence of gate operations each acting only on a few qubits. A well-known set for this purpose is a two-qubit controlled NOT (CNOT) gate combined with single qubit rotations. However, gates that connect more than two qubits could facilitate quantum computations. One example is the three-qubit Toffoli gate, which is a valuable tool for quantum error correction. The Toffoli gate acts on a register of two control qubits $|c_1, c_2\rangle$ and one target qubit $|t\rangle$ as $|c_1, c_2, t\rangle \rightarrow |c_1, c_2, (c_1 \wedge c_2) \oplus t\rangle$. We implement this gate with a string of trapped ions, where we use the ion's internal states as qubits and manipulate these with suitable laser pulses. Our implementation relies on an extension of the Cirac-Zoller gate proposal [1]: First a carefully designed sequence of laser pulses encodes the information $(c_1 \wedge c_2)$ in one of the ion string's vibrational modes. Then a CNOT gate between the target qubit and the vibrational mode realizes the operation $|t\rangle \rightarrow |(c_1 \wedge c_2) \oplus t\rangle$. Finally, the initial encoding procedure is reversed. We analyze the Toffoli gate operation by quantum process tomography, and obtain a mean gate fidelity of 79%.

[1] J. I. Cirac and P. Zoller, Phys. Rev. Lett. 74, 4091 (1995).

Q 2.6 Mo 15:30 1B

Coupling trapped ions via transmission lines — Rob Clark[1,2], Sankaranarayanan S[1], •Nikos Daniidilis[1], and Hartmut Häffner[1] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Innsbruck, Österreich — [2]Center for Ultracold Atoms, Massachusetts Institute of Technology, START project Cambridge, MA, USA

An oscillating trapped ion induces oscillating image charges in the trap electrodes. If this current is send to the electrodes of a second trap, it influences the motion of an ion in the second trap. The expected time for a complete exchange of the ion motions is 1 ms for a trap with a characteristic size of 50 μm. This inter–trap coupling may be used for scalable quantum computing, cooling ion species that are not directly accessible to laser cooling, for the non-invasive study of superconductors, and for coupling an ion–trap quantum computer to a solid–state quantum computer, e.g. a system of Josephson junctions.

We will discuss the feasibility of experiments towards these goals with trapped Calcium ions. The most relevant source of decoherence is heating of the ion motion due to noise in the trap electrodes (e.g. Johnson–noise). By operating ion traps at cryogenic temperatures, heating will be greatly reduced, allowing the coherent coupling of two ions. In this context, we will present results from currently operating planar traps, as well as efforts in developing microfabricated planar traps. In particular, we will discuss the influence of an electrically floating coupling electrode on trap performance.

Q 2.7 Mo 15:45 1B

Long-distance atom-photon entanglement and its coherence properties — •Michael Krug[1], Wenjamin Rosenfeld[1], Fred Hocke[1], Florian Henkel[1], Andreas Deeg[1], Christian Jakob[1], Markus Weber[1], and Harald Weinfurter[1,2] — [1]Sektion Physik, Ludwig-Maximilians-Universität München, Schellingstrasse 4, D-80799 München — [2]Max-Planck Institut für Quantenoptik, D-85748 Garching

Long-distance Atom-Photon Entanglement: The distribution of entanglement between quantum memories at remote locations is one major challenge for the first demonstration of a quantum repeater. Entanglement between matter and light [1] is crucial for achieving this task. Here we report the observation of entanglement between a single trapped atom and a single photon, separated 300 m via an optical fiber. The entanglement is verified by appropriate correlation measurements of the atom-photon pair after communicating the photon through the fiber. In addition we analyzed the temporal evolution of the atomic density matrix after projecting the atom-photon pair via a state measurement of the photon onto a well defined atomic spin state. We find that the atomic Zeeman qubit decoheres after 100 μs. Our results represent important steps towards the realization of entanglement between single neutral atoms at distances of several 100 m.

[1] J. Volz, M. Weber, D. Schlenk et al., Phys. Rev. Lett. **96**, 030404 (2006).

Q 3: Präzisionsmessungen und Metrologie I

Zeit: Montag 14:00–16:00 Raum: 3D

Gruppenbericht Q 3.1 Mo 14:00 3D

A Michelson-Morley Type Test of Lorentz Invariance using electromagnetic Resonators — •Alexander Senger[1], Katharina Möhle[1], Moritz Nagel[1], Sven Herrmann[2], Evgeny Kovalchuk[1], Holger Müller[2], and Achim Peters[1] — [1]Institut für Physik, Humboldt-Universität zu Berlin — [2]Physics Department, Stanford University, USA

The experiment of A. A. Michelson and E. W. Morley, has served as a sensitive test of special relativity and Lorentz invariance for more than a century now. Modern versions of this experiment rely on the comparison of electromagnetic eigenfrequencies of rotating high-finesse resonators. This approach allows to search for tiny violations of Lorentz Invariance in the optical sector of the underlying test theory (SME, Standard Model Extension), and also for deviations regarding the electronic properties of the material used to build the resonators.

We report on the progress made in our improved version of the experiment, where the measurement is performed by monitoring an optical resonator continuously rotating on a precision turntable, which currently allows for a sensitivity at the 10^{-17} level for a direction dependent variation of the speed of light. We discuss limiting effects in our setup and present steps towards a measurement spanning more than one year which should give an improvement of at least an order of magnitude in accuracy compared to previous tests. Furthermore, we present results from a collaboration employing two complementary experiments leading to limits on Lorentz Violation in the electronic sector of the SME.

Gruppenbericht Q 3.2 Mo 14:30 3D

A Picometer Resolution Heterodyne Interferometer for LISA and its Application to Technology Verification — •Dennis Weise[1], Martin Gohlke[1,2], Thilo Schuldt[2,3], Thomas Heinrich[3], Ulrich Johann[1], Achim Peters[2], and Claus Braxmaier[3] — [1]EADS Astrium GmbH — [2]Humboldt-Universität zu Berlin — [3]HTWG Konstanz

Within the LISA Mission Formulation study currently funded by ESA, EADS Astrium has developed and investigated various concepts for the LISA payload architecture, all of which utilize an Optical Readout (ORO) to detect relative motion between the inertial reference (i. e. the proof mass) and the spacecraft. In collaboration with the Humboldt University Berlin and the HTWG Konstanz, a prototype ORO has been realized over the past years, which meanwhile is close to achieving the required picometer-sensitivity in translation and nanorad-sensitivity in attitude metrology. The polarizing heterodyne interferometer is characterized by a highly symmetric setup and employs differential wavefront sensing for determination of the proof mass tilt in 2 degrees of freedom. We will discuss the experimental setup and its latest performance, as well as its application to first verification of critical LISA subsystems. For example, the interferometer has been applied to characterize the CTE of various CFRP samples with ultra-high sensitivity, including "near-zero-CTE" tubes. Our current activities further include novel developments for other critical parts of the optical metrology chain, namely the laser source and the phasemeter, where the respective approach and first results will be presented.

Gruppenbericht Q 3.3 Mo 15:00 3D

LISA Pathfinder: spaceborne testbed towards millihertz gravitational wave astronomy — •Felipe Guzman Cervantes[1], Frank Steier[1], Antonio Francisco Garcia Marin[1], Michael Troebs[1], Anneke Monsky[1], Martin Hewitson[1], Gudrun Wanner[1], Ingo Diepholz[1], Oliver Jennrich[2], Gerhard Heinzel[1], and Karsten Danzmann[1] — [1]Albert-Einstein-Institut Hannover — [2]ESA-ESTEC

LISA Pathfinder is a ESA technology demonstration mission planned to be launched in 2010 to test LISA core technologies that cannot be tested on ground. The LISA Pathfinder satellite carries two experiments: the LISA Technology Package (LTP) from ESA, and the Disturbance Reduction Noise (DRS) from NASA. The LISA Technology Package will primarily demonstrate test mass drag-free control and isolation to better than 3×10^{-14} $\mathrm{ms}^{-2}/\sqrt{\mathrm{Hz}}$, and spacecraft control with micronewton thrusters. A set of 4 heterodyne Mach-Zehnder interferometers is utilized for the read out of test mass displacement and rotation to better than 10 $\mathrm{pm}/\sqrt{\mathrm{Hz}}$ and 10 $\mathrm{nrad}/\sqrt{\mathrm{Hz}}$ in the frequency range from 3-30 mHz respectively. Currently we are testing engineering models of different subsystems and preparing a test bed for investigations on flight hardware. This talk presents the current status in the development and implementation of the LISA Technology Package and a series of tests conducted as software and hardware simulations for on-orbit operation.

Gruppenbericht Q 3.4 Mo 15:30 3D

LISA: Laser interferometry for the spaceborne gravitational wave detection — •Antonio Francisco Garcia Marin[1], Felipe Guzman Cervantes[1], Frank Steier[1], Simon Barke[1], Christian Diekmann[1], Roland Fleddermann[1], Benjamin Sheard[1], Michael Tröbs[1], Juan Jose Esteban Delgado[1], Iouri Bykov[1], Jens Reiche[1], Oliver Jennrich[2], Gerhard Heinzel[1], and Karsten Danzmann[1] — [1]Albert-Einstein-Institut Hannover, Max-Planck-Institut für Gravitationsphysik and Universität Hannover, Germany — [2]ESA ESTEC, Noordwijk, The Netherlands

The Laser Interferometer Space Antenna (LISA) is a joint ESA-NASA mission designed to observe gravitational waves in the frequency range between 0.1 to 100 mHz, where ground-based detectors are limited by terrestrial noise. Sources in this frequency range include supermassive black holes and galactic binary stars. LISA consists of three identical spacecraft separated by 5 million kilometers carrying a total of six free flying test masses in heliocentric drag-free orbit. The fluctuations in separation between two of these test masses located in different satellites will be measured by laser interferometry with picometre precision. I will present a brief overview of the LISA mission with special emphasis on the laser interferometry, the research field at the Albert Einstein Institute.

Q 4: Laserentwicklung (Festkörperlaser I)

Zeit: Montag 14:00–16:00 Raum: 3H

Q 4.1 Mo 14:00 3H

Yb-Faserverstärker bei Wellenlängen abseits des Verstärkungs-Maximums — •Mathias Sinther, Hanne Beck, Sergej Molleker und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, Schlossgartenstr. 7, D-64289 Darmstadt

Neben Yb-Faserlasern erfreuen sich auch Yb-dotierte Faserverstärker in letzter Zeit immer größerer Beliebtheit. In diesem Beitrag werden schmalbandige Yb-Faserverstärker mit Leistungen im Watt-Bereich präsentiert, deren Betriebswellenlängen sowohl unterhalb als auch oberhalb des Verstärkungsmaximums liegen.

Q 4.2 Mo 14:15 3H

Ein ns-Titan:Saphir Laser als nahezu universelle Lichtquelle — •Daniel Depenheuer, Henning Glässer und Thomas Walther — TU Darmstadt, Institut für angewandte Physik, Laser- und Quantenoptik, Schlossgartenstr. 7, 64297 Darmstadt

Wir stellen ein gepulstes Titan:Saphir Lasersystem vor, das durch nichtlineare Frequenzkonversionsprozesse den Spektralbereich von 190nm bis 6300nm nahezu lückenlos abdecken kann. Durch injection-seeding werden fourierlimitierte Pulse erreicht. Aufgrund seiner kompakten Bauweise bietet das System sehr stabile und kurze Buildup Zeiten. Dies ermöglicht nicht nur Summen- und Differenzfrequenzmischen des Titan:Saphir Pulses mit dem Pumppuls, sondern auch die Synchronisation mehrerer Lasersysteme. Die nichtlinearen Konversionsprozesse sind aufgrund der sehr hohen (spektralen) Energiedichte äußerst effizient.

Q 4.3 Mo 14:30 3H

Theoretische und experimentelle Limits von modengekoppelten Scheibenlasern mit Cavity-Dumping — •Martin Siegel, Guido Palmer, Nils Pfullmann, Andy Steinmann und Uwe Morgner — Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland

Mittels modengekoppelter Scheibenlaser mit Cavity-Dumping können Pulsenergien von drei Mikrojoule bei Repetitionsraten von einem Megahertz erreicht werden [1]. Dies macht sie zu interessanten Strahlquellen für viele Anwendungen in der Mikromaterialbearbeitung, der nichtlinearen Spektroskopie sowie der Augenchirurgie.

Numerische Simulationen erlauben die Modellierung der dynamischen Eigenschaften solcher Systeme und ermöglichen damit ein besseres Verständnis des Zusammenspiels der verschiedenen Designparameter. Im Vergleich mit jüngst veröffentlichten experimentellen Daten können so prinzipielle Limitierungen eines solchen Laserdesigns identifiziert und erklärt werden. Aufbauend hierauf werden Optimierungsmöglichkeiten sowie Abschätzungen über zukünftig erreichbare Pulsenergien vorgestellt [2].

[1] G. Palmer, et al. Opt. Letters 32, 1593 (2007)
[2] M. Siegel, et. al. Opt. Express accepted (2007)

Q 4.4 Mo 14:45 3H

Passiv modengekoppelter Yb:KYW-Oszillator mit Cavity-Dumping im positivem Dispersionsregime — Guido Palmer, Moritz Emons, Martin Siegel, Andy Steinmann und •Uwe Morgner — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

Viele Anwendungen, wie z.B. die nichtlineare Spektroskopie oder die Laser-Mikromaterialbearbeitung profitieren von hochenergetischen Laserpulsen im Femtosekunden-Regime mit MHz-Repetitionsraten. Der Einsatz von passiv modengekoppelten Lasern mit Cavity-Dumping ermöglicht die Erschließung des Mikrojoule-Bereiches mit Oszillatoren ohne weitere Verstärkungseinheiten. Mit der Leistungsskalierung solitär modengekoppelter Systeme geht ein deutlicher Anstieg der Kerr-Nichtlinearitäten insbesondere in der Luft im Resonator einher. Mit Hilfe der Modenkopplung im positiven Dispersionsregime konnte bereits für Ti:Saphir-basierte Systeme eine deutliche Reduktion der resonatorinternen Spitzenleistung bei Mikrojoule-Energien erreicht werden. Wir präsentieren einen auf Yb:KY(WO4)2 basierenden, direkt diodengepumpten Oszillator mit Cavity-Dumping, der im positiven Dispersionsbereich betrieben wird. Der durch einen sättigbaren Absorber modengekoppelte Laser emittiert Pulsenergien über 2 Mikrojoule bei einer Repetitionsrate von 1 MHz und einer Zentralwellenlänge von 1030 nm. Im Vergleich zum solitären Betrieb (1,3 Mikrojoule) konnte dadurch eine deutliche Steigerung der Pulsenergie demonstriert werden. Die positiv gechirpten Pulse aus dem Oszillator werden durch eine Transmissionsgitterkonfiguration extern auf etwa 400 fs komprimiert.

Q 4.5 Mo 15:00 3H

Faser-basierte Nachverstärkung eines Yb:KYW Lasers mit Cavity-Dumping — •Andy Steinmann, Moritz Emons, Guido Palmer und Uwe Morgner — Institut für Quantenoptik, Leibniz Universität Hannover

Lasersysteme, die Femtosekundenpulse mit Energien im Mikrojoulebereich bei MHz-Repetitionsraten emittieren, sind ideale Lichtquellen für eine Vielzahl von Anwendungen wie z.B. dem Wellenleiterschreiben in transparenten Materialien, der Mikromaterialbearbeitung, der Multiphotonen-Mikroskopie oder der nichtlinearen Spektroskopie. Diodengepumpte Yb:KYW Laser mit elektrooptischem Cavity-Dumping ermöglichen Pulsenergien über einem Mikrojoule bei Wiederholraten von einem MHz.

Wir präsentieren ein Faser-basiertes CPA-System, das durch externe Nachverstärkung eine weitere deutliche Steigerung der Pulsenergie ermöglicht. Zum Strecken der Pulse dient dabei ein Gitterstretcher, der aus einem einzelnen Gitter und zwei konzentrischen Spiegeln besteht, als Verstärkerfaser kommt eine 50 cm lange Yb-dotierte rod-type-Faser zum Einsatz, und als Kompressor wird ein Paar Quarz-Transmissionsgitter verwendet.

Auf diese Weise können 420 fs Pulse mit einer Pulsenergie von 9 μJ realisiert werden. Das System ist eine ideale Pumpquelle für optisch parametrische Verstärker mit MHz-Repetitionsraten.

Q 4.6 Mo 15:15 3H

Photophysical Characterisation of Pyrromethene 597 Laser Dye in Cross-linked Silicon-containing Organic Copolymers — •Amit Tyagi[1], David del Agua[2], Alfons Penzkofer[1], O. García[2], Robert Sastre[2], Angel Costela[3], and Immaculata García-Moreno[3] — [1]Institut II - Physik, Universität Regensburg, D-93040 Regensburg — [2]Instituto de Ciencia y Tecnología de Polímeros, CSIC, Juan de la Cierva 3, 28006 Madrid, Spain — [3]Instituto de Química Física "Rocasolano", CSIC, Serrano 119, 28006 Madrid, Spain

Dipyrromethene-BF_2 PM597 dye-doped copolymers resembling inorganic-organic hybrids were characterized towards their application as solid-state laser rods. The inorganic function was entered by the silicon containing constituent 3-(trimethoxysilyl)propyl methacrylate (TMSPMA). The organic constituents are monomers with one [methyl methacrylate (MMA)], two [ethylene glycol dimethacrylate (EGDMA)], three [pentaerythriol triacrylate (PETA)], and four [pentaerythriol tetraacrylate (PETRA)] polymerizable groups. The thermo-mechanical stability of the samples increased with the number of cross-linking groups (studied by thermogravimetry and differential scanning calorimetry), while the optical and lasing parameters were found to be similarly good for all investigated silicon containing samples (fluorescence quantum yield around 60 %, excited-state absorption less than 10 % of ground-state absorption, more than 3 million excitation cycles before degradation).

Q 4.7 Mo 15:30 3H

Frequency stabilized pulsed dual rod Nd:YAG ring-oscillator following a Pound-Drever-Hall method — •Martin Ostermeyer and Alexander Strässer — Universität Potsdam, Am neuen Palais 10, 14469 Potsdam

An injection seeded pulsed Nd:YAG ring laser oscillator has been setup for single frequency operation. A monolith ring-laser (NPRO) serves as seed laser. It has been frequency stabilized following a radio-frequency-sideband scheme. This dual rod oscillator emits pulses with 23 ns duration and 20 mJ energy. The beam quality is almost diffraction limited (M2 = 1.2). The frequency stability was characterized with a heterodyne method to 1.0 MHz (rms) [1]. This oscillator will serve as front-end for a series of Lidar devices for spectrally sensitive measurements. The ring resonator comes up with a less critical isolation from the seed laser, a wider stability range, and a wider separation of the longitudinal modes compared to a linear standing wave resonator. The Pound-Drever-Hall-method (PDH) supplies an unambiguous error signal for the length control of the cavity. However there are time dependent length and phase changes in the resonator due to time dependent pumping and Q-switching. They pose a challenge for reaching a fast and accurate length control of the resonator.

Q 4.8 Mo 15:45 3H

Resonatorinterne Frequenzverdopplung von GaN-laser-diodengepumpten cw-Pr:LiLuF$_4$-Lasern — •Nils-Owe Hansen, André Richter, Nicky Thilmann, Ernst Heumann und Günter Huber — Institut für Laser-Physik, Luruper Chaussee 149, 22761 Hamburg

Es wird erstmals über laserdiodengepumpte Praseodym(Pr)-Laser berichtet, die resonatorintern frequenzverdoppelt sind und UV-Licht bei 320 nm emittieren. Die verwendeten LiLuF$_4$(LLF)-Laserkristalle unterschiedlicher Länge sind unbeschichtet und besitzen eine Praseodymkonzentration von 0,45 at.%. Als Pumpquellen wurden zwei GaN-Laserdioden mit einer geeigneten Emissionswellenlänge von 444 nm und Ausgangsleistungen von je 500 mW eingesetzt. Auf der Grundwellenlänge des Pr-Lasers konnten bei einer absorbierten Pumpleistung von 650 mW und 3,6% Auskopplung maximal 208 mW Laserleistung erzielt werden. Die resonatorinterne Frequenzverdopplung erfolgt durch LiB$_3$O$_5$ (LBO) unter Typ I Phasenanpassung im einfach gefalteten Resonator. Die Länge des verwendeten LBO-Kristalls für die ersten Experimente bei reduzierter Pumpleistung betrug 8 mm. Damit konnte eine maximale UV-Leistung von 14,3 mW bei einer absorbierten Pumpleistung von 275 mW erreicht werden. Das entspricht einer Umwandlungseffizienz von 19% von der Fundamentalen in die frequenzverdoppelte Strahlung und einem optisch-optischen Wirkungsgrad von 5%. Im Vortrag wird auch über Ergebnisse aus Experimenten zur Leistungsskalierung berichtet.

Q 5: Quantengase II [gemeinsam mit A]

Zeit: Montag 16:30–19:00 Raum: 1A

Hauptvortrag Q 5.1 Mo 16:30 1A

Dynamical quantum phase transitions — •Ralf Schuetzhold — TU Dresden, Institut fuer Theoretische Physik

A sweep through a quantum phase transition by means of a time-dependent external parameter entails non-equlilibrium phenomena (break-down of adiabaticity): Since the energy gap vanishes at the critical point, the response time diverges and thus the external time-dependence drives the system away from the ground state (assuming zero temperature initially). In this way, the initial quantum fluctuations are amplified and may become observable. By means of several examples based on ultra-cold atoms, possible effects of these amplified quantum fluctuations are studied and universal features (such as freezing) are discussed.

Gruppenbericht Q 5.2 Mo 17:00 1A

Bose-Einstein condensates in presence of defects and disorder. — •Tobias Paul, Mathias Albert, Nicolas Pavloff, and Patricio Leboeuf — Laboratoire de Physique Théorique et Modèles Statistiques, Universite Paris Sud, F-91405 Orsay

Superfluidity and Anderson localization are genuine many-body manifestations of quantum coherence which are nowadays revisited in dilute Bose gases. Recent theoretical results obtained in our group in Orsay are reviewed: First, we study the coherent flow of interacting Bose-condensed atoms in presence of a single defect or an extended disorder potential. We discuss the different regimes of quantum transport induced by a variation of the condensate flow-velocity v: We point out that for v much smaller than the sound velocity c the flow is in general superfluid, whereas beyond a critical velocity the formation of solitons and shockwaves sets on. For $v \gg c$, a regime of quasi-dissipationless transport is found. There, for long disorder samples, the system enters an Anderson localized phase.

In a second step, we consider the experimental relevant case where a harmonic trap is superimposed to the defect potential. We obtain a global picture characterizing the dynamical properties of the dipole oscillations where we recover the different regimes of quantum transport introduced in the first part of the talk. We discuss our findings in the context of recent experiments [1,2] and address the question under which circumstances Anderson localization could be observed.

[1] J. E. Lye et al., Phys. Rev. A 75, 061603 (2007)

[2] P. Engels and C. Atherton, Phys. Rev. Lett. 99, 160405 (2007)

Gruppenbericht Q 5.3 Mo 17:30 1A

Tailoring quasi-particles in ultra-cold matter: soliton oscillations, longest lifetimes and fillings. — •Christoph Becker[1], Parvis Soltan-Panahi[1], Simon Stellmer[1], Sören Dörscher[1], Eva-Maria Richter[1], Mathis Baumert[1], Jochen Kronjäger[1], Kai Bongs[1,2], and Klaus Sengstock[1] — [1]Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]Midlands Centre for Ultracold Atoms, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK

Solitons are distinguishing features of many non-linear physical systems. Stabilized by a balance between spreading due to dispersion and focusing mediated by non-linearities, solitons emerge as non-spreading wavepackets. BEC's provide fascinating possibilities concerning quantum-state engineering, necessary for the creation and observation of solitons. Dark solitons appear as dips in the density distribution and have so far been produced in few experiments limited by very short lifetimes.

Here we report on the generation of dark solitons in an optically trapped ^{87}Rb BEC with an extraordinary life-time of up to several seconds. For the first time, we observe oscillations of dark solitons with a characteristic frequency in excellent agreement with theoretical predictions. By filling the dark soliton with atoms in another hyperfine state we are able to create dark-bright solitons with a substantially greater oscillation period.

The experimental results are combined with theoretical studies based on the Gross-Pitaevskii equation.

Gruppenbericht Q 5.4 Mo 18:00 1A

Strongly interacting Fermi gases in an optical lattice — •Henning Moritz[1], Niels Strohmaier[1], Robert Jördens[1], Kenneth J. Günter[1,2], Yosuke Takasu[1,3], Michael Köhl[1,4], and Tilman Esslinger[1] — [1]Institute of Quantum Electronics, ETH Zürich, Hönggerberg, CH-8093 Zürich, Switzerland — [2]Department for Electronic Science and Engineering, Kyoto University, Japan — [3]Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, United Kingdom — [4]Laboratoire Kastler Brossel, 24, rue Lhomond, 75005 Paris

When fermionic atoms are placed in the periodic potential of an optical lattice, they behave very much like electrons in a solid. However, the properties of this synthetic material can be changed at will. Here, we report on the experimental realization and investigation of strongly interacting Fermi gases with tunable interactions.

By changing the attractive interaction strength we are able to control the transport properties: while dipole oscillations are observed for a non-interacting gas, the cloud relaxes very slowly to its equilibrium position for strong attractive interactions. We suggest an interpretation in the framework of the Hubbard model including external confinement. The strong attraction induces bound states, which can only tunnel very slowly via second order processes.

Furthermore, experiments on the behavior of repulsive Fermi gases will be presented.

Gruppenbericht Q 5.5 Mo 18:30 1A

First Bose-Einstein Condensate in microgravity — •Tim van Zoest[1], Wojtek Lewoczko-Adamczyk[2], and Anika Vogel[3] for the QUANTUS-Collaboration — [1]Institut für Quantenoptik, Leibniz-Universität Hannover — [2]Institut für Physik, Humboldt Universität Berlin — [3]Institut für Laserphysik, Universität Hamburg

Promising techniques for fundamental tests in the quantum domain are matter-wave sensors based on cold atoms, which use atoms as unperturbed microscopic test bodies for measuring inertial forces or as frequency references. Microgravity is of high relevance for matter-wave interferometers and experiments with quantum matter, like Bose-Einstein-condensates , as it permits the extension of an unperturbed free fall in a low-noise environment.

The project QUANTUS is a feasibility study of a compact, robust and mobile experiment for the creation of a BEC in a weightlessness environment at the droptower in Bremen (ZARM). The experiment has to be implemented in a dropcapsule with a length of 215 cm and 60 cm diameter and has to withstand forces up to 50 g (1). The experimental setup as well as the latest results, the realization of the first weightlessness Bose-Einstein Condensate with longest time of flights and the adiabatic expansion to very shallow traps (less than 20 Hz), are described. In future, the apparatus will serve as an experimental platform to investigate various aspects of ultra-cold gases in microgravity like adiabatic release, extended coherent evolution and features of atom lasers.

(1) A. Vogel et al., Appl. Phys. B, 84, 04 (2006)

Q 6: Quanteninformation (Atome und Ionen II)

Zeit: Montag 16:30–19:00 Raum: 1B

Q 6.1 Mo 16:30 1B

A table-top experiment on the early universe — •Hector Schmitz, Axel Friedenauer, Jan Glückert, Lutz Petersen, Steffen Kahra, Günter Leschhorn, Christian Schneider, Robert Matjesch, and Tobias Schätz — MPQ Garching

Having a look at the conditions of the early universe isn't easy. Even state of the art accellerators are not able to create the extremely high energies gouverning the very first cosmological period in which quantum phenomena become crucial in the development of space and time.

Some details might be accessible for investigations in an analog way, namely the creation of new particle-antiparticle pairs within the violent days of the inflationary epoch of the universe. Following calculations [1,2] an analog vaccuum quantum processes that might have lead to the creation of new pairs of photons and other particles during a phase of rapid expansion should create pairs of phonons in an ion crystal if the confining potential is changed exponentially.

Here we present and discuss the realisation of this simulation in a linear Paul trap. A single ion is cooled via sideband cooling down to the motional ground state – mimicing the ground state of the vaccuum. Then the confining potential is lowered slowly. While the potential raises nonadiabatically back to its initial strength, pairs of phonons will show up, whose signature is discriminated form heating processes.

[1] R. Schützhold, T. Schätz et. al., Phys. Rev. Lett. 99, 201301 (2007)
[2] "Quantum quirk may reveal early universe", New Scientist 2607, p. 11 (2007)

Q 6.2 Mo 16:45 1B

Experimental techniques for quantum information processing with trapped ^{43}Ca$^+$ ions — •Gerhard Kirchmair[1,2], Jan Benhelm[1,2], René Gerritsma[1,2], Florian Zähringer[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 demonstrate the complete set of experimental techniques that are necessary to employ the isotope ^{43}Ca$^+$ for quantum information processing. Ground state cooling, robust state initialization and efficient read out are experimentally realized on a single ^{43}Ca$^+$ ion. With microwave transitions, we find the coherence time for storing quantum information in the hyperfine qubit ($F = 4, m_F = 0 \leftrightarrow F = 3, m_F = 0$) to be many seconds. Phase coherence during the interaction with a Raman laser is sustained for more than 200 ms. All techniques are also applicable to ion strings and the ability to move the ions makes individual addressing possible. We show that the motional coherence of a single ion is preserved during the shuttling process.

Q 6.3 Mo 17:00 1B

Realization of decoherence-free ion trap quantum computation — •Kihwan Kim[1], Thomas Monz[1], Alessandro Villar[2], Philipp Schindler[1], Michael Chwalla[1], Mark Riebe[1], Markus Hennrich[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, Austria

Quantum computation is limited by decoherence from technical noise and coupling of the qubits to the environment. However, certain states were shown to be protected from decoherence due to their symmetry [1]. These states form a decoherence-free subspace (DFS) of the Hilbert space. Using the DFS as a robust computational space will help to realize large scale quantum computing. In this talk we show the first realization of a universal set of gate operations in a DFS with ion strings. We use trapped ^{40}Ca ions and store quantum information in the ion's electronic states $S_{1/2}$ and $D_{5/2}$. A DFS is formed by the two states $|SD\rangle$ and $|DS\rangle$ which are used as logical qubits $|0_L\rangle$ and $|1_L\rangle$. In this DFS, single-qubit rotations are realized using a Mølmer-Sørensen gate between the two ions of the logical qubit. For two-qubit operations between logical qubits a σ_z-type geometric phase gate is applied to neighbouring ions of two adjacent logical qubits [2]. We obtain fidelities of around 94% for a single qubit $\pi/2$-rotation and around 75% for a CNOT gate in DFS.

[1] D. Kielpinski et al., Nature 417, 709 (2002).
[2] L. Aolita et al., Phys. Rev. A 75, 052337 (2007).

Q 6.4 Mo 17:15 1B

Optimised particle transport in a potential well — •Michael Murphy and Tommaso Calarco — Inst. f. Quanteninformationsverarbeitung, Ulm, D

We analyse a quantum system with which we require non-adiabatic transport of a specified quantum state. We first consider analytically the situation of a 1-d harmonic potential confining a particle in a given quantum state, corresponding to the motional states of bound particles such as ions in a microtrap, or atoms in an optical lattice. We show analytic solutions exist for the transport function such that perfect transport is achieved in an arbitrary time, by which we mean that given an initial quantum state, the final state is the same as the initial state but displaced by our transport distance, and the state has evolved only as one would have found in a static harmonic potential. We also show that the system is robust against a class of distorting functions that describe homogeneous broadening. Furthermore, we apply Optimal Control Theory to optimise the transport function when the system is coupled to the environment.

Q 6.5 Mo 17:30 1B

Nichtadiabatischer Transport von Ionen in einer segmentierten, linearen Paulfalle in Leiterplattentechnologie — •Gerhard Huber, Thomas Deuschle, Wolfgang Schnitzler, Max Hettrich, Rainer Reichle, Kilian Singer und Ferdinand Schmidt-Kaler — Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, 89069 Ulm

Wir beschreiben die Konstruktion und den Betrieb einer segmentierten, linearen Paulfalle, gefertigt in Leiterplattentechnologie mit einer Segmentbreite von 500 μm [1]. Um die Eignung dieser Technologie zum Fangen und Manipulieren geladener Teilchen zu demonstrieren, speichern und laserkühlen wir Kristalle aus einzelnen ^{40}Ca$^+$-Ionen. Die gemessenen radialen und axialen Fallenfrequenzen stimmen bis auf wenige Prozent mit den durch numerische Rechnungen vorhergesagten Werten überein.

Um die Vielseitigkeit und Verlässligkeit dieser Fallentechonologie zu demonstrieren, untersuchen wir den Transport einzelner Ionen entlang der Fallenachse über eine Distanz von 2 mm hin und zurück. Die durchgeführten Experimente ergeben hohe Erfolgsraten auch im Bereich sehr schneller, nichtadiabatischer Transporte, die nur noch wenige axiale Oszillationsperioden des Ions dauern. Wir untersuchen in numerischen Simulationen und experimentell die durch solche schnellen Transporte erzeugte Vibrationsanregung des Ions.

[1] G. Huber et al., arXiv:0711.2947v1

Q 6.6 Mo 17:45 1B

Efficient coupling of light to a single molecule and the observation of its fluorescence Mollow triplet — •Martin Pototschnig, Gert Wrigge, Ilja Gerhardt, Jaesuk Hwang, Lutz Petersen, and Vahid Sandoghdar — Laboratory for Physical Chemistry, ETH Zurich, CH-8093 Zurich, Switzerland

Dye molecules in organic matrices are solid-state quantum emitters that can have lifetime limited linewidths at temperatures below 2K. Single molecules in such systems have been conventionally detected with fluorescence excitation spectroscopy, where the molecule is excited via its narrow zero-phonon line and its Stokes-shifted emission is detected. We report here on the coherent detection of a single molecule in transmission. Our experiments in the near- [1,2] and far-field [3] directly show between 5 and 12% dip on the transmission of a laser beam without using any noise suppression methods such as lock-in detection. Our efficient coupling of light to a single molecule has allowed us to study its resonance fluorescence over 9 orders of magnitude. We will show the power dependent coherent scattering and the first direct measurement of the Mollow fluorescence triplet in a solid-state system [3]. In the weak excitation regime we show that it is possible to detect a single molecule by using excitation powers below a femtoWatt. The efficient coupling combined with the coherent nature of extinction detection pave the way for further fundamental quantum optical experiments. [1]I.Gerhardt et. al., PRL 98,033601(2007). [2]I.Gerhardt et. al., OL 32,1420(2007). [3]G.Wrigge et. al., arXiv:0707.3398 to appear in Nature Physics.

Q 6.7 Mo 18:00 1B

Erzeugung zweidimensionaler Cluster-Zustände mit gespeicherten Ionen — •Harald Wunderlich und Christof Wunderlich — Fachbereich Physik, Universität Siegen, 57068

Cluster-Zustände bilden die Grundlage für den sogenannten *One-Way Quantum Computer* [1]. Die zu Grunde liegenden Cluster können in unterschiedlichen Dimensionen existieren. Zur Realisierung eines universellen Satzes von effizienten Quanten-Gattern mit dem One-Way Quantum Computer werden mindestens zwei Dimensionen benötigt. Wir zeigen, dass die Erzeugung von zweidimensionalen Cluster-Zuständen mit Ionen, welche in einem linearen elektrodynamischen Käfig gespeichert werden, effizient möglich ist, wenn diese über eine, durch ein zusätzliches Magnetfeld induzierte Spin-Spin-Wechselwirkung gekoppelt sind [2] . Ein beliebiger zweidimensionaler $n \times m$-Cluster kann durch einen $n \times 2$-Cluster simuliert werden. Es wird ein Verfahren entwickelt, um solche $n \times 2$-Cluster zu generieren, welches lediglich auf einem linearen Cluster-Zustand und Selective-Recoupling-Sequenzen mit vier Ionen beruht. Der experimentelle Aufwand zur Realisierung eines zweidimensionalen Clusters wächst nach diesem Schema lediglich linear mit der Anzahl der Ionen.

[1] R. Raussendorf, H. J. Briegel, Phys. Rev. Lett. **86**, 5188-5191 (2001).
[2] Chr. Wunderlich, in *Laser Physics at the Limit* (Springer, Heidelberg, 2002), p. 261; auch quant-ph/0111158.

Q 6.8 Mo 18:15 1B

A quantum memory of light in nuclear spins of a quantum dot — •Heike Schwager, Geza Giedke, and Ignacio Cirac — Max-Planck Institut für Quantenoptik, 85748 Garching

A quantum memory is an essential building block for quantum information and communication. Nuclear spins have long decoherence times and are thus a good candidate for a quantum memory.

We couple the field of an optical microcavity to the polarized nuclear spins of a charged quantum dot by a detuned Raman process. Eliminating the trion, we show that STIRAP allows to map the state of the cavity field to the nuclei. Similar techniques can be used to generate two-mode squeezed states of the nuclear spin-cavity system, enabling e.g. a light matter interface through teleportation.

Q 6.9 Mo 18:30 1B

Gauss sum factorization with cold atoms — •Michael Gilowski, Thijs Wendrich, Christian Schubert, Ernst M. Rasel, and Wolfgang Ertmer — Institut für Quantenoptik, Leibniz Universität Hannover

A factorization scheme taking advantage of the periodicity properties of Gauss sums has been proposed [1] and recently verified by two NMR-experiments [2] and one experiment based on short laser pulses [3]. In the present contribution we report the first implementation of a Gauss sum factorization based on matter-wave interferometry with cold rubidium atoms [4].

The implementation of the Gauss sums is performed by applying a sequence of light pulses which imprints on a two-level quantum system a sequence of well-defined phases. For appropriately chosen pulses the excitation probability takes the form of a Gauss sum. With this technique we factor the number N=263193. In contrast to the Shor algorithm our method in the present form is based on classical atomic ensembles and does not take benefit of the parallel computing of quantum information. The experimental realization as well as the results of the factorization experiment will be presented. This work is supported by SFB 407 and the FINAQS cooperation of the European Union.

[1] Clauser, et al. Phys. Rev. A **53**, 4587 (1996) and Harter, et al. Phys. Rev. A **64**, 012312 (2001) [2] Mehring, et al. Phys. Rev. Lett. **98**, 120502 (2007) and Mahesh, et al. Phys. Rev. A **75**, 062303 (2007). [3] Bigourd, et al. Phys. Rev. Lett. in press. [4] Gilowski, et al. Phys. Rev. Lett. in press.

Q 6.10 Mo 18:45 1B

Efficiency of entanglement of distant atoms by projective measurement — Georgina Olivares Renteria[1], Stefano Zippilli[1], Giovanna Morigi[1], Felix Rohde[2], •Carsten Schuck[2], and Jürgen Eschner[2] — [1]Departament de Fisica, Universitat Autonoma de Barcelona, 08193 Bellaterra, Spain — [2]ICFO - Institut de CIencies Fotoniques, 08860 Castelldefels (Barcelona), Spain

We compare the efficiency of two schemes for the preparation of entangled states of distant atoms proposed in [1,2]. In these proposals the atoms do not interact and the entanglement is realized by means of the measurement of the scattered field which project the two atoms into the desired state. We quantify the efficiency of the schemes using the fidelity between the state of the system after the detection of a photon and an ideal entangled state of the two atoms. In [1] the atoms interact with two optical cavities and the enhanced probability of emission into the cavities allows for high detection efficiency. This scheme is limited by the finite probability of emission of two photons. Thus, even under the assumption of perfect detection efficiency, the fidelity of the scheme never reaches unity. In [2] emission of two photons is suppressed by low excitation strength, but the detection efficiency is low since the atoms scatter into free space and only a small fraction of the photons is measured. In this case the fidelity is conditioned on single-photon detection and results to be higher. The comparison is quantitatively evaluated for an ongoing experiment with two distant trapped single Ca+ ions. [1] S. Bose, et al, Phys. Rev. Lett. 83, 5158 (1999). [2] C. Cabrillo, et al, Phys. Rev. A 59, 1025 (1999).

Q 7: Ultrakurze Pulse (Attosekundenphysik) [gemeinsam mit A und K]

Zeit: Montag 16:30–18:15 Raum: 3C

Hauptvortrag Q 7.1 Mo 16:30 3C

Coherent Control with Shaped Attosecond Soft-X-Rays: Techniques and Application — •Thomas Pfeifer — Departments of Chemistry and Physics, University of California & Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

Recent progress in ultrafast laser technology enables the generation of soft-x-ray pulses down to $\sim$ 100 attoseconds in duration, thus allowing access to the unexplored realm of electron dynamics. On the other hand, coherent control of matter with shaped laser fields has reached its maturity with regard to controlling the *relative motion of atoms* (vibrations/phonons, phase transitions, molecular reactions and rotation). However, due to the lack of laser pulse shaping techniques in the soft-x-ray spectral region, coherent control has so far had only limited capability of controlling the *electronic wavefunction* directly, which is of fundamental importance to physics (multi-electronic correlation) and chemistry (bonding dynamics). In this talk, it will be shown how Coherent Control can be transferred to, and combined with Attosecond Science towards the goal of gaining comprehensive mastery of matter on the quantum scale. Experimental results, theoretical concepts, and simulations demonstrate the feasibility of using a) multicolor laser fields, b) phase-shaped laser pulses, and c) medium control in high-harmonic generation to enable shaping of pulses and pulse trains in the attosecond soft-x-ray domain. Also, the first experimental application of shaped coherent soft-x-rays towards the optimal control of electronic quantum processes (dissociative photoionization of SF_6) will be presented.

Q 7.2 Mo 17:00 3C

Molecular orbital tomography using short laser pulses — •Elmar van der Zwan, Ciprian Chirila, and Manfred Lein — Institute for Physics, University of Kassel, Germany

Recently a method to perform tomographic imaging of molecular orbitals using high-harmonic generation has been proposed [1]. The method is based on the simplification that the returning electron in the three-step model can be modeled as a plane wave. Orbitals of arbitrary symmetry can be reconstructed if one uses extremely short laser pulses that ensure the continuum wave packet recombines from one side only. We compare two different forms for the reconstruction, and introduce an error-reduction algorithm that can be used to optimize the results. One of the challenges of the scheme lies in the accurate determination of the continuum wave packet. We determine the continuum wave packet in the Lewenstein model, assuming that the molecular orbital is known, and compare this with various methods to determine the continuum wave packet without knowledge of the orbital.

[1] J. Itatani, J. Levesque, D. Zeidler, H. Niikura, H. Pépin, J.C. Kieffer, P.B. Corkum and D.M. Villeneuve. *Tomographic imaging of molecular orbitals.* Nature 432, 867-871 (2004)

Q 7.3 Mo 17:15 3C

Dressing and high-order harmonic generation in small molecules — •Ciprian Chirila and Manfred Lein — Universität Kassel, Institute of Physics, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

The strong-field approximation was recently extended to take into account the effect of vibrational motion and laser-induced coupling of the Born-Oppenheimer states on high-harmonic generation in molecules. We present detailed calculations of the harmonic spectra in H_2 and D_2 for long laser wavelengths (2000 nm), comparing the effects of the dressing to the case of 800 nm. The main effect of dressing is an overall reduction of the harmonic generation and, at long wavelengths, a non-negligible change in the ratio of harmonic signals from different isotopes.

Q 7.4 Mo 17:30 3C

Extended Strong-Field Approximation including Collectivity — •Michael Ruggenthaler and Dieter Bauer — Max-Planck-

Institut für Kernphysik, Heidelberg

High-order harmonic generation may often be treated within a single active electron picture using the so-called strong-field approximation (SFA) [1] to propagate the initial wave-function. However, if collective phenomena are to be included the standard SFA treatment will not suffice. Although the SFA may be extended via an extra term in the Hamiltonian accounting for the collective behavior of the multi-electron system, there is no straightforward definition of this term.

The problem can be reformulated in time-dependent density-functional theory [2,3] where the so-called Kohn-Sham orbitals are propagated such that total single-particle density is the same as those of the interacting system. The linear response of the density to the external potential gives rise to a time-dependent Hartree-exchange-correlation potential which then can be used within the framework of the extended SFA.

[1] W. Becker et al, Phys. Rev. A 56, 645 (1996)
[2] E. Runge and E. K. U. Gross, Phys. Rev. Lett. 52, 997 (1984)
[3] M. A. L. Marques et al, Time Dependent Density Functional Theory, Lect. Notes Phys. 706 (Springer, Heidelberg, 2006)

Q 7.5 Mo 17:45 3C

Formation of Amplitude and Phase during High Harmonic Generation — •Markus Gühr, Brian K. McFarland, Joe P. Farrell, and Philip H. Bucksbaum — Stanford PULSE Center, Stanford University and SLAC, California, USA

High Harmonics of a laser field are generated during the interaction of an intense laser pulse with an atomic or molecular gas. The amplitude and phase of the harmonics contain information about the generation process and the symmetry of the electronic wave functions of the involved atoms or molecules [1].

We measure the amplitude of high harmonics generated in N_2 and Ar. Furthermore, we obtain the relative phase between the harmonics from N_2 and Ar by interferometric measurements on mixtures of the two gases. We observe phase jumps at the 33rd and the 25th harmonic. The first is accompanied by an amplitude minimum in Ar and attributed to a Cooper minimum. The second is accompanied by an amplitude minimum and a linewidth broadening in N_2. It results from the symmetry of the N_2 highest occupied molecular orbital.

The discussed phenomena have important implications for the amplitude and phase of attosecond pulses generated via high harmonic generation.

[1] M. Gühr, B. K. McFarland, J. P. Farrell and P. H. Bucksbaum, J. Phys. B: At. Mol. Opt. Phys., 40, 3745-3755 (2007)

Q 7.6 Mo 18:00 3C

Enhancement of high-order harmonic generation by rare gas mixtures — •Mirko Prijatelj, Tobias Vockerodt, Daniel Steingrube, Uwe Morgner, and Milutin Kovacev — Institut für Quantenoptik, Leibniz Universität Hannover

We study the enhancement of high-order harmonic generation (HHG) by rare gas mixtures. Our experiment confirms recent results mixing He and Xe atoms. The harmonics from Xe atoms enhance the observed yield from He atoms by about two orders of magnitude. Moreover the cut-off position is extended compared to the spectrum of pure He atoms. We report on the experimental parameter sensitivity of the enhancement process and show first results which indicate that the atomic state structure is an important prerequisite. Our investigation extends as well towards experimental conditions suited for low-energy pump pulses as for example mode-locked Ti:sapphire femtosecond oscillator pulses with MHz repetition rates. These conditions are interesting for generating harmonics either intracavity or directly from a femtosecond oscillator. This experimental approach promises to lead to a joint frontier of precision spectroscopy and ultrafast science by extending frequency comb technology into the XUV spectral region.

Q 8: Präzisionsmessungen und Metrologie II

Zeit: Montag 16:30–18:00 Raum: 3D

Q 8.1 Mo 16:30 3D

The SYRTE's fountain clocks: towards 10^{-16} accuracy — •Peter Rosenbusch, Sébastien Bize, Frédéric Chapelet, Jocelyne Guéna, Philippe Laurent, Daniele Rovera, Giorgio Santarelli, and André Clairon — SYRTE, Observatoire de Paris, FRANCE

Today's best microwave clocks are atomic fountains. About 10^9 atoms are laser cooled to 1μK and launched up vertically, where they pass, rising and falling, through a microwave cavity. This Ramsey interrogation leads to a 10^{10} quality factor of the central fringe [S. Bize *et al.*, J. Phys. B vol. 38, S449 (2005)]. The SYRTE disposes of three fountain clocks, one of which uses Cs and Rb, operating quasi-continuously thanks to an interference-filter stabilised laser system [X. Baillard *et al.*, Opt. Comm., vol. 266, 609 (2006)]. The fountains exhibit a relative accuracy of 4×10^{-16}, making the second the best realised SI unit. Here, we present efforts to further decrease the uncertainty to 10^{-16}. Additionally, measurements of the ^{87}Rb hyperfine transition and their relevance to possible variations of the fine structure constant α are presented.

Q 8.2 Mo 16:45 3D

Absolute frequency measurement of the $4s\ ^2S_{1/2} \leftrightarrow 3d\ ^2D_{5/2}$ clock transition of a single ^{40}Ca$^+$ in a Paul trap — •Michael Chwalla[1], Kihwan Kim[1], Gerhard Kirchmair[2], Mark Riebe[1], Thomas Monz[1], Mark Riebe[1], Philipp Schindler[1], Alessandro Villar[2], Christian F. Roos[2], Wolfgang Hänsel[1], Rainer Blatt[1,2], Michel Abgrall[3], Daniele Rovera[3], and Philippe Laurent[3] — [1]Institut für Experimentalphysik, Universität Innsbruck, Techikerstr. 25, A-6020 Innsbruck — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto Hittmair-Platz 1, A-6020 Innsbruck — [3]SYRTE, Observatoire de Paris, 61 Av. de l'Observatoire, 75014 Paris, France

We present an absolute frequency measurement of a single, trapped ^{40}Ca$^+$ ion at the 10^{-15} level, where a Cs referenced frequency comb is used to measure the frequency of the $4s\ ^2S_{1/2} \leftrightarrow 3d\ ^2D_{5/2}$ quadrupole transition at 411 042 129 776 396.2 ± 1.2 Hz. This is the most accurate measurement of Ca$^+$ at present. A careful analysis of the estimated systematic shifts is given as well as an outlook on future improvements, which are required to possibly exceed the current precision of Cs-based frequency standards.

Q 8.3 Mo 17:00 3D

Frequenzkamm-Spektroskopie des 1S-3S Übergangs in atomarem Wasserstoff – Statusreport — •Elisabeth Peters[1], Sascha Reinhardt[1], Scott Diddams[2], Thomas Udem[1] und Theodor Hänsch[1] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]NIST, Boulder

Das Wasserstoffatom ist ein einfaches Modellsystem, was uns erlaubt, fundamentale Theorien wie die QED gebundener Zustände, zu überprüfen. Für einen Test der QED werden die Rydbergkonstante und die Lambverschiebung aus experimentell gewonnenen Daten bestimmt. Dazu müssen mindestens zwei Übergangsfrequenzen mit einer hohen Genauigkeit gemessen werden.
Einer der Frequenzen ist die bereits mit der relativen Genauigkeit von $1.4 * 10^{-14}$ bekannte Frequenz des 1S-2S Übergangs in Wasserstoff. Als zweite Frequenz wollen wir die Übergangsfrequenz des 1S-3S zwei Photonenübergangs bei 205nm messen.
Die für die Spektroskopie erforderliche Wellenlänge wird durch zweifache Frequenzverdopplung (SHG) des modengekoppelten Ti:Saphir Lasers erzeugt. Unter Verwendung eines modengekoppelten Lasers lassen sich höhere Ausgangsleistungen bei nichtlinearen Prozessen erzielen, in unserem Fall bis zu 50mW bei 205nm. Bei der Zweiphotonenspektroskopie tragen alle Moden des Frequenzkamms bei, der AC-Starkeffekt resultiert aus der mittleren Leistung und die Auflösung ist durch die Linienbreite einer Frequenzmode und nicht durch die Bandbreite des Lasers gegeben.

Q 8.4 Mo 17:15 3D

A mobile atom interferometer for high precision measurements of local gravity — •Malte Schmidt, Alexander Senger, Tais Gorkhover, Ulrich Eismann, Evgeny Kovalchuk, and Achim Peters — Humboldt Universität zu Berlin, Institut für Physik, Hausvogteiplatz 5-7, 10117 Berlin, Germany

In recent years, matter wave interferometry has developed into a powerful tool for the ultra precise measurement of accelerations and rotations. It is used in various laboratories for experiments in the fields of fundamental physics and metrology.

We present a new design for a gravimeter based on atom interferometry which is optimized for mobility and mechanical stability. This setup will open up the possibility to perform on-site high precision measurements of local gravity. We report on the status of the project and its subsystems including a rack-mounted cooling and raman laser system.

This gravimeter is developed within the FINAQS project, a collaboration of five European research groups that aims at developing new atomic quantum sensors.

Q 8.5 Mo 17:30 3D

Frequenzverdoppeltes Hochleistungs-Faserlasersystem zur Laserkühlung von Rubidium Atomen bei 780 nm — •Evgeny Kovalchuk und Achim Peters — Humboldt-Universität zu Berlin, Institut für Physik, Hausvogteiplatz 5-7, 10117 Berlin

Wir stellen ein Dauerstrich Hochleistungs-Lasersystem vor, das speziell für die Laserkühlung von Rubidium Atomen im Rahmen des europäischen Kooperationsprojekts FINAQS für Anwendungen in der Atominterferometrie entwickelt wurde. Es basiert auf einem schmalbandigen durchstimmbaren External-Cavity Diodenlaser (ECDL) bei 1560 nm, der in einem polarisationserhaltenen Erbium-Faserverstärker (Spektralbereich von 1545 nm bis 1565 nm) verstärkt wird. Die Ausgangsstrahlung mit einer Leistung von bis zu 15 W wird danach in einem periodisch gepolten Lithiumniobat Kristall (PPLN) frequenzverdoppelt. Die erreichte Laserleistung von mehr als 6 W bei 780 nm entspricht einer Konversionseffizienz von ca. 50 %. Durch optimierte Verdopplungskristalle mit besserer Qualität der Kristallpolung, in Kombination mit einer höheren Verstärkerleistung, sollten in Zukunft auch Ausgangsleistungen deutlich über 10 W realisierbar sein.

Weiterhin diskutieren wir Möglichkeiten zur simultanen Erzeugung von zwei phasengelockten Ausgangsfrequenzen, zum Beispiel für Anwendungen als Raman-Beamsplitter in der Atominterferometrie.

Q 8.6 Mo 17:45 3D

Laserinterferometer für eine GRACE-Nachfolgemission — •Marina Dehne, Ben Sheard, Gerhard Heinzel und Kartsen Danzmann — Albert-Einstein-Institut Hannover, Max-Planck-Institut für Gravitationsphysik und Universität Hannover, Callinstr. 38, D-30167 Hannover

Das Ziel einer zukünftigen GRACE Nachfolgemission wird es sein, das Erdgravitationsfeld mit einer höheren Auflösung aufzunehmen. Die beiden im Low-Earth Orbit (LEO) mit einem Abstand von 10 km hintereinander fliegenden identischen Satelliten reagieren empfindlich auf kleinste Änderungen in der Gravitationsbeschleunigung. Diese Längenänderungen im Frequenzbereich 1...100 mHz sollen von einem Laser-Interferometer mit nm-Präzision beobachtet werden.

Für die Bereitstellung einer konstanten thermischen Umgebung, sowie um Einstrahlungen auf der optischen Achse zu vermeiden, stellt ein kreisförmiger sonnensynchroner Orbit ($i = 96.78°$) die geeignete Wahl dar. Der Luftwiderstand in einem solchen Orbit ist signifikant und muss kompensiert werden. Für diesen Zweck ist die bereits für LISA Pathfinder entwickelte "drag-free"Technologie geeignet.

Das vorgeschlagene Interferometer benutzt weiterhin einige für LISA und LISA Pathfinder entwickelten Phasenauslesungs- und Regelungstechnologien. Im Vortrag wird ein mögliches Interferometer vorgestellt, welches die Anforderungen ($2.5\,\mathrm{nm}/\sqrt{\mathrm{Hz}}$ von 10 bis 100 mHz mit einem 1/f-Anstieg zwischen 10 und 1 mHz) unter den gegebenen Randbedingungen erfüllen könnte.

Q 9: Laserentwicklung (Halbleiterlaser)

Zeit: Montag 16:30–19:00 Raum: 3H

Q 9.1 Mo 16:30 3H

Spektral breitbandige Diodenlaser zur Erzeugung energiereicher, ultrakurzer Pulse — •Thorsten Ulm, Florian Harth, Johannes L'huillier und Richard Wallenstein — Technische Universität Kaiserslautern, Fachbereich Physik, Erwin-Schrödinger-Straße 46, 67663 Kaiserslautern

Die Entwicklung neuartiger Hochleistungsverstärker mit über 1 W Ausgangsleistung im Pulsbetrieb und guter räumlicher Strahlqualität macht modengekoppelte Diodenlaser heute zu einer interessanten Alternative zu Festkörper-Strahlquellen wie z.B. Titan-Saphir-Lasern. Elektrisch gepumpte Diodenlaser eignen sich außerdem zum Aufbau miniaturisierter Strahlquellen.

Das von uns realisierte passiv modengekoppelte Diodenlaser-MOPA-System erzeugt Pulse mit mehr als 4 nm spektraler Breite. Allein durch Kompensation des linearen Chirps können so 480 fs kurze Pulse erzeugt werden. Dabei wurden mittlere Leistungen von 740 mW und Pulsspitzenleistungen von 340 W erreicht. Zur Modenkopplung wurde ein in den Wellenleiter integrierter sättigbarer Absorber verwendet. Die sättigbaren Verluste lassen sich durch Anlegen einer DC-Gegenspannung einstellen und wurden im Hinblick auf die anschließende Verstärkung und Pulskompression optimiert. Die verwendeten Halbleiter-Bauelemente werden hinsichtlich ihrer Bandbreite, Ausgangsleistung, der zeitlichen und spektralen Pulsform sowie ihres Sättigungsverhaltens charakterisiert. Durch Modellierung der Gewinnsättigung im Wellenleiter konnte gezeigt werden, dass im Oszillator bereits bei einer geringen Rückkopplung von 20% Gewinnsättigung auftritt.

Q 9.2 Mo 16:45 3H

Kompaktes Diodenlasersystem mit variabler Repetitionsrate im MHz-Bereich — •Florian Harth, Thorsten Ulm, Johannes L'huillier und Richard Wallenstein — Technische Universität Kaiserslautern, Fachbereich Physik, Erwin-Schrödinger-Straße 46, 67663 Kaiserslautern

Kompakte, effiziente Strahlquellen auf Diodenlaserbasis mit einstellbarer Repetitionsrate und Pulsenergie sind für eine Vielzahl von Anwendungen wie z.B. der Mikromaterialbearbeitung von Interesse.

Es wird ein System vorgestellt, das aus einem modengekoppelten Diodenlaser mit externem Resonator, einem nachgeschaltetem $LiNbO_3$-Mach-Zehnder-Modulator und einem Yb-Faserverstärker besteht. Der Oszillator emittiert Impulse mit einer Impulslänge von 6 ps und einer Repetitionsrate von 500 MHz bei einer Wellenlänge von 1066 nm. Mit Hilfe des Modulators können einzelne Impulse oder auch Impuls-Bursts aus dem Pulszug des Oszillators ausgeschnitten werden. Die Impulsenergien der verstärkten Impulse betrugen 380 pJ, bei nur geringen Änderungen in der zeitlichen und spektralen Impulsform. Diese Impulsenergie ist ausreichend für die Verstärkung in nachfolgenden Hochleistungsverstärkern.

Bei der gewählten Impulswiederholrate von 10 MHz bildete sich im Yb-Faserverstärker verstärkte Spontanemission (ASE) aus. Es werden Konzepte zur Unterdrückung der ASE vorgestellt.

Q 9.3 Mo 17:00 3H

Optimierung und Automatisierung eines ECDLs basierend auf einem Modell zur Modensprungdynamik — •Thorsten Führer und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, AG Laser und Quantenoptik, Schlossgartenstr. 7, D-64289 Darmstadt

ECDLs finden in vielen Bereichen Anwendung, beispielsweise für Sensor-Applikationen oder in der Präzisionsspektroskopie. Dabei ist ein großer modensprungfreier Durchstimmbereich von Vorteil. Um diesen zu erreichen werden bei einem ECDL in Littrow-Konfiguration typischerweise sowohl die Position und der Winkel des Reflexionsgitters als auch der Strom durch die Laserdiode aufeinander abgestimmt variiert. Die manuelle Justage aller Parameter ist zeitaufwändig und schwierig. Darüberhinaus müssen diese Parameter aufgrund äußerer Störungen oft angepasst werden, um den modensprungfreien Betrieb aufrecht zu erhalten.

Es wird ein Modell präsentiert, mit dem sich die Dynamik der Modensprünge als Funktion der freien Parameter beschreiben lässt. Basierend auf diesem Modell und der Detektion der Modensprünge während des Durchstimmens des ECDLs wird ein Fehlersignal erzeugt und damit eine Regelung implementiert. Zusätzlich werden etwaige Nichtlinearitäten beispielsweise der Piezoaktoren durch eine selbstoptimierende nichtlineare Nachführung des Laserdiodenstroms ausgeglichen. Mit der Automatisierung wird der modensprungfreie Betrieb eines ECDLs schnell erreicht und aufrechterhalten.

Q 9.4 Mo 17:15 3H

Erzeugung von sub-300-fs-Pulsen mit einem Halbleiterscheibenlaser — •Peter Klopp[1], Florian Saas[1], Uwe Griebner[1], Martin Zorn[2] und Markus Weyers[2] — [1]Max-Born-Institut, Max-Born-Straße 2a, D-12489 Berlin — [2]Ferdinand-Braun-Institut, Gustav-Kirchhoff-Straße 4, D-12489 Berlin

Die Erzeugung von ultrakurzen Pulsen mit einem optisch gepumpten, oberflächenemittierenden Halbleiterlaser wird vorgestellt. Die Verstärkungsstruktur besteht aus mehreren Quantentrögen (QWs) in spezieller, unregelmäßiger Anordnung. Die Absorption der 840 nm–Diodenlaser–Pumpstrahlung erfolgt in gradierten Barrieren zwischen den QWs [1]. Ein sättigbarer single–QW–Halbleiter–Absorberspiegel mit Relaxationszeiten < 5 ps dient zur passiven Modenkopplung des Lasers. Mit diesem rein halbleiterbasierten Laser konnten optische Pulse mit einer Dauer von 290 fs erzeugt werden. Bei einer Pulsfolgefrequenz von 3 GHz wird eine mittlere Leistung von 10 mW im Wellenlängenbereich um 1030 nm erzielt. Unter Ausnutzung des AC–Stark–Effekts und ohne weitere Elemente zur Dispersionskontrolle im Resonator gelang die Erzeugung nahezu Fourier–limitierter, solitonenartiger Pulse.

[1] F. Saas et al., Appl. Phys. Lett. **89**, 151120 (2006).

Q 9.5 Mo 17:30 3H

Active frequency stabilization of an infrared diode laser at 1115 nm for the generation of UV light — •Steffen Oppel[1], Günter Guthöhrlein[2], Wilhelm Kaenders[3], and Joachim von Zanthier[1] — [1]Institut für Optik, Information und Photonik, Max-Planck-Forschungsgruppe, Universität Erlangen-Nürnberg, Germany — [2]Fachbereich Elektrotechnik, Lasertechnik und Werkstofftechnik, Helmut Schmidt Universität der Bundeswehr Hamburg, Germany — [3]Toptica Photonics AG, Gräfelfing (München), Germany

We present a novel method of active frequency stabilization of a commercial high power external-cavity diode laser near 1115 nm to atomic transitions in praseodymium (Pr I). The spectrum of neutral Pr is recorded in a hollow cathode lamp via laser-induced fluorescence (LIF). Laser irradiation between 1105 and 1123 nm leads to a wide variety of excitation lines with Doppler linewidths of typically 500 MHz, identified via fluorescence light in the visible. The excitation signals are strong enough to enable the lock of the laser onto most of the lines of the spectrum by means of a lock-in detection technique. In this way the frequency drifts of the unlocked laser (of more than 30 MHz/h) can be reduced to below 2 MHz/h. Frequency quadrupling of the referenced infrared diode laser can produce in the future frequency-stable UV-light in the range 276 - 281 nm. In particular, using a strong hyperfine component of the excitation line $E = 16502,616_{J=7/2}\,\mathrm{cm}^{-1} \rightarrow E' = 25442,742^{o}_{J=9/2}\,\mathrm{cm}^{-1}$ of Pr at 1118,54 nm allows - after frequency quadruplification - to excite the D_2-transition of trapped Mg^+ ions at 279,64 nm.

Q 9.6 Mo 17:45 3H

Kohärente Addition von twei TA verstärkten Laserstrahlen für eine kontinuierliche Hochleistungslaserquelle — •Daniel Kolbe, Martin Scheid, Frank Markert und Jochen Walz — Johannes Gutenberg Universität Mainz, Institut für Physik

Kohärente kontinuierliche Strahlung bei 121,56 nm, dem 1S – 2P Übergang in Anti-Wasserstoff, kann durch Vierwellenmischen in Quecksilber erzeugt werden. Zur effizienten Produktion werden drei Laser mit Wellenlängen in der Nähe von atomaren Resonanzen im Quecksilber benötigt. Eine dieser Resonanzen, die 6^3P – 7^1S Resonanz, liegt bei einer Wellenlänge von 407,9 nm und kann durch einen frequenzverdoppelten Titan:Saphir-Laser erzeugt werden.

Alternativ können auch gitterstabilisierte Laserdioden bei 815,8 nm frequenzverdoppelt werden. Jedoch ist deren Fundamentalleistung auf wenige 100 mW beschränkt. Durch die Weiterentwicklung von Halbleiterverstärkerchips (*tapered amplifier*; kurz: TA) lassen sich Laserdioden im nahinfraroten Spektrum auf Leistungen bis zu 1 Watt verstärken. Um eine weitere Leistungssteigerung zu ermöglichen, wird ein System vorgestellt, das zwei durch TAs verstärkte Laserstrahlen kohärent addiert und damit Ausgangsleistungen von bis zu 1,6 Watt ermöglicht. Die Effizienz dieser Überlagerung ist dabei hauptsächlich durch die Strahlprofile der beiden TA-Strahlen begrenzt.

Q 9.7 Mo 18:00 3H

Entwicklung eines Diodenlasersystems mit Frequenzverdopplung zur zweistufigen Anregung von Cäsium-Atomen in Rydbergzustände — •Andreas Müllers, Frank Markert, Daniel Kolbe, Martin Scheid und Jochen Walz — Johannes Gutenberg Universität Mainz, Institut für Physik

Für die Anregung von Cäsium-Atomen in Rydbergzustände wird ein zweistufiges Diodenlasersystem entwickelt. Der erste Übergang des Anregungsschemas von $6S_{1/2}$ nach $6P_{3/2}$ benötigt Laserlicht einer Wellenlänge von 852 nm. Hierfür verwenden wir eine gitterstabilisierte Laserdiode. Die zweite Anregungsstufe von $6P_{3/2} \rightarrow 38D_{5/2}$ ist bei 511 nm Wellenlänge. Für diesen Schritt wird eine antireflexbeschichtete Laserdiode ebenfalls per Gitterstabilisierung auf 1022 nm abgestimmt, mit einem *Tapered Amplifier (TA)* verstärkt und anschließend in einem externen Resonator frequenzverdoppelt. Gewöhnlich verwendet man für die Verdopplung einen Aufbau bestehend aus Ein- und Auskoppelspiegel sowie zwei Umlenkspiegeln *(Doppel-Z-Aufbau)*. Wir ersetzen die beiden Umlenkspiegel durch ein Prisma und erhalten so einen dreieckigen Resonator. Die Strahllänge reduziert sich für diese Geometrie von ca. 80 cm auf 15 cm.

Anwendung findet das System bei der Erzeugung von kaltem Antiwasserstoff über einen zweifachen Ladungstransfer: Positronen bilden mit den Rydberg-Elektronen der Cäsium-Atome Positronium ($Cs^* + e^+ \rightarrow Ps^* + Cs^+$), welches wiederum mit Anti-Protonen zu Anti-Wasserstoff reagiert ($Ps^* + \bar{p} \rightarrow \bar{H}^* + e^-$).

Der Stand des Systems wird vorgestellt und diskutiert.

Q 9.8 Mo 18:15 3H

Hocheffiziente Frequenzverdopplung von Diodenlasern mit periodisch gepolten Wellenleiterkristallen bei 488 nm — •Andreas Jechow und Ralf Menzel — Universität Potsdam, Institut für Physik, Photonik, Am Neuen Palais 10, 14469 Potsdam

Die Entwicklung von periodisch gepolten Wellenleiterkristallen auf der Basis von Lithiumniobat (PPLN) ermöglicht hocheffiziente Frequenzverdopplung (SHG) im Einfachdurchgang für Pumplaser mit moderaten cw-Ausgangsleistungen [1].

Sowohl DFB-Diodenlaser als auch Breitstreifenlaserdioden im externen Resonator [2] liefern Ausgangsleistungen von mehreren Hundert Miliwatt bei sehr guter Strahlqualität und schmalbandiger spektraler Emission. Aufgrund der sehr guten Strahleigenschaften war es möglich mehr als 60% des infraroten Lichtes in einen Wellenleiter mit einer Apertur von $3{,}5\mu m \times 5\mu m$ und 10 mm Länge einzukoppeln.

Bei einer Zentralwellenlänge von 488 nm konnten Leistungen von mehr als 150 mW und Konversionseffizienzen von über 50% realisiert werden. Die Gesamteffizienz (wall-plug efficiency) konnte dabei auf Werte von über 5% gesteigert werden.

[1] A. Jechow, D. Skoczowsky, and R. Menzel, Opt. Express **15**, 6976–6981 (2007)

[2] A. Jechow, V. Raab, and R. Menzel, M. Cenkier, S. Stry, and J. Sacher, Opt. Commun. **277**, 161–165 (2007)

Q 9.9 Mo 18:30 3H

Passive Modenkopplung eines Breitstreifen-Diodenlasers im externen Resonator mit Hilfe eines sättigbaren Absorbers — •Danilo Skoczowsky, Axel Heuer, Andreas Jechow und Ralf Menzel — Universität Potsdam, Lehrstuhl Photonik, Am Neuen Palais 10, 14469 Potsdam

Breitstreifen-Diodenlaser mit einem externem Resonator zeigen unter bestimmten Bedingungen eine Selbst-Modenkopplung und emittieren ps-Pulse mit einer Wiederholrate, die der reziproken Resonatorumlaufzeit entspricht. Bei einem streifig kontaktierten Laserchip in einem V-förmigen Resonator konnten so Pulse von 25 ps Dauer mit einer Pulsspitzenleistung von 4,7 W bei einer Repetitionsrate von 3 GHz beobachtet werden [1].

Möchte man unabhängig vom Aufbau der Diode und der Resonatorgeometrie einen ps-Laser realisieren, so bietet sich eine passive Modenkopplung mit einem sättigbaren Absorber an. Auf Basis einer Breitstreifen-Laserdiode wird ein Resonator vorgestellt, der eine Modenkopplung und damit eine gepulste Emission bei einer Emissionswellenlänge von 976 nm ermöglicht. Entsprechend der Länge des externen Resonators von 15 cm ergibt sich eine Pulsfolgefrequenz von 1 GHz. Zusätzlich kann der Laser über eine Strommodulation aktiv modengekoppelt werden.

[1] D. Skoczowsky, A. Heuer, A. Jechow and R. Menzel. Opt. Com. **279**, 341–345, 2007.

Q 9.10 Mo 18:45 3H

Waveguide mode dynamics of (Al,In)GaN Laser Diode — •Ulrich Schwarz and Harald Braun — Institute for Experimental and Applied Physics, University of Regensburg, D-93040 Regensburg,

Germany

We measure the waveguide mode dynamics of (Al,In)GaN laser diodes emitting in the near UV to blue wavelength range. The combination of a scanning near–field microscope (SNOM) with a high spectral resolution monochromator and/or temporal resolution allows collecting multi–dimensional data sets (space, time, and wavelength) of the laser diode during pulsed operation. For highest temporal resolution — to measure relaxation oscillations and delay of lasing onset — we use a streak camera in combination with the SNOM. The measurements are then compared with basic simulations within the framework of rate equations. The central question is whether the physical effects which are particular for the group III-nitrides (i.e. carrier localization caused by indium fluctuations and quantum confined Stark effect) result in a fundamentally different behavior when compared to standard laser diodes operating in the red and infrared spectral region. We demonstrate how optical gain measurements already indicate the impact of indium fluctuations on (Al,In)GaN laser diode properties.

Q 10: Kalte Moleküle I [gemeinsam mit MO]

Zeit: Dienstag 8:30–10:30 Raum: 3G

Hauptvortrag Q 10.1 Di 8:30 3G

Cold Polar Molecules: From Production to State-Selective Detection — •Pepijn W.H. Pinkse, Laurens D. van Buuren, Michael Motsch, Markus Schenk, Christian Sommer, Martin Zeppenfeld, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Cold polar molecules promise opportunities in various research fields such as chemistry, metrology, molecular physics and quantum information processing. To this end, advanced production, trapping and cooling techniques are required.

An overview will be given of the methods developed in our laboratory: we filter slow molecules out of a thermal ensemble by exploiting the Stark effect in polar molecules such as formaldehyde, ammonia and water. The thermal ensemble in the source can be at room temperature or at cryogenic temperature, in which case helium is used as a cold buffer gas. Using suitably shaped electric fields, slow polar molecules are guided into ultrahigh vacuum, where we can store them in an electric trap.

While the motional energy of the filtered molecules is in the 1K range, the rotational temperature is higher. Depending on the temperature of the source and the molecular constants, many rotational states can be occupied. As a preparation for optical measurements, we performed high-resolution molecular UV spectroscopy on formaldehyde. With the gained information, we can now measure the distribution over the internal states of guided formaldehyde by state-selectively depleting the beam by optical pumping. Precise knowledge over the state distribution will be vital for further cooling down the molecules, for instance by means of an optical cavity.

Q 10.2 Di 9:00 3G

Cryogenic buffer-gas cooling and magnetic trapping of CrH and MnH molecules — •Michael Stoll[1], Joost Bakker[2], Gerard Meijer[1], and Achim Peters[3] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft , Berlin — [2]FOM Institute for Plasma Physics, Rijnhuizen, the Netherlands — [3]Humboldt Universität zu Berlin, Institut für Physik

Buffer gas loading of molecules into a cryogenic He-filled cell and magnetic trapping of the thermalized molecules has been proven to be a powerful method for the production of samples of trapped cold molecules.

We report on the successful cooling of MnH and CrH molecules to sub-Kelvin temperatures using a He dilution refrigerator. Subsequently the molecules were loaded into a trapping field generated by a superconducting quadrupole magnet. Storage times of ˜120 ms could be demonstrated for both molecules.

We modeled the dynamics of our system using a Monte Carlo approach in order to investigate different possible inelastic scattering processes responsible for limitations to the trapping time. Collision cross sections were obtained by fitting this model to the measured diffusion times of both molecules. Combining our system with the already demonstrated methods for rapid extraction of the buffer gas should in principle allow for the preparation of thermally isolated samples with then much longer lifetimes.

Q 10.3 Di 9:15 3G

The electrostatic analogue of a Ioffe-Pritchard trap — •Moritz Kirste, Melanie Schnell, and Gerard Meijer — Fritz-Haber-Institut der MPG, Abt. Molekülphysik, Faradayweg 4-6, D-14195 Berlin

By exploiting the Stark effect one can trap polar molecules. In an electric field the molecules separate, due to the Stark effect, in low-field seeking and high-field seeking states, where molecules in low-field seeking states can be confined in the minimum of an electrostatic quadrupole trap. Trapped molecules are useful in the study of dipole-dipole interaction, the alignment of molecules in external fields and for high-resolution spectroscopy. These techniques are limited by the density of trapped molecules, the trap depth, trap frequency and trapping-time. Trap losses arise from inelastic collisions and from Majorana transitions. In electrostatic traps, the Majorana losses can be compensated by the use of an electric analogue to a magnetic Ioffe-Pritchard trap, which generates a trapping field that is non-zero at the center. In this talk we will introduce the first Ioffe-Pritchard like electrostatic trap. We will present our experimental results, characterizing the trap and will sketch its possible applications.

Q 10.4 Di 9:30 3G

Lifetime measurements with electrostatically trapped cold molecules — •Joop J. Gilijamse, Steven Hoekstra, Markus Metsälä, Sebastiaan Y.T. van de Meerakker, and Gerard Meijer — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany

With a Stark decelerator, bunches of state-selected molecules with a controlled velocity and with longitudinal temperatures as low as a few mK can be produced. These slow bunches of molecules can subsequently be trapped in an electrostatic trap. We will report on the deceleration and trapping of ground state OH, and metastable CO and NH molecules. The OH radicals are trapped at a density of 10^7 - 10^8 cm^{-3} and at a temperature of around 50 mK, and their trap lifetime is measured to be 2.8 s. The long interaction time afforded by the trap can be exploited to measure lifetimes of vibrationally excited states or electronically excited metastable states. Such lifetimes can be used as an accurate test of theoretical models. We will present experiments on the lifetime of OH ($X^2\Pi_{3/2}, v = 1$) and of metastable CO ($a^3\Pi, v = 0$). The different loss processes that play a role in the trap, like optical pumping by blackbody radiation, were studied in detail.

[1] S. Hoekstra *et al.*, Optical pumping of trapped neutral molecules by blackbody radiation, PRL 98: 133001 (2007)

[2] J.J. Gilijamse *et al.*, The radiative lifetime of metastable CO ($a^3\Pi, v = 0$), J.Chem.Phys, [in press], Arxiv:0710:2240 (2007)

Q 10.5 Di 9:45 3G

Guiding and decelerating polar molecules above a microstructured electrode array — •Samuel A. Meek, Hendrick L. Bethlem, Horst Conrad, and Gerard Meijer — Fritz-Haber-Institut der MPG, Faradayweg 4-6, 14195 Berlin

The feasibility of manipulating polar molecules by means of inhomogeneous electric fields has been successfully demonstrated by various devices, such as Stark decelerators, electrostatic traps and storage rings. While previous electrode configurations at the mm scale require potential differences of tens of kV at the electrodes, similar fields can be produced between 10μm-sized electrodes using potentials of hundreds of volts. Here, we present an electrostatic decelerating and trapping device consisting of a periodic array of 1254 microstructured linear electrodes deposited on a planar glass substrate. Application of harmonic waveforms to periodic groups of six electrodes forms a series of periodic minima which move along the array in a continuous manner without changing their distances above the electrodes. Deceleration is achieved by linearly reducing the frequency of the applied waveforms.

First experiments have been performed using a supersonic beam of $a^3\Pi_1$ CO, which has a lifetime of 2.6 milliseconds. Molecules are excited with a laser directly after the nozzle and later detected using Auger deexcitation at a gold surface. TOF spectra clearly demonstrate the velocity-selective guiding of CO*, with guided velocities proportional to the frequency of the applied waveforms. First results of decelerating the CO* molecules by linearly decreasing the frequency of the waveforms, i.e. velocity of the minima, are also presented.

Q 10.6 Di 10:00 3G

Spatially separating individual conformers of neutral molecules — •Frank Filsinger, Undine Erlekam, Henrik Haak, Gert von Helden, Jochen Küpper, and Gerard Meijer — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, Berlin, Germany

Large (bio)molecules exhibit multiple conformers (structural isomers), even under the cold conditions present in a supersonic jet. For various applications, i. e., scattering experiments, it would be highly desirable to prepare molecular packets of individual conformers.

It is well-known that polar molecules can be manipulated using strong electric fields. Many techniques have been developed for the manipulation of small molecules in low-field-seeking quantum states. However, application of these techniques to large molecules is not straightforward, because, for larger molecules, all states are high-field seeking at the relevant electric field strengths. To manipulate the motion of large molecules one has to use Alternate Gradient (dynamic) focusing. This method has been successfully demonstrated in the Alternate Gradient deceleration of CO and YbF. Using the same Alternate Gradient focusing principle, applying switched electric fields in a *quadrupole* guide, we have set up a new experiment to spatially separate individual conformers of large molecules. This experiment exploits the different mass-to-dipole (m/μ) ratios, similar to a quadrupole mass-to-charge (m/q) filter for ions.

In a proof-of-principle experiment, we have demonstrated the conformer selection of cis- and trans-3-aminophenol.

Q 10.7 Di 10:15 3G

Formation of ultracold heteronuclear dimers in electric fields — •Michael Mayle[1], Rosario Gonzalez-Ferez[2], and Peter Schmelcher[1,3] — [1]Theoretische Chemie, Universität Heidelberg, Im Neuenheimer Feld 229, 69120 Heidelberg — [2]Instituto 'Carlos I' de Física Teórica y Computacional and Departamento de Física Atómica Molecular y Nuclear, Universidad de Granada, E-18071 Granada, Spain — [3]Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg

The effects of a strong electric field on the radiative and steric properties of heteronuclear alkali dimers are investigated. In particular, we study the formation of ultracold LiCs molecules via stimulated emission followed by a radiative deexcitation cascade in the presence of a static electric field. By analyzing the corresponding cross sections, we demonstrate the possibility to populate the lowest rotational excitations via photoassociation. The modification of the radiative cascade due to the electric field leads to narrow rotational state distributions in the vibrational ground state. External fields might therefore represent an additional valuable tool towards the ultimate goal of quantum state preparation of molecules.

Q 11: Laserentwicklung (Festkörperlaser II / Andere Laserquellen)

Zeit: Dienstag 8:30–10:30 Raum: 3H

Q 11.1 Di 8:30 3H

Eine verstimmbare Dauerstrich-Laserlichtquelle geringer Linienbreite bei 546 nm mit einer Ausgangsleistung von 4 W realisiert durch externe Frequenzverdoppelung eines Ytterbium-dotierten einmodigen Faserlasersystems — •Frank Markert, Martin Scheid, Daniel Kolbe und Jochen Walz — Institut für Physik, Johannes Gutenberg-Universität, Staudingerweg 7, D-55128 Mainz, Germany

In diesem Vortrag wird eine kohärente kontinuierliche Hochleistungs-Lichtquelle bei 545,5 nm vorgestellt [1]. Wir verwenden 8,3 W Laserlicht eines Ytterbium-dotierten einmodigen Faser-Oszillator/Verstärker-Systems als Eingangsleistung in einen externen Frequenzverdoppelungsresonator. Dieser Aufbau liefert bis zu 4,1 W stabile grüne einfrequente Laserstrahlung, die über einen Bereich von ±95 GHz um die Zentralwellenlänge durchgestimmt werden kann. Eine Jod-Absorptionsspektroskopie über den vollen verstimmbaren Bereich des Faserlasers und Sättigungsspektroskopie an einer starken Jodlinie des dopplerverbreiterten Spektrums dienen zur Charakterisierung des Lasersystems.

[1] F. Markert, M. Scheid, D. Kolbe, and J. Walz, Optics Express **15**, 14476-14481 (2007).

Q 11.2 Di 8:45 3H

Towards a compact high-average-power femtosecond supercontinuum source — Felix Hoos[1], •Bernd Braun[2], and Harald Giessen[1] — [1]4. Physikalisches Institut, Universität Stuttgart — [2]FH Nürnberg

In this talk we will present a way towards a cost effective, compact, and highly efficient pump source for high-average-power femtosecond supercontinuum lasers.

Supercontinuum sources have become an important tool for measurements and experiments in various fields of science. There are many experiments for which it is desirable to have a controllable spectral power over a wide wavelength range, e.g., for white light interferometry with low reflective samples, spectroscopy over a wide wavelength range or pump-probe experiments with pump and probe light being extracted from the supercontinuum. Especially for the latter case it might also be important to provide femtosecond pulses for improved temporal resolution. Currently, commercial supercontinuum systems are available with average powers in the order of several watts based on nonlinear fibers pumped by pico- or nanosecond sources. However, until now there exist to our knowledge no high average power femtosecond supercontinuum sources.

We will present our approach for a suitable pump laser for supercontinuum generation based on Yb:KGW in a slab geometry which is pumped by a single laser diode resulting in an average power of several watts. We will discuss the heat removal in the case of a slab geometry of the laser crystal as well as the influence of thermal effects.

Q 11.3 Di 9:00 3H

Photoleitungsmessungen zur Identifizierung nicht-linearer Verluste in hoch-dotiertem Yb:YAG — •Christian Hirt, Susanne Teruko Fredrich-Thornton, Friedjof Tellkamp, Klaus Petermann und Günter Huber — Insitut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Yb-dotierte Oxide werden häufig in Hochleistungslasern verwendet, da aufgrund ihres einfachen Energieniveauschemas interne Verlustprozesse wie Kreuzrelaxation, Up-conversion und ESA nicht zu erwarten sind.

Scheibenlaserexperimente an hochdotiertem Yb:YAG zeigten jedoch, dass nicht-lineare Verlustprozesse auftreten, die abhängig von der Dotierungskonzentration und Anregungsdichte die Lasertätigkeit stark einschränken und bei Konzentrationen über 15% einen Scheibenlaserbetrieb sogar unmöglich machen.

Photoleitungsmessungen zeigen, dass ein Up-conversion Mechanismus von angeregten Yb-Ionen existiert, über den Elektronen in das Charge Transfer Band gelangen. Ein Model für diesen Up-conversion Prozess wird vorgestellt, und der Zusammenhang mit den im Scheibenlaser beobachteten Verlusten wird diskutiert.

Q 11.4 Di 9:15 3H

Hocheffizienter Yb:Lu_2O_3-Scheibenlaser — •Rigo Peters, Christian Kränkel, Klaus Petermann und Günter Huber — Institut für Laser-Physik, Universität Hamburg

Aufgrund der herausragenden thermomechanischen Eigenschaften des Wirtskristalls und des bekannt geringen Quantendefektes von Yb^{3+} ist Yb:Lu_2O_3 ein hervorragend geeignetes Material für Hochleistungs-Festkörperlaser im Bereich um 1 μm. Durch die Verwendung dünner Kristallscheiben im Scheibenlaserkonzept lassen sich prinzipiell Ausgangsleistungen von mehreren kW pro Scheibe erzielen.

In Laserexperimenten wurden hochreine Kristalle mit einer Dotierung zwischen 1 at.% und 10 at.%, sowie Scheibendicken zwischen

0,08 mm und 0,45 mm untersucht. Für einen 0,15 mm dicken, 5 at.%-dotierten Kristall konnte für die maximale Pumpleistung von 49,8 W bei 976 nm eine Laserausgangsleistung von 36,3 W bei 1034 nm und einem differentiellen Wirkungsgrad von 80% erzielt werden. Der dabei erreichte optisch-zu-optische Wirkungsgrad von 73% übertrifft damit den des am häufigsten in Hochleistungsscheibenlasern verwendeten Materials Yb:YAG deutlich [1].

Bis zu einer Yb-Konzentration von 5 at.% konnte keine Beeinflussung der Lasereffizienz durch die Scheibendicke oder Dotierhöhe beobachtet werden. Dies verdeutlicht die gleich bleibend sehr hohe optische Qualität der Kristalle in den unterschiedlichen Zuchten und zeigt das große Potential von Yb:Lu_2O_3 für zukünftige Hochleistungsanwendungen.

[1] A. Giesen et al., Photonics Spectra 41, 52-58 (2007)

Q 11.5 Di 9:30 3H

Efficient cw Thin Disk Laser Operation of Yb:$Ca_4YO(BO_3)_3$ with 20W Output Power — •Christian Kränkel, Rigo Peters, Klaus Petermann, and Günter Huber — Institut für Laser-Physik, Universität Hamburg

We report on continuous-wave (cw) laser operation with Yb(15 at.%):$Ca_4YO(BO_3)_3$ (Yb:YCOB) exceeding 20 W of output-power in the thin disk laser setup.

50% of optical-to-optical efficiency at a slope efficiency of more than 60% were realized in E ∥ X-polarization. A tuning range of 95 nm with high output powers could be obtained.

Furthermore, applying the pinhole method the fluorescence lifetime was determined to be 2.2 μs.

The obtained results revealed that Yb:YCOB is a promising candidate for the generation of very short pulses at high pulse energies in the thin disk laser setup.

Q 11.6 Di 9:45 3H

Novel approach for mode-selective polarization measurement and its application in few-mode fiber amplifier systems — •Niklas Andermahr[1], Thomas Theeg[1], and Carsten Fallnich[2] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Institut für Angewandte Physik - WWU Münster, Corrensstraße 2, 48149 Münster, Germany

In the field of high-power fiber amplifiers large core diameters are of advantage to reduce the power density. However, these fibers often loose pure single transverse mode behavior. A better understanding of the propagation and interaction of higher order modes (HOMs) can help either to suppress or to use them.

We present a polarization-sensitive measurement of HOMs from a few-mode optical fiber using a three-mirror ring resonator. Measuring the power fraction as well as the polarization state we analyze a few-mode fiber amplifier system and show that the HOMs prefer orthogonal polarization states. This is explained, as the fiber modes thereby maximize the overlap of the intensity profile with the gain region.

Q 11.7 Di 10:00 3H

Erhöhung der Effizienz eines Er:ZBLAN Faserlasers bei 546 nm — •Florian Engel, Ortwin Hellmig, Klaus Sengstock und Valeri Baev — Institut für Laserphysik, Universität Hamburg

Ein Er:ZBLAN upconversion Faserlaser bei 546 nm wird durch eine zweistufige Anregung mit einer Laserdiode bei 975 nm optisch gepumpt. Bei dieser Anregung wird zusätzlich ein Zwischenniveau $^4I_{13/2}$ mit einer Lebensdauer von ca. 10 ms bevölkert, was die Effizienz des Lasers bei 546 nm senkt. Dieses Problem lässt sich durch die Abregung dieses Niveaus mit einem zusätzlichen IR-Laserbetrieb bei ca. 1,6 μm beseitigen. Es wurde gezeigt, dass die zusätzliche Laseremission bei 1,556 μm eine bessere Unterstützung für die grüne Emission liefert als die Laseremission bei 1,536 μm. Dabei konnte die Reduzierung der Laserschwelle bei 546 nm um 60% und die Erhöhung der Leistung um 35% demonstriert werden. Mit einer 1000 ppm Er-dotierten 50 cm ZBLAN-Faser wurde bei einer absorbierten Pumpleistung von ca 20 mW eine Leistung von 1,15 mW bei 546 nm erreicht.

Die entwickelte Methode ist nicht nur auf Faserlaser beschränkt und bietet deshalb auch für andere Er-dotierten Festkörperlaser eine Möglichkeit, die Effizienz zu steigern.

Q 11.8 Di 10:15 3H

Fourier Domain Mode Locked (FDML) Laser mit hochgradig linearer Frequenz-Zeit Abstimmcharakteristik — •Christoph Eigenwillig, Benjamin Biedermann, Gesa Palte und Robert Huber — Lehrstuhl für biomolekulare Optik, Fakultät für Physik, LMU München

Die optische Kohärenztomographie (OCT) [1] stellt ein optisches Bildgebungsverfahren mit zahlreichen biomedizinischen Anwendungen dar. Mit dem Ziel höherer Abtastraten werden zunehmend schmalbandige, wellenlängenabstimmbare Laser-Quellen eingesetzt. Dabei konnte durch den Einsatz von FDML-Lasern die OCT-Abbildungsgeschwindigkeit um das 100 bis 1000-fache gesteigert werden [2]. FDML Laser erreichen Abstimmraten von 370kHz, instantane Linienbreiten von 50pm und optische Abstimmbereiche von über 150nm bei 1300nm. Da in OCT Anwendungen zur Extraktion der tiefenabhängigen Streuintensität die Messwerte in einem äquidistanten Frequenzraster vorliegen müssen, wäre eine Lichtquelle mit einer nahezu perfekt linearen Frequenz-Zeit Abstimmcharakteristik wünschenswert, jedoch konnten bisherige abstimmbare Laser- und Spektrometer-Anordnungen für OCT keine ausreichende Linearität erreichen. Es wird ein FDML-Laser mit hochgradig linearem Abstimmverhalten vorgestellt, verschiedene Strategien zur hochgenauen Linearisierung diskutiert und die Anwendung dieses Lasers für die OCT-Bildgebung demonstriert.

1. Huang D. et al. Science 254:1178-1181 (1991).
2. Huber R. et al. Optics Express 14:3225-3237 (2006).

Q 12: Kalte Moleküle II [gemeinsam mit MO]

Zeit: Dienstag 11:00–13:00 Raum: 3G

Q 12.1 Di 11:00 3G

Deceleration, trapping and accumulation of NH molecules — •Steven Hoekstra, Markus Metsälä, Peter C. Zieger, Ludwig Scharfenberg, Joop J. Gilijamse, Sebastiaan Y.T. van de Meerakker, and Gerard Meijer — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany

We report on the Stark-deceleration and electrostatic trapping of metastable NH molecules. Furthermore, the progress towards higher densities of cold neutral molecules by accumulation of multiple Stark-decelerated packets of NH molecules in a magnetic trap will be presented.

NH molecules in the long-lived metastable $a^1\Delta(v=0, J=2)$ state are ideally suited for Stark deceleration experiments because of their relatively large Stark shift and low mass. The metastable molecules ($\tau > 2.7s$) are produced in a supersonic expansion with a velocity of $\sim$ 450 m/s, and are decelerated to a standstill by a 108-stage decelerator. Subsequently the metastable molecules are trapped electrostatically, with a temperature of about $50-100$ mK, a density of $\sim 10^6$ cm^{-3} and a $1/e$ trapping lifetime of 1.4 s.

Following the deceleration and trapping, the metastable NH molecules are detected by the excitation of a spin-forbidden transition, resulting in spontaneous decay to the electronic ground state ($X^3\Sigma^-$). The electronic ground state has a negligible Stark shift, but can be trapped magnetically. The first experiments on the accumulation of ground state NH molecules in a magnetic trap will be presented.

Q 12.2 Di 11:15 3G

Alternating gradient focusing and deceleration of large molecules — Kirstin Wohlfart, •Fabian Grätz, Frank Filsinger, Gerard Meijer, and Jochen Küpper — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany

During the last decade, fascinating progress has been made in the spectroscopy of the “molecular building blocks of life”. Meanwhile, our group has been developing methods to decelerate neutral, polar molecules using time varying inhomogeneous electric fields. Extending these techniques to bio-molecules would allow, for instance, to increase observation times for precision spectroscopy or to separate different conformers. However, for such large molecules all states are practically high-field seeking. Therefore, alternating gradient focusing has to be applied. Here, we demonstrate the focusing and deceleration of benzonitrile (C_7H_5N) from a molecular beam. Benzonitrile is prototypical for large asymmetric top molecules that exhibit rich rotational structure and a high density of states. It is decelerated in its absolute ground state from 320 m/s to 289 m/s, and similar velocity changes are obtained for excited rotational states. We are setting up a longer alternating gradient decelerator, which will enable us to decelerate benzonitrile or larger molecules to much lower velocities and to thereby completely separate the decelerated packet from the rest of the beam pulse.

Q 12.3 Di 11:30 3G

On the Stark effect of NaK — •Andreas Gerdes, Horst Knöckel, and Eberhard Tiemann — Institut für Quantenoptik, Gottfried Wilhelm Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

After preliminary measurements in a heatpipe setup [1] and characterization of our new molecular beam aparatus we show the next step of investigation concerning the heteronuclear molecule NaK. A homogeneous electric field in the detection zone will modify the rotational structure of the spectral lines under consideration. For a model description of the line shapes, not only the molecular Stark effect of the absolute ground state $X\,^1\Sigma^+$ of the molecule, but also the splitting of the excited state $B\,^1\Pi$ has to be taken into account. Results of our investigation into this direction will be shown. A comparison with theoretical predictions is possible [2]. Prospects heading to the target molecule KRb will be discussed.

[1] A. Gerdes *et al.*, To be published
[2] M. Aymar and O. Dulieu, J. Chem. Phys **122** 204302 (2005)

Q 12.4 Di 11:45 3G

Simulations of LiCs spectra — •Anna Grochola, Johannes Deiglmayr, Jörg Lange, Karin Mörtlbauer, Christian Glück, Roland Wester, and Matthias Weidemüller — Albert-Ludwigs Universität, Physikalisches Institut, Hermann-Herder-Str. 3, 79104 Freiburg i.Brsg., Germany

Recently the formation of ultracold LiCs molecules was achieved in our group [1] and spectra of resonant enhanced one-color two photon ionization were recorded.

Here we present predictions for photoassociation and REMPI spectra of the LiCs molecule based on theoretical potential energy curves [2-4] and experimental data [5,6]. Hund's cases (a) and (c) are taken into account. The Franck-Condon factors are calculated for the $B^1\Pi \leftarrow X^1\Sigma^+$ system for the free-bound and bound-bound transitions. The results of spectra simulations are compared with the experimental results.

[1] S. D. Kraft *et al.*, J. Phys. B **39**, S993 (2006)
[2] M. Aymar and O. Dulieu, J. Chem. Phys. **122**, 204302 (2005)
[3] M. Korek *et al.*, Can. J. Phys. **78**, 977 (2000)
[4] Dunia Houalla, Master Thesis, Beirut Arab University (2005)
[5] P. Staanum *et al.*, Phys. Rev. A **75**, 042513 (2007)
[6] A. Pashov, private communication

Q 12.5 Di 12:00 3G

Triplet spectroscopy on ultracold 87Rb2 molecules — •Florian Lang[1], Gregor Thalhammer[1,2], Klaus Winkler[1], Christoph Strauss[1], Rudolf Grimm[1,3], and Johannes Hecker Denschlag[1] — [1]Institut für Experimentalphysik und Forschungszentrum für Quantenphysik, Universität Innsbruck — [2]LENS European Laboratory for Nonlinear Spectroscopy and Dipartimento di Fisica, Università di Firenze — [3]Institut für Quantenoptik und Quanteninformation,Österreichische Akademie der Wissenschaften

Starting from a pure sample of ultracold 87Rb2 Feshbach molecules held in a 3D optical lattice we have performed spectroscopic measurements on electronically excited triplet molecules. We investigate the vibrational ladder down to the vibrational ground state with high resolution in the order of 1 MHz and find good coupling strength to the electronic ground state. In combination of our previous results[1],[2] this offers a promising route towards the production of molecules in the triplet ground state. In my talk I will report on the latest progress in our work.

[1] Coherent optical transfer of Feshbach molecules to a lower vibrational state, K. Winkler, F. Lang, G. Thalhammer, P. v.d. Straten, R. Grimm, J. Hecker Denschlag Phys. Rev. Lett. 98, 043201 (2007)

[2] Cruising through molecular bound state manifolds with radio frequency, F. Lang, P.v.d. Straten, B. Brandstätter, G. Thalhammer, K. Winkler, P.S. Julienne, R. Grimm, J. Hecker Denschlag, submitted for publication, arXiv:0708.3958

Q 12.6 Di 12:15 3G

Photoexcitation and photodissociation of H_3^+ — •Dennis Bing[1], Max H. Berg[1], Holger Kreckel[2], Annemieke Petrignani[1], Sascha Reinhardt[1,3], Xavier Urbain[4], and Andreas Wolf[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Columbia University, 550 West 120th Street, New York, NY 10027, USA — [3]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [4]Département de Physique, Université Catholique de Louvain, B-1348, Louvain-la-Neuve, Belgium

We present ro-vibrational laser spectroscopy of cold H_3^+ towards the dissociation limit and photodissociation of vibrationally excited H_3^+ ions, using two distinct experimental setups. The photoexcitation of H_3^+ was performed in a 22-pole radiofrequency ion trap, where the ions were cooled down to their lowest rotational states and then ro-vibrationally excited by ∼1 eV (∼5 vibrational quanta), i.e., above the molecule's barrier to linearity. Transitions of about 11230 - 13330 cm^{-1} were scanned with a Titanium-Sapphire laser, finding lines with predicted Einstein A-coefficients down to $<10^{-1}$ s^{-1}. The photodissociation of H_3^+ was performed in a crossed photon and ion-beam setup using a pulsed frequency-doubled dye laser at 294 nm and H_3^+ ions from a hot ion source. Both dissociation channels, H_2^+ + H and H^+ + H_2, were found and investigated.

Q 12.7 Di 12:30 3G

Photodetachment of cold negative ions — •Petr Hlavenka, Rico Otto, Sebastian Trippel, Jochen Mikosch, Mathias Weidemüller, and Roland Wester — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

With the recent detection of negative carbon clusters in the interstellar molecular clouds, laboratory studies of negative ions are becoming exceedingly important. We study absolute OH^- photodetachment cross sections as a model for the low temperature behavior of this fundamental light-matter interaction, which is a main loss channel of the anions in interstellar medium (ISM). To reach ISM-relevant conditions we study the photodetachment interaction of laser light with anions captured in a 22-pole RF trap [1]. The sympathetic cooling of ions captured in the flat effective potential yields well defined rotational-state distributions. We record the relative loss of stored anions due to the photodetachment while scanning the volume of the trap with a focussed, 2D movable laser beam. A column-density map and the absolute photodetachment cross section are obtained. We present results for OH^- photodetachment at different temperatures and laser wavelengths. This gives insight to the rotational dependence of the photodetachment process,which gives us better understanding of the processes leading to the anion abundances in the ISM.
[1] S. Trippel et al., Phys. Rev. Lett. **97**, 193003 (2006)

Q 12.8 Di 12:45 3G

Trapping and cooling of single molecular ions for time resolved diffraction experiments — •Günther Leschhorn, Steffen Kahra, and Tobias Schaetz — Max-Planck-Institut für Quantenoptik, Garching

The interest in observing structural changes in molecules with a time resolution of a few femtoseconds and below give rise to discussions about modifying the establised target schemes. The TIaMo-project (trapped ions and molecules) aims for a electron or X-ray diffraction experiment using single molecular ions. We report on the progress towards a setup for the preparation of single, cold and well (spacial resolution: $1\,\mu m$) localized molecular ions, that can be continously replaced to achieve suitable statistics in a single target experiment. By combining numerous experimental techniques like Paul-traps, sympathetic cooling, light pressure and separation of molecular ions from a Coulomb-crystal using electric fields, it should be possible to achieve a replacement in the kHz-regime. In the future, this scheme together with electron or X-ray diffraction on a single molecular ion can be used to directly observe fast molecular reaction dynamics. Supported by: MAP, IMPRS-APS, MPG

Q 13: Laserentwicklung (Nichtlineare Effekte und Anwendungen)

Zeit: Dienstag 11:00–13:00 Raum: 3H

Q 13.1 Di 11:00 3H

Resonatorinterne Frequenzkonversion von fs-Lichtimpulsen in den sichtbaren Spektralbereich mit sektioniert periodisch gepoltem MgO:LiNbO$_3$ — •Felix Rübel, Peter Haag, Richard Wallenstein und Johannes L'huillier — Technische Universität Kaiserslautern, Fachbereich Physik, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern

Ultrakurze Lichtimpulse im sichtbaren Spektralbereich sind für viele wissenschaftliche und technische Anwendungen, wie z.B. der zeitaufgelösten Spektroskopie, der Medizin oder der Display-Technologie, von besonderem Interesse. Der Wellenlängenbereich zwischen 500 nm und 700 nm kann jedoch nicht von kerrlinsen-modengekoppelten Ti:Saphir-Lasern oder deren Harmonischen abgedeckt werden. Eine Möglichkeit zur Erzeugung von fs-Impulsen in diesem Bereich bietet die Frequenzkonversion der IR-Strahlung synchron gepumpter OPOs. Durch resonatorinterne, kaskadierte Frequenzverdopplung der Signalstrahlung konnten fs-Impulse im gelben Spektralbereich bei 593 nm erzeugt werden. Hierzu wurden periodisch gepolte MgO:LiNbO$_3$-Kristalle mit unterschiedlichen, kaskadierten Polungsperioden verwendet, so dass sowohl der OPO- als auch der SHG-Prozess im gleichen Kristall realisiert werden konnte. Gepumpt mit 1,3 W und 100 fs bei einer Repetitionsrate von 82 MHz, wurde in dem kaskadierten OPO-SHG-Prozess eine maximale Ausgangsleistung von 220 mW erzeugt. Für die Konversion von Pumpstrahlung zu sichtbarer Strahlung entspricht dies einer Effizienz von 17 %. Die minimale Impulsdauer betrug 280 fs. Es ergab sich ein Zeit-Bandbreiten-Produkt von 1,09.

Q 13.2 Di 11:15 3H

Temperaturabhängigkeit des Koerzitivfeldes in VTE-LiTaO$_3$ — •Alexander Quosig[1], Volker Wesemann[2], Daniel Rytz[2] und Johannes L'Huillier[1] — [1]Technische Universität Kaiserslautern, Fachbereich Physik, Erwin-Schrödinger-Strasse 46, 67663 Kaiserslautern — [2]FEE GmbH, Struthstrasse 2, 55743 Idar-Oberstein

Kongruentes LiTaO$_3$ (CLT) ist aufgrund des hohen nichtlinearen Koeffizienten d_{33}=14,6pm/V und der hohen Transparenz im mittleren infraroten, sichtbaren und ultravioletten Spektralbereich ein geeignetes Material zur Frequenzkonversion von Laserstrahlung durch Quasiphasenanpassung (QPM) mittels periodisch angeordneter ferroelektrischer Domänen. Die mit dem Czochralski-Verfahren gezüchteten Kristalle weisen ein Lithium-Defizit auf. Daraus resultierende nachteilige Eigenschaften wie grün-induzierte Infrarotabsorption (GRIIRA) und Photorefraktivität lassen sich durch eine Nachbehandlung des Materials mittels Vapour-Transport-Equilibration (VTE) stark reduzieren. Die Verringerung des Koerzitivfeldes durch VTE von 21kV/mm bei CLT auf bis zu 0,1kV/mm ermöglicht darüber hinaus die Herstellung dicker QPM-Kristalle (>1mm). In Ferroelektrika mit niedrigem Koerzitivfeld sind die thermische Stabilität der Domänenwände und die Polungsdynamik von besonderem Interesse. Temperaturerhöhung von 13°C auf 80°C bewirkt in VTE-LT mit einem Li$_2$O-Anteil von 49,95mol% eine Abnahme des Koerzitivfeldes um 23% von 256V/mm auf 198V/mm. Die Polungsdynamik und die Temperaturabhängigkeit des Koerzitivfeldes konnte durch ein quantitatives zweidimensionales Modell des Domänenwachstums theoretisch beschrieben werden.

Q 13.3 Di 11:30 3H

Diodengepumpter einfachresonanter dauerstrich-optisch-parametrischer Oszillator — •Jens Kiessling, Rosita Sowade, Ingo Breunig, Bastian Knabe und Karsten Buse — Physikalisches Institut, Universität Bonn, Wegelerstr. 8, 53115 Bonn

Dauerstrich-optisch-parametrische Oszillatoren (OPOs) zeichnen sich durch ihren weiten Durchstimmbereich bei schmaler Linienbreite aus und sind deshalb beliebte Lichtquellen für spektroskopische Anwendungen. Longitudinal und transversal einmodige Laserdioden sind für solche Systeme kompakte und preisgünstige Pumpquellen, jedoch ist ihre Ausgangsleistung begrenzt. Um sie dennoch hierfür einsetzen zu können, muss die Pumpschwelle des OPOs deutlich unter 1 W gesenkt werden. Dafür bieten sich doppelt- und dreifachresonante Oszillatoren an, deren Aufbau und Stabilisierung im Vergleich zu einfachresonanten Systemen allerdings aufwändiger ist. Wir demonstrieren einen alternativen Ansatz, der es ermöglicht, eine transversal und longitudinal einmodige Laserdiode mit weniger als 100 mW Ausgangsleistung als Pumpquelle für einen einfachresonanten OPO zu verwenden.

*Gefördert von der Deutsche Telekom AG.

Q 13.4 Di 11:45 3H

Ramanstreuung in einem einfachresonanten dauerstrich-optisch-parametrischen Oszillator — •Ingo Breunig, Jens Kiessling, Rosita Sowade, Bastian Knabe und Karsten Buse — Physikalisches Institut, Universität Bonn, Wegelerstr. 8, 53115 Bonn

In einem einfachresonanten optisch-parametrischen Oszillator (OPO) entstehen aus einem Pumpfeld ein Idler- und ein Signalfeld, wobei letzteres resonant überhöht wird. Die Bandbreite der parametrischen Verstärkung liefert eine obere Grenze für die spektrale Breite des Signalfelds. In unserem Aufbau beobachten wir Linien außerhalb dieses Verstärkungsprofils, deren Anzahl sich mit steigender Pumpleistung erhöht. Die ermittelten Frequenzabstände von 1.4 THz bzw. 7.5 THz stimmen mit bekannten Ramanverschiebungen des verwendeten nichtlinearen Materials (Lithiumniobat) überein. Weiterhin lässt sich ein Zusammenhang zwischen spektraler Reinheit des Signalfelds und Idlerleistung feststellen.

*Gefördert von der Deutsche Telekom AG.

Q 13.5 Di 12:00 3H

Messung von Emissionsspektren der Brillouin Streuung in Ytterbium dotierten einfrequenten Faserverstärkern mit 130 W Ausgangsleistung — •Sebastian Büsche, Matthias Hildebrandt, Maik Frede und Dietmar Kracht — Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover

Es werden Heterodyn-Messungen von Emissionsspektren der spontanen und stimulierten Brillouinstreuung eines einfrequenten Faserverstärkers vorgestellt. Dazu wurde ein schmalbandig emittierender Ringlaser (NPRO) mit einer diodengepumpten Ytterbium dotierten Doppelkernfaser auf bis zu 130 W verstärkt. Durch Überlagerung der gestreuten Brillouinstrahlung mit einem zweiten schmalbandigen Ringlaser wurden Brillouinspektren über den gesamten Verstärkerleistungsbereich detektiert. Mit steigender Ausgangsleistung zeigen die Spektren einen Übergang von Lorentz- zu Gaußprofilen bei einer exponentiellen Abnahme der Halbwertsbreiten. Ein zweites Experiment mit ungepumpter Faser, bei der ein zweiter Ringlaser gegenläufig zur Seedquelle in die Faser gekoppelt und mit seiner Kristalltemperatur diskret über den Frequenzbereich des Brillouin Verstärkungsprofils gestimmt wurde, verifizierte die Heterodyn-Messung. Die gemessenen Verstärkungsprofile stimmen gut mit den Profilen bei niedriger Verstärkerleistung überein. Die experimentellen Ergebnisse sollen zum Verständnis der Entwicklung stimulierter Brillouinstreuung in Hochleistungsverstärkerfasern beitragen und zukünftig eine weitreichende Unterdrückung dieses leistungslimitierenden Effekts ermöglichen.

Q 13.6 Di 12:15 3H

Fourier Domain Mode Locking (FDML): Ein neuer Operationsmodus von Lasern und dessen Anwendungen — Christoph Eigenwillig[1], Benjamin Biedermann[1], Desmond Adler[2], James Fujimoto[2] und •Robert Huber[1] — [1]Lehrstuhl für BioMolekulare Optik, Fakultät für Physik, LMU München — [2]Department of Electrical Engineering and Computer Science, and Research Laboratory of Electronics, Massachusetts Institute of Technology

Fourier Domain Mode Locking (FDML) stellt einen neuartigen, stationären Betriebszustand von Lasern dar [1]. Im Gegensatz zur herkömmlichen Modenkopplung basiert FDML nicht auf einem Amplituden- oder Phasen-Modulationsmechanismus, sondern es kommt ein schnell abstimmbarer, schmalbandiger spektraler Filter zum Einsatz. FDML-Laser emittieren sehr schnelle, schmalbandige Wellenlängendurchläufe mit Bandbreiten von mehr als 150nm und instantanen Linienbreiten von etwa 50pm bei Repetitionsraten von mehreren 100 kHz. Die Emissionscharakteristik ist äquivalent zu einer Serie extrem dispersiver (gechirpter) Lichtimpulse. Neben der Hauptanwendung von FDML Lasern für die optische Kohärenztomographie (engl.: optical coherence tomography - OCT) in der biomedizinische Bildgebung, wird der Einsatz von FDML Lasern für Profilometrie-Anwendungen mit pm-Auflösung, für die Echtzeitspektroskopie an chemischen Reaktionsprozessen in Verbrennungsmotoren und für die Zustandsanalyse von Gemälden vorgestellt.

1. Huber R. et al. Optics Express 14:3225-3237 (2006).

2. Huang D. et al. Science 254:1178-1181 (1991).

Q 13.7 Di 12:30 3H

PLD-hergestellte, kristalline Antireflexbeschichtungen und dichroitische Spiegel — •Friedjof Tellkamp, Teoman Gün, Bilge Ileri, Klaus Petermann und Günter Huber — Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Mittels Pulsed Laser Deposition (PLD) hergestellte kristalline Vielschichtsysteme wurden bezüglich ihrer strukturellen und optischen Qualität analysiert. Die Schichtsysteme werden in situ mittels Reflection High Energy Electron Diffraction (RHEED) und Reflektometrie sowie ex situ mittels Röntgenstrukturanalyse (XRD) und Spektroskopie auf Transmissivität und Struktur untersucht.

Es konnte anhand der Antireflexsysteme Sc2O3/Al2O3 auf (0001)-Saphir und LuAG/YAG auf {100}-YAG gezeigt werden, dass sich die Reflexion um das theoretisch zu erwartende Maß reduzieren lässt. Die XRD-Messungen lassen auf ein texturiertes Wachstum der Schichten schließen. Die RHEED-Analyse an dem System LuAG/YAG auf YAG zeigt einkristallines Schichtwachstum.

Ferner wurden gitterangepasste LuGdAG-Schichten untersucht. Die mittels XRD gemessene Gitterfehlanpassung lag bei < 0,5 %; mit RHEED konnte epitaktisches Wachstum auch nach Deposition von 29 Schichten bei einer Gesamtdicke von 1850 nm gezeigt werden. Allerdings wurde eine sich kontinuierlich vermindernde Depositionsrate festgestellt, sodass die Reflexionseigenschaften dieser dichroitischen Spiegel noch nicht zu beobachten waren. Eine in situ Schichtdickenregelung wird dieses Problem in Zukunft beheben.

Q 13.8 Di 12:45 3H

Neue Entwicklungen bei ps-Laserstrahlquellen für die Mikromaterialbearbeitung — •Achim Nebel — Lumera Laser GmbH, Opelstr. 10, 67661 Kaiserslautern

Ultrakurzpulslaser haben für die Mikromaterialbearbeitung eine Vielzahl von Vorteilen. Sie bearbeiten alle Materialien und das mit höchster Qualität. Für den industriellen Einsatz besonders ausgezeichnet haben sich ps-Laser. Sie sind diodengepumpt, ermöglichen höchste Wiederholraten und hohe Leistungen. Ihre beugungsbegrenzte polarisierte Strahlung ermöglicht zudem eine effiziente Frequenzkonversion bis in den UV-Bereich, so dass Prozessoptimierungen auch mit hohen Leistungen bei 532nm- und 355nm möglich sind. Vorgestellt werden u.a. verstärkte Nd:YVO4 ps-Laser. Die neueste Generation dieser Laser hat mittlere Leistungen größer 50 W bei Wiederholraten von 1MHz (50 μJ Pulsenergie). Anhand von Bearbeitungsbeispielen wird der große Nutzen der Pikosekundenlaser für die Präzisionsmikromaterialbearbeitung dargestellt.

Q 14: Quanteninformation (Quantencomputer I)

Zeit: Dienstag 14:00–15:45 Raum: 1B

Gruppenbericht Q 14.1 Di 14:00 1B

Simulation of a Quantum Magnet — •Axel Friedenauer[1], Hektor Schmitz[1], Jan Glueckert[1], Lutz Petersen[2], and Tobias Schaetz[1] — [1]Max Planck Institut für Quantenoptik, Garching, Deutschland — [2]ETH Zuerich

Simulating quantum mechanical systems is a hard task since the amount of degrees of freedom scale exponentially with the number of constituents. We are aiming to circumvent this difficulty by introducing a quantum simulator based on the idea that systems governed by the same Hamiltonian evolve alike.

Our system for a feasibility study is a linear chain of magnesium ions. External fields and interactions between the ions are simulated/controled via rf- and laser-fields respectively. To initialize our system, we cool up to three ions close to the axial-motional ground state $\bar{n} < 0.05$.To calibrate our operational fidelities, we implemented a geometric phase gate[1] and prepared an entangled Bell state of two ions with a fidelity exceeding 95%. Subsequently, we were able to simulate an adiabatic evolution of two spins described by the Quantum-Ising-Hamiltonian from paramagentic into ferromagnetic order[2,3] with an fidelity of 95%. We proof that this transition is driven by quantum (not thermal) fluctuations providing us even an entangled state with a lower bound for the fidelity of 70%. We discuss these results and comment on the possibilities to increase the size of our system.

[1] D. Leibfried et al., Nature **422**, 412 (2003)
[2] D. Porras and J.I. Cirac, Phys. Rev. Lett. **92**, 207901 (2004)
[3] to be published

Q 14.2 Di 14:30 1B

Effects of imperfections for Shor's factorization algorithm — •Ignacio Garcia-Mata, Klaus M. Frahm, and Dima L. Shepelyansky — Laboratoire de Physique Theorique, UMR 5152 du CNRS, Universite Toulouse III

We study effects of imperfections induced by residual couplings between qubits on the accuracy of Shor's algorithm using numerical simulations of realistic quantum computations with up to 30 qubits. The factoring of numbers up to $N = 943$ show that the width of peaks, which frequencies allow to determine the factors, grow exponentially with the number of qubits. However, the algorithm remains operational up to a critical coupling strength ϵ_c which drops only polynomially with $\log_2 N$. The numerical dependence of ϵ_c on $\log_2 N$ is explained by analytical estimates that allows to obtain the scaling for functionality of Shor's algorithm on realistic quantum computers with a large number of qubits.

Q 14.3 Di 14:45 1B

Quantum Simulator for the Ising model with electrons floating on helium film — •Sarah Mostame and Ralf Schützhold — Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

We propose a physical setup that can be used to simulate the quantum dynamics of the Ising model. Our scheme consists of electrons floating on liquid helium which interact via Coulomb forces. In the limit of low temperatures (0.1 kelvin) the system will stay near the ground state where its Hamiltonian is equivalent to the Ising model. Furthermore, the proposed design is relevant to study the adiabatic quantum computers.

Q 14.4 Di 15:00 1B

Quantum Computation with Gaussian Continuous-Variable Cluster States — •Peter van Loock — Optical Quantum Information Theory Group, Max Planck Research Group, Institute of Optics, Information and Photonics, Staudtstr. 7/B2, 91058 Erlangen, Germany

We describe an extension of the cluster-state model for universal quantum computation from qubits to quantized harmonic oscillators, i.e., a translation from discrete to continuous quantum variables [1]. Compared to the discrete case, many features of the continuous-variable model have their direct analogues: cluster-state preparation via Gaussian (Clifford) operations, realization of any Gaussian transformation via Gaussian measurements in arbitrary order (Clifford computation and parallelism), and universal quantum computation via at least one non-Gaussian (non-Clifford) measurement including feedforward. For the optical creation of approximate cluster states in form of multimode squeezed Gaussian states [2] and the optical implementation of small-scale cluster computations [3], we discuss various protocols including linear-optics generation schemes and protocols for finite-squeezing-induced error filtration.

[1] N. C. Menicucci, P. van Loock, M. Gu, C. Weedbrook, T. C. Ralph, and M. A. Nielsen, Phys. Rev. Lett. **97**, 110501 (2006).
[2] P. van Loock, C. Weedbrook, and M. Gu, Phys. Rev. A **76**, 032321 (2007).
[3] P. van Loock, J. Opt. Soc. Am. B **24**, 340 (2007).

Q 14.5 Di 15:15 1B

Pseudo bound entanglement in NMR quantum computing — •Hermann Kampermann[1], Xinhua Peng[2], Dagmar Bruss[1], and Dieter Suter[2] — [1]Theoretische Physik III, Universität Düsseldorf — [2]Experimentelle Physik IIIa, Universität Dortmund

In NMR we have precise coherent control of small qubit systems (up to roughly 12 qubits), but NMR systems used today consist of large ensembles of nuclear spin quantum processors in a higly mixed (separable) state. So-called pseudo pure states are used to circumvent this problem. We use liquid state Nuclear Magnetic Resonance (NMR) to generate a 3-qubit "pseudo bound entangled state" and characterize it via state tomography and by detection of a witness operator for this class of states.

Q 14.6 Di 15:30 1B

A Quantum CISC Compiler and Scalable Assembler for Quantum Computing on Large Systems — •Thomas Schulte-Herbrüggen, Andreas Spörl, and Steffen Glaser — Dept. Chemistry, Technical University of Munich (TUM), 85747 Garching

Using the cutting edge high-speed parallel cluster HLRB-II (with a total LINPACK performance of 63.3 TFlops/s) we present a quantum CISC compiler into time-optimised or decoherence-protected complex instruction sets. They comprise effective multi-qubit interactions with up to 10 qubits. We show how to assemble these medium-sized CISC-modules in a scalable way for quantum computation on large systems. Extending the toolbox of universal gates by optimised complex multi-qubit instruction sets paves the way to fight decoherence in realistic Markovian and non-Markovian settings.

The advantage of quantum CISC compilation over standard RISC compilations into one- and two-qubit universal gates is demonstrated *inter alia* for the quantum Fourier transform (QFT) and for multiply-controlled NOT gates. The speed-up is up to factor of six thus giving significantly better performance under decoherence. – Implications for upper limits to time complexities are also derived.

Q 15: Quantengase (Gitter I)

Zeit: Dienstag 14:00–16:00 Raum: 1C

Q 15.1 Di 14:00 1C

Bogoliubov *vs.* chaotic energy spectrum for Bose atoms in optical lattices — •Andrey Kolovsky — Kirensky Institute of Physics, 660036 Krasnoyarsk, Russia

Recent experiments with cold bosonic atoms in optical lattices has renewed the theoretical studies of the Bose-Hubbard model, which constitutes one of the fundamental Hamiltonians in the condensed matter theory. The number of phenomena, discussed in the frame of this model, is so diverse that sometimes it is difficult to see any link between them. In particular, this concerns the phenomena of superfluidity and Quantum Chaos. Indeed, the former phenomenon assumes the regular phononlike excitation spectrum, described by the Bogoliubov theory, while the latter phenomenon implies a highly irregular excitation spectrum, described by the random matrix theory. This seeming contradiction is resolved by noting that these two spectra refer to different characteristic energies of the system. In the talk I shall explain of how the regular Bogoliubov spectrum of the Bose-Hubbard system evolves into an irregular one as the system energy is increased. A manifestation of this transition for the excitation dynamics of the superfluid state of cold atoms in optical lattices is discussed as well [1].

[1] A. R. Kolovsky, Phys. Rev. Lett. **99**, 020401 (2007); Phys. Rev. E **76**, 026207 (2007).

Q 15.2 Di 14:15 1C

Many-body Wannier-Stark dynamics — •Patrick Plötz[1,2] and Sandro Wimberger[1,2] — [1]Institut für Theoretische Physik, Universität Heidelberg, Philsophenweg 19, 69120 Heidelberg — [2]Heidelberg Graduate School of Fundamental Physics, Albert-Ueberle-Str. 3-5, 69120 Heidelberg

Interacting bosons in a one-dimensional optical lattice are studied in the presence of an additional and tunable tilting force in the strongly-correlated many-particle regime. We use a multi-band Bose-Hubbard model to describe this many-body Wannier-Stark problem. Tomadin *et al.* [Phys. Rev. Lett. **98**, 130402 (2007)] perturbatively included the first excited energy band on top of the widely used single band approximation, and found clear signatures of complex quantum dynamics in the interband tunneling rates. We investigate, in turn, the dynamics of a complete two-band model non-perturbatively. The dominant coupling channels between the bands are found for a realization with ultracold atoms. Our model allows us to study the vertical transport in energy space as well as the horizontal quantum transport along the lattice and their interdependence.

Q 15.3 Di 14:30 1C

Bloch oscillations and Landau-Zener tunneling of interacting ultracold atoms — •Ghazal Tayebirad and Sandro Wimberger — Institut für Theoretische Physik, Universität Heidelberg, D-69120 Heidelberg

A series of recent experiments measured the impact of atom-atom interactions on Bloch oscillations [1,2] and on Landau-Zener interband tunneling [3] of ultracold atoms in a tilted periodic (washboard) potential. We investigate the effect of interactions in the mean-field regime on these dynamical processes. Moreover, we discuss possibilities of controlling quantum transport in the interacting Wannier-Stark system by time-dependent and spatially inhomogeneous potentials.

[1] M. Fattori *et al.*, arXiv:0710.5031.
[2] M. Gustavsson *et al.*, arXiv:0710.5083.
[3] C. Sias *et al.*, Phys. Rev. Lett. **98**, 120403 (2007).

Q 15.4 Di 14:45 1C

Phase Diagram of Spin-1 Bosons in Optical Lattice at Non-Zero Temperature — •Matthias Ohliger[1] and Axel Pelster[2] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Fachbereich Physik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg, Germany

We extend previous zero-temperature mean-field studies [1,2] for the location of the superfluid-Mott insulator transition of spin-1 bosons in an optical lattice to finite temperatures. We find that the phase boundary changes continuously with the magnetization of the system and that a complete magnetization reproduces the phase diagram of spin-0 bosons [3,4]. For an antiferromagnetic interaction, however, the zero-temperature limit of our phase diagram deviates significantly from the zero-temperature mean-field studies [1,2], where a degenerate perturbation theory is applied for an odd number of bosons per site.

[1] S. Tsuchiya, S. Kurihara, and T. Kimura, Phys. Rev. A **70**, 043628 (2004)
[2] T. Kimura, S. Tsuchiya, M. Yamashita, and S. Kurihara, J. Phys. Soc. Japan **75**, 074601 (2006)
[3] P. Buonsante and A. Vezzani, Phys. Rev. A **70**, 033608 (2004).
[4] K.V. Krutitsky, A. Pelster, and R. Graham, New J. Phys. **8**, 187 (2006).

Q 15.5 Di 15:00 1C

Diagrammatic Calculation of Finite-Temperature Properties of the Bose-Hubbard Model — Henrik Enoksen[1], Alexander Hoffmann[2], •Matthias Ohliger[3], and Axel Pelster[4] — [1]Department of Physics, Norwegian University of Science and Technology, N-7491 Trondheim, Norway — [2]Arnold Sommerfeld Center for Theoretical Physics, Theresienstr. 37, Department Physik, Universität München, 80333 München, Germany — [3]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [4]Fachbereich Physik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg, Germany

Following an approach first worked out by Metzner in the context of electrons in conductors [1], we use a diagrammatic hopping expansion to calculate finite-temperature Green's functions for the Bose-Hubbard model which describes bosons in an optical lattice. This allows us to reconstruct in a qualitative way the time-of-flight absorption pictures, which are taken after the optical lattice is switched off. Furthermore, the technique makes summations of subsets of diagrams possible, leading to non-perturbative results for locating the boundary between the superfluid and the Mott phase for finite temperatures. Whereas the first-order calculation reproduces the seminal mean-field result, the second order goes beyond and shifts the phase boundary in the immediate vicinity of the critical parameters determined by Monte-Carlo simulations of the Bose-Hubbard model.

[1] W. Metzner, Phys. Rev. B **43**, 8549 (1993)

Q 15.6 Di 15:15 1C

Quantum Corrections of Mean-Field Phase Diagram for Bosons in Lattices — •Francisco Ednilson Alves dos Santos[1]

and Axel Pelster[2] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Fachbereich Physik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg, Germany

We improve the zero-temperature mean-field calculations for bosons in optical lattices by systematically working out the effect of quantum corrections. To this end we decompose the underlying nonlocal Bose-Hubbard Hamiltonian into the local mean-field Hamiltonian and treat the difference between them perturbatively. Using a diagrammatic technique, we calculate the ground-state energy up to second order in the quantum corrections. Therein, we interpret the order parameter ψ as a variational parameter, which is determined from optimizing the ground-state energy. With this analytical approach we obtain for arbitrary spatial dimension an improved boundary between Mott insulator and superfluid phase in accordance with previous high-precision results from quantum Monte-Carlo simulations.

Q 15.7 Di 15:30 1C

AC-induced superfluidity — •André Eckardt and Martin Holthaus — Institut für Physik, Carl von Ossietzky Universität, 26111 Oldenburg

In previous work we have shown that it should be possible to coherently control the transition from a superfluid to a Mott insulator in the Bose-Hubbard model by an oscillating force through an effective modification of the tunneling matrix element [Eckardt et al., PRL 95, 260404 (2005)]. The effective tunnel modification has recently been observed experimentally by the Arimondo group in Pisa, without notable loss of coherence caused by the drive [Lignier et al., cond-mat/0707.0403 (2007)]. In this talk we will consider a Bose-Hubbard system that is subjected to a static potential tilt such that tunneling is strongly suppressed due to the localization of the Wannier-Stark states. We show that tunneling can be restored partially in a coherent way by resonantly driving the system at high frequencies (a few kHz for a typical experiment with Alkali atoms in an optical lattice). For integer filling, the interplay between interparticle repulsion and this kind of "photon"-assisted tunneling should give rise to a Mott-like transition, with (quasi) long-range order (i.e. superfluidity) being established by switching on the AC-drive [Eckardt & Holthaus, EPL 80, 50004 (2007)]. It is also possible to control the sign of the effective tunneling matrix element by varying the amplitude of the drive. We argue that an adiabatic passage of the system's ground state through such a sign change is a many-body effect that relies on the existence of a Mott-insulator phase.

Q 15.8 Di 15:45 1C

Ultracold bosons in optical superlattices with and without disorder: A numerical approach — •Dominik Muth, Alexander Mering, and Michael Fleischhauer — Fachbereich Physik, Technische Universität Kaiserslautern, D-67663 Kaiserslautern

The time-evolving block decimation algorithm (TEBD) for one-dimensional systems and its modification for infinite size systems (iTEBD) can be used to determine the ground state for various Hamiltonians. We apply this method to determine the superfluid to Mott-insulator phase transition for a Bose-Hubbard model with a superlattice. While for small hopping parameter J the loophole-shaped insulator domains, derived by a mean-field approach [1], fit quite well to our numerical results, the results differ for large hopping as expected. Adding disorder to the system, we show that the loophole domains detach from the J=0 axis, creating insulating islands surrounded by a Bose-glass phase.

[1] P. Buonsante, A. Vezzani - Phys. Rev. A 72, 013614 (2005)

Q 16: Photonik I

Zeit: Dienstag 14:00–16:00 Raum: 2B/C

Q 16.1 Di 14:00 2B/C

Nonlinear optical response of metal nanoantennas — •Barbara Wild, Jörg Merlein, Tobias Hanke, Alfred Leitenstorfer, and Rudolf Bratschitsch — Departement of Physics and Center for Applied Photonics, University of Konstanz, D-78464 Konstanz, Germany

We have investigated the nonlinear optical response of bowtie-shaped gold nanoantennas fabricated with the colloidal mask technique. The structures were excited by picosecond light pulses with a center wavelength of 790 nm. The excitation frequency is equal to the plasmon resonance of the nanoantennas, which has been determined via dark-field scattering spectroscopy. The spectrum emitted by the nanoantennas consists of a broadband continuum overlapped with a narrowband second harmonic signal at $\lambda = 395$ nm. We will discuss the influence of the exciting laser spectrum on the nonlinear response of the metal nanoantennas and possible applications of this effect.

Q 16.2 Di 14:15 2B/C

Volumenholographie durch Löcher mit Sub-Wellenlängen Durchmesser* — •Felix Kalkum, Sebastian Broch und Karsten Buse — Physikalisches Institut, Universität Bonn, Wegelerstraße 8, 53115 Bonn

Licht trifft auf einen Metallfilm mit einem Loch, das einen Durchmesser kleiner als die Wellenlänge hat. Hinter dem Metallfilm befindet sich ein photosensitiver Kristall. In diesem kann das Beugungsmuster, die sogenannte Signalwelle, durch Überlagerung mit einer kohärenten Referenzwelle holographisch gespeichert werden. Phasenkonjugiertes Lesen erzeugt das phasenkonjugierte Signallicht, welches fokussiert wird und wieder durch das Loch nach außen tritt. Das Ziel ist, eine besonders gute Fokussierung zu erreichen, da sich Strahlen aus allen Richtungen im Fokus überlagern können. Dies entspricht einer sehr hohen Numerischen Apertur. Außerdem sollen kompliziertere Muster auf der Oberfläche, zum Beispiel für die Nanolithographie, effizient ausgeleuchtet werden können. Wir haben hierfür einen aktiv stabilisierten Aufbau hergestellt. Die Hologramme werden in eisendotierten Lithiumniobatkristallen gespeichert. Zum Schreiben und Lesen verwenden wir Licht der Wellenlänge 532 nm. Die Leistung des rekonstruierten Lichts erreicht zum Beispiel bei einem Loch mit Durchmesser 500 nm bis zu 10^{-4} des einfallenden phasenkonjugierten Referenzlichts. Dieser Anteil kann unter anderem maximiert werden, indem die Kristallgröße geeignet gewählt wird.

*Gefördert von der DFG (FOR 557) und der Deutschen Telekom Stiftung.

Q 16.3 Di 14:30 2B/C

Bindungsmechanismus von Solitonenmolekülen in dispersionsalternierenden Glasfasern — •Alexander Hause, Haldor Hartwig und Fedor Mitschke — Universität Rostock, Fachbereich Physik, Universitätsplatz 3, 18051 Rostock

Kürzlich konnte von uns gezeigt werden[1], dass in Glasfaserstrecken mit periodisch wechselnder Dispersion stabile Verbundzustände aus Solitonen, so genannte Solitonenmoleküle, existieren. Die phasensensitive Charakterisierung dieser Koppelzustände mit Hilfe des neuartigen und eindeutigen Vampire-Messverfahrens [2] (*very advanced method of phase and intensity retrieval of E-fields*) sowie numerische Simulationen lieferten Hinweise auf die Phasendynamik als Ursache der Bindung des Moleküls.

Abhängig vom Abstand und Chirp der Einzelimpulse ergibt sich ein anziehendes oder abstoßendes Verhalten des Doppelimpulses. Bei einem bestimmten Abstand ist die resultierende Kraft null, bei kleineren Abständen zeigt sich eine Abstoßung und bei größeren Abständen eine Anziehung. Dies definiert einen stabilen Gleichgewichtsabstand.

Störungstheoretische Betrachtungen der Phasendynamik liefern ein Modell, das dieses typische Verhalten zeigt und die Bindung der Solitonen erklären kann.

[1] M. Stratmann et. al., Phys. Rev. Lett. **95**, 143902 (2005)
[2] A. Hause et. al., Phys. Rev. A **75**, 063836 (2007)

Q 16.4 Di 14:45 2B/C

Eine Unschärferelation für optische Solitonen — •Michael Böhm und Fedor Mitschke — Universität Rostock, Institut für Physik, Universitätsplatz 3, 18055 Rostock

Numerische Simulationen der Ausbreitung optischer Lichtimpulse in Glasfasern, welche man beispielsweise bei der Datenübertragung verwendet, können erfolgreich die Veränderung der Impulsform, Dauer, etc. beschreiben. Wegen der Nichtlinearität der Faser enthalten die Lichtimpulse im allgemeinen Solitonen. Der Solitonengehalt geht allerdings nicht aus der Simulation hervor. Er kann mit der Inversen

Streutheorie [1] bestimmt werden. Diese ist allerdings auf integrable Systeme beschränkt und daher streng genommen nicht auf reale Fälle anwendbar. Mit einem kürzlich eingeführten Verfahren, dem „soliton-radiation beat analysis“ [2], kann man nun den Solitonengehalt auch für nichtintegrable Systeme ermitteln, insbesondere auch für Systeme in denen sich die Energie ändert. Mithilfe dieses Verfahrens konnten wir eine Unschärferelation zwischen der Energie und der Position in der Glasfaser für Solitonen formulieren.

[1] V. E. Zakharov and A. B. Shabat, *Exact theory of two-dimensional self-focusing and one-dimensional self-modulation of waves in nonlinear media*, Soviet Phy. JETP, **34** 1, (1972) 62-69
[2] M. Böhm und F. Mitschke, *Soliton-radiation beat analysis*, Phys. Rev. E **73** 066615, (2006)

Q 16.5 Di 15:00 2B/C

Selbstorganisierte Erzeugung von Superkontinuum in einem passiven, nichtlinearen Faser-Ring-Resonator — •Toralf Ziems, K. V. Adarsh, Michael Böhm und Fedor Mitschke — Universität Rostock, Institut für Physik, Universitätsplatz 3, 18055 Rostock

Optisches Superkontinuum ist für eine Fülle photonischer Anwendungen nutzbar. Meistens wird dieses Superkontinuum erzeugt, indem intensive ultrakurze (ps, fs) Laserpulse durch hoch-nichtlineare Glasfasern geleitet werden. Wir verfolgen einen modifizierten Ansatz, bei dem die Glasfaser zu einem nichtlinearen Ringresonator geschlossen wird. Ein modengekoppelter Nd:YAG-Laser (1064 nm) liefert Pikosekundenpulse. In dem nichtlinearen Rückkoppelsystem bilden sich spontan komplexe, sehr kurze zeitliche Strukturen, die ein extrem breites Spektrum bedingen. Mit einer „holey fiber“ geeigneter Dispersion erreichen wir derzeit mit einer eingekoppelten Spitzenleistung von lediglich 500 W experimentell ein etwa 150 THz breites Spektrum. Dies ist das selbstorganisierte Ergebnis eines Wechselspiels der verschiedenen physikalischen Prozesse, wie Selbstphasenmodulation, Modulationsinstabilität, Ramaneffekt etc. sowie Dispersion (auch höherer Ordnung) in Verbindung mit der Interferenz bei der Rückkopplung. Zusätzlich durchgeführte numerische Simulationen sollen dazu dienen, diese komplexe Interaktion aufzuschlüsseln.

Q 16.6 Di 15:15 2B/C

Charakterisierung eines integriert-optischen Nahfeldsensors mit erhöhter evaneszenter Feldintensität — •Julia Hahn, Frank Fecher, Jürgen Petter und Theo Tschudi — Institut für Angewandte Physik, Technische Universität Darmstadt

Zur Verbesserung der Empfindlichkeit eines Evaneszentfeldsensors soll bei gleich bleibender Eindringtiefe der Anteil der im zu untersuchenden Medium vorliegenden Intensität erhöht werden.

Die evaneszenten Felder über den zu diesem Zweck mit hochbrechendem Titandioxid beschichteten Wellenleiterstrukturen in Lithiumniobat charakterisieren wir im sichtbaren Spektralbereich mit einem SNOM (Scanning Near-Field Optical Microscope) im Vergleich zu unbeschichteten Wellenleitern. Die angespitzte Glasfaser des im Kollektionsmodus betriebenen SNOMs nimmt hierbei in präszise positionierten Scans punktgenau die Intensität des evaneszenten Feldes auf.

Es wurden sowohl Scans entlang der Wellenleiteroberfläche als auch senkrecht zur Oberfläche als Funktion des Abstandes aufgenommen. Hierbei konnte gezeigt werden, dass die Titandioxid-Beschichtung auf dem Wellenleiter zu einer fünfzehnfachen Erhöhung der evaneszenten Feldintensität an der Oberfläche zum Deckmedium führt. Hierbei bleibt die Eindringtiefe unverändert in der Größenordnung von wenigen zehn Nanometern.

Q 16.7 Di 15:30 2B/C

Monolithische dielektrische mikrostrukturierte Oberfläche mit 100% Reflektivität — •Frank Brückner, Tina Clausnitzer, Ernst-Bernhard Kley und Andreas Tünnermann — Institut für Angewandte Physik, Friedrich-Schiller-Universität Jena, Deutschland

In der Optik werden hochreflektierende Oberflächen meist durch den Einsatz dielektrischer Vielschichtsysteme realisiert. Aufgrund der Kombination von Materialien unterschiedlicher Festkörperstruktur wird die ursprünglich hohe mechanische Güte des Substrats erheblich reduziert. An diese werden jedoch für spezielle Anwendungen sehr hohe Anforderungen gestellt. Alternative Spiegelarchitekturen sind als Wellenleitergitter bekannt, welche mit Hilfe einer mikrostrukturierten hochbrechenden Schicht auf einem niedrigbrechenden Substrat hohe Reflektivitäten erreichen. Somit ist mindestens noch eine Schicht aus einem substratfremden Material erforderlich. Wir schlagen deshalb eine rein monolithische Spiegelgeometrie vor, die auf der Mikrostrukturierung einer dielektrischen Oberfläche basiert. Dadurch wird der Einsatz eines zusätzlichen Materials überflüssig und die mechanische Güte des Substrats nur minimal gestört. Die Strukturierung der Oberfläche resultiert dabei in T-förmigen Stegen eines Subwellenlängengitters, wodurch ein resonantes Koppelverhalten des einfallenden Lichts zum Erhalt höchster Reflektivität aus Luft ausgenutzt werden kann. Dies wird basierend auf der Funktion herkömmlicher Wellenleitergitter und der Einführung eines effektiven niedrigbrechenden Mediums theoretisch erklärt. Neben systematischen Designbetrachtungen werden auch potenzielle Herstellungsmöglichkeiten präsentiert.

Q 16.8 Di 15:45 2B/C

Fabrication and Characterization of Silicon Inverse Spiral and Slanted Pore Structures — Martin Hermatschweiler[1,2], •Isabelle Staude[1], Michael Thiel[1], Martin Wegener[1,2], and Georg von Freymann[2] — [1]Center for Functional Nanostructures and Institut für Angewandte Physik, Universität Karlsruhe (TH), 76128 Karlsruhe — [2]Institut für Nanotechnologie, Forschungszentrum Karlsruhe GmbH, 76021 Karlsruhe

We here realize a variety of silicon inverse (SI) photonic crystal (PC) structures for the first time. Direct laser writing of polymeric templates and a silicon single-inversion procedure [1] allow for the fabrication of 3D photonic band gap (PBG) structures. This leads to broad and prominent stop bands in the near infrared.

Several different types of structures that theoretically exhibit large PBGs are demonstrated: (i) SI spiral PCs consisting of circular/square spirals arranged on a bcc/tetragonal lattice, respectively. [2,3] (ii) SI slanted pore structures arranged on a tetragonal lattice. [4] To our knowledge, none of the structures (i) can be accessed by any different method. Optical reflectance and transmittance measurements suggest the existence of PBGs for all proposed geometries. The experimental formation of PBGs shall be verified by comparison of the measurements to scattering-matrix as well as band structure calculations.

[1] M. Hermatschweiler et *al.*, Adv. Funct. Mater. **18**, 2273 (2007)
[2] A. Chutinan et *al.*, Phys. Rev. B **57**, R2006 (1998)
[3] O. Toader et *al.*, Science **292**, 1133 (2001)
[4] O. Toader et *al.*, Phys. Rev. Lett. **90**, 233901-1 (2003)

Q 17: Ultrakalte Atome I [gemeinsam mit A]

Zeit: Dienstag 14:00–16:00 Raum: 2F

Q 17.1 Di 14:00 2F

Cold bosonic atoms in a π − flux lattice — •Stephan Rachel and Martin Greiter — Institut für Theorie der Kondensierten Materie, Universität Karlsruhe, 76128 Karlsruhe

We present a model where the rare phenomenon of fragmented Bose–Einstein condensation occurs: we consider a system of neutral, bosonic atoms on a square lattice subject to an effective magnetic field. We focus on a magnetic flux of half a Dirac flux quantum through every lattice cell. The effective flux yields two minima in the lower single particle band. We show that in the many particle ground state, the particles are evenly distributed over both minima. The two macroscopically occupied minima correspond to two distinct Bose condensates.

Regarding the low-energy excitations of the system, we show that Josephson tunneling is only possible for pairs of bosons, while single particle tunneling between both condensates is absent. We further find a massive mode describing fluctuations in the relative density of the two condensates.

Q 17.2 Di 14:15 2F

Bose-Einstein condensation in a periodic potential: A perturbation approach — •Ming-Chiang Chung[1], Victor Lopez-Richard[2], Carlos Trallero-Giner[3], and Andreas Buchleitner[4] — [1]Max-Planck-Institut für Physik Komplexer Systeme* Noethnitzer Str. 38, D-01187 Dresden, Germany — [2]Departamento de Fisica, Universidade Federal de S\~{a}o Carlos, 13.565-905, S\~{a}o Carlos,

S\~{a}o Paulo, Brazil — [3]Faculty of Physics, Havana University, 10400 Havana, Cuba — [4]Quantum Optics and Statistics Institute of Physics Albert-Ludwigs-Universitaet Freiburg Hermann-Herder-Str. 3 D-79104 Freiburg, Germany

Considering the Gross-Pitaevskii equation for Bose-Einstein condensate in a stationary one dimensional optical lattice with period \$d\$ in reduced coordinates, we are able to formally obtain closed analytical solutions for the order parameter and for the chemical potential. We report solutions for different range of values for the repulsive and the attractive non-linear interactions in the condensate and laser parameters creating the lattice. We have preformed a quantitative analysis with numerical solutions and theoretical estimation of the reported analytical equations allowing the determination of validity ranges of the perturbation approach. This study gives a very useful result establishing the universal range of the non-linear coupling term and lattice parameter values where each solution can be easily implemented.

Q 17.3 Di 14:30 2F

Improving the analytical determination of bound state energies and scattering lengths in molecular potentials – especially near threshold — •Patrick Raab and Harald Friedrich — Physik Department T30a, Technische Universität München, D-85747 Garching

Conventional WKB quantization can be improved substantially by including the appropriate reflection phases at the classical turning points. By application of the Effective-Range-theory we are able to calculate the reflection phase at the outer turning point in an attractive potential up to linear order in energy. For arbitrary energy we estimate the reflection phase by matching the low energy expansion with known formulas for high energies. This model, which includes only one free parameter is a significant improvement over the approximate eigenenergies obtained by other methods. The scattering length is completely determined by the knowledge of one of the highest bound energy levels (not necessarily by the highest one) and the asymptotic behavior of the potential.

Q 17.4 Di 14:45 2F

Jost-Functions & Attractive Singular Potentials — •Florian Arnecke, Javier Madronero, and Harald Friedrich — Physik Department T30a, Technische Universität München, D-85747 Garching

We use Jost-functions to determine the leading and next-to-leading terms of the phase shifts $\delta_l(k)$ in the case of homogeneous attractive singular potentials $-1/r^\alpha$, $\alpha > 2$, for arbitrary angular momentum l with incoming boundary conditions at small distances. The Jost-solutions are obtained by solving a Volterra-equation and a more general ansatz is used to fit the Jost-solutions to the WKB-waves in the inner region, where the WKB-approximation is accurate. A connection between the phase shifts of attractive and repulsive homogeneous singular potentials is presented.

Q 17.5 Di 15:00 2F

Stable dark solitons in three-dimensional dipolar Bose-Einstein condensates — •Rejish Nath[1], Paolo Pedri[2], and Luis Santos[1] — [1]Institute of Theoretical Physics, Leibniz university of Hannover, Appelstrasse 2, 30167, Hannover, Germany — [2]Laboratoire de Physique Théorique de la Matière Condensée, Université Pierre at Marie Curie, case courier 121 , 4 place Jussieu, 75252 Paris Cedex, France

We study the dynamical stability of dark solitons in dipolar Bose-Einstein condensates. In the absence of non-locality due to the dipolar interaction, stationary dark solitons (nodal planes) are unstable against transversal excitations (snake instability) in 2D and 3D. On the contrary, due to its non local character, the dipolar interaction allows for stable 3D stationary dark solitons. We discuss in detail the conditions to achieve this stability, which demand the use of an additional optical lattice.

Q 17.6 Di 15:15 2F

Correlation dynamics of strongly-correlated lattice bosons out of equilibrium — •Karen Rodriguez and Luis Santos — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover

We analyze by means of matrix product states techniques the dynamics of strongly-correlated Bose gases in a finite one-dimensional optical lattice after a change of the lattice parameters within the superfluid region. We analyze different regimes of perturbation, which range from adiabatic to non-adiabatic. In particular, we are interested in the evolution of different correlations in the system in time, showing that the different correlations present different time scales in their reaction to the change of parameters. As a consequence, when local quantities are converged correlation to distant neighbours or the quasi-condensate fraction may still present a significant dynamics. In addition, the different time scales for different correlations open the possibility to have different criteria for adiabaticity in the system.

Q 17.7 Di 15:30 2F

Laser Cooling and Trapping of a Leaky System: Barium — •Subhadeep De, Joost van den Berg, Aran Mol, Klaus Jungmann, and Lorenz Willmann — KVI, University of Groningen, Groningen, The Netherlands

Heavy alkaline earth elements like radium are excellent candidates to test fundamental symmetries by searches for permanent electric dipole moments and atomic parity violation. Sensitive experiments require the trapping of these isotopes. Nevertheless, the two electron atoms have no simple two-level system for laser cooling due to the strong transitions between the singulet and the triplet system. The strongest transition from the ground state $^1S_0$-$^1P_1$ show a leak of 1:500 to metastable D-states. We have studied such a system with barium, where the branching into the D-states is 1:330(30). Repumping from these states uses the same excited state as the cooling transition, which leeds to coherent Raman transitions. Trapping and cooling of barium requires a set of seven lasers running at the same time. We report on the first successful trapping of barium in a magneto optical trap. The performance of the cooling and trapping will be discussed.

Q 17.8 Di 15:45 2F

Non-Abelian Statistics in a Quantum Antiferromagnet — •Martin Greiter and Ronny Thomale — Institut für Theorie der Kondensierten Materie, Universität Karlsruhe, D 76128 Karlsruhe

We propose a novel spin liquid state for a S=1 antiferromagnet in two dimensions. The ground state is a spin-singlet, fully invariant under the symmetries of the underlying lattice, and possess a threefold topological degeneracy. The spinon and holon excitations obey non-abelian statistics, with the braiding of half-quantum vortices governed by zero energy modes in the vortex cores. We present numerical evidence that the universality class of this topological liquid can be stabilized by a model Hamiltonian involving three-spin interactions. We discuss possible realizations with polar molecules in optical lattices as well as potential applications in quantum computing.

Q 18: Präzisionsmessungen und Metrologie III

Zeit: Dienstag 14:00–15:45 Raum: 3D

Q 18.1 Di 14:00 3D

Gequetschtes Licht für den Gravitationswellendetektor GEO 600 — Henning Vahlbruch, •Alexander Khalaidovski, Simon Chelkowski, Moritz Mehmet, Boris Hage, Hartmut Grote, Benno Willke, Harald Lück, Karsten Danzmann und Roman Schnabel — Max-Planck-Institut für Gravitationsphysik (Albert Einstein Institut), Hannover, Deutschland

Eine der großen Herausforderungen der modernen Experimentalphysik ist der direkte Nachweis der im Jahre 1916 von Albert Einstein vorhergesagten Gravitationswellen. Im Laufe der letzten Jahre hat daher ein weltweites Netzwerk interferometrischer Detektoren den Betrieb aufgenommen, um eine direkte Messung der durch Gravitationswellen bedingten winzigen Längenänderungen zu erbringen. Zukünftige Detektoren werden in ihrer Empfindlichkeit im wesentlichen durch Quantenrauschen limitiert sein. Einen Ansatz, dieses zu verringern und somit die Sensitivität der Interferometer weiter zu erhöhen, bietet der Einsatz gequetschter Zustände des elektromagnetischen Feldes mit nichtklassischer Rauschdistribution. Der Beitrag diskutiert den Aufbau eines "table-top" Interferometers mit nichtklassisch verbesserter Sensitivität sowie die geplante Implementierung der vorgestellten Konzepte in den britisch/deutschen Gravitationswellendetektor GEO 600.

Q 18.2 Di 14:15 3D

Charakterisierung einer Siliziumnitrid-Membran — •Tobias Westphal, Yanbei Chen, Stefan Danilishin, Daniel Friedrich, Stefan Gossler, Kentaro Somiya, Kazuhiro Yamamoto, Karsten Danzmann und Roman Schnabel — Max-Planck-Institut für Gravitationsphysik (AEI), Institut für Gravitationsphysik der Leibniz Universität Hannover, Callinstraße 38, 30167 Hannover

Quantenmechanisches Strahlungsdruckrauschen gewinnt in den Gravitationswellendetektoren der nächsten Generation zunehmend an Bedeutung. Zur Bestätigung der bisherigen theoretischen Modelle bauen wir ein strahlungsdruckdominiertes Interferometer auf. Die optomechanische Kopplung dieses Quanteneffekts wird durch einen beidseitig genutzten Endspiegel realisiert, welcher durch eine Siliziumnitrid-Membran ausgeführt wird.

Die ersten Ergebnisse der Charakterisierung dieser Membran hinsichtlich mechanischer Güte und optischer Eigenschaften sowie das Layout des darauf basierenden Interferometers werden hier vorgestellt.

Q 18.3 Di 14:30 3D

Phasengenauigkeit von elektro-optischen Modulatoren für die wissenschaftliche Weltraummission LISA — •Simon Barke, Michael Tröbs, Benjamin Sheard, Gerhard Heinzel und Karsten Danzmann — Max-Planck-Institut für Gravitationsphysik, Hannover, Germany

Die Laser Interferometer Space Antanna (LISA) besteht aus drei jeweils 5 Millionen Kilometer entfernten Satelliten, die ein Interferometer aufspannen und über Phasenverschiebungen der Schwebungssignale Gravitationswellen detektieren.

Da die Größe der erwarteten Phasenverschiebungen im Bereich von wenigen $\mathrm{pm}/\sqrt{\mathrm{Hz}}$ liegt, stellt dies enorme Anforderungen an die Phasenmessung: Phasenänderungen aufgrund von Schwankungen in der Referenzfrequenz können nicht von Gravitationswellen-Signalen unterschieden werden. Die für LISA zur Verfügung stehenden Taktgeber erfüllen jedoch nicht die nötigen Anforderungen an die Frequenzgenauigkeit. Um die Missionsziele zu erreichen, soll das Frequenzrauschen der Taktgeber miteinander vergleichen werden, um es nachträglich vom Messsignal zu subtrahieren. Dazu wird das Signal der Taktgeber mittels elektro-optischer Modulatoren (EOMs) als Seitenbänder auf die Laserstrahlen aufgeprägt, so dass das Rauschen der Taktgeber zu den entfernten Satelliten übertragen werden kann. Das durch die EOMs zusätzlich eingefügte Phasenrauschen darf hierbei nicht mehr als $1\,\mathrm{pm}/\sqrt{\mathrm{Hz}}$ betragen. Der Vortrag beschreibt mögliche Rauschquellen der untersuchten EOMs und stellt neben dem Messaubau für die Bestimmung der Phasengenauigkeit auch erste Ergebnisse vor.

Q 18.4 Di 14:45 3D

LTPDA - Datenanalyse für LISA Pathfinder — •Anneke Monsky, Ingo Diepholz, Felipe Guzman, Frank Steier, Martin Hewitson, Gerhard Heinzel und Karsten Danzmann — Albert-Einstein-Institut, Callinstr. 38, Hannover

LISA (Laser Interferometer Space Antenna) ist eine gemeinsame Satellitenmission von ESA und NASA und soll den direkten Nachweis von Gravitationswellen im Bereich 0,1 mHz - 1 Hz liefern. Um kritische Technologien vorab zu testen, wird zuvor die Mission LISA Pathfinder durchgeführt. LISA Pathfinder wird vorraussichtlich 2010 gestartet.

Zur Datenanalyse von LISA Pathfinder wurde in MATLAB ein Softwaretool zusammengestellt, das aus einer Vielzahl für die Auswertung nötiger Algorithmen aufgebaut ist, die von jedem Benutzer individuell zusammengestellt werden können. Die Idee ist, dass die Ergebnisse einer jeden Auswertung zu jeder Zeit vollständig reproduzierbar und genau nachvollziehbar bleiben. Relevante Ergebnisse werden in Form spezieller Konstrukte auf einem gemeinsamen Server gespeichert und für weitere Analysen zur Verfügung gestellt. Jede Analyse kann so exakt wiederholt oder auch modifiziert werden, wobei wiederum alle durchgeführten Prozesse gespeichert werden.

Weiter wurden, basierend auf einem einfachen Model des Experiments Daten generiert und ausgewertet. Erste Ergebnisse dieser Datenanalyse für das LISA Technology Package werden vorgestellt.

Q 18.5 Di 15:00 3D

Novel LISA Payload Architectures with In-Field Pointing — •Dennis Weise[1], Pierangelo Marenaci[1], Peter Weimer[1], Hans Reiner Schulte[1], Peter Gath[1], Claus Braxmaier[2], Ulrich Johann[1], and Marcello Sallusti[3] — [1]EADS Astrium GmbH, Claude-Dornier-Str., 88039 Friedrichshafen — [2]HTWG Konstanz, Brauneggerstr. 55, 78462 Konstanz — [3]European Space Agency, P.O. Box 299, 2200 AG Noordwijk ZH, The Netherlands

As ESA's prime contractor within the on-going LISA Mission Formulation Study, EADS Astrium has recently suggested and investigated payload architectures utilizing so-called "In-Field Pointing" for accommodation of seasonal constellation dynamics. Here, the annual variation in the angle between the interferometer arms of roughly $\pm 1°$ is compensated by steering the lines of sight of the individual telescopes with a comparatively small actuated mirror located in an intermediate pupil plane inside the telescopes. This introduces a high flexibility for the overall payload configuration and allows for the realization of very compact designs. We will show that despite the presence of an active mirror in the measurement chain it should be feasible to achieve the required pciometer pathlength stability over relevant timescales by employing a specifically designed telescope and a special Gimbal-type pointing mechanism. In combination, these minimize pathlength disturbances to design-values below $1\,\mathrm{pm}/\sqrt{\mathrm{Hz}}$ by passive means in the measurement band. According payload architectures with both a single active proof mass and two active proof masses per spacecraft will be presented.

Q 18.6 Di 15:15 3D

Messung des nichtreziproken Phasenrauschens einer polarisationserhaltenden Glasfaser für LISA — •Roland Fleddermann, Frank Steier, Michael Tröbs, Gerhard Heinzel und Karsten Danzmann — Albert-Einstein-Institut Hannover, Max-Planck-Institut für Gravitationsphysik und Universität Hannover, Callinstr. 38, D-30167 Hannover

Laser Interferometer Space Antenna (LISA) ist eine gemeinschaftliche Mission der ESA und der NASA mit dem Ziel, Gravitationswellen im Frequenzbereich zwischen 0,1 mHz und 0,1 Hz zu messen.

Drei Satelliten befinden sich hierzu in speziellen heliozentrischen Umlaufbahnen die ein gleichseitiges Dreieck bilden. Die Richtung der zur interferometrischen Distanzmesung ausgesandten Laserstrahlen muss dabei variabel sein, da sich der Winkel zwischen den Satelliten um bis zu $\pm$ 1,5° ändert. Da es wünschenswert ist, das relativ schwache ankommende Licht mit einem Teil des Lichts zu Überlagern, das zum anderen Satelliten ausgesandt wird, ist eine flexible Verbindung zwischen beiden an Bord befindlichen optischen Bänken notwendig. Glasfasern sind hierfür die vielversprechendsten Kandidaten.

Wir messen das nichtreziproke Phasenrauschen einer polarisationserhaltenden Glasfaser, um zu verifizieren, dass diese Rauschquelle die Phasenmessungen bei LISA mit einer Genauigkeit von 10 $\mu\mathrm{rad}/\sqrt{\mathrm{Hz}}$ $\hat{\approx}$ $2\,\mathrm{pm}/\sqrt{\mathrm{Hz}}$ @ 1064 nm nicht zerstört.

Wir geben eine Übersicht über mögliche Messaufbauten, erste Ergebnisse und über Untersuchungen der externen Einflüsse auf das beobachtete nichtreziproke Phasenrauschen.

Q 18.7 Di 15:30 3D

Interspacecraft laser ranging for LISA — •Juan Jose Esteban Delgado, Antonio Francisco Garcia Marin, Iouri Bykov, Gerhard Heinzel, and Karsten Danzmann — Albert-Einstein-Institut Hannover, Max-Planck-Institut für Gravitationsphysik*und Universität Hannover

The Laser Interferometer Space Antenna (LISA) is an international space project to detect and observe Gravitational waves in the frequency regime from 0.1 mHz to 100 mHz. LISA is a cluster of three spacecraft separated by five millions kilometers communicating with each other via three bidirectional laser links and forming an equilateral triangle.

The LISA data processing requires ranging between the spacecraft to monitor continuously their huge separation with an absolute precision of ten meters. The laser links are not only used to measure this distance but also to transmit information and clock synchronization between the satellites.

We present a possible implementation of the onboard processing system dedicated to extract the required information from the incoming laser phase using a binary phase shift keying demodulation scheme.

Q 19: Kalte Moleküle III [gemeinsam mit MO]

Zeit: Dienstag 14:00–16:00 Raum: 3G

Q 19.1 Di 14:00 3G

Cumulenic carbon chains: giant absorbers — •Dmitry Strelnikov and Wolfgang Krätschmer — Max-Planck-Institut für Kernphysik, 69117 Heidelberg.

Cumulenic carbon chains have extremely strong IR and UV-Vis absorptions, a feature which facilitates their detection even in minute quantities. We present our results obtained by IR and UV-Vis spectroscopy on bare carbon chains and their oxides trapped in cryogenic matrices. IR spectra of a novel hybrid molecule consisting of a C3 carbon chain attached to a C60 fullerene will also be presented and discussed.

Q 19.2 Di 14:15 3G

Internal-state thermometry by depletion spectroscopy in a cold guided beam of formaldehyde — •Michael Motsch, Markus Schenk, Laurens D. van Buuren, Martin Zeppenfeld, Pepijn W.H. Pinkse, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

Velocity filtering by means of an electrostatic quadrupole guide is an efficient technique to produce slow beams of polar molecules from a thermal reservoir. For formaldehyde, fluxes of $10^{10}\,\mathrm{s}^{-1}$ with velocities down to ~10 m/s have been demonstrated [1]. However, so far the internal-state distribution of the velocity filtered molecules was not accessible in the experiment.

We present measurements of the internal-state distribution of electrostatically guided formaldehyde [2]. Upon excitation with continuously tunable ultraviolet laser light, molecules can be excited to a dissociating state, leading to a decrease in the molecular flux. The population of individual guided states is measured by addressing transitions originating from them. The measured populations of selected states show good agreement with theoretical calculations for different temperatures of the molecule reservoir. The purity of the guided beam as deduced from the entropy of the guided sample using a reservoir temperature of 150 K corresponds to that of a thermal ensemble with a temperature of about 30 K.

[1] S.A. Rangwala et al., Phys. Rev. A **67**, 043406 (2003)
[2] M. Motsch et al., arXiv:chem-phys 0710.3316v1 (2007), accepted for publication in Phys. Rev. A

Q 19.3 Di 14:30 3G

Cooling and Slowing in High Pressure Jet Expansions — •Wolfgang Christen and Klaus Rademann — Institut für Chemie, Humboldt-Universität zu Berlin, Brook-Taylor-Strasse 2, 12489 Berlin

The expression for the mean flow velocity in supersonic beams of ideal gases is extended to include real gas properties. This procedure yields an explicit dependence of the flow velocity on pressure, as observed in recent experiments of free jet expansions [1,2]. Applied to stagnation conditions slightly above the critical point, the model suggests that seeded high pressure jets might be suitable for slowing down virtually any molecule with high efficiency. Moreover, we discuss the consequence of a pressure-dependent flow velocity v_0 for the speed ratio $S = v_0/\Delta v_\|$ with respect to collisional cooling and suggest to use the velocity spread $\Delta v_\|$ as a more non-ambiguous measure of translational temperature in high pressure jet expansions.

[1] L. W. Bruch, W. Schöllkopf, J. P. Toennies, *J. Chem. Phys.* **117**, 1544 (2002).
[2] W. Christen, T. Krause, K. Rademann, *Rev. Sci. Instrum.* **78**, 073106 (2007).

Q 19.4 Di 14:45 3G

Überschallexpansion von überkritischen Fluiden - Ethen und Propan — •Oliver Korup, Klaus Rademann und Wolfgang Christen — Institut für Chemie, Humboldt-Universität zu Berlin, Brook-Taylor-Strasse 2, 12489 Berlin

Mit hochaufgelösten Flugzeitmessungen gepulster Überschallmolekularstrahlen wird die Geschwindigkeitsverteilung von reinem Ethen und Propan als Funktion des Stagnationsdrucks und der Stagnationstemperatur bestimmt. Beide Spezies werden hierzu unter präzise definierten Stagnationsbedingungen [1] ins Vakuum expandiert. Der untersuchte Druck- und Temperaturbereich umfasst den gasförmigen, flüssigen und überkritischen Aggregatzustand. Die Messungen werden durch Untersuchungen zur Clustergrößenverteilung, unter Verwendung der Gegenfeldmethode [2], ergänzt. Ausgangspunkt zu den hier präsentierten Ergebnissen sind vorangegangene Untersuchungen [3] zur überraschend effizienten Kühlung bei der Überschallexpansion von CO und CO_2, die in dieser Arbeit eine Erweiterung auf größere Moleküle finden.

[1] W. Christen, T. Krause, K. Rademann, *Rev. Sci. Instr.* **78**, 073106 (2007).
[2] J. Bauchert, O.-F. Hagena, *Z. Naturforschg.* **20a**, 1135-1142 (1965).
[3] W. Christen, K. Rademann, U. Even, *J. Chem. Phys.* **125**, 174307 (2006).

Q 19.5 Di 15:00 3G

Competing chemical dynamics in F^- + CH_3Cl — •Rico Otto, Jochen Mikosch, Sebastian Trippel, Christoph Eichhorn, Matthias Weidemüller, and Roland Wester — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

Chemical reactions often show a variety of competing reaction mechanisms depending on the energy available. We have studied this for anion molecule nucleophilic substitution (S_N2) reactions [1], which are described by a complex potential energy surface with a submerged barrier and by weak coupling of the relevant rotational-vibrational quantum states.

Here we present results for the anion molecule reaction F^- + CH_3I which we studied in a crossed beam imaging experiment at low energies between 0.3 - 12.5 eV. We have observed three distinct reaction channels which we identified by time of flight analysis of the formed product ions. By mapping the transfer from translational energy into internal vibrational modes we could identify different reaction mechanisms for each of these channels.

[1] J. Mikosch, S. Trippel, C. Eichhorn, R. Otto, U. Lourderaj, J. X. Zhang, W. L. Hase, M. Weidemüller, R. Wester, Science (in press)

Q 19.6 Di 15:15 3G

Nonequilibrium magnesium complexes formed in helium nanodroplets — •Andreas Przystawik, Sebastian Göde, Josef Tiggesbäumker, and Karl-Heinz Meiwes-Broer — Institut für Physik, Universität Rostock, Universitätsplatz 3, 18051 Rostock

Doping helium droplets with alkaline earth atoms is an interesting tool to investigate the interaction with the superfluid helium. Magnesium is a corner case regarding the degree of solvation in helium [1,2] which may enable the detection of quantized vortices in helium droplets.

In this contribution we add another facet to the discussion. The absorption of helium droplets doped with magnesium atoms is measured with resonant two-photon ionization at different combinations of droplet size and the number of doped Mg atoms. This enables the unambiguous identification of the absorption of an isolated atom inside the droplet centered around 279 nm. When increasing the Mg content of the droplet we find evidence for the formation of metastable, weakly bound Mg complexes. After excitation of such a complex it collapses to a Mg cluster on a timescale of 20 ps.

[1] J. Reho *et al.*, J. Chem. Phys. **112**, 8409 (2000)
[2] Y. Ren and V.V. Kresin, Phys. Rev. A **76**, 043204 (2007)

Q 19.7 Di 15:30 3G

High Resolution Spectroscopy of Acetylene-Furan in Ultracold Helium — •Anja Metzelthin, Özgür Birer, and Martina Havenith — Physikalische Chemie II, Ruhr Universität Bochum, Universitätsstr. 150, D-44780 Bochum

The acetylene-furan system is an interesting benchmark system for the evaluation of hydrogen bonds. Since acetylene is the smallest molecule containing two hydrogens and a π-system it is interesting to study the influence of a C-H "lone-pair" hydrogen-bond and a CH-π or even a π-π interaction.

The global and local minimum structures have been predicted in a recent study [1]. For the experiment the molecules have been embedded in superfluid helium nanodroplets. The radiation source was a single-resonant OPO with an output power of up to 2.7 W and a resolution of up to 4×10^{-5} cm^{-1}. Helium clusters, which have a temperature of 0.37 K are doped with acetylene (pick-up pressure 1.3×10^{-5} mbar) and furan (pick-up pressure 0.9×10^{-5} mbar) and are then excited with the OPO-radiation. A mass-spectrometer is used to detect the depletion of the cluster beam. With this setup measurements were carried out in the region of the asymmetric stretch vibration of the acetylene. Between 3256 cm^{-1} and 3280 cm^{-1} five acetylene-furan cluster peaks could be detected. Two of these could be assigned to the acetylen-furan dimer. We will present a detailed analysis of the data.

[1] E. Sánchez-García, A. Mardyukov, A. Tekin, R. Crespo-Otero, L.A. Montero, W. Sander, G. Jansen, submitted

Q 19.8 Di 15:45 3G

Molecular Spectroscopy in Superfluid Helium Nanodroplets Created in a Pulsed Even-Lavie Nozzle — •Dominik Pentlehner and Alkwin Slenczka — Universität Regensburg, Institut für Physikalische und Theoretische Chemie, 93053 Regensburg, Germany

Pulsed molecular beam sources provide enhanced particle density while the average flux of gas is reduced. Therefore, molecular spectroscopy with pulsed lasers provides a better signal to noise ratio in a pulsed molecular beam than obtained in a continuous beam. One of the most reliable pulsed molecular beam sources developed by U. Even and N. Lavie [1] was tested at low temperatures to produce a pulsed beam of superfluid helium droplets. By the observation of Rayleigh scattering and laser induced fluorescence the pulsed droplet source was characterized. The reliability of the Even-Lavie nozzle as helium droplet source appears to be excellent for repetition rates below 30 Hz. The fluorescence excitation spectra of organic molecules doped into the droplets generated in the pulsed nozzle expansion will be presented.

[1] U. Even, J. Jortner, D. Noy, and N. Lavie, C. Cossart-Magos, J. Chem. Phys. 112 (2000), 8068.

Q 20: Laseranwendungen (Lebenswissenschaften und Umwelt)

Zeit: Dienstag 14:00–15:45 Raum: 3H

Q 20.1 Di 14:00 3H

Quantitative Analyse von ^{14}NO und ^{15}NO aus menschlichem Blut — •Thomas Fritsch[1], Paris Brouzos[2], Kathrin Heinrich[1], Petra Kleinbongard[2], Malte Kelm[2], Peter Hering[1] und Manfred Mürtz[1] — [1]Institut für Lasermedizin, Universitätsklinikum Düsseldorf, Universitätsstr. 1 , 40225 Düsseldorf — [2]Molekulare Kardiologie/Medizinische Klinik I, Universitätsklinikum Aachen, Pauwelstr. 30, 52074 Aachen

In den vergangenen Jahrzehnten hat sich die Chemilumineszenzdetektion (CLD) aufgrund ihrer hohen Empfindlichkeit und Zeitauflösung zum Goldstandard des Nachweises von Stickstoffmonoxid (NO) entwickelt. Um Isotopen-markierte Substanzen im Körper verfolgen zu können, müssen andere Methoden genutzt werden, da die CLD prinzipiell nicht zwischen unterschiedlichen Isotopologen unterscheiden kann.

Wir präsentieren hier die Evaluation eines Cavity Leak-Out Spektrometers (CALOS) bei 5,2 μm. Zum Vergleich der Methoden wurden Prüfgasmischungen, Nitritlösungen und menschliche Blutproben genutzt. Neben einer hohen Übereinstimmung der Messergebnisse erreichen beide Methoden vergleichbare Nachweisgrenzen im ppt-Bereich (parts per trillion, 10^{-12}) bei Zeitauflösungen im Bereich weniger Sekunden. CALOS ergänzt diese Eigenschaften mit der Möglichkeit eines höchstempfindlichen isotopologenselektiven Nachweises.

Diese Evaluation öffnet den Weg in ein weites Gebiet von Anwendungen im biologischen und medizinischen Bereich.

Q 20.2 Di 14:15 3H

Laser-spectroscopic online analysis of hydrocarbons in exhaled human breath — •Sven Thelen, Daniel Halmer, Peter Hering, and Manfred Mürtz — Heinrich-Heine-Universität Düsseldorf, Institut für Lasermedizin, 40225 Düsseldorf, www.ilm.uni-duesseldorf.de/tracegas

The quantitative and single breath-resolved analysis of trace gases contained in human breath has constantly gained importance for medical diagnostics. A prominent example is the ethane molecule which is released as a by-product of free radical induced lipid peroxidation in the human body. Thus a rapid and non-invasive detection of ethane as a volatile marker for the oxidative stress status is very attractive for medical diagnostics.

We use Cavity Leak-Out Spectroscopy (CALOS) implementing a 50 cm long absorption cell enclosed with two high reflectivity mirrors resulting in an effective absorption path length of 3.6 km. Our Difference-Frequency Generation (DFG) laser source provides a continuous tuning range between 3.30 μm and 3.67 μm and a laser power of 280 μW.

With this technique we have analyzed the washout dynamics of ethane in the human body. We have also investigated single breath exhalations of methane regarding reproducibilty of concentration and slope of the alveolar phase. Furthermore we present the results of an intercomparison study with Gas Chromatography/Flame Ionization (GC-FID).

Q 20.3 Di 14:30 3H

Echtzeitanalyse von ^{13}CO mittels Cavity Leak-Out Spektroskopie im mittleren Infrarot — •Marcus Sowa, Thomas Fritsch, Peter Hering und Manfred Mürtz — Institut für Lasermedizin, Universitätsklinikum Düsseldorf, Universitätsstr. 1, 40225 Düsseldorf

Kohlenmonoxid (CO) entsteht im Körper beim Abbau des Häm-Moleküls, einem Bestandteil der roten Blutkörperchen. Das abgeschiedene CO wird auf Grund seiner hohen Affinität zum Hämoglobin, von diesem als Carboxyhämoglobin (HbCO) gebunden. In der Lunge wird das CO zwischen der Atemluft und dem Blut ausgetauscht. Die zu bestimmenden Konzentrationen von ^{13}CO liegen im Normalfall im Bereich weniger ppb. Die Messung beruht auf dem Prinzip der Cavity Leak-Out Spektroskopie (CALOS) im mittleren Infrarot bei ca. 5μm. Die Nachweisgrenze des verwendeten Systems liegt bei 0,7ppb·$Hz^{-1/2}$ für das ^{13}CO. Der verwendete Aufbau ermöglicht die isotopologenselektive und atemzugsaufgelöste Detektion des ^{13}CO aus der Atemluft, sowie die Analyse anderer biologischer Proben. Mögliche Anwendungen sind z.B. die Durchführung von CO-Atemtests mit so geringen Konzentrationen und Mengen an CO, dass die zulässigen Höchstwerte, auch bei längeren Tests, nicht überschritten werden. Des Weiteren kann unter Hinzunahme von spirometrischen Daten die Carboxyhämoglobinkonzentration der Testperson isotopologenselektiv bestimmt werden. Im Rahmen des Vortrags sollen das Messsystem und erste Ergebnisse präsentiert werden.

Q 20.4 Di 14:45 3H

Isotopologenselektive Echtzeitmessung von ^{14}NO und ^{15}NO im menschlichen Atem mittels höchstsensitiver Cavity-Leak-Out Spektroskopie — •Kathrin Heinrich, Thomas Fritsch, Peter Hering und Manfred Mürtz — Institut für Lasermedizin, Universitätsklinikum Düsseldorf, Universitätsstr.1, 40225 Düsseldorf

Mit zunehmender Erkenntnis über die Bedeutung von Spurengasen im menschlichen Atem steigt die Relevanz einer höchstempfindlichen Nachweismethode zur Detektion kleinster Molekülkonzentrationen in gasförmigen Proben. Viele für die medizinische Diagnostik interessanten Moleküle besitzen im mittleren Infrarotbereich ein charakteristisches Absorptionsspektrum. Die Cavity-Leak-Out Spektroskopie ermöglicht einen Nachweis dieser Spurengase im sub-ppb Bereich bei einer Zeitauflösung von unter 1 s. Auf der Basis eines durchstimmbaren CO-Lasers (λ=5 μm) wird die Abschwächung der Laserintensität nach dem Durchgang durch die gasförmige Probe, welche sich in einem optischen Resonator befindet, gemessen. Die kontinuierliche Durchstimmbarkeit des Lasersystems bietet zudem die Möglichkeit eines isotopologenselektiven Nachweises. Als ein mögliches Anwendungsbeispiel wird der isotopologenselektive, atemzugsaufgelöste Nachweis von ^{14}NO und ^{15}NO im menschlichen Atem vorgestellt. Die rauschäquivalente Absorption beträgt 180 ppt/$Hz^{1/2}$ für ^{14}NO und 150 ppt/$Hz^{1/2}$ für ^{15}NO. Durch die simultane ^{14}NO/^{15}NO-Messung sind Veränderungen im Isotopenverhältnis detektierbar, so dass z.B. verschiedene Stoffwechselpfade nach Gabe von ^{15}N-markierten Substanzen verfolgt und differenziert werden können.

Q 20.5 Di 15:00 3H

Bohrungen in biologischem Hartgewebe mit gepulsten CO_2- Lasern — •Romina Krieg[1], Martin Werner[1,2], Manfred Klasing[2], Ulrike Endesfelder[2,3] und Peter Hering[1] — [1]Institut für Lasermedizin, Heinrich Heine Universität Düsseldorf — [2]Forschungszentrum caesar, Bonn — [3]Helmholtz Institut für Strahlen- und Kernphysik, Rheinische Friedrich Wilhelms Universität, Bonn

Mit gepulster Laserstrahlung lässt sich Knochenmaterial gut in beliebiger Geometrie abtragen. Es wird gepulste CO_2 - Laserstrahlung verwendet, die gut im Knochen absorbiert wird, und bei geeigneten Laserparametern keine thermischen Schäden im Gewebe verursacht. Das Ziel sind zylindrische Bohrungen mit beliebigem Durchmesser und Tiefe, um Implantate in den Kieferknochen ein zu bringen. Deshalb sollten die Bohrungen möglichst formtreu sein. Der Knochenabtrag wird dabei durch ein Füllmuster innerhalb der Geometrie erzeugt. Zur Verbesserung des Ergebnisses lässt sich zusätzlich der Rand der Bohrung abfahren. Bei dieser Art der Materialbearbeitung mit Lasern ist die abnehmende Effizienz mit zunehmender Tiefe problematisch, da konische Bohrungen entstehen können. Außerdem sind die Bohrungen im Profil nicht symmetrisch, was sich in unterschiedlichen Bohrwinkeln und schrägen Böden bemerkbar macht. Um diese Probleme zu beheben, wurden die effektivsten Bohrreihenfolgen bestimmt. Durch Variation der Reihenfolge von Füllmuster und Rand wurde die Konizität bereits erheblich verringert.

Q 20.6 Di 15:15 3H

Analyse der optischen und akustischen Feedback-Signale bei Ablation von biologischem Gewebe mit einem gepulsten CO_2 Laser — •Ulrike Endesfelder[1,2], Martin Werner[1,3], Manfred Klasing[1], Peter Hering[1,3] und Romina Krieg[1,3] — [1]Forschungszentrum caesar, Bonn — [2]HISKP, Universität Bonn — [3]Institut für Lasermedizin, Universität Düsseldorf

Die anwendbaren Laserapplikationen in der Medizin wurden in den letzten Jahren auch auf den Bereich der Laserosteotomie, d.h. die berührungslose Abtragung von Knochengewebe, erweitert.

Die Laserosteotomie bietet einige Vorteile im Vergleich zu den üblichen Verfahren in der Chirurgie, vor allem durch eine sehr hohe Präzision und die freie Wahl der Abtragungsgeometrie.

Die benutzten kurzgepulsten CO_2-Laser stellen in Kombination mit einem Wasserspray und einer speziellen Multi-Pass-Scan-Technik eine effiziente und thermisch minimal belastende Möglichkeit dar, Knochengewebe für medizinische Anwendungen zu bearbeiten.

Diese Arbeit stellt ein Kontrollverfahren des Bearbeitungsfortschritts vor. Entscheidend hierbei ist die Erkennung der Grenze zwischen dem Knochengewebe und dem unterliegendem Weichgewebe, welches geschont werden soll. Da die Laserablation von einem Leuchten in einem breiten Spektralbereich und von akustischen Signalen begleitet ist, liegt es nahe, beides für die Diagnostik zu nutzen.

Im Rahmen dieser Arbeit wurden die gewebespezifischen Unterschiede in den laserinduzierten Ablationssignalen untersucht. Hierbei wurden insbesondere die Grenzen des Kontrollverfahrens ausgelotet.

Q 20.7 Di 15:30 3H

Weiterentwicklung eines optischen Messverfahrens zur Untersuchung der Gemischbildung von Kraftstoff-Luft-Gemischen — •Jens Müller, Jochen Scholz und Volker Beushausen — Laser-Laboratorium Göttingen e.V., Hans-Adolf-Krebs-Weg 1, 37077 Göttingen, www.llg-ev.de

Die Emission von Schadstoffen und der Kraftstoffverbrauch von neuen Motorkonzepten hängen stark von der Präparierung des Luft-Kraftstoffgemisches und der räumlichen und zeitlichen Verteilung des Gemisches im Zylinder ab. Das Ziel unserer Arbeit ist die Entwicklung eines 2-D Messverfahrens zur ortsaufgelösten Erfassung des Luft/Kraftstoff-Verhältnisses (Lambda-Wert) im Motorbrennraum bei Einsatz von Realkraftstoffen ohne Zusatz von Kraftstofftracern. Zur Erfassung des Lambda-Wertes wird eine Variante der Laser-induzierten Fluoreszenz (LIF), das sogenannte "Fuel-Air-Ratio-LIF" (FARLIF) eingesetzt. Hierbei werden fluoreszenzlöschende Eigenschaften von Sauerstoff ausgenutzt, die unter bestimmten Randbedingungen eine direkte Proportionalität der gemessenen Fluoreszenzlichtintensität zum Lambda-Wert generieren. Bisher konnte die Einsatzfähigkeit der FARLIF-Messtechnik nur unter Verwendung von nicht fluoreszierenden Modellkraftstoffen mit dem Fluoreszenztracer Toluol und nur moderaten Temperaturen nachgewiesen werden. Die hier präsentierten Arbeiten beschäftigen sich insb. mit der Validierung des FARLIF-Verfahrens für den Einsatz in Realkraftstoffen und bei hohen Temperaturen bis zu 700K.

Q 21: Quanteninformation (Quantencomputer II)

Zeit: Dienstag 16:30–17:30 Raum: 1B

Q 21.1 Di 16:30 1B

Towards two-dimensional quantum simulations with trapped ions — •Christian Schneider, Robert Matjeschk, and Tobias Schätz — Max-Planck-Institut für Quantenoptik

An ion crystal in a Paul trap is a promising candidate for a quantum simulator or analogue quantum computer. Thereby a quantum system shall be implemented and studied which is described by the same Hamiltonian as the system to be simulated. The crucial parameters of the implemented system are accessible which is often not the case for the "real" sytem. First experimental results in building a quantum simulator for a quantum spin Ising Hamiltonian with two ions have recently been shown [1].

To gain deeper insight into quantum dynamics, we plan to extend these fundamental experiments to more ions and into two dimensions [2]. As successful studies of one-dimensional planar Paul traps have been shown [3,4], a promising approach is to realize a two-dimensional array of trapped ions in a planar two-dimensional surface trap. We want to show our visions of two-dimensional quantum simulations and first steps towards their realization by a two-dimensional Paul trap of 2×2 ions.

[1] Phys. Rev. Lett., to be submitted
[2] T. Schätz et. al., J. Mod. Opt., accepted
[3] J. Chiaverini et. al., Quant. Inf. Comp. 5, 419–439
[4] S. Seidelin et. al., Phys. Rev. Lett. 96, 253003–4

Q 21.2 Di 16:45 1B

Coherent Transport of Atoms in Arrays of Dipole Traps — •Jens Kruse, Andre Lengwenus, Malte Schlosser, Christian Gierl, Joost Sattler, and Gerhard Birkl — Institut für Angewandte Physik, TU Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt

For the experimental realization of quantum information processing it is essential to perform one- and two-qubit operations in a controlled fashion. In our approach, qubits are inscribed in the hyperfine states of rubidium atoms. The atoms are trapped in a two-dimensional array of well separated optical micro-potentials created by micro-fabricated lens arrays. We already demonstrated single-qubit operations by the coherent coupling of the hyperfine ground states of ^{85}Rb by stimulated Raman transitions.

We plan the realization of two-qubit gates by the use of ultracold collisions. For this, atoms have to be transported from one trap position to another. We demonstrate the transfer of atoms in microtraps using steering methods which are based on the variation of the incident angle of the laser beam illuminating the array of microlenses. By using Ramsey and spin-echo methods we study the effects of transport on the coherence of the system. We observed that the transfer of atoms over a distance of up to the full trap separation does not cause any additional loss of coherence.

Q 21.3 Di 17:00 1B

Grundzustandskühlung und Qubit-Manipulation in einer segmentierten Mikroionenfalle — •Stephan Schulz, Ulrich Poschinger, Frank Ziesel und Ferdinand Schmidt-Kaler — Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, 89069 Ulm

Mikrostrukturierte segmentierte lineare Paulfallen zur Speicherung und Manipulation von Qubit-Systemen mittels Ionenkristallen sind ein aussichtsreicher Ansatz auf dem Weg zum skalierbaren Quantencomputer.

Wir zeigen experimentelle Ergebnisse für eine lineare segmentierte Mikroionenfalle mit $^{40}Ca^{+}$-Ionen. Die insgesamt 31 Segmentpaare sind mit 62 verschiedenen elektrischen Spannungen ansteuerbar und in einen Speicher- (9 Segmentpaare), Transfer- (3) und Prozessorbereich (19) unterteilt. Die Breite der Segmentpaare beträgt $250\mu m$ bzw. $100\mu m$. Es werden radiale und axiale Fallenfrequenzen im MHz-Bereich gemessen.

Die gefangenen Ionen werden nach Dopplerkühlen auf dem $S_{1/2} \leftrightarrow P_{1/2}$-Übergang durch Fluoreszenz auf diesem Übergang nachgewiesen. Mittels Seitenbandspektroskopie auf dem $S_{1/2} \leftrightarrow D_{5/2}$-Übergang wird die Mikroionenfalle charakterisiert und die Mikrobewegung kompensiert. Der Quadrupolübergang erlaubt die kohärente Qubit-Manipulation. Wir berichten von Grundzustandskühlen und Rabioszillationen in der Mikrofalle.

Q 21.4 Di 17:15 1B

New universal resource states — •David Gross and Jens Eisert — Institute for Mathematical Sciences, Imperial College London, 53 Prince's Gate, London SW7 2PG, UK

Based on a previously established framework [1], we present new examples of universal resource states for measurement-based quantum computation. In particular, we discuss the concept of "quantum wires". These are quantum states on a one-dimensional string, which can be used to transport and process quantum information solely by means of local measurements. In a certain parameter regime, quantum wires can be completely parameterized and their properties explicitly computed. States of these kind may be thought of as primitives for the construction of two-dimensional resources states, universal for quantum computing. We discuss means of coupling such one-dimensional wires to form universal resources.

[1] D. Gross and J. Eisert, Phys. Rev. Lett. 98, 220503 (2007); D. Gross, J. Eisert, N. Schuch, and D. Perez-Garcia, Phys. Rev. A 76, 052315 (2007).

Q 22: Quantengase (Gitter II)

Zeit: Dienstag 16:30–18:00 Raum: 1C

Q 22.1 Di 16:30 1C

Resonant Feshbach scattering of fermions in one-dimensional optical lattices — •Michael Grupp[1], Reinhold Walser[1], Wolfgang Schleich[1], Alejandro Muramatsu[2], and Martin Weitz[3] — [1]Institut für Quantenphysik, Universität Ulm, Germany — [2]Institut für Theoretische Physik III, Universität Stuttgart, Germany — [3]Institut für Angewandte Physik der Universität Bonn, Germany

We consider Feshbach scattering of fermions in an one-dimensional optical lattice. By formulating the scattering theory in the crystal momentum basis, one can exploit the lattice symmetry and factorize the scattering problem in terms of center-of-mass and relative momentum in the reduced Brillouin zone scheme. Within a single-band approximation, we can tune the position of a Feshbach resonance with the center-of-mass momentum due to the non-parabolic form of the energy band. We present numerical results for the resonant scattering in an one-dimensional lattice. In order to understand this results we discuss an analytic model for the coherent tunneling of atoms and dimers in half spaces.

[1] M. Grupp et al., J. Phys. B **40** (2007) 2703-2718

Q 22.2 Di 16:45 1C

Quantum Transport Experiments in Fourier-Synthesized Optical Lattices — •Tobias Salger, Carsten Geckeler, Sebastian Kling, and Martin Weitz — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn, Germany

We report on experiments studying quantum transport of Bose-Einstein condensates in variable periodic optical potentials. We have studied the band structure of both ratchet-type asymmetric and symmetric optical potentials by the Landau-Zener effect and Bloch oscillations. The variable atom potential is realized by superimposing a conventional standing wave with $\lambda/2$ spatial periodicity with a fourth-order multiphoton potential of $\lambda/4$ periodicity. The multiphoton lattice is realized using the dispersive properties of multiphoton Raman transitions [1]. We find that the strength of interband transitions depends critically on the shape of the synthesized lattice potential [2]. Furthermore we report on studies of Bloch-oscillations in the variable lattice potential.

[1] R. Ritt et al., Phys. Rev. A **74**, 063622 (2006)
[2] T. Salger et al., Phys. Rev. Lett. **99**, 190405 (2007)

Q 22.3 Di 17:00 1C

Fermion induced long-range interaction in the Bose-Fermi-Hubbard model — •Alexander Mering and Michael Fleischhauer — Technische Universität Kaiserslautern

We present recent results on the Bose-Fermi-Hubbard model in the limit of fast (ultralight) fermions. In this case, the fermions act as virtual quanta giving rise to an effective long-range density-density interaction for the bosons. Starting from the full BFH Hamiltonian we adiabatically eliminate the fast fermions. It is important to include the mean field backaction of the bosons into the free dynamics of the fermions. This yields a renormalized long-range boson-boson interaction. The resulting bosonic Hamiltonian is studied analytically using a bosonization approach as well as numerically using the density-matrix-renormalization-group (DMRG). In particular the transition between a CDW-phase and a compressible phase with exponentially decaying bosonic correlations is studied analytically compared to DMRG results.

Q 22.4 Di 17:15 1C

Counting atoms using interaction blockade in optical superlattices — •Ute Schnorrberger[1], Patrick Cheinet[1], Stefan Trotzky[1], Michael Feld[1,2], Simon Fölling[3], and Immanuel Bloch[1] — [1]Institut für Physik der Universität Mainz — [2]Fachbereich Physik der Technischen Universität Kaiserslautern — [3]Harvard University, USA

We demonstrate the ability to accurately measure the occupation number statistics of ultra cold atoms loaded in a 3D optical lattice by means of an interaction blockade effect analogue to the Coulomb blockade observed in mesoscopic solid state systems.

We present results where a ^{87}Rb BEC was loaded in a 3D optical lattice either in the superfluid regime or in the Mott-Insulator regime. When ramping up an additional lattice on one axis with half the periodicity of the initial one we create an array of double wells. The bias, which means the tilt of the double wells, can be controlled by the relative phase between the two lattices forming this superlattice. Whenever the applied bias potential is high enough to compensate the interaction blockade, tunneling resonances occur. We observe these resonances by measuring the resulting atom numbers of each side of the double wells for the whole ensemble with different bias. The number distribution in the underlying long lattice is extracted from the resonance amplitudes measured for the ensemble of the double wells. This allows us to fully characterize the markedly different number distributions in the superfluid and Mott-Insulator regime.

Q 22.5 Di 17:30 1C

A new experiment towards single site addressability in optical lattices — •Christof Weitenberg, Jacob Sherson, Oliver Loesdau, Manuel Endres, Jan Petersen, Immanuel Bloch, and Stefan Kuhr — Institut für Physik,Universität Mainz, Staudingerweg 7, 55128Mainz

We build a new experiment with ^{87}Rb atoms in an optical lattice which will allow for atom detection and manipulation with single site resolution. The central part of the new experiment is an ultra-high resolution imaging system with a spatial resolution of 300 nm. Single site manipulation will be achieved by focussing an addressing laser onto individual lattice sites.

Ultracold atoms will be loaded into the lattice from a Bose-Einstein condensate (BEC). It is generated in a crossed optical dipole trap formed by a 50 W YAG laser. The trap can be dynamically compressed by moving the foci of the laser beams. The BEC will be transported by a single beam dipole trap in front of the imaging system and transferred into the optical lattice.

The aim of our project is to prepare and to study single one- and two dimensional quantum systems. Single site addressability will allow us to modify or perturb the system on a local scale and to observe the ensuing dynamics of the many-body system in real time. Quantum gates and entanglement between neighbouring atoms can, for example, be obtained by collisions in a spin-dependent lattice.

Q 22.6 Di 17:45 1C

Controlled Loading of an Ultracold Bose-Fermi-Mixture into an Optical Lattice Potential — •Sebastian Will, Thorsten Best, Ulrich Schneider, Lucia Hackermüller, Dries van Oosten, and Immanuel Bloch — Johannes Gutenberg-Universität Mainz

The formation of heteronuclear molecules is a major goal of multi-species experiments with ultracold atoms. In this context optical lattices are expected to enhance the lifetime of weakly bound Feshbach molecules considerably by protective enclosure of single molecules on single lattice sites. However, the achievement of this configuration necessitates appropriate loading of the atomic clouds into the lattice before association.

In our setup we cool fermionic ^{40}K with bosonic ^{87}Rb sympathetically, reaching simultaneous quantum degeneracy with about $2 \cdot 10^5$ atoms per species. We load this mixture into a blue-detuned optical lattice and adjust the external confinement independently with additional red-detuned laser beams. This allows for the creation of an almost homogeneous lattice potential. Together with tuneable interspecies interactions our setup permits controlled loading - suitable for the creation of molecules in the lattice.

Q 23: Photonik II

Zeit: Dienstag 16:30–18:00 Raum: 2B/C

Q 23.1 Di 16:30 2B/C

Limits for kinematical diffraction of visible light from three dimensional photonic crystals — •Marcel Roth[1], Ullrich Pietsch[1], Georg von Freymann[2], and Martin Wegener[2] — [1]Institute of solid state physics, University of Siegen, 57072 Siegen, Germany — [2]Institute of applied physics, University of Karlsruhe, 76131 Karlsruhe, Germany

For the majority of research studies with photonic crystal the existence and spectral width of a photonic band gap are of main interest. Light diffraction experiments with wavelengths in the visible and near infrared spectrum are predominantly used to verify the structural quality of the crystals.
The usage of photonic crystals as purely diffractive elements in optical detectors is a relatively new idea. Due to the three dimensional periodic structuring an incoming white beam is spatially seperated into symmetry equivalent coloured spots that can be used for object recognition.
All geometrical aspects can be understood in the framework of the von Laue equations. On the other side an analytical description for diffraction efficiencies is restricted to the case of kinematical scattering well known from the x-ray diffraction. This approximation is typically not valid for most photonic crystals because of large dielectric contrasts.
In this talk we present experimental investigation and results of numerical calculations based on Maxwell equations which show that the limit for kinematical diffraction at photonic crystals is estimated for a relative dielectric mismatch of about 5%.

Q 23.2 Di 16:45 2B/C

Optical properties of three-dimensional photonic quasicrystals and their periodic approximants — •Alexandra Ledermann[1], Costanza Toninelli[2], Diederik S. Wiersma[2], Martin Wegener[1], and Georg von Freymann[1] — [1]Institut für Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft, DFG-Center for Functional Nanostructures (CFN) and Institut für Angewandte Physik, Universität Karlsruhe (TH) — [2]European Laboratory for Nonlinear Spectroscopy (LENS) and INFM, Firence

Quasicrystals (QC) represent a class of solids which lack translational symmetry, but exhibit perfect long-range order and reveal well-defined rotational symmetries, not necessarily consistent with periodicity.

Using direct laser writing [1] we fabricate three-dimensional icosahedral SU-8 photonic QCs of high quality [2] and their so-called periodic approximants [3]. The optical properties of both QC and approximants are studied experimentally and show good agreement with corresponding simulations for the approximants. Time-resolved pulse propagation studies reveal the strongly diffracting character of QC which causes a strong delay and pulse reshaping during the propagation.

This work is an important step towards a better understanding of the effects of quasiperiodicity.

[1] M. Deubel et al., Nature Materials, 3, 444 (2004).
[2] A. Ledermann et al., Nature Materials, 5, 942 (2006).
[3] C. Janot, Quasicrystals- A Primer, Clarendon, Oxford (1992).

Q 23.3 Di 17:00 2B/C

Photonic Metamaterials by Direct Laser Writing and Silver Chemical Vapor Deposition — •Christine Plet[1], Michael Rill[1], Michael Thiel[1], Stefan Linden[2], Georg von Freymann[2], and Martin Wegener[1,2] — [1]Institut für Angewandte Physik, Universität Karlsruhe (TH), 76128 Karlsruhe, Germany — [2]Institut für Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft, 76021 Karlsruhe, Germany

Metamaterials are man-made composite structures composed of metallic sub-wavelength scale functional building blocks that are densely packed into an effective material [1,2]. This approach especially allows for artificial magnetism at elevated frequencies.

We fabricate planar magnetic photonic metamaterials via direct laser writing [3] and silver chemical vapor deposition, an approach, which is also suitable for three-dimensional structures.

When retrieving effective metamaterial parameters for normal incidence of light, one has to be cautious because the fabricated structures are non-centrosymmetric. Thus, a description in terms of just electric permittivity ε and magnetic permeability μ is fundamentally not possible. Here, we follow the bi-anisotropic retrieval described in Ref. [4].

[1] V.M. Shalaev, Nature Phot. **1**, 41 (2006)
[2] C.M. Soukoulis, S. Linden, and M. Wegener, Science **315**, 47 (2007)
[3] see, e.g., http://www.nanoscribe.de
[4] X. Chen, B. Wu, J. Kong, and T. Grzegorczyk, Phys. Rev. E **71**, 046610 (2005)

Q 23.4 Di 17:15 2B/C

3D analysis of polarization singularities in Laser speckle — •Florian Flossmann[1], Kevin OHolleran[1], Miles J. Padgett[1], and Mark R. Dennis[2] — [1]University of Glasgow, United Kingdom, Department of Physics and Astronomy — [2]University of Bristol, United Kingdom, H.H. Wills Physics Laboratory

Singularities of the polarization of light are the vectorial analogies to optical vortices (phase singularities) in scalar optics. Two types are known: L lines of linear polarization and C points of circular polarization, the latter can be further devided into lemon, star and monstar type C points. In 3D, they occur as L surfaces and C lines. Laser speckle fields, as a random superposition of coherent plane waves, form the most natural interference pattern and are therefore an obvious place to look for generic optical singularities "in the wild". Following our earlier work on the 3D topology of phase singularity lines in laser speckle (O'Holleran, submitted PRL) and on the natural unfolding of optical vortices into generic polarization singularities (Flossmann,PRL 2005), we investigate both experimentally and numerically the singularities of polarization (C lines and L surfaces) in a random vector field as found in polarized laser speckle. With that we present the (to our knowledge) very first truely 3 dimensional visualization of polarization singularities in optics from experimentally obtained data. We show for example, how C loops always consist of lemon, star and monstar type C points and perform a statistical analysis of the ratios of those types per line length.

Q 23.5 Di 17:30 2B/C

Controlled coupling of emitters to SiN photonic crystal cavities — •Johannes Stingl[1], Michael Barth[1], Josef Kouba[2], Bernd Löchel[2], and Oliver Benson[1] — [1]Nano-Optik, Institut für Physik, Humboldt-Universität zu Berlin, Hausvogteiplatz 5-7, 10117 Berlin — [2]Anwenderzentrum für Mikrotechnik, BESSY GmbH, Albert-Einstein-Str. 15, 12489 Berlin

The controlled coupling of emitters to photonic crystal (PC) cavities is a crucial issue for future applications of integrated PC structures. Here we present a versatile approach to this problem based on the manipulation of nanoscopic particles on the PC surface by scanning probe techniques. This method allows a deterministic and reversible coupling of one or more light emitting particles to the cavities after the fabrication of the samples. We apply this approach to couple diamond nanocrystals containing NV color centers to SiN PC cavities. These cavities operate in the visible wavelength range between 550 nm and 800 nm and are therefore ideally suited to manipulate the emission properties of a broad variety of emitters in the visible. Despite the relatively small refractive index of SiN (n = 2.0) the cavity quality factors have been optimized to values of up to 1500 by carefully designing the cavity geometry. Our experimental studies are accompanied by numerical simulations investigating the influence of nanoscopic particles on the optical properties of PC cavities. For the system studied here, the impact on the resonance frequency and quality factor turns out to be negligible for particle diameters well below 100 nm.

Q 23.6 Di 17:45 2B/C

A model for the photon — •Karl Otto Greulich — Fritz Lipmann Institute Jena Beutenbergstr. 11 07745 Jena

Hundred years of research into the photon have not resulted in a model beyond the photon being the result of field quantisation. Quantum mechanics has no suitable operator to describe space details, quantum electrodynamics is inherently non relativistic. Here, a semi classical model is presented, which correctly predicts that E = h * v, that the space requirements are governed by the wavelength and that the spin is h / 2pi. Also, the cross section of electron / positron pair production is predicted. The model is based on an LC oscillator and therefore requires formal / virtual charged matter as oscillating entity. The amomunt of charge required is, in a wavelength independent manner, the 1 / square root of alpha times the elementary charge. This at a first glance surprising result is supported by quantum electrodynamics, since 1 / square root of alpha is the inverse coupling constant, which can be interpreted as the probability of an electron to emit a photon. The fine structure constant alpha itself can then be interpreted as the inverse square of the formal number of elementary charges required to quantitatively describe a photon. Ref: K.O. Greulich in: The nature of light : what are photons R.Roychoudhuri et al eds. 2007 SPIE Vol 66640B, 1

Q 24: Ultrakalte Moleküle [gemeinsam mit MO]

Zeit: Dienstag 16:30–18:00 Raum: 3G

Q 24.1 Di 16:30 3G

Photoassociation of ultracold molecules by shaped femtosecond laser pulses — •Wenzel Salzmann[1], Terry Mullins[1], Simone Götz[1], Roland Wester[1], Magnus Albert[1], Judith Eng[1], Matthias Weidemüller[1], Fabian Weise[2], Andrea Merli[2], Stefan Weber[2], Franziska Sauer[2], Mateusz Plewicki[2], Ludger Wöste[2], and Albrecht Lindinger[2] — [1]Physikalisches Institut, Universität Freiburg, Herrmann-Herder-Str.3, 79104 Freiburg — [2]Institut für Physik, Freie Universität Berlin, Arnimallee 14

We present first experiments on the formation on photoassociation of ultracold molecules with shaped femtosecond laser pulses. In a pump-probe sequence of laser pulses, molecules are produced in their excited state from an ultracold gas of rubidium atoms and subsequently ionized. Molecular ions are mass selectively detected with single ion efficiency. Pulse shaping techniques are used to restrict the pump pulse spectral intensity to address only bound molecular potentials of the first electronically excited state and to suppress atomic losses from the trap due to ionization [1]. The pump-probe detected molecular ion signal shows rich oscillatory dynamics, caused by coherent interactions of molecular electronic dipole with the electric field of the pump pulse [2]. Analysis of the data is accompanied by quantum dynamical simulations which give detailed insight into the pulsed photoassociation process. We further find indications for the formation of molecules in their electronic ground state by spontaneous decay.

[1] W. Salzmann *et al.*, PRA 73, 023414 (2006)
[2] A. Monmayrant *et al.*, PRL 96, 103002 (2006)

Q 24.2 Di 16:45 3G

Engineering an all-optical route to ultracold molecules in their vibronic ground state — •Christiane P. Koch[1] and Robert Moszynski[2] — [1]Freie Universität Berlin, Institut für Theoretische Physik, Arnimallee 14, 14195 Berlin, Germany — [2]Dept. of Chemistry, University of Warsaw, Pasteura 1, 02-093 Warsaw, Poland

We propose an improved photoassociation scheme to produce ultracold molecules in their vibronic ground state. Formation of molecules is achieved by short laser pulses in a Raman-like pump-dump process where an additional (near-)infrared laser field couples the excited state to an auxiliary state. The efficiency of population transfer is determined by the shape of the excited state potential; it is dauntingly low for typical potentials. In our proposal, the coupling due to the additional field effectively changes the shape of the excited state potential, allowing for efficient population transfer to v=0. Such a field-induced coupling can significantly enhance any short pulse Raman-like process.

Q 24.3 Di 17:00 3G

Photoassociation of ultracold LiCs — •Christian Glück, Jörg Lange, Johannes Deiglmayr, Stephan Kraft, Karin Mörtlbauer, Anna Grochola, Roland Wester, and Matthias Weidemüller — Albert-Ludwigs Universität, Physikalisches Institut, Hermann-Herder-Str. 3, 79104 Freiburg i.Brsg., Germany

We recently demonstrated the formation of ultracold LiCs molecules by the trapping light of a double species magneto optical trap [1]. After spontaneous decay into the electronic ground state and one-color two-photon ionization, the molecular ions are detected by a high-resolution time-of-flight mass spectrometer [2].

Here we present the active photoassociation of ultracold LiCs molecules, leading to a significantly increased production rate. Photoassociation resonances in the $B^1\Pi$ potential correlated to the $2S_{1/2}$-$6P_{3/2}$ asymptote are identified and the ro-vibrational state distribution of the produced ground state molecules is discussed. The perspectives for the production of LiCs molecules in the absolute ground state are evaluated and future experiments with an ultracold gas of polar LiCs molecules are outlined.

[1] S. D. Kraft *et al.*, J. Phys. B **39**, S993
[2] S. D. Kraft *et al.*, to appear in Applied Physics B

Q 24.4 Di 17:15 3G

Towards a BEC of Ground State Molecules — •Johann Georg Danzl, Mattias Gustavsson, Elmar Haller, Manfred Mark, and Hanns-Christoph Nägerl — Institut für Experimentalphysik und Forschungszentrum für Quantenphysik, Universität Innsbruck, Innsbruck, Austria

We report on recent progress on optical spectroscopy of ultracold Cs_2 Feshbach molecules. Our ultimate goal is the production of ultracold molecules in the rovibrational ground state of the singlet molecular potential [1] and the production of a BEC of ground state molecules. Coherent state transfer with an efficiency approaching unity should be possible by means of stimulated Raman adiabatic passage (STIRAP) [2]. We plan to apply two consecutive two-photon STIRAP steps where the first step will transfer the molecules from the initial Feshbach state to an intermediate vibrational level near ν=70 of the singlet potential. As part of the first step, we have found several strong bound-bound transitions in the wavelength region 1120 nm to 1130 nm, far off resonance from the atomic D1 and D2 lines.

[1] D. Jaksch, V. Venturi, J. I. Cirac, C. J. Williams, and P. Zoller, Creation of a Molecular Condensate by Dynamically Melting a Mott Insulator, Phys.Rev. Lett. 89, 040402 (2002).
[2] K. Winkler, F. Lang, G. Thalhammer, P. v.d. Straten, R. Grimm, J. Hecker Denschlag, Coherent optical transfer of Feshbach molecules to a lower vibrational state, Phys. Rev. Lett. 98, 043201 (2007)

Q 24.5 Di 17:30 3G

Few-body physics with ultracold Cs atoms and molecules — •Steven Knoop[1], Francesca Ferlaino[1], Martin Berninger[1], Harald Schöbel[1], Michael Mark[1], Hanns-Christoph Nägerl[1], and Rudolf Grimm[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Innsbruck, Austria

Ultracold atomic gases are versatile systems to study few-body physics because of full control over the external and internal degrees of freedom and the magnetic tunability of the scattering properties using Feshbach resonances. Here we experimentally study three- and four-body physics by investigating ultracold atom-dimer and dimer-dimer collisions with Cs Feshbach molecules in various molecular states and Cs atoms in different hyperfine states. Resonant enhancement of the atom-dimer relaxation rate is observed and interpreted as being induced by a trimer state [1]. For dimer-dimer collisions we have observed an unexpected temperature dependence and a suppression of the collisional loss rate [2].

[1] S. Knoop et al., in preparation [2] F. Ferlaino et al., in preparation

Q 24.6 Di 17:45 3G

Photoassociation spectroscopy in a mixture of ultracold Rb and Yb atoms — Nils Nemitz, •Florian Baumer, Frank Münchow, and Axel Görlitz — Institut für Experimentalphysik, HHU Düsseldorf, Germany

Currently, many groups are pursuing the production of ultracold heteronuclear molecules in the electronic ground state. Among the most fascinating features that such a system would offer are the study of strongly dipolar quantum gases and potentially fundamental precision measurements for suitably chosen molecules.

The goal of our experiment is the formation of molecules through photoassociation of ultracold paramagnetic Rb atoms and diamagnetic Yb atoms. The first step towards this goal is the investigation of one-photon spectroscopy from the atomic ground state of the two atomic species to an electronically excited state of the heteronuclear RbYb molecule.

Here, we report on recent results of photoassociation spectroscopy close to the Rb D1-transition at 795 nm in a combined magneto-optical trap. By detecting the Yb trap loss as a function of the frequency of the photoassociation laser, we are able to observe spectral lines corresponding to several vibrational states and resolve the rotational substructure of the excited RbYb molecule.

The next steps will be photoassociation spectroscopy of conservatively trapped RbYb mixtures and the extension to two-photon photoassociation in order to produce ultracold ground state molecules.

Q 25: Laseranwendungen (Spektroskopie)

Zeit: Dienstag 16:30–18:45 Raum: 3H

Q 25.1 Di 16:30 3H

Laserinduzierter, polarisationsabhängiger Übergang von Absorption zu Transparenz im Cäsiumatomstrahl — •Katrin Dahl, Luca Spani Molella, Rolf-Hermann Rinkleff und Karsten Danzmann — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Institut für Gravitationsphysik, Leibniz Universität Hannover, Callinstr. 38, D-30167 Hannover

Ein geschlossenes N-System zeigt üblicherweise elektromagnetisch induzierte Absorption, wenn es mit einem resonanten Koppel- und einem Probelaser wechselwirkt. Die Absorptionsprofile für verschiedene Polarisationskombinationen beider Laser (linear und senkrecht zueinander, entgegengesetzt zirkular zueinander, linear-zirkular sowie zirkular-linear) wurden in Abhängigkeit der Laserleistungen detektiert. Dabei ist beim Koppellaser für alle Polarisationskombinationen, außer der rein zirkularen, Absorption in Transparenz [1] beobachtet worden. Anders ausgedrückt war im Bereich um die 2-Photonen-Resonanz die Absorption kleiner als die der 1-Photonen-Resonanz. Zusätzlich befand sich ein Peak auf der 2-Photonen-Resonanz. Bei entgegengesetzt zirkular polarisiertem Licht wurde in Abhängigkeit der Laserleistungen ein Umklappen dieses Peaks beobachtet. Das Medium wurde für den Koppellaser transparenter. Es lag Transparenz in Transparenz vor.

Dieses Projekt wurde im Rahmen des SFB407 der DFG gefördert.

[1] L. Spani Molella, R.-H. Rinkleff, K. Danzmann, Phys. Rev. A 72, 041802(R) (2005)

Q 25.2 Di 16:45 3H

Photo-induced electron and energy transfer in pyrene-flavin-phenothiazine dyad and triad complexes — •Javid Shirdel[1], Alfons Penzkofer[1], Roman Procházka[2], Zhen Shen[2], and Jörg Daub[2] — [1]Institut II - Physik, Universität Regensburg, D-93040 Regensburg — [2]Institut für Organische Chemie, Universität Regensburg, D-93040 Regensburg

A pyrene-isoalloxazine dyad, a phenothiazine-phenylene-isoalloxazine dyad, and a pyrene-isoalloxazine-phenothiazine triad, dissolved in dichloromethane are characterized by absorption and emission spectroscopy. The dyads studied are model compounds for the flavin based blue-light photoreceptors phototropin (interaction between FMN and Cys) and BLUF (interaction between FAD and Tyr). The triad was designed to mimic the dye-based functions of blue-light cryptochrome photoreceptors (interaction between MTHF, FAD, and likely Trp). Absorption cross-section spectra, fluorescence quantum distributions, quantum yields, and decay times are determined. The absorption spectra of the dyads and the triad resemble the superposition of the absorption spectra of the constituents (1-methylpyrene, isoalloxazine, and phenylphenothiazine). Photo-excitation of the flavin moiety causes fluorescence quenching by reductive electron transfer in thermodynamic equilibrium with the exited flavin subunit. The charge-separated states recover by charge recombination. Photo-excitation of the pyrene or phenylphenothiazine moiety causes oxidative electron transfer with successive recombination, and additionally Förster-type and Dexter-type energy transfer.

Q 25.3 Di 17:00 3H

Photo Dynamics of BLUF domain mutant H44R of AppA from *Rhodobacter sphaeroides* — •Peyman Zirak[1], Alfons Penzkofer[1], Peter Hegemann[2], and Thilo Mathes[2] — [1]Institut II - Experimentelle und Angewandte Physik, Universität Regensburg, Universitätsstrasse 31, D-93053 Regensburg, Germany — [2]Institut für Biologie, Experimentelle Biophysik, Humboldt-Universität zu Berlin, Invalidenstr.42, D-10115 Berlin

The photo-cycle dynamics of the H44R mutant of the BLUF domain of the protein AppA (AppA-H44R) from the purple bacterium *Rhodobacter sphaeroides* is studied. The amino acid residue histidine at position 44 is replaced by arginine. A 12 nm red-shifted signalling state is formed upon blue-light excitation, while in wild-type AppA (AppA-wt) the red-shift is 16 nm. The recovery time to the receptor dark state is 6.5 min. It is approximately a factor of 2.5 faster than the recovery of the wild-type counterpart. Extended light exposure of the mutant causes photo-degradation of flavin (mainly flavin conversion to lumichrome). No photo-degradation was observed for AppA-wt. The quantum efficiency of signalling state formation determined by intensity dependent absorption measurements is found to be 0.3 (for AppA-wt: 0.24). A two-component single-exponential fluorescence relaxation was observed with lifetimes of 80 ps and 900 ps (for AppA-wt: 1.3 ps and 270 ps), which is interpreted as fast fluorescence quenching to an equilibrium by photo-induced electron transfer followed by slower fluorescence decay due to charge recombination. Based on the experimental findings, a photo-cycle model for BLUF domains is proposed.

Q 25.4 Di 17:15 3H

Spectroscopy of the two-photon resonance in atomic mercury vapour — •Thomas Beyer, Martin Scheid, Daniel Kolbe, Frank Markert, and Jochen Walz — University of Mainz, Germany

We investigated the $6^1S - 7^1S$ two-photon resonance in mercury vapour driven by two different tuneable laser fields, one of them near the $6^1S - 6^3P$ transition. This laser field is provided by a frequency-quadrupled solid-state Yb:YAG disk laser system generating up to 750mW output power at 253.7nm. The second laser field is provided by a grating-stabilized GaAs diode laser, boosted by tapered amplifiers and then frequency-doubled to 408.7nm, yielding output powers up to 30mW.

Spectra for different detunings and mercury vapour pressures are presented and compared to theory involving solutions to the Optical Bloch Equations in a three-level quantum system. The results are of interest for the generation of continuous-wave coherent radiation at 121.56nm, which is needed for cooling of anti-hydrogen, because the conversion efficiency for this process is strongly enhanced by selecting fundamental wavelengths near these mercury resonances.

Q 25.5 Di 17:30 3H

Doppler-free Spectroscopy of Rubidium Rydberg Transitions in a Room-temperature Gas Cell — Thomas Becker[1,2], •Pierre Thoumany[1,2], Thomas Germann[1], Gernot Stania[1], Linas Urbonas[1], and Theodor Hänsch[1] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Physik Departement, Ludwig-Maximilians-Universität, Munich, Germany

Until recently, Doppler-free detection of Rydberg transitions was limited to techniques, where the subsequent ionization of Rydberg atoms allows for an electronic detection. This requires the use of an atomic beam apparatus or thermionic diodes. In our setup, we use a two stage cascaded laser setup (780 nm, 480nm) or a two stage V-scheme (297 nm, 780 nm) to excite and detect Rydberg transitions in a room temperature gas cell. In both cases, the population of the Rydberg levels is monitored optically via the decreased absorbtion of the 780 nm radiation (rubidium D2 line). We discuss the general setup, the observed lineshapes and present results on laser frequency stabilization to Rydberg transitions using this technique. In addition, we discuss similarities to the well known electron shelving technique used to detect weak transitions in trapped ions.

Q 25.6 Di 17:45 3H

Stimmgabelverstärkte photoakustische Spektroskopie zur Sauerstoffdetektion — •Andreas Pohlkötter[1], Stefan Böttger[2], Christoph Bauer[2], Ulrike Willer[1,2] und Wolfgang Schade[1,2] — [1]Institut für Physik und Physikalische Technologien, TU Clausthal — [2]Laser AnwendungsCentrum, TU Clausthal

Das Verfahren der stimmgabelverstärkten photoakustischen Spektroskopie (engl.: quartz enhanced photoacoustic spectroscopy - QEPAS) ist eine Weiterentwicklung der klassischen photoakustischen Spektroskopie [1]. Hierbei wird ein modulierter Laserstrahl zwischen die Zinken einer Quarz-Stimmgabel fokussiert. Die durch die modulierte Lichtintensität erzeugte Schallwelle fungiert als treibende Kraft der erzwungenen Schwingung der Stimmgabel, welche durch den piezoelektrischen Effekt eine messbare Wechselspannung erzeugt. Die Vorteile der QEPAS Technik sind ein sehr kompakter Aufbau und bedingt durch die Stimmgabelgeometrie eine weitestgehende Unempfindlichkeit gegenüber Störgeräuschen. Mit dieser Technik wurde ein Sensorsystem aufgebaut, welches in der Lage ist, Sauerstoff in geringen Konzentrationen nachzuweisen. Ein weiterer Vorteil der photoakustischen Spektroskopie ist, dass kein optischer Detektor nötig ist, der eine Abhängigkeit von der Wellenlänge des Lichtes zeigt. Die Sensoren eignen sich daher in Kombination mit Quantenkaskaden-Lasern dazu, Spektroskopie im mittleren Infrarotbereich ohne gekühlte Detektoren durchzuführen. Erste Ergebnisse werden präsentiert.

[1] A. A. Kosterev et. al., Opt. Lett. 27, 21 (2002) 1902-1904

Q 25.7 Di 18:00 3H

Evanescent-field-sensor for detection of CO_2 dissolved in water — •Rozalia Orghici, Ulrike Willer, and Wolfgang Schade — TU Clausthal, Institute of Physics and Physical Technologies, Leibnizstraße 4, 38678 Clausthal Zellerfeld

The increase of the carbon dioxide (CO_2) concentration in the earth atmosphere is considered to be one of the main factors responsible for global warming. Experts agree that one promising approach for the reduction of the CO_2 amount entering the atmosphere is the storage of CO_2 deep underground. A test site is available at Ketzin, Germany, for the study of the sequestration process, its dynamics and the temporal and spatial distribution of CO_2. Carbon dioxide is injected into a saline aquifer at a depth of 800 m, whereas two observation boreholes allow the monitoring of the storage process. Therefore, sensors are needed which are able to monitor the concentration of the dissolved CO_2 in water on-line and in situ. Evanescent-field-spectroscopy is an advantageous spectroscopic technique for detection and analysis of species in places difficult to access and in corrosive, absorbing or highly scattering media. Compared to other spectroscopic methods, which require open optical paths, this sensing method can be attained in an all fiber coupled sensor by using optical fibers as sensing elements as well as for guiding the light to and from the sensor. The sensing region can be inserted into fluids, therefore enabling the real-time determination of the CO_2 content in water. The experimental setup and the sensitivity of the evanescent-field-sensor will be presented.

Q 25.8 Di 18:15 3H

Untersuchung der Hyperfeinstruktur von Praseodym mittels laserinduzierter Fluoreszenzspektroskopie — •Bettina Gamper[1], Imran Siddiqui[1], Günter Guthöhrlein[2] und Laurentius Windholz[1] — [1]Institut für Experimentalphysik, Techn. Univ. Graz — [2]Fachbereich Elektrotechnik, Helmut Schmidt-Univ. der BW Hamburg, Holstenhofweg 85, 22043 Hamburg

Das komplexe Praseodym-Spektrums ist bislang noch nicht vollständig analysiert. Die Liniendichte von Praseodym ist, vor allem im sichtbaren Wellenlängenbereich, sehr hoch, weshalb eine Identifizierung der zugehörigen Energieniveaus allein aus der Wellenzahl der Linien meistens nicht möglich ist. Auch unter Einbeziehung der in den Fouriertransformations-Spektren aufgelösten Hyperfeinstruktur gelingt eine Klassifizierung nicht immer. Sehr viele Strukturen, die im Fourier-Spektrum als einzelne Linie oder als Blend von 2 bis 3 Linien erscheinen, stellten sich als Überlagerung von bis zu acht verschiedenen Übergängen dar. Mit Hilfe von laserspektroskopischen Untersuchungen können einzelne Linien einer Blend-Situation durch ihre Fluoreszenzlinien getrennt aufgezeichnet und somit klassifiziert werden. Bisher wurden sehr viele Linien, die meisten zwischen 570 und 600 nm, klassifiziert und mehr als 50 neue Energieniveaus entdeckt.

Q 25.9 Di 18:30 3H

Anomale Intensität der Hyperfeinkomponenten von Praseodym-I - Linien — •Imran Siddiqui[1], Bettina Gamper[1], Günter Guthöhrlein[2] und Laurentius Windholz[1] — [1]Institut für Experimentalphysik, Techn. Univ. Graz, Petersgasse 16, A-8010 Graz — [2]Fachbereich Elektrotechnik, Helmut Schmidt-Univ. der BW Hamburg, Holstenhofweg 85, 22043 Hamburg

Bei der laserspektroskopischen Anregung der Linie 578,051 nm wurde mittels laserinduzierter Fluoreszenz eine ungewöhnliche Hyperfeinstruktur beobachtet. Der niederfrequente Teil der Struktur ließ von den Komponentenabständen her auf einen Übergang Delta J=0, mit J=15/2, von den Komponentenintensitäten her aber auf einen kleinen Drehimpuls schließen. Aus den beobachteten Fluoreszenzwellenlängen wurde diese Linie als Übergang zwischen zwei neuen Energieniveaus (32486.80 cm-1, 15/2 even - 15192,08 cm-1, 15/2 odd) interpretiert. Weiters wurde bei Anregung von 578,027 nm eine weitere Linie mit ungewöhnlicher Hyperfeinstruktur auf denselben Fluoreszenzkanälen beobachtet. Damit ergab sich das Bild eines Niveautripletts, wobei die zwei weiteren unteren Niveaus J=13/2 besitzen und 0,18 bzw. 0,86 cm-1 unterhalb des Niveaus 15192,28 liegen. Diese drei eng benachbarten Energieniveaus stören sich gegenseitig, d.h., durch Wechselwirkungen wird die Lage der Hyperfeinniveaus geändert, wodurch die Formeln von Casimir nicht mehr streng gültig sind. Hier liegen nur sehr geringe Verschiebungen der Hyperfeinniveaus vor, trotzdem wird aber die Übergangswahrscheinlichkeit zwischen den Komponenten des oberen und unteren Niveaus sehr stark beeinflußt.

Q 26: Poster Ultrakurze Laserpulse

Zeit: Dienstag 16:30–19:00 Raum: Poster C1

Q 26.1 Di 16:30 Poster C1

Femtosekunden OPO basierend auf MgO:PPLN mit aktiver Wellenlängenkontrolle — •Felix Rübel, Peter Haag, Richard Wallenstein und Johannes L'huillier — Technische Universität Kaiserslautern, Fachbereich Physik, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern

Durchstimmbare Femtosekunden Impulse im nahen und mittleren Infrarotbereich werden für Untersuchungen extrem schneller Prozesse benötigt. Da in diesem Wellenlängenbereich keine direkt emittierenden Strahlquellen existieren sind alternative Konzepte erforderlich. Eine Möglichkeit bieten synchron gepumpte optisch parametrische Oszillatoren (OPO). Basierend auf periodisch gepoltem MgO:$LiNbO_3$ wurde ein signalresonanter fs-OPO bei Raumtemperatur realisiert. Durch Variation der Pumpwellenlänge kann die Signalwellenlänge von 1050 nm bis 1280 nm durchgestimmt werden. Gepumpt mit 1,3 W und 100 fs bei einer Repetitionsrate von 82 MHz wurde eine maximale Ausgangsleistung von 450 mW und eine minimale Impulsdauer von 215 fs erreicht. Durch aktive Kontrolle der Resonatorlänge konnte die Wellenlänge der Signalstrahlung über einen Zeitraum von mehr als 14 Stunden mit einer Abweichung von kleiner 0,5 nm stabil gehalten werden. Die relative Abweichung von der spektralen Breite des Signalimpulses liegt unter 3 %.

Q 26.2 Di 16:30 Poster C1

Messung und Stabilisierung der Träger-Einhüllenden-Phase von Laseroszillatoren und Verstärkersystemen — •Anne Harth, Niels Meiser, Emilia Schulz, Thomas Binhammer, Stefan Rausch, Milutin Kovacev und Uwe Morgner — Institut für Quantenoptik, Leibniz Universität Hannover

Ein bezüglich der Träger-Einhüllenden-Phase (CEO-Phase) stabilisierter Laseroszillator ist für aktuelle Gebiete der Physik von großer Bedeutung. Die genaue Position der Trägerwelle unter seiner Einhüllenden ist z.B. für die Erzeugung von einzelnen Attosekunden-Pulsen notwendig. Für diese stark nichtlinearen Prozesse sind Pulsintensitäten von über 10^{15} W/cm^2 notwendig, die problemlos durch Nachverstärkung erreicht werden. Daher müssen sowohl der Oszillator als auch der Verstärker bezüglich der CEO-Phase stabilisiert werden. Darüber hinaus bietet ein phasenstabiler Laser einen hochpräzisen Frequenzkamm mit entsprechenden Anwendungen in der Präzisionsmetrologie, aber auch einzelne phasenstabile Laserpulse direkt aus einem Oszillator, dessen Pulsdauern unter 10 fs liegen, eröffnen neue Anwendungsgebiete, wie z.B. die Untersuchung der Photoionisation von Metalloberflächen. In Hinblick auf solche Anwendungen werden die experimentellen Methoden zur Messung und Stabilisierung der Träger-Einhüllenden-Phase von verschiedenen Titan:Saphir Lasersystemen dargestellt.

Q 26.3 Di 16:30 Poster C1

Specially parameterized evolutionary algorithm for spatial optimization — •Jan Lohbreier, Stefan Eyring, Christian Kern, Robert Spitzenpfeil, Dominik Walter, and Christian Spielmann — Universität Würzburg, Physikalisches Institut, Am Hubland, 97074 Würzburg

We present a method to achieve an optimal spatial phase shape for a femtosecond laser pulse via an evolutionary algorithm. 'Optimal' here is meant to be specifically designed for one signal (e.g. overall intensity as fitness) that is fed back to the computer. The 768x768 pixels of our pulse shaper allow high-resolution phase shaping but also need a lot of computing power for a real-time optimization. Our new approach is to minimize the required informational size of a generation and thus to reduce the computing time per generation. Furthermore the technique to use planes instead of meta-pixels generates a smoother phase mask which is generally preferred to a rough surface. To test this scheme a picture was set to be the ideal phase mask and the time for the algorithm to match the intended picture was measured. Thus it was possible to downsize the controlling environment to make the optimization as good and fast as possible for its current challenges.

Q 26.4 Di 16:30 Poster C1

The impact of the dipole phase on the population dynamics of bound-bound transitions — •Xiao-Tao Xie, Mihai Macovei, Martin Kiffner, and Christoph H. Keitel — Max-Planck-Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany

The dipole phase plays an important role in strong-field processes and determines, e.g., the coherence properties of high-order harmonic radiation [1]. Here we consider the weak-field regime such that tunneling processes and multiphoton ionization are negligible, and investigate the impact of the permanent dipole phase on the population dynamics of bound-bound transitions that are illuminated by a few-cycle pulse. It is shown that the population of the excited states depends on the carrier-envelope phase as well as on the dipole phase. A scheme that allows to determine the dipole phase via the controlled adjustment of the carrier-envelope phase is discussed.

[1] P. Salières, A. L'Huillier, and M. Lewenstein, Phys. Rev. Lett. **74**, 3776 (1995).

Q 26.5 Di 16:30 Poster C1

Analytical theory for the propagation of laser beams in nonlinear media — •Larisa Tatarinova and Marin Garcia — University of Kassel, Kassel, Germany

The propagation of a laser beam of intensity I in a nonlinear media with a refraction index n(I) of arbitrary form is studied. In particular, the influence of the functional form n=n(I) on self-focusing and self-trapping is investigated. We also explicitly analyze the case of nonlinear self-focusing accompanied by multiphoton ionization. Influence of the spatial beam shape on the self-focusing is investigated. Case of propagation of two pulses with different intensities is studied analytically. For particular, already studied cases we considerably improve the accuracy of the results with respect to previous semi-analytical studies and obtain very good agreement with recent numerical simulations.

Q 26.6 Di 16:30 Poster C1

Compensation of undesired amplitude and phase effects in polarization pulse shaping — •Jens Köhler, Marc Krug, Cristian Sarpe-Tudoran, Matthias Wollenhaupt, and Thomas Baumert — Universität Kassel, Institut für Physik und Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), Heinrich-Plett-Str. 40, D-34132 Kassel, Germany

Undesired polarization dependent amplitude modulations and phase shifts are of great importance in femtosecond polarization pulse shaping. These effects are introduced by components of the pulse shaper itself as well as additional optical elements. For accurate generation of pulses with a desired time-dependent polarization profile on an ultrashort timescale it is important to understand and to control these effects. Here we present two approaches allowing for the compensation of these disturbing factors. Using VPHGs (Volume Phase Holographic Gratings) the polarization dependent losses normally present in polarization pulse shapers could be minimized. The phase shifts can be handled by the use of an appropriate retardation plate. Femtosecond laser pulses with different polarization states were generated with our high-resolution polarization pulse shaper based on a 2x640 pixel LC-SLM (Liquid Crystal-Spatial Light Modulator). The shaped pulses were analyzed using a simple optical scheme and employing PEIS (Photoelectron Imaging Spectroscopy). First results demonstrating the successful compensation of the above mentioned amplitude and phase effects are presented.

Q 26.7 Di 16:30 Poster C1

Supercontinuum generation in a photonic crystal fiber, characterization and transient absorption spectroscopy — •Jutta Mildner, Johannes Schneider, Matthias Wollenhaupt, and Thomas Baumert — Universität Kassel, Institut für Physik und Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), Heinrich-Plett-Str. 40, D-34132 Kassel, Germany

Broadband ultrashort laserpulses are an important tool in ultrafast spectroscopy. Since Alfano and Shapiro generated the first supercontinua (SC) in diverse glass plates in 1970 [1], great interest and development has evolved on that subject. In this work, we present the setup of such a SC light source, its characterization and finally a first application. The SC are generated in a photonic crystal fiber being pumped by a common Ti:Sapphire femtosecond laser system in a setup analogous to [2]. The advantages of photonic crystal fibers lie in their high flexibility and low pump energies needed. The results of SC generation i.e. spectral properties and stability are discussed. Furthermore we present different approaches of SC pulse characterization containing autocorrelation, spectral interference and crosscorrelation techniques. Finally as an example of a first application of this light source, a transient absorption experiment of the laser dye DCM as a standard is conducted in a pump-SC probe setup. First results are shown.

[1] R.R. Alfano and S.L. Shapiro: PRL **24**, 592 (1970)

[2] B.v. Vacano, W. Wohlleben and M. Motzkus: Opt. Lett. **31**, 413 (2006)

Q 26.8 Di 16:30 Poster C1

Construction of an Ultrafast Electron Diffraction Apparatus — •Christian Gerbig, Marc Winter, Matthias Wollenhaupt, and Thomas Baumert — Universität Kassel, Institut für Physik und Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), Heinrich-Plett-Str. 40, D-34132, Germany

In order to directly observe structural changes on a femtosecond or picosecond timescale with atomic resolution, a combination of an optical technique offering high temporal resolution (fs pump-probe) and a structural characterization technique (for example electron diffraction) is needed [1-3]. We show the setup and construction of an apparatus for time-resolved electron diffraction measurements based on an amplified 30 fs Ti:Sapphire laser system and present first characterization data and current modifications.

[1] B.J. Siwick, J. R. Dwyer, R.E. Jordan, R.J.D. Miller, Science 302 (2003) 1382

[2] W.E. King, G.H. Campbell, A. Frank, B. Reed, J.F. Schmerge, B.J. Siwick, B.C. Stuart, P.M. Weber, J. Appl. Phys. 97 (2005) 11101

[3] A.H. Zewail, Annu. Rev. Phys. Chem. 57 (2006) 65

Q 26.9 Di 16:30 Poster C1

Erzeugung und Detektion von gepulster Terahertz Strahlung mit GaP-Kristallen — •Mathias Hoffmann[1], Matthias Pospiech[1], Andy Steinmann[1], Guido Palmer[1] und Uwe Morgner[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland — [2]Laserzentrum Hannover e.V.

Wir verwenden einen modengekoppelten Yb:Glass Laser [1] mit Cavity-Dumping (375 fs, 100 nJ, 1 MHz), um in GaP-Kristallen durch Optische Gleichrichtung intensive gepulste Strahlung im THz-Spektralbereich zu erzeugen. GaP bietet sich hierfür an, da es im Bereich von 1030 nm Phasenanpassung bietet [2]. Die THz Strahlung wird im Time-Domain Verfahren über einen elektrooptischen Detektor – ebenfalls auf GaP Basis – aufgezeichet, und mittels Fouriertransformation wird aus diesen Daten das zugehörige Frequenzspektrum berechnet [3]. Wir berichten über Erzeugung und Detektion mit diesen Verfahren und zeigen die Skalierung der Parameter bei verschiedenen Kristalldicken.

[1] A. Killi et. al., Opt. Lett. 29, 1288-1290 (2004)
[2] Chang et. al., Optics Express (2006), Bd. 14(17):S. 7909–7913
[3] Wu et. al. Applied Physics Letters (1997), Bd. 70(14):S. 1784 – 1786

Q 26.10 Di 16:30 Poster C1

Spatial characterization and wavefront measurements of high-order harmonics — •Stefan Eyring[1], Christian Kern[1], Jan Lohbreier[1], Robert Spitzenpfeil[1], Matthias Weger[2], and Christian Spielmann[1] — [1]Universität Würzburg, Physikalisches Institut, Am Hubland, Würzburg, Deutschland — [2]ETH Zürich, Institut für Quantenelektronik, Zürich, Schweiz

High-order harmonic radiation provides coherent light up to the soft x-ray regime. Because of the fundamentally low photon yield one needs to focus the generated radiation. The focussing of the beam of harmonics depends strongly on its wavefront. Therefore detailed information on the beam profile and wavefront are necessary.

We present experimental measurements with a Hartmann-type wavefront sensor suited for use in the EUV region. For analysing the data Zernicke polynomials are used and quantitative physical interpretation is therefore possible. In addition we present measurements with a knife-edge scan to determine the beam parameter M^2 which is a wavelength-independent measure of beam quality. This scheme allows us to calculate different beam parameters of the beam of high-order harmonics.

Using the information gained through this setup we utilise an adaptive spatial pulse shaping technique. Changing the wavefront of the incident driving laser beam of the generating process makes it possible to increase the high-order harmonic yield at the detector.

Q 26.11 Di 16:30 Poster C1

Resonant strong-field control of potassium atoms by spectral θ-step phase modulation — •Tim Bayer, Matthias Wollenhaupt, and Thomas Baumert — Universität Kassel, Institut für Physik und CINSaT, Heinrich-Plett-Str. 40, D-34132 Kassel, Germany

Selective Population of Dressed States (SPODS) is the key to coherent control of resonant quantum phenomena in strong laser fields. Recently two SPODS control schemes have been devised which make use of shaped femtosecond laser pulses [1,2]. It was shown that chirped pulses as well as pulse sequences can be used to steer potassium atoms into single dressed states, achieving high efficiency and selectivity. The underlying control mechanisms are based on continuously varying temporal phases (adiabatic SPODS) and discrete temporal phase jumps (non-adiabatic SPODS) respectively. Here, we employ a spectral phase modulation function of the form $\varphi(\omega) = \theta/2 \cdot \sigma(\omega - \delta\omega)$, where σ denotes the *signum* function, which produces a double pulse structure in time with a linearly varying phase and a phase jump in between the two pulses. Hence, this pulse shape combines adiabatic with non-adiabatic aspects. We present measured photoelectron spectra from resonant multi-photon ionization of potassium atoms as a function of the spectral step size θ and the detuning $\delta\omega$. Our results show, that both parameters provide an efficient means to exert control on the dressed state populations.

[1] M. Wollenhaupt *et al.*: PRA **73**, 2006
[2] M. Wollenhaupt *et al.*: APB **82**, 2006

Q 26.12 Di 16:30 Poster C1

Kohärente Kontrolle nanoplasmonischer Ausbreitung mit ultrakurzen polarisationsgeformten Laserimpulsen — •Philip Tuchscherer[1], Dmitri V. Voronine[1], F. Javier García de Abajo[2], Walter Pfeiffer[3] und Tobias Brixner[1] — [1]Institut für Physikalische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]Instituto de Óptica, CSIC, Serrano 121, 28006 Madrid, Spain — [3]Fakultät für Physik, Universität Bielefeld, Universitätsstr. 25, 33516 Bielefeld, Germany

Elektromagnetische Nahfelder zeigen Variationen auf Längenskalen unterhalb des optischen Beugungslimits und können partiell durch Methoden der kohärenten Kontrolle manipuliert werden. Von besonderem Interesse für verschiedene Anwendungen ist die räumliche Ausbreitung kohärenter Anregungen in Nanostrukturen.

Wir untersuchen in Simulationsrechnungen, wie solche Anregungen mittels phasen- und polarisationsgeformter ultrakurzer Lichtimpulse gesteuert werden können.

Die Größe der verwendeten metallischen Nanostrukturen wird entsprechend der Plasmonenresonanz gewählt, und durch Fokussieren der Lichtimpulse wird eine partielle Anregung der Nanostruktur bewirkt. Die Ausbreitung der Plasmonen soll dann durch geeignet geformte Laserpulse gesteuert werden, wobei die Pulsform durch einen Lernalgorithmus optimiert wird.

Q 27: Poster Quantengase

Zeit: Dienstag 16:30–19:00 Raum: Poster C2

Q 27.1 Di 16:30 Poster C2

Transport properties of Bogoliubov excitations in correlated disorder — •Christopher Gaul, Christian J. Harrer, and Cord A. Müller — Universität Bayreuth

We study 2D quantum transport in a many-body system by considering a Bose-Einstein condensate in a correlated disordered optical potential. The correlation length of the disorder potential together with the healing length are the two relevant length scales of the problem. The effective transport characteristics of Bogoliubov excitations are investigated by calculating suitable configuration averages. We obtain the disorder-broadened Bogoliubov dispersion relation, the scattering length, and the transport mean free path. In particular we examine the regime where the disorder correlation length is not the shortest of all length scales.

Q 27.2 Di 16:30 Poster C2

Bloch dynamics of a BEC: mean-field vs. microscopic descriptions — •Eva-Maria Graefe[1], Andrey R. Kolovsky[2], and Hans Jürgen Korsch[1] — [1]TU Kaiserslautern, Germany — [2]Kirensky Institute of Physics, Krasnoyarsk, Russia

Recently much attention is paid to the Bloch dynamics of a BEC loaded into an optical lattice, subject to a static, for example, gravitational field. We compare two theoretical approaches to this problem, the mean-field description, based on the discrete nonlinear Schrödinger equation (DNLSE), and the microscopic description, based on the Bose-Hubbard model. Within the mean-field approach the main phenomena related to the Bloch dynamics are the dynamical instability (also known as modulation instability) and self-thermalization due to the onset of classical chaos in the DNLSE. We argue that the quantum manifestations of these phenomena are the depletion of the Floquet-Bogoliubov states, defined as the "low-energy" eigenstates of the evolution operator over one Bloch period, and the decoherence of the BEC. The correspondence between mean-field and microscopic description is analysed in dependence on the number of particles as well as on the magnitude and direction (for 2D or 3D lattices) of the static field.

Q 27.3 Di 16:30 Poster C2

Atom Laser by all-optical means for Atom Interferometry — •Maic Zaiser, Temmo Wübbena, Stefan Jöllenbeck, Wolfgang Ertmer, and Ernst Maria Rasel — Leibniz Universität Hannover

We present the current status of our all-optical ATom LASer (ATLAS), an experiment aiming at Bose-Einstein-Condensation (BEC) in a dilute atomic gas of ^{87}Rb by all-optical means. The project is motivated by the possible improvements of the accuracy of matter-wave interferometers based on quantum degenerated atoms. Optical dipole traps allow a high repetition rate in an interferometer and are also able to trapp all m_F-substates, especially $m_F = 0$, which is in the first order insensitive to magnetic fields. We investigate the potential of such an atomic source for precision atom interferometers, such as the Cold Atom Sagnac Interferometer (CASI) [1] currently being set up in Hanover.

The atomic source consists of a three dimensional magneto-optical trap (3D-MOT) loaded by a 2D-MOT. We present the very compact vacuum chamber and a compact laser system for atom cooling employing modular integrated and fiber-based optics ensuring a high stability of the system. We will discuss the suitability of a high power Thulium fiber laser at 2 μm wavelength for trapping and evaporatively cooling atoms to quantum degeneracy. This work is part of the project FINAQS funded by the European Union. (www.finaqs.uni-hannover.de)

[1] Versatile compact atomic sources for high resolution dual atom interferometry; T. Müller, T. Wendrich, M. Gilowski, C. Jentsch, E.M. Rasel, W. Ertmer Phys. Rev. A, in press.

Q 27.4 Di 16:30 Poster C2

Bose-Einstein condensation and atom optical experiments — •Thomas Lauber[1], Susanne Hertsch[1], Markus Krutzik[1], Johanna Nes[1], Oliver Wille[1], Anna Sanpera[2], and Gerhard Birkl[1] — [1]Institut für Angewandte Physik; Technische Universität Darmstadt, Schlossgartenstr. 7, D-64289 Darmstadt — [2]Department of Physics, Theoretical Physics Group, Universitat Autónoma Barcelona, E-08193 Bellaterra

Optical trapping and guiding configurations have evolved as a powerful tool for the manipulation of ultracold atoms. In our experiment, rubidium atoms are loaded in a crossed optical dipole trap of 1030nm laser beams directly from a MOT. We create ultracold atom samples in the sub-microKelvin temperature range by evaporative cooling.

The advantage of a pure optical setup is its flexibility and independence of the magnetic properties of the trapped atoms. It is also possible to superimpose arbitrary magnetic fields on the trapping configuration. Our work aims at studying the coherence properties of ultracold thermal atoms and degenerate quantum gases in traps created by miniaturized optical lens structures. With these elements we can realize various trap geometries including a storage ring for atom interferometry experiments, and optical waveguides, in which the ultracold gas can be transferred.

Recent calculations promise an interesting velocity selective behaviour in one-dimensional periodic structures superimposed on a waveguide. We can implement these structures either with standing waves or microlens arrays.

Q 27.5 Di 16:30 Poster C2

Mesoscopic physics in quantum gases — •Bruno Zimmermann, Torben Müller, Henning Moritz, and Tilman Esslinger — Institute of Quantum Electronics, ETH Zürich, Hönggerberg, CH-8093 Zürich, Switzerland

We present an experimental setup which allows us to study an ultracold fermionic quantum gas in a potential that can be arbitrarily controlled down to the smallest relevant length scale, i.e. that of the atomic wavefunction. The basic idea is to prepare an ultracold gas of fermionic lithium in a region of high optical access by using standard laser cooling and trapping technics, followed by a transport and direct evaporation in an optical dipole trap. In the final position the gas will be sandwiched between two microscopes. The shape of the laser beams focused by these microscopes, i.e. the shape of the optical potential, will be controlled by spatial light modulators. The interaction strength of colliding atoms can be tuned by accessing a Feshbach resonance. This setup will allow us to study Josephson oscillations in the BEC-BCS crossover regime and to manipulate strongly correlated atomic samples on a local scale. First results on the cooling and trapping will be shown.

Q 27.6 Di 16:30 Poster C2

Far-From-Equilibrium Dynamics of an Ultracold Fermi Gas — •Matthias Kronenwett and Thomas Gasenzer — Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg

The dynamics of ultracold Fermi gases far from thermal equilibrium is studied. A functional-integral approach based on the Schwinger-Keldysh closed time path integral is employed to derive the two-particle irreducible (2PI) effective action. From this, the two-point correlation functions are determined self-consistently. The action is expanded in inverse powers of the number of field components $\mathcal{N}$, and the dynamic equations are derived in next-to-leading order of this expansion. This approach reaches far beyond mean-field theory and includes quantum statistical aspects of equilibration dynamics. It enables to describe, e. g., the dynamical evolution of trapped Fermi gases in optical lattices, as well as the BEC-BCS crossover dynamics.

Q 27.7 Di 16:30 Poster C2

Towards a degenerate mixture of ^{6}Li and ^{40}K — •Antje Ludewig, Tobias Tiecke, Sebastian Kraft, Steve Gensemer, and Jook Walraven — Van der Waals-Zeeman-Instituut, Universiteit van Amsterdam, The Netherlands

We have constructed an apparatus for the simultaneous cooling of the fermionic isotopes ^{6}Li and ^{40}K. Our goal is to get a degenerate mixture to search for novel pairing mechanisms involving fermions of different masses.

Instead of using a Zeeman slower as a source for cold lithium atoms we have developed a lithium 2D-MOT which is loaded directly from thermal vapor emitted by an hot oven at 400C. A second 2D-MOT, loaded from ^{40}K enriched vapor, serves as a potassium source.

Using these bright sources we load via differential pumping sections 10^9 atoms of both ^{6}Li and ^{40}K into a dual MOT in the main vacuum chamber. We then transfer both species into a magnetic trap and cool them by forced evaporation.

The current status of the experiment is summarized on the poster.

Q 27.8 Di 16:30 Poster C2

Interacting Rubidium and Caesium Atoms — •Shincy John, Michael Haas, Nicolas Spethmann, Lars Steffens, Claudia Weber, Artur Widera, and Dieter Meschede — Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, 53115 Bonn

In our experimental set up we magnetically trap a mixture of Rubidium and a few Caesium atoms simultaneously. We selectively cool only Rubidium atoms by a microwave field tuned to the Rubidium ground state hyperfine transition. Caesium is sympathetically cooled via elastic collisions with Rubidium. We are able to cool down the mixture to temperatures below 1μK. Analysing the dynamics of sympathetic cooling we have estimated a lower limit for the Rubidium-Caesium s-wave scattering length to 150 a_0. Our next step is to load the mixture in an optical dipole trap. Using an external homogeneous magnetic field we intend to tune the inter-species interaction. We will present our latest results.

Q 27.9 Di 16:30 Poster C2

Lattice physics in ultracold Bose-Fermi mixture gases — •Philipp Ernst[1], Sören Götze[1], Karsten Pyka[1], Kai Bongs[2], and Klaus Sengstock[1] — [1]Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]Midlands Centre for Ultracold Atoms, School of Physics and Astronomy, University of Birmingham, Edgbaston, Birmingham B15 2TT, United Kingdom

Ultracold gas experiments have the huge advantage of being pure and tunable systems. In our experiment we use a KRb mixture giving access to different statistics which can be loaded into a far red-detuned optical lattice at 1030nm. The system furthermore offers several options to manipulate the gases from excellent magnetic field control to access Feshbach resonances over microwave and rf tools for spectroscopic as well as state preparation purposes. We present recent developments in the preparation, manipulation and detection of quantum states in optical lattices.

Q 27.10 Di 16:30 Poster C2

Transport of a quantum degenerate heteronuclear Bose-Fermi mixture in a harmonic trap — Carsten Klempt, Thorsten Henninger, •Oliver Topic, Johannes Will, Stephan Falke, Wolfgang Ertmer, and Jan Arlt — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, D-30167 Hannover, Germany

We report on the simultaneous transport of mixed quantum degenerate gases of bosonic ^{87}Rb and fermionic ^{40}K in a harmonic potential. The samples are transported over a distance of up to 6 mm to the geometric center of the anti-Helmholtz coils of the QUIC trap.

This magnetic transport scheme is an important tool for the manipulation of quantum degenerate gases, since it enables transport experiments with large quantum degenerate samples in macroscopic trap configurations without disturbances added by close by surfaces. Since the mechanism may be cascaded to cover even larger distances, it is of particular relevance for interference experiments which can particularly profit from the signal-to-noise ratio available with large samples.

In addition, this novel method allows all experiments using QUIC traps to significantly improve the experimental conditions. We demonstrate two particular experiments which profit from the transport scheme. By transporting the atoms to the centre of the trap, the highly homogeneous magnetic field that can be created there is available to experiments which exploit Feshbach resonances to tune the atomic interaction. The mechanism may also be used to accelerate and launch atomic clouds for further experiments.

Q 27.11 Di 16:30 Poster C2

From BEC to fermionization in 1-D double-well traps — •Sascha Zöllner[1], Hans-Dieter Meyer[1], and Peter Schmelcher[1,2] — [1]Universitaet Heidelberg, Theoretische Chemie, Im Neuenheimer Feld 229, 69120 Heidelberg — [2]Universitaet Heidelberg, Physikalisches Institut, Philosophenweg 12, 69120 Heidelberg

We investigate the transition of a quasi-one-dimensional few-boson system from weak correlations to the fermionization limit of infinitely repulsive forces. Based on a numerically exact multi-configurational method (MCTDH), we show that the ground state reveals 'localization' of the particles, which can be interpreted as mimicking Pauli's exclusion principle. We provide a deeper understanding of that transition by relating it to the loss of coherence in the one-body density matrix and to the emerging long-range tail in the momentum distribution.

This crossover has striking effects on the tunnel dynamics of few atoms in a double well. Starting from Rabi oscillations in the noninteracting limit, correlated pair tunneling evolves as the interaction is slightly increased, reminiscent of self-trapping for BECs. Toward the fermionization limit, however, we observe modulated Rabi oscillations of a strongly correlated atom pair.

Q 27.12 Di 16:30 Poster C2

Transport of Bose-Einstein condensates through two-dimensional mesoscopic structures — •Timo Hartmann, Michael Hartung, Klaus Richter, and Peter Schlagheck — Institut für theoretische Physik, Universität Regensburg

The tremendous progress over the last decade in the experimental techniques for Bose-Einstein condensates permits the creation of almost arbitrarily shaped confinement geometries for interacting matter waves on the basis of atom chips or atom-optical billiards [1]. This opens new experimental possibilities for probing the transport properties of Bose-Einstein condensates through mesoscopic scattering geometries.

We numerically investigate the quasi-stationary propagation of a condensate through two dimensional cavities within the mean-field approximation of the condensate. This is accomplished using a generalisation of the approach used in Ref. [2] to two dimensions. Special attention is paid to the resonance structures in the transmission spectrum which are strongly modified through the non-linear term in the Gross-Pitaevskii equation.

[1] V. Milner et al. Phys. Rev. Lett. 86, 1519 (2001), N. Friedman et al. Phys. Rev. Lett. 86, 1518 (2001)
[2] T. Paul et al., Phys. Rev. Lett. 94 (2005)

Q 27.13 Di 16:30 Poster C2

How Dissipation Fermionizes a One-Dimensional Gas of Bosonic Molecules and Atom-Molecule Oscillations in a Mott Insulator — •Dominik Bauer, Matthias Lettner, Niels Syassen, Thomas Volz, Daniel Dietze, Stephan Dürr, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

Here we report on our latest results about ultracold molecules in optical lattices.

First, we show how dissipation creates a Tonks gas of molecules. If a gas of bosons is confined to 1D, the interaction between particles can become so important that the strongly correlated regime is reached. This is called a Tonks-Girardeau gas. In the limit of infinite interaction strength, one cannot find two bosons at the same position. Previous studies of the Tonks Gas relied on elastic interactions.

Second, we observe large-amplitude Rabi oscillations between an atomic and a molecular state near a Feshbach resonance. The frequency and amplitude of the oscillations are well described by a two-level model. The observed density dependence of the oscillation frequency agrees well with the theoretical prediction. We confirm that the state produced after a half-cycle contains exactly one molecule at each lattice site. In addition, we show that for energies in a gap of the lattice band structure, the molecules cannot dissociate.

Q 27.14 Di 16:30 Poster C2

Bosonic and fermionic metastable neon atoms in optical and magnetic traps — •Jan Schütz, Eva-Maria Kriener, Wouter van Drunen, Norbert Herschbach, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt

We experimentally investigate the interactions of laser cooled metastable neon atoms in a magneto-optical trap (MOT), in magnetic traps, and optical dipole traps. For the bosonic isotopes ^{20}Ne and ^{22}Ne we determined the rate coefficients for inelastic collisions and the scattering lengths for atoms in the metastable $^3P_2$ state.

As the next step, we succeeded in optically trapping both bosonic isotopes in the metastable $^3P_0$ state and are currently determining the two-body loss coefficients.

Recent extensions of our laser configuration allow us to trap the fermionic isotope ^{21}Ne and mixtures of bosonic and fermionic isotopes. We report on the status of these experiments.

Q 27.15 Di 16:30 Poster C2

Ultracold Atomic Gases in 1D Optical Lattices: Qualitative behaviour of the DMRG method in inhomogenous topologies — •Felix Schmitt, Markus Hild, Sven Binder, and Robert Roth — Institut fuer Kernphysik, Technische Universitaet Darmstadt

The Density Matrix Renormalisation Group (DMRG) has become the state of the art method to treat ultracold atomic gases in optical lattices. While the infinite-size algorithm is usually sufficient to describe cold atoms in homogenous lattices with high precision even with moderate numbers of many-particle states, it becomes unreliable once inhomogenities occur. In most cases this can be cured by the finite-size DMRG algorithm. We focus on the problem of the Bose-Glass transition in order to study the behaviour of DMRG when unequal degrees of freedom are appended. This may shed light on the behaviour of DMRG applied to other quantum mechanical many-body problems, e.g. for nuclei or nuclear matter.

Q 27.16 Di 16:30 Poster C2

Exact theoretical description of two ultracold atoms in a 3D optical lattice — •Sergej Grishkevich and Alejandro Saenz — AG Moderne Optik, Institut für Physik, Humboldt-Universität zu Berlin, Hausvogteiplatz 5-7,10117 Berlin, Germany

The physics of ultracold atoms has attracted a lot of interest since the experimental realization of Bose-Einstein condensation in dilute alkali atom gases. Besides the exciting physics at ultracold energies by itself, a further important progress was the positioning of the ultracold gas in an optical lattice formed with the aid of standing light waves. Atoms in lattice are important systems to study solid state physics since the optical lattice resembles in a certain sense the periodicity of a crystal potential. These systems are furthermore supposed to be of great interest for quantum information purposes.

A theoretical approach was developed that allows for a full numerical description of a pair of ultracold atoms trapped in a three-dimensional optical lattice. This approach includes the possible coupling between center-of-mass and relative motion coordinates in a configuration-interaction type of calculations. The atoms are allowed to interact by their full interaction potential that is, presently, only limited to be central. With the aid of the newly developed method deviations from the harmonic approximation are discussed. The developed method is also used to model experimental data [1].

[1] C. Ospelkaus, S. Ospelkaus, L. Humbert, P. Ernst, K. Sengstock, and K. Bongs, Phys.Rev.Lett. **97**, 120402 (2006).

Q 27.17 Di 16:30 Poster C2

All-optical BEC for an optical lattice experiment with single site addressability — •Jacob Sherson, Oliver Loesdau, Manuel Endres, Jan Petersen, Christof Weitenberg, Immanuel Bloch, and Stefan Kuhr — Institut für Physik,Universität Mainz, Staudingerweg 7, 55128Mainz

In optical lattice experiments, ultracold atoms have to be loaded from a Bose-Einstein condensate (BEC), in order to populate the lowest energy band of the lattice. We report on the generation of a BEC in a crossed optical dipole trap. Laser cooled atoms are transferred from a double MOT system directly into the dipole trap. The dipole trap is formed by a 50 W Yb:YAG fiber laser (1070 nm). The shape of the trap can be dynamically changed by moving the foci of the laser beams. This increases the collision rate and allows for rapid evaporative cooling to the BEC transition within typically 5 s.

The BEC will then be transported by a single beam dipole trap to the experimental region. There, the atoms are transferred into an optical lattice which is placed in front of an ultrahigh resolution optical imaging system. The imaging system is designed to operate at a wavelength of 420.3 nm, corresponding to the $5S_{1/2} \rightarrow 6P_{3/2}$ transition of ^{87}Rb. It has a numerical aperture of NA = 0.75 yielding a diffraction-limited resolution of about 300 nm, which will allow for the detection of individual sites of the optical lattice.

Q 27.18 Di 16:30 Poster C2

Preparing and Detecting Quantum States with Ultracold Atoms in an Optical Superlattice — •Stefan Trotzky[1], Ute Schnorrberger[1], Patrick Cheinet[1], Michael Feld[1,2], Jeff Thompson[1], Simon Fölling[1,3], and Immanuel Bloch[1] — [1]Johannes Gutenberg Universität Mainz — [2]Technische Universität Kaiserslautern — [3]Harvard University, USA

Ultracold atoms in optical lattices have shown to be versatile systems to mimick condensed matter physics. The concept of superlattices for ultracold atoms has recently been realized in experiments and extends the toolbox for the manipulation of the system on the many-body scale. Furthermore, it allows to control effective interactions and dynamics emerging in Hubbard-type models. In our experiments, we combine monochromatic optical lattices on two perpendicular axes with a superlattice on the third axis which is formed by the superposition of two standing light fields with periodicity d and $2d$ to yield an array of double well potentials. We demonstrate how this bichromatic superlattice can be used to realize effective spin Hamiltonians with controllable spin-spin interactions as well as how to measure the atomnumber distribution within the array by means of interaction blockade. Moreover, we are able to create entangled spin-triplet pairs in the double wells and detect these via the coherent transformation into spin-singlet pairs and back.

Q 27.19 Di 16:30 Poster C2

Optical lattice with a staggered magnetic field — •G. Wirth[1], A. Hemmerich[1], L.-K. Lim[2], and C. Morais Smith[2] — [1]Universitaet Hamburg, Institut fuer Laser-Physik, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Institute for Theoretical Physics, Utrecht University, 3508 TD Utrecht, The Netherlands

We show how an effective staggered magnetic field can be implemented in a two-dimensional bosonic square optical lattice via stimulated Raman scattering and discuss the phase diagram of this quantum system. Apart from the homogeneous superfluid and the Mott insulator, known to exist in the conventional Bose-Hubbard model, a novel kind of superfluid phase arises characterized by finite momentum and a staggered vortex lattice. Its characteristic momentum spectrum permits straight forward experimental detection of this phase.

Q 27.20 Di 16:30 Poster C2

Interaction-induced dephasing of Bloch oscillations - experiments and simulations — •Manfred Mark, Matthias Gustavsson, Elmar Haller, Johann Danzl, and Hanns-Christoph Nägerl — Institut für Experimentalphysik und Forschungszentrum für Quantenphysik, Universität Innsbruck, 6020 Innsbruck, Austria

A BEC in an optical lattice undergoes Bloch oscillations when subject to an external force. However, interactions lead to dephasing, limiting the number of oscillations one can observe.

We quantitatively characterize this dephasing by tuning the interaction strength using a Feshbach resonance. For non-zero interaction strength, structure on a scale much smaller than the Bloch momentum can be observed in the momentum distribution of a dephased condensate.

For vanishing interaction strength, we are able to follow more than 20000 oscillations over 12 s. Also a measurement of the Ramsauer-Townsend minimum with a precision of 10^{-5} was performed. In this regime breakdown and revival phenomena in the presence of an additional harmonic potential can be observed.

The performed measurements are compared to numerical simulations of discrete and non-discrete 1D Gross-Pitaevskii equations.

Q 27.21 Di 16:30 Poster C2

Interaction-controlled transport of an ultracold Fermi gas — •Robert Jördens[1], Niels Strohmaier[1], Yosuke Takasu[2], Kenneth Günter[3], Michael Köhl[4], Henning Moritz[1], and Tilman Esslinger[1] — [1]Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland — [2]Department for Electronic Science and Engineering, Kyoto University, Kyoto 615-8510, Japan — [3]Laboratoire Kastler Brossel, 75005 Paris, France — [4]Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, United Kingdom

We explore the transport properties of an interacting Fermi gas in a three-dimensional optical lattice. In analogy to the characterization of transport behavior in condensed matter systems through conductivity measurements, we study the atom cloud's center of mass motion after a sudden displacement of the trap minimum.

Different interaction strengths and lattice fillings are shown to have a characteristic influence on the dynamics. With increasingly strong attractive interactions the weakly damped oscillation, observed for the non-interacting case, turns into a slow drift: local pairs with a reduced tunneling rate are formed for strong inter-atomic attraction. This interpretation is supported by a measurement of the number of doubly occupied lattices sites. Application of this technique in other interaction regimes, lattice depths and fillings in the Fermi-Hubbard model may provide a tool for the identification of quantum phases such as the fermionic Mott-insulator. Experimental results on repulsively interacting Fermi gases will be presented.

Q 27.22 Di 16:30 Poster C2

Dynamics of localization phenomena for hard-core bosons in optical lattices — •Birger Horstmann, Ignacio Cirac, and Tommaso Roscilde — Max-Planck-Institut für Quantenoptik, Garching, Deutschland

We investigate the behavior of ultracold bosons in optical lattices with a disorder potential generated via a secondary species frozen in random configurations. The statistics of disorder is associated with the physical state in which the secondary species is prepared. The resulting random potential, albeit displaying algebraic correlations, is found to lead to localization of all single-particle states. We then investigate the real-time dynamics of localization for a hardcore gas of mobile bosons which are brought into sudden interaction with the random potential. Regardless of their initial state and for any disorder strength, the mobile particles are found to reach a steady state characterized by exponentially decaying off-diagonal correlations and by the absence of quasicondensation; when the mobile particles are initially confined in a tight trap and then released in the disorder potential, their expansion is stopped and the steady state is exponentially localized in real space, clearly revealing Anderson localization.

Q 27.23 Di 16:30 Poster C2

Degenerate ground states in a 0-π-junction of an atomic gas — •Matthias Mutschler, Oliver Crasser, Reinhold Walser, and Wolfgang P. Schleich — Institut für Quantenphysik, Universität Ulm, D-89081 Ulm

0-π-Josephson-junctions are an important tool and research subject in superconductivity [1]. In the present contribution we examine an analogous model realised with a two-componend bosonic atomic gas which is trapped in a quasi one-dimensional double well potential. Within a simple four-mode approximation we obtain an system analogous to a 0-π-junction. We present an analysis of the ground states and tunneling effects between the degenerated ground state manifold.

[1] W. Buckel and R. Kleiner, Superconductivity: Fundamentals and applications, Wiley-VCH, Berlin (2004)
[2] E. Goldobin et al., Phys. Rev. B 72, 054527 (2005)
[3] V.M. Kaurov and A.B. Kuklov, Phys. Rev. A 73, 013627 (2006)
[4] E. Goldobin et al., New J. Phys., in preparation

Q 27.24 Di 16:30 Poster C2

Barrier transmission for the one–dimensional nonlinear Schrödinger equation: resonances and transmission profiles — •Kevin Rapedius and Hans Jürgen Korsch — Technische Universität Kaiserslautern, FB Physik, D-67653 Kaiserslautern, Germany

The stationary nonlinear Schrödinger equation (or Gross-Pitaevskii equation) for one-dimensional potential scattering is studied. The nonlinear transmission function shows a distorted profile, which differs from the Lorentzian one found in the linear case. This nonlinear profile function is analyzed and related to Siegert type complex resonances. It is shown, that the characteristic nonlinear profile function can be conveniently described in terms of skeleton functions depending on a few instructive parameters. These skeleton functions also determine the decay behavior of the underlying resonance state. Furthermore we extend the Siegert method for calculating resonances, which provides a convenient recipe for calculating nonlinear resonances. Applications to a double Gaussian barrier and a square well potential illustrate our analysis.

Q 27.25 Di 16:30 Poster C2

Kicked Bose-Hubbard systems and kicked tops – destruction and stimulation of tunneling — •Martin P. Strzys, Eva-Maria Graefe, and Hans Jürgen Korsch — TU Kaiserslautern, Germany

In a two-mode approximation, Bose-Einstein condensates (BEC) in a double-well potential can be described by a many particle Hamiltonian of Bose-Hubbard type. We focus on such a BEC whose interatomic interaction strength is modulated periodically by δ-kicks which represents a realization of a kicked top. In the (classical) mean-field approximation it provides a rich mixed phase space dynamics with regular and chaotic regions. By increasing the kick-strength a bifurcation leads to the appearance of self-trapping states localized on regular islands. This self-trapping is also found for the many particle system, however in general suppressed by coherent many particle tunneling oscillations. By varying the kick-strength and the coupling between the two wells the quasi-energy levels undergo both avoided and even actual crossings. Therefore stimulation or complete destruction of tunneling can be observed for this many particle system. Thus real self-trapping is possible for the full quantum system and the system can be tuned from enforced tunneling to this regime. This yields the possibility of a systematic and accurate population transfer between the two potential wells.

Q 27.26 Di 16:30 Poster C2

Dynamics of a low-dimension ultracold Bose gas — •Cédric Bodet and Thomas Gasenzer — Institüt für Theoretishe Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg

The dynamical evolution of a Bose-Einstein condensate trapped in a one-dimensional lattice potential is investigated theoretically in the framework of the Bose-Hubbard model. The emphasis is set on the far-from-equilibrium evolution in a case where the gas is strongly interacting. This is realized by an appropriate choice of the parameters in the Hamiltonian, and by starting with an initial state, where one lattice well contains a Bose-Einstein condensate while all other wells are empty. Oscillations of the condensate as well as non-condensate fractions of the gas between the different sites of the lattice are found to be damped as a consequence of the collisional interactions between the atoms. We approach this problem by numerically solving the Schrödinger equation for this model. We study in detail the particle number fluctuations on-site and between sites in order to investigate the conditions for producing squeezed states in experimentally realistic configurations.

Q 27.27 Di 16:30 Poster C2

Bose-Einstein condensates coupled to solid state systems — •Stephan Camerer[1,2], David Hunger[1,2], Daniel König[2], J.P. Kotthaus[2], T.W. Hänsch[1,2], Jakob Reichel[3], and Philipp Treutlein[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München — [3]LKB, Ecole Normale Superieure, Paris

The experimental fusion of quantum optics and solid-state physics is an emerging and auspicious field of fundamental research. Due to their capability to control atom clouds near surfaces, atomchip experiments seem to be particularly well suited to provide an experimental interface between a quantum optics and a condensed matter system.

Our experiment aims at studying the interaction between small atom clouds, particularly Bose-Einstein condensates (BECs), and nanomechanical resonators. We consider two different coupling schemes: the coupling of a nanoresonator to the magnetic spin of the atoms [P. Treutlein et al., Phys. Rev. Lett. 99, 140403 (2007)] and the coupling of a resonator to the motion of the atoms. In both cases, the BEC serves as a quantum probe for the mechanical motion of the resonator.

The current status of the experiment is reported.

Q 27.28 Di 16:30 Poster C2

Functional renormalisation group approach to far-from-equilibrium quantum field dynamics — •Stefan Kessler, Jan M. Pawlowski, and Thomas Gasenzer — Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg

We present a derivation of dynamic equations for quantum fields far from equilibrium by use of functional renormalisation group techniques. The obtained equations are non-perturbative and lead substantially beyond mean-field and quantum Boltzmann type approximations. The approach is based on a regularised version of the generating functional for correlation functions, where times greater than a chosen cutoff time are suppressed. As a central result a time evolution equation for the non-equilibrium effective action is derived. The time evolution of Green functions is computed within a vertex expansion. In a truncation of the flow equations the dynamic equations as known from the 1/N-expansion of the 2PI effective interaction are recovered.

Q 28: Poster Quanteninformation

Zeit: Dienstag 16:30–19:00 Raum: Poster C2

Q 28.1 Di 16:30 Poster C2

Adaptive Estimation of Qubits by Linear Optical Measurements — •Christof Happ and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, 89069 Ulm

Optical measurement methods for the estimation of an unknown qubit, of which only a limited number N of copies is available, are discussed. The studied methods compare a single copy of the unknown state $|\psi\rangle$ to an arbitrary ruler state $|r_\nu\rangle$ by beam splitter measurements. Using Monte Carlo simulations, schemes for estimating $|\psi\rangle$ as well as for adapting a reference state $|r_\nu\rangle$ for further measurements on remaining copies of $|\psi\rangle$ were investigated. We present simulation results assessing the quality of estimation by the average fidelity $\left|\langle\psi|\psi_N^{\mathrm{est}}\rangle\right|^2$ between unknown and finally estimated state $|\psi_N^{\mathrm{est}}\rangle$.

Q 28.2 Di 16:30 Poster C2

Dephasing of two Qubits — •Julius Helm and Walter T. Strunz — Theoretical Quantum Dynamics, Institute of Physics, University of Freiburg, Hermann-Herder-Strasse 3, 79104 Freiburg, Germany

We study quantum channels applied to systems of two qubits that may be described in terms of stochastically fluctuating classical fields (so-called random external fields or REF). For arbitrary pure initial states we examine the sensitivity of purity and entanglement of the composite quantum system when subject to dephasing channels, i.e., dissipationless quantum channels. With concurrence as entanglement measure we are able to identify certain accessible regions in the purity-concurrence diagram, generalizing results obtained for local unital channels [1]. Furthermore, we identify a class of initial states that are robust against disentanglement when only dephasing channels acting on both qubits simultaneously are involved.

[1] Ziman, M and Bužek, V, "Concurrence vs. purity: Influence of local channels on Bell states of two qubits", Phys. Rev. A 72, 052325 (2005)

Q 28.3 Di 16:30 Poster C2

Effect of local operations on entanglement-induced state ordering of two qubits — •Lars Erik Würflinger and Walter T. Strunz — Theoretical Quantum Dynamics, Institute of Physics, University of Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg

Any measure of entanglement E induces an ordering of states. Local operations on a bi-partite quantum system cannot create entanglement; but in what way do they affect the ordering of states? Focussing on the two qubit case we find that there are no unital local channels that preserve the ordering for all states, with unitary and entanglement breaking channels being the only (trivial) exceptions, as has been conjectured by Ziman and Buzek [1]. However, when restricted to certain one-parameter families of states such as Werner states, or pure states, ordering based on concurrence is preserved under all local unital channels. We therefore investigate in more detail to what extend entanglement-induced state ordering is preserved for a restricted class of states (or channels).

[1] M. Ziman and V. Bužek: *Entanglement-induced state ordering under local operations*, Phys. Rev. A **61**, 012312 (2006).

Q 28.4 Di 16:30 Poster C2

A planar Paul trap — •Robert Matjeschk, Christian Schneider, Hector Schmitz, Axel Friedenauer, Jan Glückert und Tobias Schätz — MPI für Quantenoptik, Hans-Kopfermann Str. 1, 85748 Garching

In recent years, along with the idea of quantum-computing, the concept of quantum-simulations arose. This is considered to be a new approach to investigate the dynamics of quantum many-body systems in nature. A promising realization is the simulation based on trapped ions, in particular in Paul traps. Besides the principle study of feasibility, an important issue is scalability - the possibility to confine and control many ions. A magnitude of 100 to 1000 ions is supposed to lead to new insight into quantum many-body dynamics.

In linear traps this scalability is hindered by the fact that all ions are trapped in one effective oscillator potential. This leads for example to a non-homogeneous distance distribution and thus to a non-homogeneous interaction strength distribution between the ions. Also in such assemblies only one dimensional systems could be simulated.

We are developing a 2D-surface-trap where each ion is confined in its own effective oscillator potential, while the (homogeneous) distance between the ions is still small enough (30-50 μm) to maintain a non-negligible ion-ion interaction (mediated by coulomb forces). The ions will be aranged in a two-dimensional plane, adressing yet unsolved two-dimensional problems like spin frustration in 2D lattices.

Q 28.5 Di 16:30 Poster C2

Techniques minimizing noise in a quantum simulation using trapped Mg ions — •Jan Tibor Glückert — Max-Planck-Institut für Quantenoptik, Garching, Deutschland

Creating a robust experimental setup is a essential task for experiments in the quantum regime e.g. quantum simulation. Disturbing effects before and during a quantum simulation must be minimized in order to reach a suitable fidelity. In a quantum simulation using Mg ions in a linear Paul trap we were confronted with three types of disturbance mainly. Thermal motion of the ions is a handicap for gaining high precision in the most experiments but a knock-out criterion for experiments which require knowledge of the system's exact motional state. Furthermore the radio-frequency fields used to confine the ions in the trap can lead to periodical motion of the ions (so called micromotion) which can be responsible for further heating effects. The third effect originates in fluctuations of the ion's energy levels itself. Induced by Zeeman effect these level follow (periodical) disturbance in the applied magnetic fields. We present the impact of these effects on a feasibility study on quantum simulation and techniques to cope with them. Namely, these techniques are first and second sideband cooling to ground state ($\bar{n} < 0.05$), a procedure minimizing micromotion and a setup reducing magnetic field fluctuation.

Q 28.6 Di 16:30 Poster C2

Quantum Information Processing with Atoms in Arrays of Dipole Potentials — •Malte Schlosser, Jens Kruse, Andre Lengwenus, Christian Gierl, Joost Sattler, and Gerhard Birkl — Institut für Angewandte Physik, TU Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt

Quantum information processing with neutral atoms represents an important experimental approach complementing systems based on trapped ions. Especially the question of scalability might be easier addressed in the case of neutral atoms. By using ultra-cold atoms in optical dipole traps, one can realize highly controllable systems with long coherence times. In our experiment, we use two-dimensional arrays of optical micro-potentials created by micro-fabricated lens arrays as the architecture for a scalable quantum proecessor. Due to the large lateral separation of neighboring potential wells, each trap is individually addressable. For the qubit manipulation, we apply coherent Raman coupling to the hyperfine ground states of small ensembles of ^{85}Rb atoms. We demonstrate the transport of atoms from one trap position to another which is needed for a realization of a two-qubit gate based on ultracold collisions. The scalability of this transport process up to macroscopic distances is shown by performing a repeated hand over of atoms from trap to trap. We present investigations of the coherence of the system using Ramsey and spin-echo methods and observe nearly no loss of coherence while moving the atoms.

We give a detailed overview of the experimental configuration, the experiments performed, and the results obtained.

Q 28.7 Di 16:30 Poster C2

Quantum cryptography with qudits using one- and two-way entanglement purification — •Kedar Ranade and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt

Well-known quantum cryptographic protocols can be generalised to qudits, i. e. to d-dimensional quantum systems. We analyse the security of these protocols using entanglement purification involving one-way and two-way classical communication, focussing on protocols which can be reduced to practically feasible prepare-and-measure schemes. We further attempt to provide precise bounds for the maximally tolerable error rates of these protocols using generic methods to determine such bounds.

Q 28.8 Di 16:30 Poster C2

Towards Einstein-Podolsky-Rosen quantum channel multiplexing — •Aiko Samblowski, Boris Hage, and Roman Schnabel — Institut für Gravitationsphysik, Leibniz Universität Hannover und Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstraße 38, 30167 Hannover, Germany

We present an experiment to utilize a single broadband squeezed field as a source for a large number N of quantum channels, based on distributed Einstein-Podolsky-Rosen (EPR) entangled states. Each of those channels can serve as a resource for independent quantum communication protocols. N-fold channel multiplexing can be realized by accessing $2N$ squeezed modes at different Fourier frequencies of a single squeezed field. We demonstrate the experimental implementation of the $N = 1$ case through the interference of two squeezed modes.

Q 28.9 Di 16:30 Poster C2

Fiber based Quantum Cryptography with Continuous Variables — •Josef Fürst[1], Carlos H. Wiechers M.[1,3], Dominique Elser[1], Christoffer Wittmann[1], Ulrik L. Andersen[1,2], and Gerd Leuchs[1] — [1]Institut für Optik, Information und Photonik, Max-Planck-Forschungsgruppe, Universität Erlangen-Nürnberg, Günther-Scharowsky-Str. 1 / Bau 24, 91058 Erlangen, Germany — [2]Department of Physics, Technical University of Denmark, Building 309, 2800 Kgs. Lyngby, Denmark — [3]Instituto de Física de la Universidad de Guanajuato, Lomas del Bosque 103, 37150 León, Guanajuato, Mexico

Quantum Key Distribution (QKD) offers a secure method of sharing a secret key between two parties, commonly called Alice and Bob. In general, there are two different kinds of QKD protocols either with discrete variables or with continuous variables. We implement a continuous variable protocol with binary encoded coherent states, which offers convenient state preparation and measurement. No entanglement source is present in our prepare and measure scheme. However, the nonorthogonality of the signal states, encoded by discrete phase and amplitude modulation, leads to effective entanglement [1]. The encoded states (ES) and the Local Oscillator (LO) are sent from Alice to Bob via a single optical fiber using time multiplexing. Thereby, scattering from the LO into the ES, which generates noise, is prevented. Subsequently, we measure both conjugate quadratures of the ES by homodyne detection and generate the raw key using postselection.

[1] S. Lorenz et al., Phys. Rev. A 74, 042326 (2006)

Q 28.10 Di 16:30 Poster C2

Free Space Quantum Key Distribution with Coherent Polarization States — •Tim Bartley[1], Dominique Elser[1], Christoffer Wittmann[1], Ulrik L. Andersen[1,2], and Gerd Leuchs[1] — [1]Institut für Optik, Information und Photonik (Max-Planck-Forschungsgruppe), Universität Erlangen-Nürnberg, Günther-Scharowsky-Str. 1, Bau 24, 91058 Erlangen — [2]Department of Physics, Technical University of Denmark, Building 309, 2800 Kgs. Lyngby, Denmark

Quantum key distribution (QKD) is the process of establishing a secret shared key between two parties, traditionally named Alice and Bob. The security is based on the laws of quantum mechanics, in contrast to classical schemes, where security relies only on unproven mathematical assumptions.

In our free space QKD setup we encode the signal in coherent states which allow for convenient and fast state preparation and measurement. We utilize a pair of conjugate polarization variables (Stokes parameters) as signal carriers. This produces an excellent interference between signal and local oscillator without the need for stabilization. After the successful demonstration of this QKD scheme in the laboratory [1], we now present a proof-of-principle experiment under real free space conditions: the quantum states are transmitted over 100 m on the roof of our institute's building. The use of a retro-reflector enables us to place Alice's and Bob's station on the same optical table. In the future, we plan to establish a QKD link between two distinct buildings 1.5 km apart.

[1] S. Lorenz et al., Phys. Rev. A **74**, 042326 (2006).

Q 28.11 Di 16:30 Poster C2

QKD Decoy Protocol with Photon Number Measurement

— •Malte Avenhaus[1], Wolfgang Mauerer[1], Patrick Bronner[2], and Christine Silberhorn[1] — [1]Max Planck Research Group IOIP, Günther-Scharowsky-Str. 1 / Bau 24, 91058 Erlangen — [2]Friedrich-Alexander-Universität Erlangen Nürnberg, Staudtstr. 7, 91058 Erlangen

Quantum decoy protocols provide an advantageous alternative to various conventional QKD protocols. Decoy protocols feature a lower threshold for detecting a potential eavesdropper and thus increase the secure communication distance. The principle of operation is that Alice uses photons as quantum carriers and interposes a decoy photon distribution within the signal.

We investigate the experimental implementation of a decoy protocol. On Alice's side, a pulsed laser beam pumps a PDC process in a PPKTP wave-guide. The PDC process shows high source brightness and converts photons from the pump mode at 1550nm in signal and idler mode of 800nm and 1550nm respectively. The signal mode is particularly apt for photon number measurements on Alice's side, whereas the idler mode is used for low loss transmission via telecommunication fibre to recipient Bob. The decoy subset during communication may be chosen a posteriori while performing a classical communication.

Q 28.12 Di 16:30 Poster C2

Spectral effects in Quantum Key Distribution — •Wolfram Helwig, Wolfgang Mauerer, and Christine Silberhorn — University Erlangen-Nuremberg, Max-Planck Research Group IOIP, Integrated Quantum Optics Group

In recent years tremendous research progress was made in the field of quantum key distribution (QKD). By now a variety of protocols exists for which security has been proven even for realistic imperfect devices. The proofs based on the idea of Shor and Preskill, provide us with a lower bound on the secure key generation rate. The security of BB84 relies on the fact, that well defined single-mode photonic states are prepared by the sender and used as information carriers. However, potential sources for QKD implementations like parametric down conversion (PDC) sources emit states with a multi-mode spectral distribution. These states have to be described in a higher-dimensional Hilbert space. We investigate to what extent these spectral properties affect the security considerations.

We further present a comparison of the theoretical bounds on the secure key rates for different protocols and the dependence on various experimental imperfections, e.g., dark-counts, detector efficiency, channel attenuation etc. Only single-photon signals contribute to the secure key, but unfortunately such sources don't exist at present. Hence we consider different photon statistics in our simulations.

Q 28.13 Di 16:30 Poster C2

Beyond the three-partite GHZ and W states using a bimodal cavity — •Denis Gonta[1], Thomas Radtke[2], and Stephan Fritzsche[1,3] — [1]Max–Planck–Institut für Kernphysik, Postfach 103980, D–69029 Heidelberg — [2]Institut für Physik, Universität Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel — [3]Physikalisches Institut der Universität Heidelberg, Philosophenweg 12, D-69120 Heidelberg

In the framework of cavity QED, we propose two novel schemes to engineer the four-partite entangled GHZ and W states. The entangled states are produced between the two-level Rydberg atoms in a deterministic way. In contrast to standard (single-mode) cavity schemes, our proposal is based on a *bimodal* cavity that possesses two independent modes of the light field. In addition, we suggest two schemes to reveal the non-classical correlations of the entangled states and to ensure that no statistical (uncorrelated) mixtures of states have been produced. An extension of the schemes to produce N-partite entangled GHZ and W states is also possible.

Q 28.14 Di 16:30 Poster C2

Wigner-Ionenkristalle für Quanteninformationsverarbeitung — •Jens Baltrusch[1], Jacob Taylor[2] und Tommaso Calarco[1] — [1]Institut für Quanteninformationsverarbeitung, Universität Ulm, 89079 Ulm — [2]Department of Physics, Massachusetts Institute of Technology, Cambridge, MA 02139

In einer Penningfalle gefangene Ionen formieren sich bei geeignet gewählten Fallenparametern und Temperaturen zu 2D- oder 3D-Wigner-Kristallen. Typische Ionenabstände in einem solchen Wigner-Kristall sind in der Größenordnung von 10 μm, so dass Adressierung und Quantenkontrolle einzelner Ionen mit Hilfe von stark fokussierten Lasern realisierbar sind. Weiter sind bei thermischen Phononenanregungen robuste Zwei-Qubit-Quantengatter genauso implementierbar wie hochverschränkte Zustände, sogenannte Cluster-States, so dass dieses System ein vielversprechenden und skalierbaren Zugang für zahlreiche Anwendungen in der Quanteninformationsverarbeitung bietet.

Der Schwerpunkt unserer theoretischen Untersuchungen liegt dabei in der Bestimmung der für eine experimentelle Umsetzung geeigneten Übergänge und Laserkonfigurationen, um insbesondere eine möglichst hohe Genauigkeit der Gatteroperationen bei gleichzeitig kurzen Gatterzeiten zu erzielen. Offene Fragestellungen betreffen unter anderem die Ausweitung bisheriger Konzepte auf 3D-Kristalle sowie den Einfluß der Zyklotronbewegung auf die Genauigkeit und Stabilität der implementierten Gatter.

Q 28.15 Di 16:30 Poster C2

Towards long distance atom-atom entanglement — •Wenjamin Rosenfeld[1], Florian Henkel[1], Michael Krug[1], Christian Jakob[1], Andreas Deeg[1], Fredrik Hocke[1], Jürgen Volz[1], Markus Weber[1], and Harald Weinfurter[1,2] — [1]Fakultät für Physik der LMU, 80799 München — [2]Max-Planck Institut für Quantenoptik, 85748 Garching

Entanglement is a central part of quantum information and communication applications. Of special interest is entanglement between different quantum objects like photons and atoms. It allows to combine the advantages of long atomic coherence times with the ability of photons to transport quantum information over large distances.

In our experiment we generate entanglement between the spin of a single optically trapped Rb87 atom and the polarization of a photon in a spontaneous decay process in a lambda-type transition[1]. Based on this entanglement we performed a first demonstration of a quantum communication protocol between an atomic qubit and a photonic communication channel[2]. More recently we have demonstrated faithful distribution of entanglement over a 300 m long optical fiber. Here we report on the realization of a second atom trap and on the progress towards generating entanglement between two distant atoms via entanglement swapping.

[1] J. Volz et al., PRL 96, 030404 (2006)
[2] W. Rosenfeld et al., PRL 98, 050504 (2007)

Q 28.16 Di 16:30 Poster C2

Single-Atom Single-Photon Quantum Interface — •Tatjana Wilk[1], Simon C. Webster[1], Axel Kuhn[2], and Gerhard Rempe[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching — [2]Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU, UK

Atom-cavity systems with the ability to generate single photons provide an ideal toolbox for quantum networks. Atoms stored in an intracavity dipole trap act as quantum memories, whereas photons can be used to interconnect distant atom-cavity nodes. The cavity provides an interface between the stationary and flying qubits that boosts the overall efficiency of single photon generation compared to freespace, thus allowing quantum state transfer from a single atom onto a single photon [1]. This is demonstrated by entangling a single atom with a single photon emitted into the cavity mode and subsequently mapping the quantum state of the atom onto a second photon. The latter step disentangles the atom from the light and results in an entangled photon pair. [1] Wilk et al., *Science* **317**, 488 (2007).

Q 28.17 Di 16:30 Poster C2

Observing Free-Space and Cavity Emission of one Atom in a High-Finesse Optical Cavity — •Holger Specht, Bernhard Weber, Tobias Müller, David Moehring, and Gerhard Rempe — Max-Planck-Institute for Quantum Optics, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany

Using state of the art trapping techniques and cavity cooling schemes we are able to trap a single neutral atom inside a high-finesse cavity for several tens of seconds. In [1] we showed that our coupled atom-cavity system can be used to generate single photons in a controlled way. With our long trapping times and a single-photon production efficiency of 9% we produced on average 10ˆ5 single photons with a single trapped atom. The non-classical properties of the emitted light has been shown in the photon correlations of just one trapping event.

With a new high-resolution camera system we are now able to monitor the atom within the cavity mode from the side, allowing the simultaneous observation of free-space emission and scattering into the cavity. Finally, we also discuss new insights into the dynamics of the system with single and multiple trapped atoms.

[1] Hijlkema et al, Nature Physics 3, 253-255 (2007).

Q 28.18 Di 16:30 Poster C2

Cooling, storing, and manipulating single atoms in an optical cavity — •Jörg Bochmann, Martin Mücke, David Moehring, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

Single atoms coupled to high finesse cavities provide unique systems to study light-matter interactions in the quantum regime. Deterministic generation of single photons and application as a single photon server has been demonstrated [1]. Naturally, these systems are well suited for generation of entangled states between atoms and photons [2].

Efficient operation of these experiments relies on cavity-mediated cooling of the atom within the cavity mode [3]. In our new setup, we reliably trap and cool Rb atoms in a cavity using a 2D-optical lattice of far detuned dipole traps. The cavity parameters put the system at the boundary of the strong coupling regime and we have observed constant coupling of atoms to the cavity over many seconds. Photons generated inside the cavity are outcoupled to an optical fiber and transmitted to a detection setup with ca. 50% efficiency. Improvements regarding a 3D-dipole trap configuration and fast photon generation schemes are in progress.

[1] M. Hijlkema, et al., Nature Physics 3, 253 (2007)
[2] T. Wilk, et al., Science 317, 488 (2007)
[3] S. Nußmann, et al., Nature Physics 1, 122 (2005)

Q 28.19 Di 16:30 Poster C2

Experimental techniques for quantum information processing with trapped ^{40}Ca$^+$ ions — •Michael Brownnutt[1], Felicity Splatt[1,2], Max Harlander[1], Wolfgang Hänsel[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Österreich — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Innsbruck, Österreich

One of the outstanding requirements for realising quantum computing with trapped ions is the implementation of a truly scalable trap architecture. Proposals for such architectures include segmented linear Paul traps, where the segmentation allows the axial confining potential to be varied. Ions can thereby be independently held in - and moved between - separate trapping regions. We present numerical models of linear shuttling of ions in such traps, and of optimised shuttling through junctions. We also report on developments in fabrication and testing of various segmented trap designs. Finally, work regarding practical aspects of vacuum chamber design will be outlined.

Q 28.20 Di 16:30 Poster C2

Application of optimal control techniques in scalable ion trap quantum logic — •Ulrich Poschinger, Kilian Singer, and Ferdinand Schmidt-Kaler — Institut für Quanteninformationsverarbeitung, Universität Ulm, Albert-Einstein-Allee 11, 89069 Ulm

Strings of laser cooled ions in a Paul trap provide a yet unmatched degree of quantum control[1]. The drawback of this concept lies in the limited scalability, which can be overcome by operating a microstructured array of Paul traps and shuttling the ions between different trap sites. The shuttling operations are carried out by dynamically changing the confining voltages at the trap segments. They have to be fast, robust and should not contribute excess energy to the ion qubit as this would spoil subsequent quantum logic operations. This setting suggests the application of optimal control (OCT) techniques. We present numerical results showing that OCT should indeed make such shuttling operations possible[2]. Furthermore, quantum logic logic gates can benefit from OCT as well since achieving high fidelities is crucial for attaining the quantum error correction threshold[3]. We demonstrate numerically that shaped pulse sequences obtained by OCT allow for the implicit compensation of parameter offsets. Analogously to NMR experiments, the logic operations can therefore be robustified[4].

[1] H.Häffner et al., Nature 438, 643 (2005)
[2] S. Schulz et al., Progress of Physics, Wiley 54, No. 8-10, 648 (2006)
[3] C. Roos, arXiv:0710.1204v3 (2007)
[4] N. Timoney et al. quant-ph/0612106 (2006)

Q 28.21 Di 16:30 Poster C2

HC-PCF based Rubidium vapor cell — •wenjia zhong[1], christoph marquardt[1], ulrik l. andersen[2], and gerd leuchs[1] — [1]Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg, 91058 Erlangen, Germany — [2]Department of Physics, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark

Using hollow core photonic crystal fiber as a vapor cell has the advantage of long interaction length and small laser beam area. We filled the core of a HC-PCF with liquid Rubidium using microfluidic methods and put the fiber ends inside vacuum chambers to prevent oxidization and quenching. With a constant temperature along the entire length of the fiber, the rubidium will be evaporated to prevent bulk condensation. The Rb density will be monitored by the help of absorption spectroscopy.

We plan to use the D1 transition of Rb and a femtosecond laser beam to achieve the sharp-line limit of self-induced transparency. The nonlinearity inherent in detuned SIT will then be exploited for the generation of squeezed states.

Q 28.22 Di 16:30 Poster C2

Controlled dynamic generation of entanglement — •Thomas Häberle[1], Kilian Singer[2], and Matthias Freyberger[1] — [1]Institut für Quantenphysik, Universität Ulm, 89069 Ulm — [2]Institut für Quanteninformationsverarbeitung, Universität Ulm, 89069 Ulm

We discuss two compact particles in a harmonic trap which interact via pointlike collisions. The interaction can be modelled by a δ-potential in the relative coordinate of the particles. Each collision will dynamically entangle the particles by a certain amount. Therefore, the time evolution of entanglement will show a step-like behaviour [1]. We now study if it is possible to maximize the entanglement at an arbitrarily fixed time by dynamically varying the trap frequency. We approach this problem by using appropriate techniques [2] from optimal control theory.

[1] M. Bußhardt and M. Freyberger, Phys. Rev. A **75**, 052101 (2007).
[2] T. Calarco et al., Phys. Rev. A **70**, 012306 (2004).

Q 28.23 Di 16:30 Poster C2

Optimiertes Atom-Ion-Quantengatter — •Hauke Doerk-Bendig[1], Zbigniew Idziaszek[2] und Tommaso Calarco[1] — [1]Institut für Quanteninformationsverarbeitung, Universität Ulm, 89079 Ulm, Deutschland — [2]Center for Theoretical Physics, Polish Academy of Science, 02-668 Warschau, Polen

Die gleichzeitige Verwendung von neutralen Atomen und Ionen in der Quanteninformationsverarbeitung ist durch die Kombination der Vorteile beider Spezies motiviert. Einerseits ist die Dekohärenzzeit von Atomen in optischen Gittern lang, andererseits lassen sich Gatteroperationen mit Ionen wegen ihrer relativ starken Wechselwirkung mit hoher Geschwindigkeit durchführen.

Wir wollen die theoretische Grundlage für ein solches Quantengatter schaffen, indem wir die von der inneren Struktur abhängigen Wechselwirkung gefangener Atome mit gefangenen Ionen studieren und mit Hilfe einer durch ein externes Magnetfeld gesteuerten Feshbach-Resonanz kontrollieren.

Unsere weitere Arbeit besteht darin, geeignete Hyperfeinzustände von Atom und Ion für die Kodierung von Qubits zu finden und Fidelity und Laufzeit eines Quantengatters mittels Quantum Optimal Control zu optimieren.

Q 28.24 Di 16:30 Poster C2

Photo-ionization studies of Calcium atoms — •Carsten Schuck, Marc Almendros, Felix Rohde, Francois Dubin, Markus Hennrich, and Jürgen Eschner — ICFO - Institut de Ciencies Fotoniques, 08860 Castelldefels (Barcelona), Spain

We present a novel method for the efficient ionization of neutral Calcium atoms, which is used in our ion trap experiment. The atoms are resonantly excited from the ground state via the intermediate 4s4p $^1P_1$ level close to the continuum, where they are ionized in the strong electric fields of the Paul trap [1]. For the first step a laser source at 423 nm is used while an incoherent source around 390 nm is sufficient for the second step [2]. We use a temperature-stabilized periodically poled $KTiOPO_4$ crystal to create coherent 423 nm light in second harmonic generation from a 170 mW extended cavity diode laser in single pass [3]. A hollow cathode lamp is used to tune the laser to the ^{40}Ca resonance. The 390 nm light is obtained from a high power indium gallium nitride LED, which emits approximately 85 mW of optical output power around its 380 nm peak wavelength. Using achromatic doublet lenses we focus the light from both sources into a multimode fiber and then image the fiber end to a 200 μm spot at the center of the trap, where they are overlapped with the atomic beam.

[1] S. Gulde, et al., Appl. Phys. B **73**, 861 (2001),
[2] D.M. Lucas, et al., Phys. Rev. A **69**, 012711 (2004),
[3] F. Torabi-Goudarzi, E. Riis, Opt. Comm. **227**, 389 (2003).

Q 28.25 Di 16:30 Poster C2

Counterpropagating PDC photon source with PPLN waveguides — •Andreas Christ, Andreas Eckstein, and Christine Silberhorn — Günther-Scharowsky-Str. 1, Bau 24

We investigate the properties of a quasi-phasematched parametric downconversion process in a periodically poled $LiNbO_3$ waveguide. Our aim is to provide a bright source of pure single photon pairs at the telecom wavelength, i.e. 1550 nm. To quantify the amount of frequency entanglement we perform a Schmidt-decomposition of the joint spectrum.

Our focus lies on the creation of counterpropagating photon-pairs and applications in integrated quantum networks:

Firstly these counterpropagating and uncorrelated photons enable us to design a photon source without spatial and spectral filtering. Combined with the application of a waveguide instead of a bulk crystal, we propose an ultrabright source of decorrelated photon pairs.

Secondly we investigate one of the most interesting aspects of counterpropagating photon pairs: The included separation between the signal and idler beams, offering the possibility to separately access the signal and idler photons even for degenerate type-I phasematching.

Q 28.26 Di 16:30 Poster C2

Maple tools for teaching and exploring quantum computation and information protocols — •Thomas Radtke[1] and Stephan Fritzsche[2] — [1]Institut für Physik, Universität Kassel, 34132 Kassel, Germany — [2]Gesellschaft für Schwerionenforschung (GSI), 64291 Darmstadt, Germany

During the last decade, the field of quantum information and computation has been growing rapidly. Beside of the great promise and the potential of various quantum information protocols, such as Shor's factorization algorithm, quantum teleportation and others, however, there are still many open problems to be solved. Although entanglement has been recognized today as a crucial resource for quantum information, it is still not fully understood, especially in the multipartite setting [1].

To assist in the teaching and study of multi-qubit quantum states and algorithms, several software tools have been presented and discussed in the web. More often than not, however, these tools only implement a rather limited set of features or they were focused on special protocols. Therefore, in order to provide a flexible toolbox, we developed the FEYNMAN program within the framework of MAPLE [2]. Apart from a catalogue of frequently used quantum gates and noisy channels this program implements a variety of separability criteria as well as entanglement measures. In this poster, we show how this toolbox can be utilized for teaching basic but also more advanced topics in quantum information theory.

[1] R. Horodecki et al., quant-ph/0702225v2
[2] T. Radtke, S. Fritzsche, Comput. Phys. Commun. 176 (2007) 617

Q 29: Poster Quanteneffekte

Zeit: Dienstag 16:30–19:00 Raum: Poster C2

Q 29.1 Di 16:30 Poster C2

A single photon source with a Ca^+ cavity-QED system — •Andreas Stute[1,2], Carlos Russo[1,2], Helena G. Barros[1,2], François Dubin[1], Piet O. Schmidt[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universiät Innsbruck, Technikerstr. 25, A-6020 Innsbruck — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, A-6020 Innsbruck

Linear optics quantum computation as well as quantum cryptography require a source of single, indistinguishable photons. We realize a deterministic source of single photons in a setup consisting of a single trapped $^{40}Ca^+$ ion coupled to a single mode of a high finesse optical resonator. A single trapped ion can be stored for days and can be precisely positioned in the cavity mode.

Photons are generated in a vacuum-stimulated Raman process driven by a pulsed pump laser and the cavity vacuum field. During the pump pulse a photon is emitted into the cavity mode, subsequently leaves the cavity and is detected with a Hanbury Brown & Twiss setup. The system is initialized again by repumping the ion back to the ground state and the sequence is repeated.

The resulting intensity correlation $g^{(2)}(\tau)$ reveales the signature of a single photon source. The experimental results are in excellent agreement with numerical simulations of the process.

Q 29.2 Di 16:30 Poster C2

Towards controlled Cavity-QED experiments with toroidal microresonators — •Rico Henze[1], Markus Gregor[1], Tim Schröder[1], Helmar Kostial[2], Edith Wiebicke[2], and Oliver Benson[1] — [1]AG Nano-Optik, Institut für Physik, Humboldt-Universität zu Berlin, Hausvogteiplatz 5-7, 10117 Berlin — [2]Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin

Optical microresonators are interesting systems to study the light-matter interaction on the nanometer scale. The so-called Whispering Gallery Modes (WGM) in spherical resonators offer high spatial and temporal light confinement, a prerequisite for Cavity-QED experiments. We report the production and optical characterization of chip-based SiO_2 toroidal microresonators which we produce by standard clean room techniques. A tapered optical fiber is implemented as an efficient light coupler. Combined with scanning probes (SNOM and AFM) a versatile setup is created that allows to study the optical mode structure of the WGMs in a toroidal cavity or to position nanoscopic emitters on the resonator surface at will.

Q 29.3 Di 16:30 Poster C2

Double-Slit Light Diffraction in Strong Electromagnetic Fields — •Ben King, Antonino Di Piazza, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

In [1] the vacuum-polarisation effects of change in ellipticity and polarisation of a laser probe beam passing through an ultra-intense standing wave, were calculated. We further develop these results to increase the measurable polarisation and ellipticity, by calculating diffraction effects from the double-slit-like setup of two parallel and off-centre, gaussianly-focused, strong field waves propagating against each other. We move towards a measurable set-up through calculations of the off-axis effects on a focused probe beam, allowing alternative detection of these vacuum effects.

[1] A. Di Piazza, K. Z. Hatsagortsyan, and C. H. Keitel, Phys. Rev. Lett. 97, 083603 (2006)

Q 29.4 Di 16:30 Poster C2

Thermodynamics and quantum effects — •Stefanie Hilt[1] and Eric Lutz[2] — [1]Institut für Quantenphysik, Universität Ulm, Deutschland — [2]Institut für Physik, Universität Augsburg, Deutschland

We consider a system coupled to a heat reservoir modelled by a harmonic chain and discuss the influence of quantum effects on the equilibrium properties of the system. Special emphasis is put on the low temperature regime where quantum fluctuations play an important role. In particular, we use the negativity to quantify the entanglement created between the system and the reservoir.

Q 29.5 Di 16:30 Poster C2

Dekohärenz molekularer Konfigurationszustände — •Johannes Trost und Klaus Hornberger — Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians-Universität, München

Superpositionszustände von Enantiomeren, d.h. von isomeren Molekülen mit unterschiedlicher Konfiguration, werden bei komplexeren Molekülen nicht beobachtet. Bei einfachen chiralen Molekülen wie Dihydrogendisulfid, HSSH, (oder der deuterierten Form DSSD) ist zu erwarten, dass die Kohärenz solcher quantenmechanischer Superpositionen durch Streuprozesse mit Molekülen des Umgebungsgases beschränkt wird. Wir entwickelten ein Modell, das dispersive Wechselwirkungen des chiralen Moleküls mit einfachen Hintergrundgasen realistisch und konsistent beschreibt. Anhand dieser chiralitätsabhängigen Wechselwirkungen lässt sich die Dekohärenzrate durch Stöße streutheoretisch berechnen und eine Abhängigkeit spektroskopischer Übergangslinien von der Stoßrate demonstrieren.

Q 29.6 Di 16:30 Poster C2

Creating and Ascertaining Entanglement of Atoms by Photon Scattering — •Torsten Scholak and Cord A. Müller — Physikalisches Institut, Universität Bayreuth, 95440 Bayreuth, Germany

We study the light-scattering dynamics of two tightly trapped atoms with internal spin degrees of freedom. The aim is to manipulate populations and coherences by a selective tuning of photon field parameters like polarization. We are particularly interested in the preparation of entanglement and its subsequent witnessing [1] by interaction with the driving laser field.

[1] arXiv:0710.0825

Q 29.7 Di 16:30 Poster C2

Coherent beam splitting with a single spontaneously emitted photon — •Jiri Tomkovic[1], Michael Schreiber[1], Inka Benthin[1], Arne Schietinger[1], Jörg Schmiedmayer[2], and Markus Oberthaler[1] — [1]Kirchhoff Institut für Physik,Universität Heidelberg, 69120 Heidelberg — [2]Atominstitut der Österreichischen Universitäten, TU-Wien, Stadionallee 2, A-1020 Vienna, Austria

Spontaneous emission of a photon leads to a momentum transfer to the emitting atom. In free space this leads to a incoherent momentum distribution of the atom which is typically used in laser cooling schemes. In case the atom is close to a mirror, the situation can drastically change since directly emitted and reflected light can principally not be distinguished in certain directions. Thus at distances of few micrometers the spontaneous emission of a single photon leads to a coherent superposition of two momentum states of the atom. We will present our experimental results revealing the expected coherence.

Q 29.8 Di 16:30 Poster C2

Electromagnetically induced transparency and retrieval of light pulses in a Pr^{3+}:Y_2SiO_5 crystal — •Georg Heinze, Fabian Beil, Jens Klein, and Thomas Halfmann — Institut für Angewandte Physik, TU Darmstadt, Hochschulstraße 6, 64289 Darmstadt

Recent research on coherent interactions between light and matter already led to a large variety of applications. In particular electromagnetically induced transparency (EIT) and the closely related concepts of slow light and light storage play an important role in quantum information processing and optical data storage. A very promising approach is the implementation of these techniques in solids, e.g. in particular rare earth doped solids. These media offer the advantages of solids, i.e. high density and scalability, while still exhibiting sharp optical transitions - like free atoms in the gas phase. We apply EIT and related techniques in a Pr^{3+}:Y_2SiO_5 crystal, cooled to cryogenic temperatures. The dopant ions are prepared by optical pumping and spectral hole-burning. This permits the generation of spectrally isolated Λ-type or V-type systems within the inhomogeneous bandwidth of the $^3H_4 \leftrightarrow {}^1D_2$ transition of the Pr^{3+} ions. We observe and compare cancellation of absorption due to EIT in the Λ-type coupling scheme as well as in the V-type coupling scheme. By EIT, we also excite persistent nuclear spin coherences between the hyperfine levels of the ground state (Λ-System) or the excited state (V-system). These coherences are probed by time delayed retrieval of light pulses. Hereby we determine the dephasing times of the nuclear spin coherences of the Pr^{3+} ions, either in the ground state or in the optically excited state.

Q 29.9 Di 16:30 Poster C2

Negative refraction in atomic two-component media — •Bastian Jungnitsch and Jörg Evers — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

We discuss the feasibility of obtaining negative refraction with low losses or even gain in an atomic gas consisting of two different species of atoms [1]. The two components yield electrical and magnetical responses, respectively, which are individually tailored via external fields to give the desired negative index of refraction. Using different atoms for magnetic and electric response allows to relax the stringent requirements to achieve negative refraction in single species systems [2]. For this, several few-level systems with different combinations of coherent and incoherent driving fields are compared with an emphasis on the problem of obtaining a sufficiently large magnetic response. Based on these results, we discuss potential candidate systems in real atoms.

[1] B. Jungnitsch and J. Evers, in preparation

[2] P. P. Orth, J. Evers, and C. H. Keitel, arXiv:0711.0303

Q 29.10 Di 16:30 Poster C2

Pulse propagation in a medium with time-dependent refractive index — •Martin Kiffner[1] and Tarak N. Dey[1,2] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Indian Institute of Technology Guwahati, Guwahati- 781 039, Assam, India

The phenomenon of electromagnetically induced transparency (EIT) gives rise to counterintuitive effects like the slowing and stopping of light and is of great importance, e.g., for the fields of quantum information theory and nonlinear optics [1]. Here we consider a standard EIT medium comprised of three-level Λ-type atoms and investigate the influence of a polychromatic control field on the propagation of the probe pulse. Our results are analyzed in terms of a time-dependent refractive index.

[1] M. Fleischhauer, A. Imamoglu, and J. P. Marangos, Rev. Mod. Phys. **77**, 633 (2005).

Q 29.11 Di 16:30 Poster C2

Stationary light in cold gases — •Gor Nikoghosyan and Michael Fleischhauer — Fachbereich Physik, TU Kaiserslautern

One of the challenging problems of practical quantum information processing with photons is to achieve a strong nonlinear coupling between two single-photon pulses. A promising approach for its realizations is based on so-called stationary light in resonant Λ-type media with electromagnetically induced transparency. Here a weak probe pulse is trapped in the medium by a stationary coupling field. Previous theoretical studies considered room-temperature ensemble where atomic motion leads to a rapid dephasing of high-frequency components of the ground-state coherence allowing for a secular approximation. In the present work we study the dynamics of the probe pulse in cold media where this approximation no longer holds. We show that in the case of one-photon resonance forward and backward components of the probe field are decoupled and no stationary light pattern is formed.

Q 29.12 Di 16:30 Poster C2

Stationary light and Klein tunneling — •Razmik Unanyan and Michael Fleischhauer — Fachbereich Physik, TU Kaiserslautern

We discuss the generation and coherent manipulation of stationary pulses of light in atomic ensemble with electromagnetically induced transparency with two counterpropagating control fields. In particular we discuss the limits on the spatial confinement of these pulses when the latter becomes comparable to the absorption length of the medium. In this case the stationary field in the dilute gas can be described by a two-component spinor which obeys the two-dimensonal Dirac-Weyl equation in an external potential generated by a spatially varying two-photon detuning. We show that a fundamental lower limit to the spatial confinement arises from Klein tunneling. We determine the linewidth of the resonances in the effective potential and discuss conditions for optimizing spatial confinement and tunneling losses.

Q 29.13 Di 16:30 Poster C2

Efficient coherent population transfer to highly excited vibrational states in NO molecules by Stark-chirped rapid adiabatic passage — •Holger Münch, Martin Oberst, and Thomas Halfmann — Institute for Applied Physics, TU Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt, Germany

The interaction of strong, coherent radiation fields with quantum states permit the efficient and selective manipulation of population distributions. Adiabatic processes, e.g. rapid adiabatic passage (RAP), allow to prepare complete population inversion between two quantum states. An extension of RAP is Stark-chirped rapid adiabatic passage (SCRAP). This process uses dynamic stark-shifts to drive the transition frequency through resonance with an initially detuned laser field and thereby realize a RAP process. The implementation of SCRAP in a L-type three state system rather than application of other coherent techniques, e.g. STIRAP, offers e.g. advantages in inhomogeneous broadened media. We demonstrate the experimental realization of SCRAP among three states in nitric oxide (NO) molecules. SCRAP permits complete population inversion between a vibrational ground state and a highly excited vibrational state. Both states are coupled through strong, pulsed laser fields (pump and Stokes laser) to an electronically excited intermediate state. An intense Stark laser pulse induces dynamic stark-shifts of the transition frequencies. Appropriate choice of laser detunings and time delays between the laser pulses permits complete and robust population inversion in the NO molecules and efficient storage of large amounts of internal energy.

Q 29.14 Di 16:30 Poster C2

Stimulated Raman Adiabatic Passage (STIRAP) in a Pr^{3+}:Y_2SiO_5 crystal — •Fabian Beil, Jens Klein und Thomas Halfmann — Institute for Applied Physics, TU Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt, Germany

STIRAP is a well-established, efficient and robust technique to manipulate population distributions in atoms and molecules. Among others, STIRAP found applications in optical data storage and quantum information processing. Experimental studies of STIRAP have been mainly constricted to media in the gas phase. However, it is solid media which are (due to their high density and scalability) of special interest for applications. Usually, ultra-fast decoherence processes in solids prevent the implementation of coherent excitations. This obstacle is overcome in rare earth ion doped inorganic crystals, which combine the advantages of solids and the coherent properties of atoms. We implemented STIRAP in a Pr^{3+}:Y_2SiO_5 crystal (Pr:YSO). The experiment yielded striking data on complete adiabatic population transfer in a solid. Population is transferred between two hyperfine levels of the $^3H_4$ ground state of a selected ensemble of Pr^{3+} ions. Efficient transfer is observed for negative pulse delay (STIRAP) as well as for positive delay. The latter is due to an alternative adiabatic passage process, i.e.b-STIRAP, which is closely related to conventional STIRAP. We record the population dynamics for both adiabatic processes by time-resolved absorption measurements. In addition to the experimental investigations, we performed numerical simulations. The results are in good qualitative agreement with the experimental observations.

Q 29.15 Di 16:30 Poster C2

Adaptive quantum estimation of continuous systems — •Sabine Wölk and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

We propose an adaptive scheme to reconstruct unknown quantum states of light via quantum comparison with certain classes of reference or ruler states. This comparison is realized by joint measurements of EPR variables on both states. The arising probability distribution contains the complete information of the unknown quantum state. Different ruler states allow us to estimate different representations of the unknown state. As an example, we have developed an adaptive algorithm to determine the quadrature representation using Gaussian states as ruler states.

Q 29.16 Di 16:30 Poster C2

Quantum theory of atom lasers — •Tobias Kramer[1], Mirta Rodríguez[2], and Christian Bracher[3] — [1]Institut I: Theoretische Physik, Universität Regensburg, Germany — [2]Institut de Ciències Fotòniques, Barcelona, Spain — [3]California State University, Long Beach, USA

We present a three-dimensional, quantum mechanical and largely analytical theory for the properties of atomic laser beams in the gravitational field. The results describe both the total emission rate and the beam profile. Depending on the trapping frequencies and the strength of interactions, the theory predicts a transverse substructure in the atomic beam. Recent experiments on atom laser beam profiles are in good agreement with the model.

T. Kramer and M. Rodriguez Quantum theory of an atom laser originating from a Bose-Einstein condensate or a Fermi gas in the presence of gravity, Phys. Rev. A, 74, 013611-1-13, (2006)

Q 29.17 Di 16:30 Poster C2

Simultaneous measurements in quantum optics — •Michael Busshardt and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, 89069 Ulm, Germany

Various possibilities for simultaneous measurements of conjugate variables in the optical domain are investigated. Here, for example, the quadratures of the electromagnetic field do not commute and therefore cannot be precisely measured simultaneously. Possible setups, necessary for measuring such non-commuting observables simultaneously by allowing the system to interact with certain classes of ruler systems, are reviewed and discussed. The question arises, which states of the ruler systems are optimal to gain specific information about the investigated system. This leads to generalized versions of the Heisenberg uncertainty relation.

Q 29.18 Di 16:30 Poster C2

Riemann's Zeta Function in Phase-Space — •Cornelia Feiler, Rüdiger Mack, and Wolfgang P. Schleich — Institut für Qunatenphysik, Universität Ulm

The Riemann hypothesis is at the very heart of number theory. We propse a novel approach where the Riemann Zeta function emerges in a quantum system. For that, we consider states, which provide us with the Riemann Zeta function when we take appropriate scalar products. Moreover, we present the corresponding Wigner and Q-functions and discuss their behaviour in phase space.

Q 29.19 Di 16:30 Poster C2

Nicht-klassische Lichtquellen für die Zweiphotonenabsorption — •Axel Heuer, Benjamin Freyer, Andreas Jechow und Ralf Menzel — Institut für Physik, AG Photonik Universität Potsdam, Am Neuen Palais 10, 14469 Potsdam

Für die Beobachtung der Zweiphotonenabsorption (TPA) von nichtklassischem Licht, wird eine Lichtquelle benötigt, die eine genügend hohe Anzahl an Photonenpaaren mit einem hohen Grad an zeitlicher und räumlicher Korrelation emittiert. Es werden zwei Lichtquellen vorgestellt, die jeweils auf der parametrischen Fluoreszenz (PDC) beruhen.

Die eine Quelle besteht aus einem BBO Kristall, der für die kollineare PDC mit Typ I Phasenanpassung geschnitten ist. Der Kristall wird gepumpt mit der dritten Harmonischen eines modengekoppelten Nd:YVO4-Laser. Bei einer mittleren Pumpleistung von 120 mW konnten Zählraten korrelierter Photonenpaare von über 1010 Photonen/s detektiert werden. Die Photonen erstreckten sich über eine spektrale Bandbreite von über 200 nm. Bei dieser Lichtquelle verteilen sich die korrelierten Photonen jedoch auch über ein Winkelspektrum von mehreren Grad, was eine geeignete Fokussierung für die Zweiphotonenabsorption schwierig macht. Daher wurde eine weitere Lichtquelle realisiert, bei der die beiden korrelierten Photonen sich in einer räumlichen Mode befinden. Dieses lässt sich realisieren, wenn ein periodisch gepolter Kristall mit Wellenleiterstruktur verwendet wird. Es werden Ergebnisse präsentiert, die mit einem 10 mm langen PPLN Kristall erzielt wurden

Q 30: Poster Präzisionsmessungen und Metrologie

Zeit: Dienstag 16:30–19:00 Raum: Poster C2

Q 30.1 Di 16:30 Poster C2

Cold Atom Sagnac Interferometer — •Christian Schubert, Thijs Wendrich, Michael Gilowski, Ernst Rasel, and Wolfgang Ertmer — Institut für Quantenoptik, Leibniz Universität Hannover

Cold atom fountains and mater-wave interferometry have enabled many very sensitive measurements methods for fundamental physics and metrology [1]. We report on the status of our dual atom interferometer for the precise determination of inertial forces. Our device is based on synchronous operation of two counter propagating atom interferometers to discriminate between accelerations and rotations. The atomic source units are horizontal fountains each consisting of a 2D-MOT which loads a 3D-MOT with cold ^{87}Rb atoms [2]. The 3D-MOT uses a moving molasses technique to launch the atoms with about 4.4 m/s with a temperature of about 8 μK. The interferometer sequence itself has a Mach-Zehnder configuration realized with three optical Raman pulses for the coherent manipulation of the atoms. The atomic interference signal is measured using the fluorescence light of both output states of each interferometer, allowing normalized results that are insensitive to changes in the number of atoms in both directions. With this compact and transportable setup we aim to reach sensitivities of $2*10^{-9}$ rad/s for $1*10^8$ atoms per shot and a velocity of 3 m/s. This work is supported by DFG SFB407 and FINAQS. [1] C. Jentsch, T. Müller, E.M. Rasel, W. Ertmer, Gen. Rel. Grav. 36(10), 2197(2004). [2] T. Müller, T. Wendrich, M. Gilowski, C. Jentsch, E.M. Rasel, W. Ertmer, arXiv:0705.4544v1, accepted by Phys. Rev. A.

Q 30.2 Di 16:30 Poster C2

Laser Doppler Interferometry Mission for Determination of

the Earth's Gravity Field — •Marina Dehne, Ben Sheard, Gerhard Heinzel, and Karsten Danzmann — Albert-Einstein-Institut Hannover, Max-Planck-Institut für Gravitationsphysik und Universität Hannover, Callinstr. 38, D-30167 Hannover

The aim of a future GRACE follow-on mission is to map with high resolution the gravitational field of the Earth. The space segment consists of two spacecraft in a Low- Earth Orbit (LEO), following each other with a seperation of about 10 km. The variations of that distance in the frequency range 1...100 mHz are to be monitored by the interferometer with nanometer precision. Data analysis to be performed on the ground will recover the information about the gravitational field from those measurements, in the form of the spherical harmonics from degree 6 to 240.

One possible orbit is a circular sun-synchronous orbit ($i = 96.78°$) in order to provide a constant thermal environment and to avoid sunlight entering the optical axis between the two spacecraft. The atmospheric drag in a Low-Earth Orbit is significant and must be compensated. For this purpose, drag-free technology such as developed for LISA Pathfinder is ideally suited. The proposed interferometer makes use of technologies developed for LISA and LISA Pathfinder.

The goal of this work is to develop an interferometer breadboard which fulfills the requirements ($2.5\,\mathrm{nm}/\sqrt{\mathrm{Hz}}$ from 10 to 100 mHz, increasing as 1/f between 10 and 1 mHz) under the given other constraints of the mission.

Q 30.3 Di 16:30 Poster C2

A quantum radiation-pressure noise dominated interferometer — •Stefan Gossler, Yanbei Chen, Stefan Danilishin, Daniel Friedrich, Kentaro Somiya, Tobias Westphal, Kazuhiro Yamamoto, Karsten Danzmann, and Roman Schnabel — MPI für Gravitationsphysik (AEI) und Institut für Gravitationsphysik der Leibniz Universität Hannover, Callinstr.38, 30167 Hannover

The second generation of interferometric gravitational-wave detectors will be limited by quantum noise of the light field in most of the detection band: while shot noise will limit the sensitivity at high frequencies it is quantum radiation-pressure noise that will be limiting at low frequencies. Despite the effort of various groups all over the world so far no interferometric measurement that is dominated by quantum radiation-pressure noise has been obtained yet. A mechanical device to couple the quantum fluctuations of the light field to displacement of a sensor is crucial to these measurements. We present our design of such a sensor and the general concept to accomplish the first ever measurement of quantum radiation-pressure noise.

Q 30.4 Di 16:30 Poster C2

Frequenzmessung eines optischen Frequenznormals über ein Glasfasernetz — •Osama Terra[1], Burghard Lipphardt[1], Gesine Grosche[1], Jan Friebe[2], Ernst Rasel[2] und Harald Schnatz[1] — [1]Physikalisch Technische Bundesanstalt, Braunschweig — [2]Institut für Quantenoptik, Universität Hannover , Hannover

Im Rahmen des SFB 407 untersuchen die Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig und das Institut für Quantenoptik (IQO) der Universität Hannover eine neue Methode zur Messung des Uhrenübergangs des Mg Frequenznormals. Bisher wurde diese Frequenz mit Hilfe einer transportablen Cs Uhr oder einem auf GPS stabilisierten Quarz vermessen. Um das Mg Normal besser charakterisieren zu können und dessen Potenzial voll auszuschöpfen, ist es erforderlich, kurzzeitstabilere Oszillatoren als Referenz zu benutzen. Mit optische Uhren, wie sie in Staatsinstituten betrieben werden, lassen sich wesentlich kleinere Unsicherheiten und höhere Kurzzeitstabilitäten erreichen als mit Mikrowellennormalen. Dazu ist es aber erforderlich, dass die hohe Stabilität und Genauigkeit der optischen Uhren auch an weit entfernten Standorten zur Verfügung gestellt werden kann. Hierzu wird ein Laser bei 195 THz (1,55 μm) mit Hilfe eines Frequenzkammes auf die optische Referenzfrequenz stabilisiert und dessen Frequenz über einen 70 km langen Glasfaserlink nach Hannover gesendet. Anschließend wird das trägerfrequente cw-Signal dort mittels zweitem Frequenzkamm mit der Frequenz des Mg Frequenznormals verglichen. Die Gesamtverbindung wird zur Zeit schrittweise aufgebaut und charakterisiert. Wir berichten über den Stand des Projektes.

Q 30.5 Di 16:30 Poster C2

High reflectivity grating waveguide coatings — •Daniel Friedrich[1], Oliver Burmeister[1], Michael Britzger[1], Tina Clausnitzer[2], Frank Brückner[2], Ernst-Bernhard Kley[2], Andreas Tünnermann[2], Karsten Danzmann[1], and Roman Schnabel[1] — [1]Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) und Institut für Gravitationsphysik der Leibniz Universität Hannover, Callinstr. 38, 30167 Hannover — [2]Institut für Angewandte Physik der Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena

Thin single-layer grating structures can be used as a high reflectivity, but low thermal noise, alternative to conventional multilayer coatings. Grating waveguide (GWG) coatings should have low mechanical loss due to the reduced coating thickness, resulting in low thermal noise. Since the coating provides the interface between a light field and a mirror device, coating thermal noise is an important design concern for various high precision experiments such as gravitational wave detection. We present concepts and ongoing investigations of different types of GWG's.

Q 30.6 Di 16:30 Poster C2

Testing the Isotropy of the Speed of Light using ULE Optical Resonators — •Christian Eisele[1], Maxim Okhapkin[2], Alexander Yu. Nevsky[1], and Stephan Schiller[1] — [1]Institut für Experimentalphysik, Heinrich-Heine-Universität, 40225 Düsseldorf — [2]Institute for Laser Physics, Novosibirsk, Russia

Modern Michelson-Morley-type experiments with ultra-stable resonators are aiming to measure a possible violation of Lorentz invariance for electromagnetic waves.

We will report about the latest results of our measurements using optical high finesse resonators (F = 190000) orthogonally embedded in a rectangular ULE (ultra low expansion coefficient glass) block. This design gives a certain amount of common mode rejection for several disturbances. A monolithic Nd:YAG laser at 1064 nm is frequency stabilized to the resonance frequencies of the resonators, and the difference frequency between the resonators is measured as a function of the orientation of the cavities in space. To improve the short term frequency stability of the laser system, we use an active vibration isolation system. For active rotation of the setup a highly-accurate air-bearing rotation table is used.

Q 30.7 Di 16:30 Poster C2

Thermal noise limit of the Fabry-Perot cavities used for laser stabilisation at sub-Hz level — •Janis Alnis, Nikolay Kolachevsky, Arthur Matveev, Thomas Udem, and Theodor Hänsch — Max Planck Institute of Quantum Optics, 85748 Garching, Germany

Precision optical spectroscopy experiments require lasers with extremely narrow spectral line widths that can be achieved by stabilising the laser to a high-finesse Fabry-Perot (FP) cavity. We have developed two independent external-cavity diode laser systems at 972 nm with 0.5 Hz spectral line width that is limited by the thermal noise properties of the FP cavity spacer and mirrors [1]. The thermal noise limit is reached thanks to a mid-plane mounting of the cavities making them insensitive to ambient vibrations. The line drift is always smaller than 0.5 Hz/s as the cavities are made from Ultra-Low-Expansion (ULE) glass possessing a zero expansion temperature. Our new design with Peltier coolers in vacuum allows us to keep any ULE FP cavity at this particularly advantageous temperature.

With this narrow laser source after amplification and frequency quadrupling to 243 nm we excite the 1S-2S two-photon transition in atomic hydrogen [2]. The diode laser has an unusually long (20 cm) resonator that significantly reduces the high-frequency noise typical to diode lasers and allows efficient doubling of the narrow optical carrier.

References

1. J. Alnis et al., in preparation for Appl. Phys. B.
2. N. Kolachevsky et al., Phys. Rev. A 73, 021801(R) (2006).

Q 31: Quanteninformation (Konzepte und Methoden I)

Zeit: Donnerstag 8:30–10:30 Raum: 1B

Q 31.1 Do 8:30 1B

Effective Spin Systems in Coupled Arrays of Cavities — •Michael Hartmann[1,2], Fernando Brandão[1,2], and Martin Plenio[1,2] — [1]Institute for Mathematical Sciences, Imperial College London, 53 Exhibition Road, London, SW7 2PG, United Kingdom — [2]QOLS, Blackett Laboratory, Imperial College London, Prince Consort Road, London, SW7 2BW, United Kingdom

We show that atoms trapped in micro-cavities that interact via the exchange of virtual photons can model an anisotropic Heisenberg spin-1/2 lattice in an external magnetic field. All parameters of the effective Hamiltonian can individually be tuned via external lasers. Since the occupations of excited atomic levels and photonic states are strongly suppressed, the effective model is robust against decoherence mechanisms, has a long lifetime and its implementation is feasible with current experimental technology. The model provides a feasible way to create cluster states in these devices.

Q 31.2 Do 8:45 1B

Possibility, Impossibility and Cheat-Sensitivity of Quantum Bit String Commitment — Harry Buhrman[1], •Matthias Christandl[2], Patrick Hayden[3], Hoi-Kwong Lo[4], and Stephanie Wehner[1] — [1]CWI Amsterdam, The Netherlands — [2]University of Cambridge, United Kingdom — [3]McGill University, Montreal, Canada — [4]University of Toronto, Canada

Unconditionally secure non-relativistic bit commitment is known to be impossible in both the classical and the quantum worlds. But when committing to a string of n bits at once, how far can we stretch the quantum limits? In this paper, we introduce a framework for quantum schemes where Alice commits a string of n bits to Bob in such a way that she can only cheat on a bits and Bob can learn at most b bits of information before the reveal phase.

Our results are two-fold: we show by an explicit construction that in the traditional approach, where the reveal and guess probabilities form the security criteria, no good schemes can exist: $a + b$ is at least n. If, however, we use a more liberal criterion of security, the accessible information, we construct schemes where $a = 4 \log_2 n + O(1)$ and $b = 4$, which is impossible classically.

We furthermore present a cheat-sensitive quantum bit string commitment protocol for which we give an explicit tradeoff between Bob's ability to gain information about the committed string, and the probability of him being detected cheating.

Q 31.3 Do 9:00 1B

Complementarity, Privacy, and Entanglement — •Joseph M. Renes[1] and Jean-Christian Boileau[2] — [1]Institut für Angewandte Physik, TU Darmstadt, Germany — [2]Center for Quantum Information and Quantum Control, University of Toronto, Canada

We develop a complementary information tradeoff which bounds the amount of information about complementary observables that can be simultaneously extracted from a quantum system. This leads directly to a simple characterization both private states (the quantum version of secret keys) and maximally-entangled states, revealing these to be a direct manifestation of the quantum mechanical phenomenon of complementarity. Furthermore, we conjecture a strengthened version of the tradeoff and show how these ideas can be adapted to create protocols for distilling secret keys or entangled states.

Q 31.4 Do 9:15 1B

Maximally entangled fermions — •Dirk-Michael Schlingemann[1,2], Lorenzo Campos Venuti[1], Marco Cozzini[1], and Michael Keyl[1,2] — [1]ISI Foundation Torino, Quantum information theory unit, Torino, Italy — [2]Institut f. Mathematische Physik, TU-Braunschweig, Germany

Fermions play an essential role in many areas of quantum physics and it is desirable to understand the nature of entanglement within systems that consists of fermions. Whereas the issue of separability for bipartite fermions has extensively been studied in the present literature, this talk reports on our recent paper [arXive:0711.3394] that is concerned with maximally entangled fermions. A complete characterization of maximally entangled quasifree (gaussian) fermion states is given in terms of the covariance matrix. This result can be seen as a step towards distillation protocols for maximally entangled fermions.

Q 31.5 Do 9:30 1B

Evolution equation for quantum entanglement — •Markus Tiersch[1,2], Thomas Konrad[3], Fernando de Melo[1,2], Christian Kasztelan[4], Adriano Aragao[5,2], and Andreas Buchleitner[1,2] — [1]Albert–Ludwigs–Universität Freiburg, Physikalisches Institut, Hermann–Herder–Str. 3, D–79104 Freiburg, Germany — [2]Max–Planck–Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, D–01187 Dresden, Germany — [3]Quantum Research Group, School of Physics, University of KwaZulu-Natal, Private Bag X54001, Durban 4000, South Africa — [4]Institut für Theoretische Physik C, RWTH Aachen, D–52056 Aachen, Germany — [5]Instituto de Física, Universidade Federal do Rio de Janeiro, Caixa Postal 68.528, CEP 21945-970, Rio de Janeiro, RJ, Brazil

Quantum systems composed of two qubits consitute the starting point for the study of quantum entanglement. The evolution of entanglement when such a system is subject to open system dynamics will be examined in this talk. We will derive a simple factorization relation which describes the system's final entanglement after one of the qubits has undergone an arbitrary physical process.

Q 31.6 Do 9:45 1B

Bound Entanglement and Entanglement Bounds — •Simeon Sauer[1,2], Fernando de Melo[2,3], Joonwoo Bae[4], Florian Mintert[2,3], Beatrix Hiesmayr[5], and Andreas Buchleitner[2,3] — [1]Physikalisch-Astronomische Fakultät, Friedrich-Schiller-Univesität Jena, Germany — [2]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Strasse 3, D-79104 Freiburg, Germany — [3]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str.38, D-01187 Dresden, Germany — [4]School of Computational Sciences, Korea Institute for Advanced Study, Seoul 130-012, Korea — [5]Faculty of Physics, University of Vienna, Boltzmanngasse 5, A-1090 Vienna, Austria

We investigate the separability of Bell-diagonal states of two qutrits. By using lower bounds to algebraically estimate concurrence, we find convex regions of bound entangled states. Some of these regions exactly coincide with the obtained results when employing optimal entanglement witnesses, what shows that the lower bound can serve as a precise detector of entanglement. Some hitherto unknown regions of bound entangled states were discovered with this approach, and delimited efficiently.

Q 31.7 Do 10:00 1B

Indirect control of open system dynamics — •Raffaele Romano — Max Planck Research Group, Institute of Optics, Information and Photonics, Staudstr. 7/B2, 91058 Erlangen, Germany

Although conceptually simpler, the standard open loop approach to the control of a quantum mechanical system offers a limited ability to drive the state of the system when the interaction with the external environment cannot be neglected. With this motivation in mind, closed loop approaches have been proposed (quantum feedback). In this contribution, we show that open loop controllability of an open system can be obtained if non standard control scenarios are adopted [1]. In particular, we consider the {\it indirect control} technique [2], based on the use of an auxiliary system whose initial state can be arbitrarily prepared. In our model, the environmental action can be engineered to give complete controllability, and it does not only represent a source of noise and decoherence.

[1] R. Romano, D. D'Alessandro, Phys. Rev. Lett. 97, 080402(2006)

[2] R. Romano, D. D'Alessandro, Phys. Rev. A 73, 022323 (2006)

Q 31.8 Do 10:15 1B

Wave particle duality in a two atom interferometer — •Uwe Schilling[1], Christoph Thiel[1], Thierry Bastin[2], and Joachim von Zanthier[1] — [1]Institut für Optik, Information und Photonik, Max-Planck-Forschungsgruppe, Universität Erlangen-Nürnberg, Germany — [2]Institut de Physique Nucléaire, Atomique et de Spectroscopie, Université de Liège, Belgium

In 1996 Englert investigated the wave-particle duality in a Ramsey interferometer and derived a quantitative complementarity relation between the contrast of the interference pattern and the maximum obtainable which-way (WW) information [1].

We examine the duality relation in a system of two two-level atoms which are coherently excited by a resonant laser pulse. The atoms subsequently scatter a single photon which is recorded by a detector in the far field region. By applying Englert's definition of the distinguishability $\mathcal{D}$ of the two pathes in this interferometer, we find that $\mathcal{D}$ becomes a function of *where* the photon is detected. As a result we derive that in this system, by choosing the detector position and the Bloch angle of the exciting laser pulse accordingly, full WW information becomes available after the detection of the photon while the contrast of the interference pattern remains close to 100 %. By introducing a quantity which describes the *average* WW information per scattered photon, it is possible to derive a quantitative relation between the wave and the particle properties of the photon in this system.

[1] B.-G. Englert, Phys. Rev. Lett. **77**, 2154 (1996)

Q 32: Quantengase (Gitter III)

Zeit: Donnerstag 8:30–10:15 Raum: 1C

Q 32.1 Do 8:30 1C

Coexistence of bosonic and fermionic atoms in a 3d optical lattice — •Thorsten Best, Sebastian Will, Ulrich Schneider, Lucia Hackermüller, Dries van Oosten, and Immanuel Bloch — Johannes Gutenberg-Universität Mainz

The investigation of mixtures of ultracold gases of distinct atomic species has gained a lot of attention recently. Depending on interaction strength and particle numbers, these systems can display rich phase diagrams with interesting analogies to condensed matter physics, especially in the presence of a periodic potential. We investigate a mixture of bosonic ^{87}Rb and fermionic ^{40}K atoms in a 3d optical lattice potential. Depending on the ratio of potassium to Rubidium atoms, the particle mobility in the lattice and the strength of interspecies interactions, we find evidence for coexistence or phase separation of the two species. We will present a characterization of the mixture in terms of both long-range coherence and onsite density distribution.

Q 32.2 Do 8:45 1C

Direct Observation and Control of Superexchange Interactions with Ultracold Atoms in Optical Lattices — •Stefan Trotzky[1], Patrick Cheinet[1], Simon Fölling[1,2], Michael Feld[1,3], Ute Schnorrberger[1], Ana Maria Rey[4], Anatoli Polkovnikov[5], Eugene Demler[2,4], Mikhail Lukin[2,4], and Immanuel Bloch[1] — [1]Johannes Gutenberg Universität Mainz — [2]Harvard University, USA — [3]Technische Universität Kaiserslautern — [4]Harvard-Smithsonian Center of Astrophysics, USA — [5]Boston University, USA

Quantum mechanical superexchange interactions form the basis of quantum magnetism in strongly correlated media. We report on the first direct observation of such superexchange processes with ultracold atoms in optical lattices. Our lattice set-up consists of a bichromatic superlattice along one spatial direction and two perpendicular monochromatic lattices, thus providing a three-dimensional array of double-wells. After preparing a spin-mixture of ^{87}Rb atoms in an antiferromagnetic order along the superlattice axis, we record the spin dynamics within the double-wells. In the regime of strong interaction, coherent superexchange oscillations are observed which can be described by an effective Heisenberg Hamiltonian. We demonstrate, how the effective coupling parameter can be controlled in magnitude and sign, thus enabling the system to be switched between ferromagnetic or antiferromagnetic spin interactions. The experimental results show very good agreement with the predictions of a two-site Bose-Hubbard model, however, we are also able to identify corrections, which can be explained by the inclusion of direct nearest-neighbor interactions.

Q 32.3 Do 9:00 1C

In situ studies of ultracold fermions in a blue detuned optical lattice — •Ulrich Schneider, Lucia Hackermüller, Thorsten Best, Sebastian Will, Dries van Oosten, and Immanuel Blocj — Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz, Germany

Ultracold atoms in optical lattices are a versatile system to study topics ranging from ultracold molecules to solid state physics. The rich phase diagram of ultracold fermions in a lattice includes both metallic and insulating phases, e.g the fermionic Mott-Insulator and antiferromagnetically ordered states.

In our experiment we sympathetically cool fermionic ^{40}K with bosonic ^{87}Rb in an optically plugged quadrupole trap and subsequently in a dipole trap to quantum degeneracy. After removing the rubidium atoms from the trap, the fermionic ^{40}K is loaded into a blue detuned 3D optical lattice. The combination of a dipole trap and a blue lattice allows for an independent control of lattice depth and harmonic confinement. We use in situ imaging to study fermionic clouds in different regimes varying from noninteracting spinpolarized clouds to strongly interacting spin mixtures.

Q 32.4 Do 9:15 1C

Controlling interaction-induced dephasing of Bloch oscillations — •Elmar Haller, Mattias Gustavsson, Manfred Mark, Johann Danzl, Gabriel Rojas-Kopeinig, and Hanns-Christoph Nägerl — Institut für Experimentalphysik, Universität Innsbruck, Austria

A BEC in an optical lattice undergoes Bloch oscillations when subject to an external force. However, interactions lead to dephasing, limiting the number of oscillations one can observe.

By tuning the interaction strength using a Feshbach resonance, we quantitatively characterize the dephasing and compare with numerical simulations. The zero crossing of the scattering length can be precisely determined by minimizing dephasing. In the weakly interacting limit, we observe more than 20000 oscillations over 12 s.

For non-zero interaction strength, we find that the momentum distribution of a dephased condensate develops structure on a scale much smaller than the Bloch momentum. This structure becomes visible when the interaction is quickly switched off during release from the lattice and the time-of-flight detection is aided by magnetic levitation to allow for long expansion times.

Q 32.5 Do 9:30 1C

Exact phase-space dynamics of the M-site Bose-Hubbard model — •Friederike Trimborn, Dirk Witthaut, and Hans Jürgen Korsch — FB Physik, TU Kaiserslautern, 67663 Kaiserslautern

The dynamics of M-site, N-particle Bose-Hubbard systems is described in quantum phase space constructed in terms of generalized $SU(M)$ coherent states. These states have a special significance for these systems as they are equivalent to the fully condensed states. Based on the differential algebra developed by Gilmore, we derive an explicit evolution equation for the (generalized) Husimi (Q) and Glauber-Sudarshan (P) distributions. Most remarkably, these evolution equations turn out to be second order differential equations where the second order terms scale as $1/N$ with the particle number. For large N the evolution reduces to a (classical) Liouvillean dynamics. The phase space approach thus provides a distinguished instrument to explore the mean-field many-particle crossover.

Q 32.6 Do 9:45 1C

Mott-insulator states of ultracold atoms in optical resonators — Jonas Larson[1], Sonia Fernandez-Vidal[2], •Giovanna Morigi[2], and Maciej Lewenstein[1] — [1]ICFO - Institut de Ciencies Fotoniques, Castelldefels (Barcelona), Spain — [2]Departament de Fisica, Universitat Autonoma de Barcelona, 08193 Bellaterra, Spain

We investigate a paradigm example of cavity quantum electrodynamics with many body systems: an ultracold atomic gas inside a pumped optical resonator, confined by the mechanical potential emerging from the cavity-field spatial mode structure. When the optical potential is sufficiently deep, the atomic gas is in the Mott-insulator state as in open space. Inside the cavity, however, the potential depends on the atomic distribution, which determines the refractive index of the medium, thus altering the intracavity-field amplitude. We derive the effective Bose-Hubbard model describing the physics of the system in one dimension and study the crossover between the superfluid – Mott-insulator quantum states. We predict the existence of overlapping stability regions corresponding to competing insulator-like states. Bistable behavior, controlled by the pump intensity, is encountered in the vicinity of the shifted cavity resonance.

Q 32.7 Do 10:00 1C

Dynamics of the Ising chain coupled to a Markovian bath — •Birger Horstmann, Tommaso Roscilde, Michael Wolf, and Ignacio Cirac — Max-Planck-Institut für Quantenoptik, Garching

In this talk we discuss the dynamics of an Ising chain coupled to a Markovian bath. We simulate the dynamics of the system with a Lindblad master equation and study the decoherence of the ground state of the Ising chain in time focussing on the effect of the quantum phase transition of the Ising chain on the decoherence rates. We propose to simulate such a system in an optical lattice.

Q 33: Ultrakalte Atome II [gemeinsam mit A]

Zeit: Donnerstag 8:30–10:00 Raum: 2F

Q 33.1 Do 8:30 2F

Towards laser cooling of negative ions — •Raoul Heyne, Jan Meier, Ulrich Warring, and Alban Kellerbauer — Max-Planck-Institut für Kernphysik, Postfach 103980, 69029 Heidelberg

Currently available ion cooling techniques do not allow the cooling of negatively charged particles confined in an ion trap to a temperature lower than that of the (cryogenic) environment. The proposed laser cooling of negative osmium ions [1] holds the prospect of achieving temperatures well below 1 mK. Cooling antiprotons with this technique might open the door to forming antihydrogen at ultra-cold temperatures, thus allowing precision antimatter studies. We will outline the unique techniques and challenges involved in this cooling scheme and report intermediate results on Os^- production, manipulation, and spectroscopy.

[1] A. Kellerbauer and J. Walz, “A novel cooling scheme for antiprotons,” New J. Phys. **8** (2006) 45.

Q 33.2 Do 8:45 2F

Slicing a Bose-Einstein Condensate: Direct observation of number squeezing — •Christian Gross, Jerome Esteve, Andreas Weller, Stefano Giovanazzi, and Markus K. Oberthaler — Kirchhoff Institut für Physik, Universität Heidelberg

Todays interferometers are very often limited by the standard quantum limit. Pushing the performance beyond this limit demands the use of number squeezed states.

We report on the direct observation of number squeezed states in Bose-Einstein Condensates (BEC). These are produced by ramping up a one dimensional optical lattice adiabatically, slicing an initially almost pure condensate of ^{87}Rb atoms into seven pieces.

Our system can be described as an array of Josephson junctions. The effective interaction between the atoms increases with barrier height and their motion is more and more restricted to single wells since the tunneling coupling across the junctions decreases. In this regime the ground state of the Josephson junction array is characterized by a loss of phase coherence and sub shot noise atom number fluctuations across the junctions.

Q 33.3 Do 9:00 2F

Observation of dark soliton oscillations in a harmonic trap — •Andreas Weller, Christian Gross, Jens Philipp Ronzheimer, Jerome Esteve, and Markus K. Oberthaler — Kirchhoff Institut für Physik, Universität Heidelberg

We experimentally create dark solitons in a Bose Einstein Condensate confined in a harmonic optical dipole trap by releasing atoms from a double well potential into a harmonic potential. The two clouds collide and form a dark soliton train. We observe the consequent dynamics (oscillations) with a novel imaging system. Furthermore we confirm that the oscillation frequency deviates from the harmonic trapping frequency and is close to the prediction of the one dimensional Gross Pitaevskii Equation (GPE): $\omega_{ds} = \omega_{trap}/\sqrt{2}$. The deviations are consistent with the results obtained by integration of the three dimensional GPE.

We will further discuss the status of the experiment creating intrinsically localized modes and bright solitons by starting with a single occupied well in an optical lattice.

Q 33.4 Do 9:15 2F

Quantum State Engineering via Dissipation — •H.P. Büchler[1], S. Diehl[2], A. Kantian[2], B. Kraus[3], A. Micheli[2], and P. Zoller[2,3] — [1]Institut für Theoretische Physik, Universität Stuttgart — [2]Institut für Quantenoptik und Quanteninformation, Universität Innsbruck — [3]Insitut für Theoretische Physik, Universität Innsbruck

An open quantum system, whose time evolution is governed by a master equation, can be driven in steady state into a given pure quantum state by an appropriate design of the system-reservoir coupling. This points out a route towards preparing many body states and nonequilibrium quantum phases by quantum reservoir engineering. Here we discuss in detail the example of a driven dissipative Bose Einstein Condensate (BEC), where atoms in an optical lattice are coupled to a bath of Bogoliubov excitations via the atomic current representing local dissipation. In the absence of interactions the lattice gas is driven into a pure state with long range order. Weak interactions lead to a weakly mixed state, which in 3D can be understood as a depletion of the condensate, and in 1D and 2D exhibits properties reminiscent of a Luttinger liquid or a Kosterlitz-Thouless critical phase at finite temperature, with the role of the “finite temperature” played by the interactions.

Q 33.5 Do 9:30 2F

Light propagation in ultracold atomic gases confined by optical lattices — •Stefan Rist and Giovanna Morigi — Departament de Fisica, Universitat Autonoma de Barcelona, 08193 Bellaterra, Spain

We develop a theory which describes photon propagation in a medium constituted by ultracold atoms confined by an optical lattice. We discuss in particular the input-output relations taking into account the finite size of the optical lattice and the atoms quantum motion and statistics. This work extends previous studies [1,2] by considering the atomic vibrations at the lattice sites, the finite tunneling matrix elements, and saturation effects of the atomic transitions. The coherence properties of the transmitted light are discussed as a function of the quantum state of the gas.

[1] Deutsch et al. Phys. Rev. A 52, 1394 (1995).
[2] Chong et al. Phys. Rev. B 75, 235124 (2007).

Q 33.6 Do 9:45 2F

Superfluid properties of a Bose-Einstein condensate in an optical lattice confined in a cavity — •Aranya bhuti Bhattacherjee — Max Planck-Institute for Physics of Complex System, Noethnitzer Str.38, 01187 Dresden, Germany

In this work, we study the effect of a one dimensional optical lattice in a cavity field with quantum properties on the superfluid dynamics of a Bose-Einstein condensate(BEC). In the cavity the influence of atomic backaction and the external driving pump become important and modify the optical potential. Due to the coupling between the condensate wavefunction and the cavity modes, the cavity light field develops a band structure. This study reveals that the pump and the cavity now emerges as a new handle to control the coherence properties of the BEC, which offer the potential for improved interferometric technique, quantum information processing and efficient control of nonlinear excitations such as solitons. A wealth of new phenomena can be expected in the many-body physics of quantum gases with pump-cavity mediated interaction. Expressions for the tunneling parameter, the Bloch energy, the Bogoliubov spectrum and the effective mass in a quantum optical lattice are new results, derived here for the first time.

Q 34: Ultrakalte Rydberggase [gemeinsam mit A]

Zeit: Donnerstag 8:30–10:00 Raum: 2G

Q 34.1 Do 8:30 2G

Rydberg excitation of a Bose-Einstein condensate — •Ulrich Raitzsch, Rolf Heidemann, Vera Bendkowsky, Björn Butscher, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Pfaffenwaldring 57, 70569 Stuttgart, Germany

We present our latest results on Rydberg excitation of a Bose-Einstein condensate [1]. Crossing the critical temperature T_c, a signature of the phase transition to Bose condensation is observed in the fraction of excited Rydberg atoms. The main features in the experimental data were reproduced by a simulation using a superatom model. A superatom is formed by N ground state atoms in a sphere with the blockade radius $r_b \propto \sqrt[6]{C_6/\hbar\Omega}$ due to the van der Waals interaction [2].
The Rydberg excitation is proven to be coherent despite strong interactions with a rotary echo technique known from nuclear magnetic resonance physics [3]. The rotary echo experiment was done for various densities of ground state atoms and excitation times, giving insight into the dephasing caused by the van der Waals interaction.

References

[1]R. Heidemann, *et al.*, arXiv:0710.5622 (2007)

[2]R. Heidemann, *et al.*, Phys. Rev. Lett. **99**(16), 163601(2007)

[3]U. Raitzsch, *et al.*, arXiv:0706.3869 (2007)

Q 34.2 Do 8:45 2G

Universal Scaling in a Strongly Interacting Rydberg gas — •Hendrik Weimer[1], Hans Peter Büchler[1], Rolf Heidemann[2], Ulrich Raitzsch[2], Vera Bendkowsky[2], Björn Butscher[2], Robert Löw[2], and Tilman Pfau[2] — [1]Institut für Theoretische Physik III, Universität Stuttgart — [2]5. Physikalisches Institut, Universität Stuttgart

We analyze the van der Waals blockade and the quantum evolution of an atomic gas resonantly driven by a laser into a strongly interacting Rydberg state. Such a system has recently been studied experimentally by Heidemann et al. [1]. The main mechanism behind the van der Waals blockade is that once a Rydberg atom is excited, the van der Waals interaction shifts the surrounding atoms out of resonance with the driving laser and therefore suppresses the excitation of additional Rydberg atoms. The combination of the van der Waals interaction with the Rabi frequency of the resonant laser gives rise to a single dimensionless parameter. We show that the experimental data exhibits a data collapse with a universal scaling function in this single dimensionless parameter. A numerical analysis of the effective theory provides excellent agreement for the scaling function with the experiment, and is evidence for universality in a strongly interacting Rydberg gas undergoing coherent quantum evolution.

[1] R. Heidemann et. al. Phys. Rev. Lett. **99**, 163601 (2007).

Q 34.3 Do 9:00 2G

Many-particle mechanical effects of an interacting Rydberg gas — •Thomas Amthor, Markus Reetz-Lamour, Christian Giese, and Matthias Weidemüller — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

Gases of ultracold Rydberg atoms have been found to spontaneously ionize and form plasmas [1]. Recent experiments showed that the initial ionization is mainly due to collisions induced by long-range forces between the cold Rydberg atoms. The acceleration and subsequent Penning ionization of Rydberg atoms has been investigated under different conditions, the underlying interactions being either of dipole-dipole [2] or van der Waals type [3]. For attractive interaction potentials, atoms excited to Rydberg states on the red-detuned wing of the resonance are observed to ionize first, as more atom pairs are prepared at short distances and experience strong attractive forces. Here we discuss the ionization dynamics of gases initially prepared in states with purely repulsive interaction. This requires a more detailed model including many-particle aspects and mechanisms for state redistribution to overcome the repulsive forces. A Monte Carlo model for the description of such a system is presented and agrees well with experimental observations [4].

[1] M. P. Robinson et al., Phys. Rev. Lett. 85, 4466 (2000)
[2] W. Li et al., Phys. Rev. Lett. 94, 173001 (2005)
[3] T. Amthor et al., Phys. Rev. Lett. 98, 023004 (2007)
[4] T. Amthor et al., Phys. Rev. A 76, 054702 (2007)

Q 34.4 Do 9:15 2G

Prospects for resonant energy transfer in structured ultracold Rydberg gases — •Christian Giese, Christoph Sebastian Hofmann, Wendelin Sprenger, Janne Denskat, Thomas Amthor, Markus Reetz-Lamour, and Matthias Weidemüller — Physikalisches Intitut, Universität Freiburg, Hermann-Herderstr. 3, 79104 Freiburg

Dynamics in cold Rydberg gases are entirely determined by long-range dipole-dipole and van der Waals interactions due to the negligible translational energy. A unique feature of the system is the tunability of these interactions in both strength and character. In this manner, two Rydberg pair states can be made energetically degenerate. This leads to energy and population transfer known as resonant energy transfer (RET) which plays an important role in the process of photosynthesis. In recent work , we have compared Monte Carlo simulations of this process to density dependent population measurements[1]. Coherent energy transfer occurs, but the signature is washed out by many-body diffusion and disorder. To overcome this, we plan to use beamshaping techniques for structuring the atomic cloud. Recently, the theoretical and experimental prospects of coherent exciton transport in linear chains in the presence of excitation traps were discussed[2]. We propose an experimental way of using cold, structured Rydberg gases as a model system for investigating the coherent and incoherent properties of this process when introducing different degrees of disorder.

[1] S. Westermann et al., Eur. J. Phys. D 40, 37 (2006)
[2] O. Mülken et al., Phys. Rev. Lett. 99, 090601 (2007)

Q 34.5 Do 9:30 2G

High-resolution spectroscopy of an ultracold Rydberg gas — •Christoph S. Hofmann, Thomas Amthor, Christian Giese, Wendelin Sprenger, Markus Reetz-Lamour, and Matthias Weidemueller — Physics Institute, Albert-Ludwig University Freiburg, 79104 Freiburg, Germany

The exaggerated properties of Rydberg atoms provide a fertile ground for investigating atomic interaction phenomena. Due to the long-range character of the interaction between highly excited atoms, the dynamics of an ultracold gas of Rydberg atoms are entirely determined by van-der-Waals and dipole-dipole interactions. Rydberg excitation-spectra reveal valuable information over a wide range of characteristic phenomena occurring in ultracold Rydberg samples, which are the scope of this talk. For instance, effects like suppression of excitation due to Rydberg-Rydberg interaction [1] can be traced back by analysing these spectra. Spectral features such as line shapes and broadening provide information on interaction potentials. Furthermore highly resolved spectra also permit the observation of long-range molecular resonances [2]. High-resolution spectroscopy requires sophisticated experimental techniques like careful electric and magnetic stray field control, frequency stabilized excitation and probe lasers with narrow line widths as well as sensitive ion detection schemes. An overview about these techniques is given in this talk.

[1] D. Tong et al.,Phys. Rev. Lett. 93, 063001 (2004); K. Singer et al., Phys. Rev. Lett. 93, 163001 (2004)
[2] S. M. Farooqi et al., Phys. Rev. Lett. 91, 183002 (2003)

Q 34.6 Do 9:45 2G

Rydberg excitations in an Ion Trap — •Igor Lesanovsky[1], Markus Müller[1], Lin-Mei Liang[1,2], and Peter Zoller[1] — [1]Institute for Theoretical Physics, University of Innsbruck, and Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, Innsbruck, Austria — [2]Department of Physcis, National University of Defense Technology, Changsha 410073, China

We investigate Rydberg excitations of ions which are trapped in a linear Paul trap. In such trap the ions are confined by an electric quadrupole field and a ponderomotive potential due to an oscillating quadrupole. We employ a two-body approach in order to model the Rydberg ions and derive the Hamiltonian governing Rydberg excitations in a linear ion crystal. We show how a strong state-dependent dipole-dipole interaction among the ions can be achieved by coupling

Rydberg states of different parity using a microwave field. This system offers the possibility to study Rydberg excitation dynamics of a mesoscopic ensemble in a structured environment and permits the experimental realization of strongly interacting spin models.

Q 35: Laseranwendungen (Optische Messtechnik)

Zeit: Donnerstag 8:30–10:00 Raum: 3H

Q 35.1 Do 8:30 3H

Photoakustische NO-Detektion mittels gepulstem Quantenkaskadenlaser — •Markus Germer[1], Marcus Wolff[1,3], Hermann Harde[2] und Hinrich G. Groninga[3] — [1]Hochschule für Angewandte Wissenschaften Hamburg — [2]Helmut-Schmidt-Universität — [3]PAS-Tech GmbH

Ziel unserer Untersuchungen ist es, einen auf photoakustischer Spektroskopie basierenden Sensor für Stickstoffmonoxid (NO) zur Asthmadiagnose zu entwickeln. Als Anregungsquelle wird ein gepulster DFB-Quantenkaskadenlaser verwendet, der bei Raumtemperatur betrieben wird. Es wurden Untersuchungen am Grundvibrationsübergang 1-0 von NO bei einer Wellenlänge von 5,27 μm durchgeführt. Zur Optimierung des photoakustischen Signals wurden verschiedene Betriebsparameter des Lasers wie Pulsbreite und Repetitionsrate untersucht. Weiter wurden die Puls-Gate-Modulation und die Repetitionsfrequenzmodulation bezüglich ihrer Eignung miteinander verglichen.

Q 35.2 Do 8:45 3H

Erzeugung mehrerer spektral getrennter Femtosekundenpulse und deren Anwendung zur Formvermessung schnell bewegter Objekte — •Thomas Hansel[1], Ruediger Grunwald[1], Günter Steinmeyer[1], Uwe Griebner[1], Jens Bonitz[2] und Christian Kaufmann[2] — [1]Max-Born-Institut, Max-Born-Straße 2a, D-12489 Berlin — [2]Technische Universität Chemnitz, Reichenhainer Straße 70, D-09107 Chemnitz

Die digital holografische 3D–Formvermessung sehr schnell bewegter Objekte erfordert die simultane Erzeugung von mindestens zwei spektral getrennten optischen Pulsen. Neben einem hohen spektralen Kontrast der Pulse ist zur Vermessung ausgedehnter Objekte eine Einzelpulsenergie $> 1\,\mu$J erforderlich [1]. Das breitbandige Spektrum eines Ti:Saphir–Laserverstärkersystems um 800 nm wird so modifiziert, dass dieser bis zu 5 Pulse mit einer Dauer von ca. 500 fs und einem spektralen Abstand von ca. 10 nm simultan emittiert. Mit dieser Quelle wurden Form– und Deformationsmessungen von MEMS mit Resonanzfrequenzen im kHz-Bereich durchgeführt. Dazu wurde ein Michelson–Interferometer mit zwei spektral um 15 nm separierten Pulsen gespeist. Die Trennung der Interferenzmuster beider Spektralanteile erfolgte durch Polarisationskodierung und der simultanen Aufnahme mit zwei CCD–Kameras. Konturplots der schnell bewegten MEMS mit Deformationen im Bereich von 10 nm wurden erstellt.

[1] T. Hansel et al., Appl. Phys. B, in press

Q 35.3 Do 9:00 3H

Interferometric testing of a deep parabolic mirror — •Hildegard Konermann, Johannes Schwider, Klaus Mantel, Norbert Lindlein, Markus Sondermann, Ulf Peschel, and Gerd Leuchs — Institut für Optik, Information und Photonik, Max-Planck-Forschungsgruppe, Staudtstraße 7 B2, Universität Erlangen-Nürnberg, 91058 Erlangen, Germany

We present the results of the testing of a deep parabolic mirror that is to be used for excitation of single atoms by single photons with high efficiency. For this purpose, the aberrations of the mirror have to be known with less than 0.1 wavelengths precision. For such a deep mirror with an aperture angle of 135 degree, i.e. nearly 4Pi solid angle, this will be at the limit of the highest possible precision which can be achieved in practice. For the characterization of the parabolic mirror, we use an interferometer of the Fizeau type. We perform a null-test with a metal sphere at the focal point of the parabolic mirror, thus circumventing ambiguities in the localization of surface errors. In order to rule out polarization dependent phase jumps upon reflection off the mirror surface, the parabolic mirror is illuminated with radially polarized light which is also the polarization of the light in the final application for the excitation of single atoms. The results of the measurements are needed for the creation of a phase plate that compensates the deviations of the mirror from an ideal parabola.

Q 35.4 Do 9:15 3H

Dreiport-Gitter-Resonator mit Power-Recycling — •Michael Britzger[1], Oliver Burmeister[1], Daniel Friedrich[1], Alexander Bunkowski[1], Tina Clausnitzer[2], Ernst-Bernhard Kley[2], Andreas Tünnermann[2], Karsten Danzmann[1] und Roman Schnabel[1] — [1]MPI für Gravitationsphysik (AEI) und Institut für Gravitationsphysik der Leibniz Universität Hannover, Callinstr. 38, 30167 Hannover — [2]Institut für Angewandte Physik der Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena

Dielektrische Reflexionsgitter können so konzeptioniert werden, dass sie als Einkoppler in einem Resonator dazu führen, dass resonantes Licht vollständig zum Eingang zurückreflektiert wird. Mit Hilfe eines Spiegels, der das reflektierte Licht erneut in den Resonator zurückleitet entsteht ein gittergekoppelter Doppelresonator. Bei einem Resonator auf Basis eines sogenannten Dreiport-Gitters als niedereffizientem Einkoppler, existiert ein weiterer Ausgang, der nichtresonante Moden aus dem Resonator auskoppelt. Diese Modenselektivität des gekoppelten Gitterresonators kann genutzt werden um mit Verwendung eines Lasermediums im Resonator Laserstrahlung mit geringer Modenfluktuation zu erzeugen. Dadurch, dass keine transmissiv genutzen Optiken verwendet werden und somit bei hohen Leistungen keine thermischen Effekte, wie thermische Linsen in Substraten verursacht werden, besteht eine weitere Anwendungsmöglichkeit in der Hochleistungslaserphysik. Es wird die erste experimentelle Realisierung eines Dreiport-Gitter-Resonators mit Power-Recycling vorgestellt und ein Ausblick auf zukünftige Anwendungsmöglichkeiten gegeben.

Q 35.5 Do 9:30 3H

Silizium als Testmassenmaterial für zukünftige Gravitationswellendetektoren — •Jessica Dück, Stefan Gossler, Sebastian Steinlechner, Karsten Danzmann und Roman Schnabel — Max-Planck-Institut für Gravitationsphysik (AEI) und Institut für Gravitationsphysik, Leibniz Universität Hannover

Um das thermische Rauschen in erdgebundenen Gravitationswellendetektoren (GWD) zu reduzieren, ist das Kühlen der Testmassen, für welche die Materialien Fused Silica, Saphir und Silizium (Si) in der engeren Auswahl stehen, der erfolgversprechendste Weg.

Fused Silica, welches in der ersten Generation von GWD verwendet wurde, besitzt eine gute optische Qualität für die verwendete Wellenlänge von 1064 nm. Die mechanischen Eigenschaften bei niedrigen Temperaturen entsprechen jedoch nicht den Anforderungen. Si hingegen besitzt insbesondere bei kryogenen Temperaturen die erforderlichen mechanischen Eigenschaften, bei einer Wellenlänge von 1064 nm weist es allerdings eine inakzeptabel hohe Absorption auf. Bei größeren Wellenlängen zeigt es aber ein ausgeprägtes Absorptionsminimum. Innerhalb dieses Minimums liegt die Wellenlänge von 1550 nm und wurde zur weiteren Untersuchung ausgewählt. Grund für diese Wahl sind die hinsichtlich Leistung und Stabilität vielversprechenden Laser, welche angetrieben durch kommerzielle Anwendungen (z.B. Telekommunikation) in den letzten Jahren entwickelt worden sind.

Wir präsentieren Methoden zur Vermessung des vermutlich im Bereich von 10^{-8}/cm liegenden Absorptionskoeffizienten von Si bei 1550 nm.

Q 35.6 Do 9:45 3H

Neuartiger THz Detektor auf Basis des Nachweises des Photonenimpulses — •Ulrike Willer[1,2], Andreas Pohlkötter[1] und Wolfgang Schade[1,2] — [1]TU Clausthal, Institut für Physik und Physikalische Technologien, Clausthal-Zellerfeld, Deutschland — [2]TU Clausthal, LaserAnwendungsCentrum, Clausthal-Zellerfeld, Deutschland

Eine Quarzstimmgabel wird zur Detektion von elektromagnetischer Strahlung verwendet. Dazu wird die Strahlung moduliert und auf die Seitenfläche einer Zinke der Stimmgabel fokussiert. Der übertragene Photonenimpuls regt die Stimmgabel zur Schwingung an. Wird als Modulationsfrequenz die Resonanzfrequenz des Oszillators gewählt, kann die Schwingung direkt über den erzeugten Piezostrom nachgewiesen werden. Eine Beschreibung des Systems mit dem Modell des getriebenen harmonischen Oszillators ist möglich. Messungen, die mit einem THz Quantenkaskadenlaser durchgeführt wurden, werden mit Simulationen verglichen, der neuartige Detektor charakterisiert und die Einsatzmöglichkeiten diskutiert.

Q 36: Quanteninformation (Konzepte und Methoden II)

Zeit: Donnerstag 11:00–13:00 Raum: 1B

Q 36.1 Do 11:00 1B

Disentanglement in qubit-qutrit systems — •Mazhar Ali[1], Gernot Alber[1], Kedar Ranade[1], and A. R. P. Rau[2] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289, Germany — [2]Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana 70803, USA

The interaction of a quantum system with an environment leads to decoherence. This decoherence gradually degrades quantum entanglement. In particular, there are situations in which entanglement can vanish after some finite time. This phenomenon has been named entanglement sudden death. We examine this phenomenon induced by local spontaneous emission for 2×3-dimensional systems [1]. Similar to 2×2-dimensional systems, the negativity of quantum states can vanish in finite time. It is possible to hasten, delay or even avert this sudden death phenomenon [2].

[1] Mazhar Ali, A. R. P. Rau and K. Ranade, arXiv:quant-ph/0710.2238.
[2] A. R. P. Rau, Mazhar Ali and G. Alber, arXiv:quant-ph/0711.0317.

Q 36.2 Do 11:15 1B

2D Multipartite Valence Bond States in Quantum Antiferromagnets — Enrique Rico[1], •Robert Hübener[1], and Hans Briegel[1,2] — [1]Institut für Quantenoptik und Quanteninformation Innsbruck, Technikerstraße 21a, A-6020 Innsbruck, Austria — [2]Institut für Theoretische Physik, Universität Innsbruck, Technikerstraße 25, A-6020 Innsbruck, Austria

A quantum anti-ferromagnetic spin-model on a lattice is characterized via projections of the Hilbert space of a spin-1/2-model on a 2D lattice into suitable subspaces. We implement the following requirements to the resulting state space: a) the states are homogeneous, translationally and rotationally invariant; b) the states are real singlet states (non-chiral); c) the states have a local spin-1 representation. We investigate the properties (e.g., decay of correlations) of this class of states, which is a set of ground states of certain Heisenberg-like Hamiltonians, and then relax the requirements to obtain more general models. Ref.: arXiv:0710.2349v1

Q 36.3 Do 11:30 1B

The structure and properties of symmetric and antisymmetric maximally entangled multidimensional bipartite states — •Denis Sych — Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg, Germany

A multidimensional generalization of the Bell states and the Pauli matrices is considered. It is shown that in the case when the dimension of the Hilbert space is equal to a power of 2, a basis of multidimensional maximally entangled bipartite states can be chosen similarly to the Bell states and constructed of only symmetric and antisymmetric states. It preserves all basic properties of the standard Bell states. An iterative method for its construction is presented and its properties are discussed. Antisymmetric states turn out to be analogous to the singlet Bell state, namely they deliver perfect anticorrelations while being rotationally invariant. The latter property is shown to be tightly connected with antisymmetry. The generalized Bell states are used to show the upper bounds of possible correlations between two quantum systems and to prove the "no-copying" principle, which is a stronger version of the "no-cloning" principle.

Q 36.4 Do 11:45 1B

Discussion of generalized monogamy relations for multipartite entanglement — •Andreas Osterloh[1], Christopher Eltschka[2], and Jens Siewert[2] — [1]Institut für Theoretische Physik, Universität Hannover, D-30167 Hannover, Germany — [2]Institut für Theoretische Physik, Universität Regensburg, D-93040 Regensburg, Germany

The analytic convex roof expression for the entanglement of pairs of qubits marked a major breakthrough in the quantification of entanglement. An equally remarkable "momogamy" relation limits the way of distibuting such pairwise qubit entanglement over a multi-qubit system and gave rise to the definition of a tri-partite entanglement measure. Already for this reason would it be desirable to have an extension of this monogamy relation in order to include multipartite entanglement beyond pairs. We discuss possible extensions of the monogamy relation for pairwise qubit entanglement. Based on recent advances for mixed state threetangle and known invariants for four qubits we systematically analyze pure states of four qubits. Though a class of states exists for which the manogamy relation can be extended in some form, we give a family of counterexamples where no monogamy equality does exist including the three- and/or some four-tangle.

Q 36.5 Do 12:00 1B

Unambiguous discrimination of many mixed states — •Matthias Kleinmann, Hermann Kampermann, and Dagmar Bruss — Heinrich-Heine-Universität Düsseldorf, Institut für Theoretische Physik III, Universitätsstraße 1, 40225 Düsseldorf

While the optimal unambiguous discrimination of two mixed states has already attracted considerable attention, only a few results [1,2] are known for the optimal case of more than two mixed states. We show that many concepts and some classes of optimal solutions known from the two-state case [3] can be generalized to the many-state case.

[1] Y.C. Eldar, M. Stojnic, and B. Hassibi, Phys. Rev. A 69, 062318 (2004), [2] Y. Feng, R. Duan, and M. Ying, Phys. Rev. A 70, 012308 (2004), [3] M. Kleinmann, H. Kampermann, and D. Bruß (in preparation)

Q 36.6 Do 12:15 1B

Characterization of superposition states via STIRAP-type back transfer — •Ruth Garcia-Fernandez[1,2], Frank Vewinger[1,3], David Dzsotjan[1], and Klaas Bergmann[1] — [1]FB Physik, TU Kaiserslautern, Kaiserslautern — [2]Current address: Institut für Physik, Johannes-Gutenberg Universität, Mainz — [3]Current address: Institut für Angewandte Physik, Universität Bonn, Bonn

We present results of an experimental technique for the characterization of coherent superposition states between magnetic sublevels. The technique is based on a multistate variant of the stimulated Raman adiabatic passage (STIRAP) method [1]. The determination of the parameters of the superposition (phases and amplitudes) is achieved using the reverse process, i.e., the transfer of the population in the superposition state back to the initial state by means of a second interaction zone with the laser beams. The experiments are carried out in a collimated supersonic beam of Neon atoms. The superposition states involves two or more degenerate levels in the $J = 2$ metastable state. The population in the initial state $J = 0$ is monitored as a function of the phase. The parameters of the unknown initial superposition state are determined from the properties of the laser radiation which lead to a maximum flow of atoms in $J = 0$.

[1] F. Vewinger et al., Phys. Rev. A 75, 043407, 2007.

Q 36.7 Do 12:30 1B

Experimental Demonstration of near-Optimal Discrimination of Optical Coherent States — •Christoffer Wittmann[1], Katiuscia N. Cassemiro[2], Masahiro Takeoka[3], Masahide Sasaki[3], Ulrik L. Andersen[1], and Gerd Leuchs[1] — [1]Institut für Optik, Information und Photonik, Max-Planck Forschungsgruppe, Universität Erlangen-Nürnberg, — [2]Instituto de Fìsica, Universidade de São Paulo, Caixa Postal 66318, — [3]National Institute of Information and Communications Technology, 4-2-1 Nukui-kitamachi, Koganei, Tokyo 184-8795, Japan

Optimal discrimination of non-orthogonal quantum states is one of the fundamental tasks in quantum detection theory. For weak coherent states, the standard detection schemes, namely homodyne detection and the Kennedy receiver, are not able to achieve error free sensitivity

in principle. Both schemes do not even reach the optimal bound for the minimum average error.

We propose and experimentally realize a novel detection strategy for the discrimination of two optical coherent states. We present the experimental comparison of the new strategy with standard detection schemes and demonstrate, that the new receiver surpasses both standard approaches for any signal amplitude.

Q 36.8 Do 12:45 1B

Quantum evolution from a snapshot — •Michael Wolf[1], Jens Eisert[2], Toby Cubitt[3], and Ignacio Cirac[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str.1, 85748 Garching — [2]Institute for Mathematical Sciences, Imperial College London — [3]Department of Mathematics, University of Bristol

We investigate what a snapshot of a quantum evolution - a quantum channel reflecting open system dynamics - reveals about the underlying continuous time evolution. Remarkably, from such a snapshot, and without imposing additional assumptions, it is possible to decide whether or not a channel is consistent with a time (in)dependent Markovian evolution, for which we provide computable necessary and sufficient criteria. Based on these, a computable measure of 'Markovianity' is introduced which quantifies the Markovian part of a quantum channel. We discuss the consistency with Markovian dynamics as encountered in quantum process tomography for physical non-Markovian processes. The results clarify the geometry of the set of quantum channels with respect to being solutions of time (in)dependent master equations or (in)divisible channels.

Q 37: Quantengase (Wechselwirkungseffekte I)

Zeit: Donnerstag 11:00–13:15 Raum: 1C

Q 37.1 Do 11:00 1C

A number filter for matter-waves — •Reinhold Walser[1], Andreas Sizmann[2], Gerrit Nandi[1], and József Fortágh[3] — [1]Institut für Quantenphysik, Universität Ulm — [2]Ludwig-Maximilians-Universität München — [3]Physikalisches Institut der Universität Tübingen

In current Bose-Einstein condensate experiments, the shot-to-shot variation of atom number fluctuates up to 10%. In here, we present a procedure to suppress such fluctuations by using a nonlinear $p-\bar{p}$ matter wave interferometer for a Bose-Einstein condensate with two internal states and a high beam-splitter asymmetry ($p, \bar{p} \neq 0.5$). We analyze the situation for an inhomogeneous trap within the Gross-Pitaevskii mean-field theory, as well as a quantum mechanical Josephson model, which addresses complementary aspects of the problem and agrees well otherwise.

[1] M. Kitagawa and M. Ueda, Phys. Rev. A, **47**, 5138 (1993).
[2] S. Schmitt, J. Ficker, M. Wolff, F. König, A. Sizmann and G. Leuchs, Phys Rev. Lett. **81**, 2446 (1998).
[3] A. Sørensen and L.-M. Duan and J. I. Cirac and P. Zoller, Nature, **409**, 63 (2001).
[4] U. V. Poulsen and K. Mølmer, Phys. Rev. A, **65**, 033613, (2002).
[5] G. Nandi, A. Sizmann, J. Fortágh, and R. Walser, arXiv:0710.1737 (2007).

Q 37.2 Do 11:15 1C

Are there semi-fluxons in cold atomic gases? — •Michael Eckart[1], Reinhold Walser[1], Wolfgang P. Schleich[1], Dieter Koelle[2], Reinhold Kleiner[2], and Edward Goldobin[2] — [1]Institut für Quantenphysik, Universität Ulm, 89069 Ulm — [2]Physikalisches Institut-Experimentalphysik II, Universität Tübingen, 72076 Tübingen

Fluxons are single quanta of magnetic flux ($\Phi_0 \approx 2.07 \times 10^{-15}$ Wb) which may exist in superconducting long Josephson junctions [1]. By making a Josephson junction out of two parts with a phase difference of π between the tunneling supercurrents, one can construct a so-called 0-π junction, where the ground state may correspond to a spontaneously created magnetic flux of $\Phi_0/2$ localized at the 0-π boundary. Such semifluxons are intensively investigated in superconducting structures [2-4].

In this contribution we propose a technique to create and study similar 0-π junctions in cold atomic gases [5,6]. We investigate the interaction of single atoms as well as BECs with laser light to gain insight into the fundamental physics that eventually also sheds light on the macroscopic behavior of the semifluxons in superconductors.

[1] W. Buckel and R. Kleiner, *Superconductivity: Fundamentals and applications*, Wiley-VCH, Berlin (2004)
[2] E. Goldobin et al., *Phys. Rev. B* **72**, 054527 (2005)
[3] K. Buckenmaier et al., *Phys. Rev. Lett.* **98**, 117006 (2007)
[4] H. Hilgenkamp et al., *Nature* **422**, 50 (2003)
[5] V.M. Kaurov and A.B. Kuklov, *Phys. Rev. A* **73**, 013627 (2006)
[6] E. Goldobin et al., *New J. Phys.*, in preparation

Q 37.3 Do 11:30 1C

Atom-molecule oscillations in a Mott insulator — •Matthias Lettner, Niels Syassen, Dominik M. Bauer, Daniel Dietze, Thomas Volz, Stephan Dürr, and Gerhard Rempe — Max Planck Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany

Near a Feshbach resonance an unbound state of two ultracold atoms is coherently coupled to a molecular one. This realizes a coupled two level system. We report on the observation of large-amplitude oscillations. The damping is so weak that 29 cycles are observed. The experiment uses ^{87}Rb in an optical lattice and a Feshbach resonance near 414 G. The frequency and amplitude of the oscillations depend on the magnetic field in a way that is well described by a two-level model. Also the observed density dependence of the oscillation frequency agrees with the theoretical expectation. We confirmed that the state produced after a half-cycle contains exactly one molecule at each lattice site. In addition, we show that for energies in a gap of the lattice band structure, the molecules cannot dissociate.

[1] N.Syassen *PRL* 99, 033201 (2007).

Q 37.4 Do 11:45 1C

Coherent backscattering of Bose-Einstein condensates in two dimensional disorder potentials — •Michael Hartung, Klaus Richter, and Peter Schlagheck — Institute for Theoretical Physics, University of Regensburg, Germany

The rapid progress in the experimental techniques for Bose-Einstein condensates permits detailed studies of mesoscopic transport dynamics of interacting matter waves with rather high accuracy and high flexibility in the control of parameters. We particularly focus on quasi-stationary transport processes of Bose-Einstein condensates through two dimensional disorder potentials by integrating the time-dependent Gross-Pitaevskii equation.

In the limit of vanishing atom-atom interaction we observe coherent backscattering, which leads to a sharp cone, centered around the backward direction, in the angle resolved density of the scattered condensate. This is a characteristic signature of weak localization and arises due to the constructive interference of semiclassical scattering paths with their time reversed counterparts. This coherent backscattering peak is transformed into a pronounced dip for weak repulsive interaction, and eventually vanishes for strong interaction. In this latter regime we find intrinsic time-dependent behavior of the condensate wavefunction, which effectively suppresses the interference phenomena that give rise to the coherent backscattering signal.

Q 37.5 Do 12:00 1C

Bifurcations in Bose-Einstein condensates with dipolar interactions — •Patrick Wagner, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

We study Bose-Einstein condensates with dipolar and contact interaction within Gross-Pitaevskii theory. As an interesting novel phenomenon we find two ground-state solutions for negative as well as for positive scattering lengths. Below a critical value of the scattering length, no solution exists. We also discuss the dependence of physical properties of the condensate on the trap frequencies.

Q 37.6 Do 12:15 1C

Linear stability of Bose-Einstein condensates with attractive $1/r$-interaction — •Jörg Main, Holger Cartarius, Tomaž Fabčič, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

We investigate the stability of the two nodeless stationary solutions, which are created in a tangent bifurcation in the Gross-Pitaevskii equation for condensates with attractive $1/r$-interaction. Using the Fréchet derivative of the time-dependent nonlinear integro-differential equation, we calculate the eigenvalues of the linearized system. The two stationary solutions are found to be an elliptic and a hyperbolic fixed point. The numerically exact solutions are compared with the results of an approximative variational approach, which leads to analytic expressions for the eigenmodes of the linearized time-dependent equation. There are quantitative differences between both approaches, however, qualitatively they agree very well.

Q 37.7 Do 12:30 1C

Dynamics of Bose-Einstein condensates with inter-particle interaction — •Tomaž Fabčič, Jörg Main, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

The time-dependent extended Gross-Pitaevskii equation for Bose-Einstein condensates with attractive inter-atomic interaction is investigated. The two stationary solutions created in a tangent bifurcation are shown to be elliptic and hyperbolic, respectively. The stable stationary state is surrounded by solutions periodically oscillating in time whereas wave functions in the unstable region undergo a collapse within finite time. Below the tangent bifurcation no stationary solutions exist, i.e., the condensate is always unstable and collapsing. Computations are presented for atomic $1/r$ as well as dipolar interactions.

Q 37.8 Do 12:45 1C

Discovery of exceptional points in stationary states of Bose-Einstein condensates — •Holger Cartarius, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

The stationary Gross-Pitaevskii equation exhibits a nodeless solution which is born together with the ground state in a tangent bifurcation. The phenomenon has been demonstrated for condensat es in a harmonic trap and, recently, has also been found for condensates with attractive $1/r$-interaction and condensates with dipole-dipole interaction. At the bifurcation point both states coalesce, i.e. the energies and the wave functions are identical, a situation known from exceptional points in linear non-Hermitian Hamiltonians. We point out that the mean field energy, the chemical potential, and the wave functions in the cases mentioned above show the same behavior as an exceptional point in a linear quantum system. For the self-trapping case of a condensate with $1/r$-interaction we find analytic expressions directly demonstrating the branch point singularity structure of the states.

Q 37.9 Do 13:00 1C

Dynamics of strongly-correlated bosons in ladder-like optical lattices — •Arturo Argüelles and Luis Santos — Appelstraße 2, 30167 Hannover, Germany

We analyze the physics of strongly-correlated bosons in ladder-like optical lattices out of equlibrium formed by two connected one-dimensional wires. In particular, we investigate Josephson-like oscillations between initially unbalanced wires, and study the effect of the in-wire correlations on the transversal dynamics between the wires. In absence of interactions, the system would perform standard Josephson-like oscillations of the relative population. Due to strong interactions, strong correlations lead to a significant damping of such population oscillations. In our analysis we study by means of matrix-product state techniques the dependence of the damping ratio as a function of the interation regime.

Q 38: Quanteneffekte (Verschränkung und Dekohärenz)

Zeit: Donnerstag 11:00–13:15 Raum: 2D

Gruppenbericht Q 38.1 Do 11:00 2D

Operational monitoring of multi-qubit entanglement classes via tuning of local operations — •Thierry Bastin[1], Christoph Thiel[2], Joachim von Zanthier[2], Lucas Lamata[3], Enrique Solano[4], and Girish S. Agarwal[5] — [1]Institut de Physique Nucléaire, Atomique et de Spectroscopie, Université de Liège, Belgium — [2]Institut für Optik, Information und Photonik,Max-Planck Forschungsgruppe, Universität Erlangen-Nürnberg, Germany — [3]Max-Planck-Institut für Quantenoptik, Garching, Germany — [4]Physics Department, ASC, and CeNS, Ludwig-Maximilians-Universität, Munich, Germany — [5]Department of Physics, Oklahoma State University, Stillwater, USA

We introduce a physical setup consisting of N emitters, incoherently radiating single photons that may be absorbed remotely by detectors equipped with polarizers and producing long-lived multiqubit entangled states in the internal ground levels of the emitters. By using optical fibers our system offers also access to remote entangled matter qubit states.

We show that it is possible to associate well-defined sets of locally tuned polarizer orientations with multiqubit entanglement classes, allowing their monitoring in an operational manner. Our method is not restricted to two or three particles but can monitor entanglement classes even for a four particle system. Hereby, multipath quantum interference, associated with qubit permutation symmetry, plays a key role in explaining the underlying physics.

Q 38.2 Do 11:30 2D

Entanglement screening by nonlinear resonances — •Ignacio Garcia-Mata[1], Andre R. R. Carvalho[2], Florian Mintert[3,4,5], and Andreas Buchleitner[3,4] — [1]Laboratoire de Physique Theorique, UMR 5152 du CNRS, Universite Toulouse III — [2]Department of Physics, Faculty of Science, Australian National University ACT 0200, Australia — [3]Albert-Ludwigs-Universitaet Freiburg, Physikalisches Institut, Hermann-Herder-Str. 3, D-79104 Freiburg, Germany — [4]Max-Planck-Institut fur Physik komplexer Systeme, Noethnitzerstrasse 38, D-01187, Dresden, Germany — [5]Department of Physics, Harvard University, 17 Oxford Street, Cambridge Massachusetts, USA

We show that nonlinear resonances in a classically mixed phase space allow us to define generic, strongly entangled multipartite quantum states. The robustness of their multipartite entanglement increases with the particle number, i.e., in the semiclassical limit, for those classes of diffusive noise which assist the quantum-classical transition. Numerical results are shown for the quantum Harper map.

Q 38.3 Do 11:45 2D

Estimation of multipartite entanglement — •Florian Mintert[1], Leandro Aolita[2], and Andreas Buchleitner[1] — [1]Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]Universidade Federal do Rio de Janeiro, Caixa Postal 68528, 21941-972 Rio de Janeiro, RJ, Brasil

We present an efficient estimation of the multipartite entanglement of mixed quantum states in terms of simple parity measurements. Similarly to the bipartite case [1] also multipartite generalizations of concurrence can be bounded by expectation values of simple parity projections on two identically prepared quantum states [2].

[1] F. Mintert and A. Buchleitner, Phys. Rev. Lett. **98**, 140505 (2007)
[2] L. Aolita, A. Buchleitner and F. Mintert, quant-ph/0710.3529

Q 38.4 Do 12:00 2D

The role of atom-cavity detuning in cavity QED experiments — •Denis Gonta[1] and Stephan Fritzsche[1,2] — [1]Max–Planck–Institut für Kernphysik, Postfach 103980, D–69029 Heidelberg — [2]Physikalisches Institut der Universität Heidelberg, Philosophenweg 12, D-69120 Heidelberg

Cavity QED provides an excellent control of the atom-field interaction, when Rydberg atoms reside or pass through the cavity. This opens up a way to obtain the coherent coupling of the atomic and photonic qubits as associated with the two-level Rydberg atoms and the cavity field states, respectively.

In this contribution, we explore the coherent evolution of the cavity states superposition in bimodal cavities and how this evolution is affected if a realistic atom-cavity detuning is considered. Comparison of our model computations has been made with experiment [1] in which the entanglement of the two field modes has been demonstrated using a bimodal cavity. A better agreement with experiment is obtained if a 'finite switch' of the atomic resonance frequency from one to the second mode of a bimodal cavity is combined with the mutual interaction between the cavity modes. We shall consider also experimental setup [2] in which the entanglement of two Rydberg atoms has been demonstrated by the cavity assisted collision.

[1] A. Rauschenbeutel *et al.*, Phys. Rev. A **64**, 050301 (2001).
[2] S. Osnaghi *et al.*, Phys. Rev. Lett. **87**, 037902 (2001).

Q 38.5 Do 12:15 2D

Semiclassical simulation of open quantum systems — •Florian Mintert[1,2] and Eric Heller[2] — [1]Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]Department of Physics, Harvard University, 17 Oxford Street, Cambridge, MA 02138, USA

We present an approach for the semiclassical treatment of open quantum systems. An expansion into localized states allows to restrict a simulation to a fraction of the environment that is located within a predefined vicinity of the system. Our approach allows to add and drop environmental particles during the simulation what provides the basis for an effective reduction of the size of the system that is being treated.

Q 38.6 Do 12:30 2D

Generation of arbitrary Dicke states in remote qubits using linear optics — •Andreas Maser[1], Christoph Thiel[1], Uwe Schilling[1], Thierry Bastin[2], Enrique Solano[3], and Joachim von Zanthier[1] — [1]Institut für Optik, Information und Photonik, Max-Planck-Forschungsgruppe, Universität Erlangen-Nürnberg, Germany — [2]Institut de Physique Nucléaire, Atomique et de Spectroscopie, Université de Liège, Belgium — [3]Physics department, ASC, and CeNS, Ludwig-Maximilians-Universität, Munich, Germany

We propose a method for generating any state out of the whole family of Dicke states (symmetric and non-symmetric) for an arbitrary number of remote qubits: The method uses the long-lived internal ground levels of remote particles as qubits and is based on linear optics and single photon detection. The scheme offers thus access to the complete basis of the Hilbert space of an N spin-1/2 particle compound system and its not yet investigated entanglement classes.

In particular, we consider a system of N localized atoms, e.g. ions stored in a Paul trap, where each of them is characterised by a Λ-configuration. All atoms are initially coherently excited into the upper state and the spontaneously emitted photons are collected by photonic fibres which are connected to photon detectors with polarization sensitive analyzers placed in front. The latter determine the polarization state of the registered photons.

Q 38.7 Do 12:45 2D

Single-Particle Interference Can Witness Bipartite Entanglement — •Torsten Scholak[1], Florian Mintert[2,3], and Cord A. Müller[1] — [1]Physikalisches Institut, Universität Bayreuth, 95440 Bayreuth, Germany — [2]Max-Planck-Institut für Physik Komplexer Systeme, Nöthnitzerstraße 38, 01187 Dresden, Germany — [3]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, 79104 Freiburg, Germany

We propose to realize entanglement witnesses in terms of the interference pattern of a single quantum probe [1]. After giving a conceptional recipe, we discuss possible realizations both with electrons in mesoscopic Aharonov-Bohm rings and with photons in standard Young's double-slit or coherent-backscattering interferometers.

[1] arXiv:0710.0825

Q 38.8 Do 13:00 2D

Decoherence properties of entangled single nuclear spins and one electron spin at room temperature in diamond — •Philipp Neumann, Torsten Gaebel, Florian Rempp, Christian Zierl, Fedor Jelezko, and Jörg Wrachtrup — 3. Physikalisches Institut, Universität Stuttgart, Germany

Generation of long-lived entanglement between single qubits is at the heart of quantum information processing. Since the coherence between single qubits in solid state systems is rather fragile one is looking for qubits with long coherence lifetimes. Those could be nuclear spins. In our case we use the electron spin of the NV-center in diamond to generate Bell States between two qubits associated with two proximal ^{13}C nuclear spins. Eventually the electron spin itself is used as a qubit and 3-particle entanglement is generated. The decoherence properties of these entangled states are investigated.

Q 39: Ultrakurze Laserpulse (Erzeugung I)

Zeit: Donnerstag 11:00–13:00 Raum: 3H

Q 39.1 Do 11:00 3H

Kurzpulslaserbasierte Erzeugung von 120 Attosekunden XUV Pulsen mit breitbandiger XUV Optik — •Martin Schultze[1], Eleftherios Goulielmakis[1], Matthias Uiberacker[2], Michael Hofstetter[1], Ulf Kleineberg[2] und Ferenc Krausz[1,2] — [1]MPI f. Quantenoptik, Garching, Germany — [2]LMU, Dept. Physik, München, Germany

Durch Ionisierung von Neon mit phasenstabilisierten Infrarotlaserpulsen mit einer Dauer von weniger als 2 Lichtzyklen und anschliessender spektraler Filterung der enstehenden Harmonischenstrahlung durch Reflektion an einem breitbandigen, gechirpten Molybdän-Silizium Multilayerspiegel wird die Erzeugung isolierter 120 Attosekunden Pulse im Energiebereich um 100 eV (XUV - Extreme Ultra Violet) mit ˜10ˆ6 Photonen/Puls bei einer Wiederholrate von 3 kHz demonstriert

Q 39.2 Do 11:15 3H

Diodenlasergepumpter Nd:YVO$_4$-Ultrakurzpulslaser mit aktiver Modenkopplung und spektraler Kontrolle der Bandbreite der Verstärkung — •Markus Lührmann, Christian Theobald und Richard Wallenstein — TU Kaiserslautern, Fachbereich Physik, Erwin-Schrödinger-Straße 46, 67663 Kaiserslautern

Diodenlasergepumpte Festkörperlaser mit hoher Impulsenergie, -wiederhohlrate und -dauer im Bereich von mehreren hundert Pikosekunden können als Pumplaser eine Basiskomponente für kompakte hochrepetierende Femtosekundenverstärker darstellen. Die Schlüsselkomponente eines solchen Pumplasers ist ein modengekoppelter Masteroszillator der Impulse mit entsprechender Dauer liefert. Laser, die direkt solche vergleichsweise langen fourierlimitierten Impulse emittieren, sind jedoch bisher nicht verfügbar. Daher wurde die Erzeugung langer Pikosekundenimpulse durch die spektrale Einengung der Verstärkung in einem herkömmlichen aktiv akustooptisch modengekoppelten Nd:YVO$_4$ Festkörperlaser untersucht. Dieser liefert direkt Impulse von 34 ps Dauer mit 6,4 W Ausgangsleistung bei einer Impulswiederhohlrate von 108 MHz und einem $M^2 < 1{,}1$. Zur Reduktion der spektralen Bandbreite der Verstärkung und somit der Erhöhung der Impulsdauer wurden Etalons im Resonator eingesetzt. Erreicht werden konnten modengekoppelte Impulse mit einstellbarer Impulsdauer im Bereich von 34 ps bis über 1 ns und Ausgangsleistungen von typisch 3 W. Bei fourierlimitierten Impulsen und Impulsdauern von 350 ps wurden Ausgangsleistungen von 5,1 W mit beugungsbegrenztem Strahl in einem stabilen Betrieb erreicht.

Q 39.3 Do 11:30 3H

Single-walled carbon nanotube saturable absorber mode-locked Yb:KLuW laser — •Andreas Schmidt[1], Simon Rivier[1], Günter Steinmeyer[1], Valentin Petrov[1], Uwe Griebner[1], Jong H. Yim[2], Won B. Cho[2], Soonil Lee[2], and Fabian Rotermund[2] — [1]Max-Born-Institut, Max-Born-Straße 2a, D-12489 Berlin, Germany — [2]Division of Energy Systems Research, Ajou University, 443-749 Suwon, Korea

Recently, single-walled carbon nanotube saturable absorbers (SWCNT-SA) have gained much attention as a potential replacement for semiconductor-based ultrafast passive mode-lockers and limiters [1]. So far, SWCNT-SAs have been utilized to mode-lock lasers in the 1.5 μm wavelength range. Here we compare the mode-locked performance of an Yb:KLuW laser in the 1 μm spectral range employing a SWCNT-SA and a semiconductor saturable absorber mirror (SAM). Using an end-pumped configuration and placing the SAM in a z-shaped laser cavity, pulses as short as 83 fs are generated at a repetition rate

of 94 MHz with a time-bandwith product of 0.32. Implementing the SWCNT-SA instead of the SAM in the cavity, nearly transform-limited pulses with a duration of 115 fs at 1047 nm in a soliton-like regime are obtained. The achieved pulse durations demonstrate the high potential of the low cost SWCNT-SA to serve as fast saturable absorber for mode locking applications in the 1–μm spectral range.

[1] Y.-C. Chen, et. al., Appl. Phys. Lett. **81**, 975 (2002).

Q 39.4 Do 11:45 3H

Selbstkompression und asymptotische Pulsformen in Filamenten — •Carsten Krüger[1,2], Ayhan Demircan[1] und Günter Steinmeyer[2] — [1]Weierstraß-Institut für Angewandte Analysis und Stochastik — [2]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie

Die Propagation von Femtosekunden-Laserpulsen in Filamenten ist ein bislang noch nicht vollständig verstandenes Phänomen. Im stationären Fall ist die Selbststabilisierung des transversalen Strahlprofils im Filament als Folge einer Balance der konkurrierenden Einflüsse von Kerr-induzierter Selbstfokussierung sowie plasmainduzierter Defokussierung durch verschiedene experimentelle und theoretische Arbeiten hingegen recht gut erklärt. Jedoch deuten experimentelle Daten darauf hin, dass sich zusätzlich zum selbststabilisierenden transversal-räumlichen Profil im Filament eine stabile Pulsform in der Zeitdomäne einstellt, um eine optimale Kompensation der konkurrierenden fokussierenden sowie defokussierenden Effekte zu jedem Zeitpunkt zu garantieren. Die sich einstellende charakteristisch asymmetrische, selbststabilisierende Pulsform ist bereits im Vergleich zum Eingangspuls auf wenige Zyklen der Trägerfrequenz komprimiert und bedarf keiner weiteren Dispersionskompensation, sondern weist im Gegenteil nach normaler Materialdispersion eine flache spektrale Phase auf. Wir führen den experimentell gefundenen negativen Chirp auf die Dispersion der Gruppengeschwindigkeit im Plasma zurück und zeigen, dass sich im Filament gegen Störungen stabile charakteristisch asymmetrische Pulsformen bilden können.

Q 39.5 Do 12:00 3H

Ytterbium Kurzpulsfaserlaser ohne Dispersationskompensation — •Heike Karow, Michael Schultz, Dieter Wand und Dietmar Kracht — Laserzentrum Hannover e.V., Hannover, Germany

In aktuellen Arbeiten über modengekoppelte Ytterbium Faserlaser wurden verschiedene Aufbauten vorgestellt und untersucht, die auf eine Kompensation der normalen Gruppengeschwindigkeitsdispersion der verwendeten Fasern vollständig verzichten [1]. Damit konnten sehr einfache all-fiber Aufbauten realisiert werden, allerdings mit Pulsdauern im Bereich von etwa 1 ps. Kürzere Pulse (170 fs) wurden kürzlich auch ohne Dispersionskompensation mit einem Faseroszillator erreicht, der mit einem resonatorinternen Interferenzfilter versehen war [2].

Wir stellen einen passiv modengekoppelten Ytterbium Faserringlaser mit resonatorinternem spektralem Filter vor, der ohne Komponenten mit anomaler Dispersion arbeitet. Der Einfluß der Bandbreite und Zentralwellenlänge des Filters auf die Lasereigenschaften wie spektrale Breite, komprimierte Pulsdauer und Energiequantisierung wird diskutiert.

Erste Ergebnisse zeigen spektrale Pulshalbwertsbreiten von 25 nm bei einer Filterbandbreite von 8 nm. Die Pulse sind stark gechirpt und können mit einer externen Gitteranordnung auf eine Halbwertsbreite von 130 fs komprimiert werden.

[1] Prochnow, et.al., Opt. Express, **15**, 6889-6893, (2007)
[2] Chong, et.al., Opt. Express, **14**, 10095-10100, (2006)

Q 39.6 Do 12:15 3H

Verkürzung hochenergetischer Laserpulse durch Selbstkompression in einem Filament — Emilia Schulz, •Thomas Binhammer, Stefan Rausch, Milutin Kovacev und Uwe Morgner — Institut für Quantenoptik, Universität Hannover

Das Streben nach immer kürzeren Laserpulsen ist ein andauerndes Forschungsgebiet. So ist für viele Experimente wie z.B. für die Erzeugung eines einzelnen Attosekunden-Pulses nicht nur eine hohe Pulsenergie, sondern auch eine sehr geringe Pulsdauer im Bereich von wenigen optischen Zyklen wesentlich. Filamentation in einer Edelgaszelle ist ein kürzlich erstmalig demonstriertes Verfahren, um mit geringem Aufwand hoch-energetische Pulse spektral zu verbreitern. Wir berichten hier über die Verkürzung von Pulsen aus einem Millijoule-Ti:Saphir-Verstärkersystem mittels Filamentation. Es werden systematische Untersuchungen bezüglich der verschiedenen Parameter wie Druck und Gassorte und die Strahleigenschaften nach dem Filament vorgestellt. Durch das Zusammenspiel unterschiedlicher nichtlinearer Effekte bei der Führung des Strahls im Filament gelingt es auf diese Weise, Pulse einer Dauer unter 10 fs zu erzeugen, ohne dass eine anschließende Kompression nötig war.

Q 39.7 Do 12:30 3H

Charakterisierung der Wellenfront von Hoher Harmonischer Strahlung — •Christian Kern, Stefan Eyring, Jan Lohbreier, Robert Spitzenpfeil und Christian Spielmann — Physikalisches Institut, Universität Würzburg, Am Hubland, 97074 Würzburg

Im Bereich der Physik auf Attosekunden-Zeitskalen spielt die Erzeugung von kohärenter, extrem-ultravioletter (XUV) Strahlung durch den Prozess der Hohen Harmonischen Erzeugung (HHG) eine wichtige Rolle. Der komplexe nichtlineare Mechanismus der HHG macht eine exakte Berechnung der Strahlqualität der erzeugten Strahlung durch Simulationen nahezu unmöglich. Es werden zwei Methoden der Charakterisierung vorgestellt: die M2-Messung durch einen Knife-Edge-Scan und die Vermessung der Wellenfront durch einen Hartmann-Sensor. Mit den so gewonnenen Daten wird die Wellenfront in der Darstellung durch Zernike-Polynome eindeutig beschrieben. Eine solche quantitative Analyse von Hoher Harmonischer Strahlung ist unseres Wissens noch nicht durchgeführt worden. Desweiteren werden Möglichkeiten diskutiert, die gewonnene Charakterisierung als Kontrollsignal für die Formung der zur Erzeugung verwendeten kurzen Laserpulse zu verwenden. In ersten Experimenten wurde so zum Beispiel eine deutliche Steigerung der detektierten Ausbeute an Hohen Harmonischen erzielt.

Q 39.8 Do 12:45 3H

Fokussierung Hoher Harmonischer — •Christian Ott, Sebastian Jung, Nico Franke, Jan Henneberger und Christian Spielmann — Physikalisches Institut, Universität Würzburg, Am Hubland, 97074 Würzburg

Die Erzeugung Hoher Harmonischer (HHG) hat sich als Methode zur Herstellung ultrakurzer Laserpulse im XUV (extreme ultraviolet) etabliert. Allerdings sind die Intensitäten der dabei erzeugten XUV-Pulse gering, was eine erhebliche Einschränkung im Bereich der experimentellen Anwendung zur Folge hat. Für eine Vielzahl von Experimenten ist es daher erforderlich, die erzeugten XUV-Pulse auf einen Interaktionsbereich zu fokussieren, um höhere Intensitäten zu erhalten. Eine bereits erfolgreich eingesetzte Technik ist die Verwendung eines Toroidalspiegels in streifendem Einfall. In diesem Vortrag werden insbesondere die durch die Strahlgeometrie verursachten Abbildungsfehler des Spiegels diskutiert. Neben einer Vorstellung der experimentellen Umsetzung wird auch die Beeinflussung der Form und Lage des Fokus diskutiert, welche durch eine schlechte Ausrichtung der verwendeten Optiken hervorgerufen werden kann.

Q 40: Quantengase (Bosonen I)

Zeit: Donnerstag 14:00–16:00 Raum: 1A

Q 40.1 Do 14:00 1A

Differences between mean-field dynamics and N-particle quantum dynamics as a signature of entanglement — Christoph Weiss[1,3] and •Niklas Teichmann[2,3] — [1]Laboratoire Kastler Brossel, École Normale Supérieure, Université Pierre et Marie-Curie-Paris 6, CNRS, Paris, France — [2]Institut Henri Poincaré, Centre Emile Borel, Paris, France — [3]Institut für Physik, Carl von Ossietzky Universität, Oldenburg, Germany

A Bose-Einstein condensate in a tilted double-well potential under the influence of time-periodic potential differences is investigated in the regime where the mean-field (Gross-Pitaevskii) dynamics become chaotic. For some parameters near stable regions, even averaging over several condensate oscillations does not remove the differences between mean-field and N-particle results. While introducing decoherence via piecewise deterministic processes reduces those differences, they are due to the emergence of mesoscopic entangled states in the chaotic regime.

Q 40.2 Do 14:15 1A

Anisotropic scattering of Bogoliubov quasi particles — •Christopher Gaul and Cord A. Müller — Universität Bayreuth

In order to study the interplay of disorder and interaction in atomic BECs, we investigate scattering of Bogoliubov quasi particles (BQP) by the spatial fluctuations of an external optical potential. We first calculate the amplitude for a single scattering event. In contrast to the case of noninteracting particles, the scattering amplitude of BQPs has a sign change and consequently a node at a certain angle. In the long-wavelength limit, we understand this as a fundamental sound-wave property, which becomes apparent in a hydrodynamic formulation. This scattering anisotropy has the curious consequence that in the 2D multiple-scattering regime the diffusive Boltzmann transport length becomes shorter than the scattering mean free path for particle-like excitations scattered by short-range correlated potentials.

Q 40.3 Do 14:30 1A

Commuting Heisenberg operators in the Wigner representation — •Bettina Berg[1], Lev Plimak[1], Murray K. Olsen[2], Michael Fleischhauer[3], and Wolfgang P. Schleich[1] — [1]Institute of Quantum Physics, Ulm University, Germany — [2]School of Physical Sciences, University of Queensland, Australia — [3]Fachbereich Physik, Technische Universität Kaiserslautern, Germany

We discuss commuting Heisenberg operators as a response problem in the phase space. In the Wigner representation one calculates averages of symmetrically ordered two-time operator pairs [1]. As the quantities that are experimentally measured are the time-normally ordered correlation functions, we need a way of commuting Heisenberg operators at different times. For an operator pair, solution to this problem is given by Kubo's linear response relation [2] expressing the commutator as a linear response function. This quantity can be found in the Wigner representation simply by adding sources to the "Langevin" equations in the phase space. By using the truncated Wigner representation [3], one can calculate the normally-ordered correlation functions approximately yet with relative ease. These techniques are demonstrated for the Bose-Hubbard model [4].

[1] L. I. Plimak, M. K. Olsen, M. Fleischhauer, M. J. Collett, Europhys. Lett. **56**, 372 (2001). [2] R. Kubo, *Lectures in Theoretical Physics, v. 1* (Wiley, New York, 1959). [3] M. J. Werner, P. D. Drummond, J. Comput. Phys. **132**, 312 (1997). [4] D. Jaksch, C. Bruder, J. I. Cirac, C. W. Gardiner, P. D. Zoller, Phys. Rev. Lett. **81**, 3108 (1998).

Q 40.4 Do 14:45 1A

Transverse instability of straight vortex lines in dipolar Bose-Einstein condensates — •Michael Klawunn[1], Rejish Nath[1], Paolo Pedri[2], and Luis Santos[1] — [1]Institut für Theoretische Physik , Leibniz Universität Hannover, Appelstr. 2, D-30167, Hannover, Germany — [2]Laboratoire de Physique Theorique et Modeles Statistiques, Universite Paris Sud, 91405 Orsay Cedex, France

The physics of vortex lines in dipolar condensates is studied. Due to the nonlocality of the dipolar interaction, the 3D character of the vortex plays a more important role in dipolar gases than in typical short-range interacting ones. In particular, the dipolar interaction significantly affects the stability of the transverse modes of the vortex line. Remarkably, in the presence of a periodic potential along the vortex line, the spectrum of transverse modes shows a roton minimum, which eventually destabilizes the straight vortex when the BEC as a whole is still stable, opening the possibility for new scenarios for vortex-line configurations in dipolar gases.

Q 40.5 Do 15:00 1A

The spectrum of a non-Hermitian two-mode Bose-Hubbard system — •Eva-Maria Graefe[1], Uwe Guenther[2], Astrid Niederle[1], and Hans Jürgen Korsch[1] — [1]TU Kaiserslautern, Germany — [2]Forschungszentrum Dresden Rossendorf, Germany

We study an N-particle, two-mode Bose-Hubbard system, modelling a Bose-Einstein condensate in a double-well potential. By introducing effective complex energies to the modes we describe a coupling to a continuum. The eigenvalues of the resulting non-Hermitian matrix model are in general complex where the imaginary parts describe the decay rate into the continuum. In dependence on the systems parameters, the eigenvalues show intricate patterns of avoided and real crossings, as well as characteristic bifurcations. In the present talk the effect of the interplay between the particle interaction and the non-Hermiticity on characteristic features of the spectrum is analysed and its peculiarities are clarified by perturbational methods.

Q 40.6 Do 15:15 1A

Phase fluctuations in one-dimensional quasi-condensates — •Stephanie Manz, Thomas Betz, Christian Koller, Robert Bücker, Wolfgang Rohringer, Aurélien Perrin, Thorsten Schumm, and Jörg Schmiedmayer — Atominstitut der Österreichischen Universitäten, Technische Universität Wien, Stadionallee 2, A-1020 Vienna, Austria

Due to the possibility to fabricate wire structures down to the micrometer scale, atomchips are ideally suited to examine ultracold one-dimensional systems. In contrast to the three-dimensional case, one-dimensional sytems do not exhibit long-range order. The respective phase fluctuations can either be seen in interference experiments with split one-dimensional Bose-Einstein condensates [1,2] or by directly observing density modulations in time-of-flight images [3].

We study the ballistic expansion of tightly confined atomic clouds and compare the results to theory.

[1] S. Hofferberth et al., Nature Phys. **2** 710 (2006).
[2] G.-B. Jo et al., arXiv:0706.4041v3
[3] D. Hellweg et al., Appl. Phys. B **73** 173 (2001).

Q 40.7 Do 15:30 1A

Bose-Einstein condensates and optical waveguides — •J. Nes, S. Hertsch, M. Krutzik, T. Lauber, O. Wille, and G. Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt

Achieving Bose-Einstein condensation in optical potentials has been tried since the early days of laser cooling. The first BEC in a dipole trap was created with a CO2 laser. Since then, achieving BEC in optical potentials is routine. However, using a CO2 laser to trap and evaporate atoms is favourable for some, but might be inconvenient for other implementations. Therefore, several groups have been trying to create BECs by trapping atoms with lasers with lower wavelengths. So far, only few groups have reached condensation with a laser having a wavelength in the one micron range by simple means.

Our work aims at creating ultracold atom samples in the submicroKelvin temperature range and especially BECs, in a crossed optical dipole trap made with a laser with a wavelength of 1030 nm. After reaching these temperatures, the atoms are transferred into an optical guiding or storing structure created by microfabricated optical elements, so that the coherence properties can be studied. One of our projects is to guide the atoms along a waveguide and past a corrugated optical potential surface, such as an optical lattice, in order to investigate the modification of the wavepacket dynamics as compared to an uncorrugated guiding structure.

Q 40.8 Do 15:45 1A

Quantum chaos limits DMRG efficiency — •Hannah Venzl[1], Florian Mintert[1], Andrew Daley[2], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany — [2]Institut für Theoretische Physik, Universität Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria

The spectrum of the Bose-Hubbard Hamiltonian exhibits quantum chaos for certain ranges of the system parameters. One possible way to probe the chaos transition in this system is by tuning the strength of an additional static force. Likewise, the efficiency of time-dependent Density Matrix Renormalization Group (t-DMRG) simulations of the system dynamics depends strongly on the applied static field. We probe the connections between this loss of efficiency and the underlying spectral structure.

Q 41: Quanteninformation (Konzepte und Methoden III)

Zeit: Donnerstag 14:00–16:00 Raum: 1B

Q 41.1 Do 14:00 1B

Channel Representation of Quantum Error-Correcting Codes — •Johannes Gütschow, Holger Vogts, and Reinhard Werner — Institut für Mathematische Physik, TU Braunschweig, www.imaph.tu-bs.de

Quantum error-correcting codes (qeccs) are essential for most of the proposed realizations of quantum computation to correct errors due to decoherence. Quantum convolutional codes (qccs) are a promising candidate for on line encoding and decoding of a flow of quantum information thus enabling the sending party to begin with the transmission of quantum information before the end of the flow (or a block) is reached. Analogously the decoding process can begin before the end of the transmission. Until now, only the noise and interaction with the environment were described in the channel formalism. We investigate qeccs and describe their encoders as channels. Block encoders are represented by memoryless channels, whereas convolutional encoders are described by memory channels. Convolutional encoders need to be "non-catastrophic", meaning an error on a single source qubit should only affect a finite number of target qubits. We investigate the relation between this condition and the "forgetfulness"-property of quantum memory channels.

Q 41.2 Do 14:15 1B

Quasi-Free States on Clifford Quantum Cellular Automata — •Sonja Uphoff[1], Zoltan Zimboras[2], and Reinhard Werner[1] — [1]Institut für Mathematische Physik, TU Braunschweig, www.imaph.tu-bs.de — [2]Theoretische Physik, Universität des Saarlands, www.uni-saarland.de/fak7/rieger

Clifford Quantum Cellular Automata (CQCA) are a particularly simple class of Quantum Cellular Automata that can be used for generating entanglement. We are interested in the asymptotics of states under CQCA action, one aspect being entanglement of invariant states. For a special class of CQCA it is possible to obtain these states on the spin chain by employing the Araki Jordan-Wigner transformation between the spin chain and the fermionic chain. In this case we can construct quasi-free states that are invariant under the time evolution of the CQCA.

Q 41.3 Do 14:30 1B

Completeness of classical spin systems and universal quantum computation — •Gemma De las Cuevas[1], Robert Hübener[1], Maarten Van den Nest[1], Wolfgang Dür[1,2], and Hans J. Briegel[1,2] — [1]Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaften, Innsbruck, Austria — [2]Institut für Theoretische Physik, Universität Innsbruck, Technikerstraße 25, A-6020 Innsbruck, Austria

It was recently shown [quant-ph/0708.2275] how classical spin models, such as the Ising and Potts models on arbitrary graphs, can be mapped onto the stabilizer formalism from quantum information theory. Moreover, by invoking the universality of the one-way quantum computer it was proven how the partition function on an arbitrary graph can be expressed as a special instance of the Ising partition function on a 2D square lattice. However, in order to obtain this result the coupling strengths and local magnetic fields on the 2D square lattice had to be complex, and thus did not allow for a physical interpretation. In this talk, we will first present the completeness of the 2D Ising model with complex parameters and we will then show that a complete model with real parameters is obtained when the 3D Ising model is considered. We will further investigate how generalizations of the 2D Ising model allow us to strengthen the completeness results, and will consider other possible mappings between the partition function and the quantum stabilizer formalism.

Q 41.4 Do 14:45 1B

Three-tangle for mixtures of generalized GHZ and generalized W states — •Christopher Eltschka[1], Andreas Osterloh[2], and Jens Siewert[1] — [1]Institut für theoretische Physik, Universität Regensburg, D-93040 Regensburg, Germany — [2]Institut für theoretische Physik, Leibnitz Universität Hannover, D-30167 Hannover, Germany

The occurrence of entanglement in multipartite systems is one of the most important and distinctive features in quantum theory. While mixed state entanglement of two qubits is already well understood, for three qubits even for the simplest case of rank-2 mixed states, no general solution is known.

We give analytic expressions for the three-tangle and corresponding optimal decompositions for a class of mixed states consisting of a generalized GHZ and an orthogonal generalized W state. We derive a characteristiic structure of the three-tangle function which is independend of the choice of the generalized GHZ and W states to be mixed. Especially we identify the "zero simplex" of *all* states inside the corresponding Bloch sphere with zero three-tangle.

Moreover, as a special case we obtain a general solution for a family of states consisting of a generalized GHZ state and an orthogonal product state. For that case, we provide an analytic solution for all mixed states inside the Bloch sphere defined by those two states.

Q 41.5 Do 15:00 1B

Phase-space Characterization of Multipartite Entanglement — •Agung Budiyono[1], Alejo Salles[1,2], Fernando de Melo[1], Thomas Wellens[1], and Andreas Buchleitner[1] — [1]Physikalisches Institut Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, D-79104, Freiburg, Germany — [2]Instituto de Física, Universidade Federal do Rio de Janeiro,

We consider a sequence of two levels atoms interacting one by one resonantly with a cavity sustaining a single mode, according to the Jaynes-Cummings model. We evaluate the amount of entanglement in the initial atomic state which is needed to prepare certain classes of target field state. Furthermore, we investigate how this entanglement should be shared by the different subsystems in order to optimize the target field state creation. In this way, we explore how the multipartite entanglement of the initial atoms is mapped onto the phase-space of the field in the cavity.

Q 41.6 Do 15:15 1B

Entanglement Quantum Nondemolition Measurement — Bruno de Moura Escher[1], •Fernando de Melo[2], Ruynet L. de Matos Filho[1], Andreas Buchleitner[2], and Luiz Davidovich[1] — [1]Instituto de Física, Universidade Federal do Rio de Janeiro, Caixa Postal 68528, Rio de Janeiro RJ 21941-972, Brazil — [2]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Strasse 3, D-79104 Freiburg, Germany

We present a quantum circuit which allows for the nondemolition measurement of a two-qubit system. The protocol employs two simultaneous copies of the state, in order to give an operational meaning to the entanglement measure, an can thus be applied for all pure states. The complementarity relation between single particle characteristics and bipartite entanglement is scrutinized in the light of the proposed measurement.

Q 41.7 Do 15:30 1B

Decoherence protection for nuclear spin quantum memory in a quantum dot — •Zoltan Kurucz[1], Martin Sørensen[2], and Michael Fleischhauer[1] — [1]Fachbereich Physik, TU Kaiserslautern — [2]Nils-Bohr Institute, Kopenhagen

We reconsider the possibility of storing quantum information in an ensemble of nuclear spins constituting a semiconductor quantum dot [1]. The nuclear magnetic moments are collectively interacting with an excess electron of the quantum dot through inhomogeneous hyperfine coupling. We present a configuration in which the collective nuclear spin states used as the qubit basis are energetically separated from the remaining states, thus protecting the quantum memory from various sources of decoherence.

[1] J. Taylor, C. Marcus, M. Lukin, Phys. Rev. Lett. 90, 206803 (2003)

Q 41.8 Do 15:45 1B

Covariance Matrices as a Tool in Entanglement Theory — •Oleg Gittsovich[1,2], Otfried Gühne[1], Philipp Hyllus[3], and Jens Eisert[4] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, *Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz, 1, 6020 Innsbruck, Austria — [2]Institut für Theoretische Physik,Universität Innsbruck, Technikerstrasse 25, 6020 Innsbruck, Austria — [3]Institut für Theoretische Physik, Universität, Hannover, Appelstrasse 2, 30167 Hannover, Germany — [4]QOLS, Blackett Laboratory, Imperial College London, Prince Consort Road, London SW7 2BW, UK, Institute for Mathematical Sciences, Imperial College London, Prince's Gate, London SW7 2PE, UK

One of the most interesting features of a quantum state from the point of view of the quantum information theory is entanglement. Entangled states are used everywhere in this field and allow to achieve such tasks as teleportation of a quantum state, quantum communication for two or more parties and intensively used in quantum computation and quantum cryptography.

In this talk we will have look at this problem from perspective of view, which uses familiar notions like variances and covariance matrix (CM).

Q 42: Ultrakalte Atome (Manipulation und Detektion / Quantengase)

Zeit: Donnerstag 14:00–16:00 Raum: 1C

Gruppenbericht Q 42.1 Do 14:00 1C
Direct observation of individual atoms in an optical lattice — •Tatjana Gericke, Peter Würtz, Daniel Reitz, Tim Langen, and Herwig Ott — Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz

Ultracold atoms in optical lattices have demonstrated to be an interesting system to study quantum phenomena such as quantum phase transitions and strongly correlated many-body systems. The lattice spacing in such systems ranges from 400 nm to 600 nm. Although many different detection schemes have been developed, a high resolution *in situ* imaging system with single atom sensitivity is still lacking. Our new imaging technique is based on the principles of scanning electron microscopy in combination with electron impact ionization. A 6 keV electron beam with a FWHM of around 200 nm is scanned across the atom cloud and ionizes an atom. The resulting ion is subsequently extracted with the aid of ion optics and detected by a channeltron detector.

We use an all optical BEC approach in a single beam CO_2 optical dipole trap and produce a ^{87}Rb condensate with up to 120000 atoms. The condensate is then loaded into an optical lattice. The optical lattice has a spacing of 604 nm and is formed by two focused laser beams with a wavelength of 854 nm intersecting each other under an angle of 90 degrees. We can observe single lattice sites of the optical lattice with the new imaging technique. The current status of the experiment is presented.

Q 42.2 Do 14:30 1C
State-selective microwave potentials on atom chips — •Max F. Riedel[1,2], Pascal Böhi[1,2], Johannes Hoffrogge[1,2], Theodor W. Hänsch[1,2], and Philipp Treutlein[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München

We report on current results of our experiment with microwave near-fields on an atom chip.

The integrated miniaturized microwave guiding structures on our chip allow the generation of microwave near-fields with unusually strong gradients. Through microwave dressing of hyperfine states, these can be used to create state-selective double-well potentials. Such potentials have applications in quantum information processing, the study of Josephson effects, and could be used to entangle atoms via state-selective collisions.

Q 42.3 Do 14:45 1C
Coupling of Bose-Einstein condensates to mechanical cantilevers on an atomchip — •David Hunger[1,2], Stephan Camerer[1,2], Daniel König[2], Jörg P. Kotthaus[2], Jakob Reichel[3], Theodor W. Hänsch[1,2], and Philipp Treutlein[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Fakultät für Physik, Ludwig-Maximilians-Universität, München — [3]LKB, E.N.S., Paris

We report on the current status of our experiment which aims at coupling a BEC on an atomchip to the motion of mechanical oscillators.

We have considered different coupling schemes to realize an interaction between the two systems. The strongest coupling can be realized by a magnetic interaction, which is mediated by a ferromagnetic island on the tip of a nanomechanical cantilever. In this scenario, the resonator motion causes an oscillating magnetic field that can drive atomic spin-flip transitions. In a first experiment we want to use this to probe the thermal motion of the cantilever with the atoms. [P. Treutlein et al., PRL 99, 140403 (2007)]

In an alternative approach we consider a pure mechanical coupling, mediated by a standing wave dipole trap that is realized by reflecting a red detuned laser on the tip of an AFM cantilever. The motion of the cantilever causes motion of the standing wave, being the trap of a BEC. If the oscillation of the cantilever is resonant with the transition to the first excited motional state of the BEC, the transfer of atoms to the excited state can be used to probe the motion of the cantilever.

Q 42.4 Do 15:00 1C
Bose-Einstein Condensation of Dark-State Polaritons in Atomic Vapour — •Johannes Otterbach, Razmik Unanyan, and Michael Fleischhauer — TU Kaiserslautern, Germany

We propose a mechanism for Bose-Einstein condensation (BEC) of dark-state polaritons in an atomic vapour. Dark-state polaritons (DSPs) are created in the Raman interaction of laser fields with atoms and are the basis of phenomena such as ultra-slow, stopped, and stationary light. In contrast to exciton-polaritons they have a very long intrinsic lifetime on the order of milliseconds. Stationary DSPs created by counter-propagating Raman pump fields have a quadratic dispersion profile with a variable mass tensor. Due to the small effective mass of these quasi-particles, the corresponding condensation temperature can be 4 orders of magnitude higher than that of the atomic vapour. After introduction of stationary light dark-state polaritons we discuss their incoherent generation and thermalization and analyze conditions for their condensation. Finally potential methods for an experimental observation of the Bose-Einstein condensation will be discussed.

Q 42.5 Do 15:15 1C
A Magnetic Ring Trap for Multiply Connected Quantum Gases and Atom Interferometry — Ryan Olf, Edward Marti, Enrico Vogt, •Anton Öttl, and Dan Stamper-Kurn — Department of Physics, University of California, Berkeley, CA 94720

We are currently constructing a novel and improved experimental apparatus to create non-trivial, multiply connected trap geometries for quantum gases and atom interferometry.

For this setup we employ specialized, microfabricated magnetic coils which will generate very smooth and tightly confining trapping fields of torroidal shape. The radius of the magnetic ring trap can be controlled and adjusted over a wide range, from tens of microns to millimeters. We aim to load the ring trap with both rubidium and lithium atoms. This will allow us to explore diverse regimes of matterwave interferometry with fermionic and bosonic atoms of differing interaction strengths and possibly overcome current limitations. A Sagnac-type atom interferometer in a mm-sized ring has the potential to greatly surpass the resolution of existing gyroscopes. However, working with smaller ring radii our goal is to fill the whole ring with degenerate quantum gases and to study the effects of this non-trivial topology on coherence and dynamics of Bose-Einstein condensates.

The ongoing status of the experiment will be presented. We describe the performance of our dual-species oven and Zeeman slower design loading the double MOT and present measurements to demonstrate the quality of our magnetic ring trap.

Q 42.6 Do 15:30 1C
Kollektive Effekte in Ringresonatoren im Quantenregime — •Gordon Krenz, Simone Bux, Sebastian Slama, Philippe Courteille und Claus Zimmermann — Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany

In unserem Experiment untersuchen wir die Wechselwirkung zwischen ultrakalten thermischen und Bose-Einstein-kondensierten Atomen und dem Lichtfeld eines High-Finesse-Resonators. Dabei werden ultrakalte ^{87}Rb-Atome in das Modenvolumen eines einseitig gepumpten Ringresonators geladen. Die Umstreuung von Pumplicht durch die Atome gehorcht einer sichselbstverstärkenden Dynamik, die durch einen Anstieg der Intensität des Lichtfeldes in der nicht gepumpten Richtung zu beobachten ist. Dieses Verhalten ist als CARL-Effekt (Collective Atomic Recoil Lasing) bekannt und von unserer Arbeitsgruppe untersucht worden. Die Impulsverteilung der Atome wird durch den CARL-Effekt beeinflusst, da bei der Umstreuung eines Photons ein Impuls der Größe $p = 2\hbar k$ übertragen wird. Beim CARL-Effekt gibt es verschiedene Regime, die sich unter anderem in der Anzahl bei einer Umstreuung gekoppelter Impulszustände unterscheiden. Unsere bisherigen Experimente beschränkten sich auf das semiklassische Regime, bei dem mehrere Impulszustände miteinander gekoppelt sind, was zu einer breiten Impulsverteilung führt. Ein verbesserter Experimentieraufbau soll uns nun die Untersuchung des Quantenregimes ermöglichen, bei dem ausschließlich benachbarte Impulszustände gekoppelt werden.

Q 42.7 Do 15:45 1C

Landau levels of cold atoms in non-Abelian gauge fields — •Andreas Jacob[1], Patrik Öhberg[2], Gediminas Juzeliunas[3], and Luis Santos[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover — [2]SUPA, Department of Physics, Heriot-Watt University, Edinburgh, UK — [3]Institute of Theoretical Physics and Astronomy of Vilnius University, Lithuania

Recent proposals have shown that by properly designed laser arrangements or lattice setups it is possible to induce artificial gauge fields, which can even be non-Abelian. In this contribution, we will first discuss simple laser setups that allow the creation of non-Abelian gauge fields. Then the Landau levels of cold atomic gases in non-Abelian gauge fields are analyzed. In particular we identify effects on the energy spectrum and density distribution which are purely due to the non-Abelian character of the fields. In a second part, we discuss non-Abelian generalizations of both the Landau and the symmetric gauge, and how these can be generated.

Q 43: Photonik III

Zeit: Donnerstag 14:00–16:00 Raum: 2B/C

Q 43.1 Do 14:00 2B/C

Discreteness in Time — •Christoph Bersch, Georgy Onishchukov, and Ulf Peschel — Institut für Optik, Information und Photonik (Max-Planck Forschungsgruppe), Universität Erlangen-Nürnberg, Günther-Scharowsky-Str. 1 / Bau 24, 91058 Erlangen

In the past nonlinear optics was restricted to homogenous systems. Only recently it was shown that periodically modulated transverse index structures can effectively discretize continuous space, thus allowing for the observation of completely new phenomena of wave propagation and soliton formation. We show that respective concepts can be transferred to the temporal domain. The idea is to launch a periodical amplitude-modulated field, which forms an effective potential for a signal wave propagating at a different wavelength. The advantage of temporal systems is that light can propagate in fibers over tens of kilometers, a span which can again be extended by several orders of magnitude by including optical amplification. In addition, time windows are basically not restricted thus providing almost unlimited space for transverse evolution. Although our main target is to reproduce spatial effects in the temporal domain, the controlled interaction of optical pulses with a temporal lattice could add new degrees of freedom to pulse shaping, regeneration and processing.

Q 43.2 Do 14:15 2B/C

Simulation und Herstellung von Subwellenlängengittern auf Basis von Aluminium und Aluminiumoxid — •Norbert Bergner, Jörg Petschulat, Ernst-Bernhard Kley, Thomas Pertsch und Andreas Tünnermann — Friedrich-Schiller-Universität Jena, Institut für Angewandte Physik (IAP)

Die Lithographie tendiert seit Jahrzehnten dazu immer kleinere Strukturen herzustellen, wobei der Bereich von wenigen Nanometern Strukturbreite noch immer mit erheblichen Schwierigkeiten verbunden ist. Unter Einbeziehung der natürlichen Schichtdicke von Aluminiumoxid wird ein Ansatz verfolgt, der Strukturbreiten von etwa 1,5 bis 3 nm in Gitterstrukturen realisieren kann. Anwendungsbeispiel des Verfahrens sind metallische Nano-Gitter, die propagierende oder lokalisierte Oberflächenplasmonen unterstützen.

Das Ziel der Untersuchung ist die Realisierung eindimensionaler Aluminiumgitter und deren gezielter Oberflächen- und Barrierenoxidation. Dies führt zur Entstehung von plasmonischen Wellenleitern, welche eine MIM (metal insulator metal) Konfigurationen darstellen. Die dabei auftretenden Resonanzen liegen im VIS / NIR. Nahfeldrechnungen mittels FDTD (finite difference time domain) und FMM (fourier modal method) zeigen, dass es sich dabei um Eigenmoden des plasmonischen Wellenleiters handelt.

Dabei wird verstärkt an der experimentellen Umsetzung solcher Geometrien mittels RIE (reactive ionbeam etching) gearbeitet. Dazu ist es nötig, die Gitterparameter mittels verschiedener Messvorrichtungen während des Prozesses zu überprüfen.

Q 43.3 Do 14:30 2B/C

Surface States and Kramers-Kronig Relations in one-dimensional Photonic Crystals — •Michael Bergmair and Kurt Hingerl — CD-Labor für oberflächenoptische Methoden, Institut für Halbleiter- und Festkörperphysik, Universität Linz, Austria

Surface states provide very interesting features such as large field enhancement and are very sensitive to the geometry and dielectric behaviour of the investigated structure. A thin metallic sheet allows to investigate the near field and permits a design of a system with negative refracting behaviour.

A one-dimensional photonic crystal consisting of layers which have a resonant dielectric behaviour in the infrared (photon-phonon coupling) show very interesting surface states: due to the coupling of bulk and surface states around the resonant frequency a dispersion with negative group velocity occurs. In this region the damping remains small yielding a large figure of merit n'/n'' which is the ratio of real and imaginary part of the dielectric function.

In our work we will calculate the dispersion of such coupled surface states and unveil the mechanism that leads to this small damping values. Furthermore we investigate whether and how Kramers-Kronig relations can be applied to systems where the internal structure is on the order of the wavelength.

Q 43.4 Do 14:45 2B/C

Time-domain investigation of backward-wave formation in negative index materials — •Ulrich Dobramysl and Kurt Hingerl — Christian Doppler Labor für Oberflächenoptische Methoden, Institut für Halbleiter- und Festkörperphysik, Johannes Kepler Universität Linz, Austria

We study the properties of negative index structures using the FDTD method by directly investigating the electromagnetic fields at the boundary between air and a region with negative μ and ϵ. The material consists of split ring resonator (SRR) structures[1] with negative permeability. These SRRs are embedded in a material exhibiting a Lorenz resonance and thus negative ϵ. The formation of a backward wave is studied. The FTDT simulation shows that it takes around 20-40 wavefronts until negative refraction is built up. During this initial time positive refraction exists and a damped wave propagates with a positive k-vector into the material.

The effective material parameters are extracted by means of the the Fresnel equations. Using the Fresnel formulas it is possible to extract the effective permeability and permittivity by investigating the wave pattern at an interface without relying on reflection and transmission measurements. The field summation method[2] is used to complement this method.

[1] J. B. Pendry, A. J. Holden, D. J. Robbins, and W. J. Stewart: IEEE Transactions on Microwave Theory and Techniques, 47, 2075 (1999)

[2] D. R. Smith, J. B. Pendry: J. Opt. Soc. Am. B, 23, 391 (2006)

Q 43.5 Do 15:00 2B/C

Räumliche photorefraktive Pikosekunden-Solitonen im Bereich hoher Lichtintensitäten — •Clemens Heese[1,2], Jörg Imbrock[1,2] und Cornelia Denz[1,2] — [1]Institut für Angewandte Physik, Westfälische Wilhelms-Universität, 48149 Münster — [2]Center for Nonlinear Science, 48149 Münster

Räumliche photorefraktive Solitonen sind aufgrund ihrer Möglichkeit,

selbstinduzierte Wellenleiter zu bilden, von großem Interesse. Ein fokussierter Laserstrahl führt in einem photorefraktiven Material zu einer Umverteilung von Ladungsträgern, so dass sich ein internes räumlich moduliertes Raumladungsfeld aufbaut, welches über den elektrooptischen Effekt den Brechungsindex verändert. Bei geeigneter Wahl der experimentellen Parameter kann die Dispersion des Laserstrahls durch die Selbstfokussierung kompensiert werden, so dass sich ein optisch räumliches Soliton bildet.

Die hier vorgestellten Ergebnisse zeigen erstmals, dass sich räumliche Solitonen in SBN (Strontium Barium Niobat) Kristallen mit Hilfe von 1 ps, 532 nm Laserpulsen großer optischer Intensität erzeugen lassen. Dazu wird der Kristall mit einem Hintergrundpuls gleicher Dauer beleuchtet, um die Sättigung der photorefraktiven Nichtlinearität einzustellen. Die zeitliche Verzögerung des Hintergrundpulses gegenüber dem Solitionenpuls hat einen entscheidenden Einfluss auf die Solitonenbildung. Genauere Untersuchungen betrachten das räumliche Intensitätsprofil und die zeitliche Dynamik der Solitonen in Abhängigkeit von den Pulsintensitäten, den Verhältnissen der Pulsintensitäten und der zeitlichen Verzögerungen von Soliton- zu Hintergrundpuls.

Q 43.6 Do 15:15 2B/C

Volumen-Holographie mit ultrakurzen Laserpulsen in photorefraktiven Kristallen — •Christian Nölleke[1,2], Jörg Imbrock[1,2] und Cornelia Denz[1,2] — [1]Institut für Angewandte Physik, Westfälische Wilhelms-Universität, 48149 Münster — [2]Center for Nonlinear Science, 48149 Münster

In photorefraktiven Kristallen lassen sich Volumen-Hologramme speichern, indem das Material mit einem räumlich modulierten Intensitätsmuster beleuchtet wird, welches dann in eine Brechungsindexänderung umgesetzt wird.

In den hier präsentierten Experimenten wird gezeigt, wie sich Hologramme mit Piko-Sekunden Pulsen in $LiNbO_3$ Kristallen speichern lassen, indem die Pulse interferometrisch räumlich und zeitlich innerhalb des Kristalls überlagert werden. Der Beugungswirkungsgrad der Hologramme wird in Abhängigkeit von der Intensität und Polarisation der Pulse bestimmt. Das Speichern der Hologramme kann entweder mit sichtbarem Licht oder mit infrarotem Licht bei gleichzeitiger Sensibilisierung der Kristalle mit blauen Licht ($\lambda = 400\,\mathrm{nm}$) durchgeführt werden. Dieses so genannte Zwei-Farben-Schreiben bietet den Vorteil, dass die Hologramme anschließend mit infrarotem Licht zerstörungsfrei ausgelesen werden können. Verantwortlich für diesen Prozess sind Polaronen, die durch das blaue Licht erzeugt werden. Die optimale Schreibwellenlänge für das Zwei-Farben-Schreiben kann experimentell zum ersten Mal bestimmt werden.

Q 43.7 Do 15:30 2B/C

High-Q whispering gallery mode resonators made of lithium niobate crystals* — •Judith R. Schwesyg, Anne S. Zimmermann, Daniel Haertle, and Karsten Buse — Physikalisches Institut, Universität Bonn, Wegelerstr. 8, 53115 Bonn

Toroidally-shaped whispering-gallery-mode resonators made of amorphous or crystal materials are very promising for confining and trapping of light. The optical quality factor and the finesse reach very high values. Special fabrication techniques now enable to build such resonators from almost every material of interest. One useful crystalline material is lithium niobate which is widely used in integrated and guided-wave optics because of its favorable optical, piezoelectric, electrooptic, and photorefractive properties. In this talk we present the fabrication process of such resonators. Quality factors exceeding 10^7 and finesses higher than 400 are achieved. Mode spectra enable to determine absorption values of the material as small as $5 \times 10^{-3}\mathrm{cm}^{-1}$. In a next step the resonators can be used as sensors maybe detecting single atoms.

*Financial support of the Deutsche Forschungsgemeinschaft (FOR557) and the Deutsche Telekom Stiftung is gratefully acknowledged.

Q 43.8 Do 15:45 2B/C

Polarization Singularities from unfolding an Optical Vortex through a Birefrigent Crystal — •Ulrich Schwarz and Florian Flossmann — Institute for Experimental and Applied Physics, University of Regensburg, D-93040 Regensburg, Germany

An optical vortex incident on a birefringent crystal unfolds into a complex topological structure of lines of circular polarization (C lines) and surfaces of linear polarization (L surfaces) [F. Flossmann, U. T. Schwarz, Max Maier, and M. R. Dennis, Phys. Rev. Letters 95, 253901 (2005)]. The incident beam splits into two orthogonally polarized beams of ordinary and extraordinary polarization. Extraordinary refraction causes a shift of the extraordinarily polarized beam even under normal incidence. This shift together with the different phase velocities of both beams is the origin of an intriguing pattern of polarization singularities. We measure spatially resolved the full set of Stokes parameters after the beam passed the crystal to determine experimentally the spatial structure of the polarization singularities in three dimensions, two spatial directions (x, y) and one (L) corresponding to relative the phase retardation between ordinary and extraordinary beam. The observed unfolding of the initial phase singularity is the most generic case of the generation of polarization singularities in uniaxial or biaxial birefringent crystals. It can be describe in a very general way in terms of Stokes parameters where the polarization singularities arise naturally from the zeroes of the Stokes parameters [F. Flossmann, U. T. Schwarz, Max Maier, and M. R. Dennis, Optics Express 14, 11402 (2006)].

Q 44: Quanteneffekte (Interferenz / Sonstige)

Zeit: Donnerstag 14:00–16:15 Raum: 2D

Q 44.1 Do 14:00 2D

Vacuum-induced couplings of dipole moments in a pair of atoms — •Sandra Isabelle Schmid and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland

In single atom systems, vacuum-coupling of different transition dipole moments can induce spontaneously generated coherences which give rise to a multitude of interesting effects. These couplings, however, only act between non-orthogonal dipole moments and thus rarely occur in real atoms. But in [1], they were demonstrated in a realistic four-level system in J=1/2 to J=1/2 configuration.

Two nearby atoms can dipole-dipole interact by exchanging virtual photons via the vacuum. This dipole-dipole interaction can also couple transitions with orthogonal dipole moments, which crucially influences the system dynamics [2,3]. Even when averaging over different geometrical setups the effects resulting from these couplings do not vanish [4].

Here, we investigate a system consisting of a pair of atoms in J=1/2 to J=1/2 configuration where both types of couplings occur. In particular, we are interested in the interplay of the two vacuum-mediated interactions. As observables, we discuss the influence of the different couplings on the resonance fluorescence intensity and the spectrum.

[1] M. Kiffner, J. Evers, and C. H. Keitel, Phys. Rev. Lett. **96**, 100403 (2006)
[2] G. S. Agarwal and A. K. Patnaik, Phys. Rev. A **63**, 043805 (2001)
[3] J. Evers, M. Kiffner, M. Macovei, and C. H. Keitel, Phys. Rev. A **73**, 023804 (2006)
[4] S. I. Schmid and J. Evers, arXiv:0709.2103 (2007)

Q 44.2 Do 14:15 2D

Phase space sub-Planck structures: experimental realization in time-frequency domain — •Ludmila Praxmeyer[1], Piotr Wasylczyk[2], Czeslaw Radzewicz[2], and Krzysztof Wodkiewicz[2] — [1]Optical Quantum Information Theory Group, Max Planck Research Group, Institute of Optics, Information and Photonics, 91058 Erlangen, Germany — [2]Faculty of Physics, Warsaw University, Poland

It was shown by Zurek [1] that sub-Planck structures in phase space play a surprisingly important role in the distinguishability of quantum states. A sub-Planck phase space shift applied to a superposition of coherent states is sufficient to produce a state which is orthogonal to the unshifted one! The effect was originally studied for a superposition of four coherent states [1], then it was shown that superpositions of just two coherent states lead to a similar result [2]. We present experimental data of the frequency resolved optical gating (FROG) measurements of light pulses revealing interference features which correspond to sub-Planck structures in phase space [3]. For superpositions of pulses a small, sub-Fourier shift in the carrier frequency leads to a state orthogonal to the initial one, although in the representation of standard time-frequency distributions these states seem to have a non-vanishing overlap.

[1] W. Zurek, Nature 412, 712 (2001).
[2] L. Praxmeyer, K. Wodkiewicz, Laser Phys. Vol.15, No.10, 1477 (2005); L. Praxmeyer, PhD thesis (2005).
[3] L. Praxmeyer, P. Wasylczyk, Cz. Radzewicz, K. Wodkiewicz, Phys. Rev. Lett. 98, 063901 (2007).

Q 44.3 Do 14:30 2D

Interference of resonance fluorescence from two distant atoms
— •Felix Rohde, Carsten Schuck, Marc Almendros, Roger Gehr, Francois Dubin, Markus Hennrich, and Jürgen Eschner — ICFO - Institut de Ciencies Fotoniques, Castelldefels (Barcelona), Spain

We trap two single calcium ions simultaneously in two independent ion traps at a distance of about 1 m. The ions are continuously excited using lasers at 397 nm and 866 nm that are frequency-stabilised by a transfer locking scheme to an atomic reference line in cesium. The continuous resonance fluorescence from the two ions is coherently superimposed and recorded with photomultipliers in photon counting mode. We present results on classical and quantum interference in the detected light. Such interference will be used for entangling the two ions by conditional state preparation.

Q 44.4 Do 14:45 2D

Microwave driven Rydberg atoms: from strong localization to single-photon ionization
— •Alexej Schelle[1,2], Andreas Buchleitner[2], and Dominique Delande[1] — [1]Laboratoire Kastler Brossel, 4, place Jussieu, F-75252 Paris, cedex 05 — [2]Institute of Physics, Department for Quantum Optics and Statistics, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

We study the atomic counterpart of Anderson localization in atomic driven Rydberg systems. By switching the initial Rydberg state from lower bound states, where destructive quantum interference suppresses the classically predicted ionization threshold, up to the single-photon absorption limit, we observe a transition in the scaling behavior of the ionization threshold field. Unlike in the strong localization regime, where the scaled ionization threshold shows a smooth and universal behavior for hydrogen and lithium atoms, strong oscillations in the few-photon absorption limit indicate the breakdown of the Anderson localization scenario.

Q 44.5 Do 15:00 2D

Quantum Phase Transitions with Polaritons and Photons
— •Michael Hartmann[1,2] and Martin Plenio[1,2] — [1]Institute for Mathematical Sciences, Imperial College London, 53 Exhibition Road, London, SW7 2PG, United Kingdom — [2]QOLS, The Blackett Laboratory, Imperial College London, Prince Consort Road, London, SW7 2BW, United Kingdom

Artificial many-body systems that permit good experimental access and control have become an important tool for the study of quantum phase transitions in the laboratory.

Here we show that arrays of coupled high-Q cavities doped with atoms can be employed to study quantum phase transitions with polaritons and photons. In particular, photons can be driven into a Mott insulator state which corresponds to light in a "crystalized" form.

An important advantage of our approach is that it allows to access and control individual lattice sites.

Q 44.6 Do 15:15 2D

Thermal equilibrium of coupled atom-light states in an ultrahigh pressure buffer gas cell
— •Ulrich Vogl, Johannes Nipper, and Martin Weitz — Institut für Angewandte Physik, Wegelerstraße 8, 53115 Bonn

Thermal equilibrium is a prerequisite for most known phase transitions, as Bose-Einstein condensation of dilute atomic gases or many solid state physics concepts. Recently, phase transitions of coupled particle-light degrees of freedom have been investigated in the framework of polariton quasiparticle condensation, and exciton polariton systems gave compelling evidence for a condensation. However, the short polariton lifetimes of around a ps arose questions whether the system is fully thermalized. We investigate the statistical distribution of coupled atom-light excitations in an atomic rubidium gas cell subject to 500 bar buffer gas pressure. The large collisional broadening of this system interpolates between usual atomic physics gas phase and solid/liquid phase conditions. An observed intensity-dependent blue asymmetry of spectra is interpreted as evidence for the approaching of thermal equilibrium of dressed atom-light states.

Q 44.7 Do 15:30 2D

Cooling of a nanomechanical resonator integrated into a superconducting box qubit
— •Konstanze Jähne[1,2] and Margareta Wallquist[1,2] — [1]Institute for Theoretical Physics, University of Innsbruck, Innsbruck, Austria — [2]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, Innsbruck, Austria

We consider the following system: a nanomechanical resonator that is integrated into a superconducting loop of a current-biased superconducting qubit, in particular a Cooper pair box. One can apply a magnetic field to the nanoresonator, which together with the current flowing through it creates a Lorentz force, which gives rise to a switchable coupling between nanoresonator and qubit. Using methods of theoretical quantum optics, we show that it is possible to cool the nanoresonator, if one drives the qubit around its optimal working point with a drive frequency that is red detuned with respect to the qubit transition. Furthermore we investigate under which conditions the nanoresonator can be cooled to its quantum mechanical ground state.

Q 44.8 Do 15:45 2D

Inverse Scattering in Application to the Riemann Problem
— •Rüdiger Mack and Wolfgang P. Schleich — Institut für Quantenphysik, Universität Ulm, 89073 Ulm

We present a method to get the values of the Riemann Zeta-function by autocorrelation measure. Therefore we need a potential with specific energy eigenvalues. We calculate this potential with a variety of techniques, either numerical by the Numerov mehtod and analytically, with a JBKW approximation.

Q 44.9 Do 16:00 2D

Resonant Interferometric Lithography beyond the Diffraction Limit
— •Jörg Evers[1], Martin Kiffner[1], and M. Suhail Zubairy[1,2] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Institute for Quantum Studies and Department of Physics, Texas A&M University, USA, and Texas A&M University at Qatar

A fundamental limit to the spatial resolution of the interferometric lithography with classical uncorrelated light arises due to diffraction. To overcome this limit, several schemes have been proposed to improve the spatial resolution of interferometric lithography beyond the diffraction limit. These schemes are based on an N-photon absorption process and achieve a spatial resolution of $\lambda/(2N)$, where λ is the wavelength of the light. The indispensable requirement of a multiphoton transition, however, is accompanied by the need for high light field intensities which makes an experimental realization of these schemes impractical.

Here, we present a novel approach for the generation of subwavelength structures in interferometric optical lithography which only comprises resonant atom-field interactions, such that no multiphoton absorber is required [1]. Our scheme relies on the preparation of the system in a position dependent trapping state via phase shifted standing wave patterns. The contrast of the induced pattern does only depend on the ratios of the applied field strengths such that our method in principle works at arbitrarily low laser intensities.

[1] M. Kiffner, J. Evers, and M. S. Zubairy, submitted

Q 45: Materiewellenoptik

Zeit: Donnerstag 14:00–15:45 Raum: 3G

Q 45.1 Do 14:00 3G

Matter wave interferometry on potassium molecules — •Sha Liu, Ivan Sherstov, Horst Knöckel, Christian Lisdat, and Eberhard Tiemann — Institut für Qantenoptik, Gottfried Wilhelm Leibniz Universität Hannover, 30167 Hannover, Deutschland

We operate a matter wave interferometer on 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, give complementary detection schemes for the interference signal. Under certain geometric conditions, observed interference signal is composed of two interference patterns, the Ramsey interference formed by two laser beam splitters, the Ramsey-Bordé interference pattern with four laser beam splitters. These two interference patterns can be separated in frequency domain. For a better understanding, we observe Ramsey fringe alone directly and analyze the contrast dependence on the transversal velocity distribution. The Ramsey-Bordé interferometer will be used in further applications, thanks to its higher phase stability compared to the Ramsey interference. By introducing a near resonant laser field to the molecules in either the excited state or the ground state between the beam splitters, the transition matrix element can be determined. Furthermore, by changing the collision characteristics of the K atoms in the K_2 molecular beam, the collision between potassium atoms and molecules can be investigated. The density of K atoms is varied by deflecting atoms through resonant laser field out of the molecular beam. The actual status of the experiment will be presented.

Q 45.2 Do 14:15 3G

Diffraction of helium atom beams from a micro-structured reflection grating — •Bum Suk Zhao[1], Stephan Schulz[2], Gerard Meijer[1], and Wieland Schöllkopf[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany — [2]Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, 89069 Ulm, Germany

We have observed high-resolution diffraction patterns of a thermal-energy helium-atom beam reflected from a micro-structured surface grating at grazing incidence. The grating has a periodicity of 20 μm and consists of 10-μm-wide Cr stripes patterned on a quartz substrate. Fully-resolved diffraction peaks up to the 7-th order are observed at grazing incidence angles up to 20 mrad. With changes in de Broglie wavelength or incidence angle the relative diffraction intensities show significant variations which are attributed to the atom-surface Casimir-van der Waals potential. In addition, the overall probability of coherent reflection is found to increase with increasing de Broglie wavelength and decreasing incidence angle. We discuss whether this behavior indicates quantum reflection at the long-range attractive branch of the atom-surface potential.

Q 45.3 Do 14:30 3G

Matter wave Talbot-Lau interferometry beyond the eikonal approximation — •Stefan Nimmrichter[1,2] and Klaus Hornberger[1] — [1]Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians-Universität München — [2]Physikalisches Institut, Universität Wien

We present a generalized phase-space description of matter wave Talbot-Lau interference experiments allowing to incorporate arbitrary grating interactions and realistic beam characteristics. These setups are being used to demonstrate the wave nature of complex molecules [1,2]. Typically they consist of three gratings and operate in the near field regime where the different diffraction orders interfere among each other. Unlike in far field diffraction, the interaction between the interfering particle and the grating crucially affects the interference contrast. The eikonal approximation used so far is expected to cease to be valid in upcoming experiments with more massive particles. Our theoretical model admits a general description of the grating interaction process using scattering theory. Based on this, we develop a semiclassical correction to the eikonal approximation.

[1] L. Hackermüller et al, Phys. Rev. Lett. 91, 090408 (2003)
[2] S. Gerlich et al, Nature Physics 3, 711 (2007)

Q 45.4 Do 14:45 3G

Bell test for the motional state of free massive particles — •Clemens Gneiting and Klaus Hornberger — Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians-Universität München

We propose a simple and robust way of generating and verifiying entanglement in the motional state of two free, macroscopically separated atoms. It is based on the concept of 'dissociation-time entanglement', allowing to formulate a special type of continuous variable entanglement in a two-dimensional state-space in analogy with the entangled spin-singlet state. We describe an interferometric setting, based only on linear elements of matter-wave optics, which reflects the general spin measurements required in the original spin-based Bell experiment. It thus allows to verify the entanglement by the violation of a Bell inequality using only single-particle interference without post-selection. The dissociation-time entangled state can be generated by the Feshbach-induced dissociation of a molecular BEC. In particular, the shape of the magnetic pulse can be used to taylor the generated wave packets as to minimize the effect of dispersion.

Q 45.5 Do 15:00 3G

Decoherence in atom interferometry — •Scott Sanders[1,2,3], Florian Mintert[2,3], and Eric Heller[2] — [1]Massachusetts Institute of Technology, Cambridge, MA, United States — [2]Harvard University, Cambridge, MA, United States — [3]Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

We consider decoherence of an atom due to scattering from a free gas. Our analysis explains why a free gas can serve as a refractive medium that gives rise to a phase shift in atom interferometry, without acquiring which way information on the interfering particles.

Q 45.6 Do 15:15 3G

The relevance of internal states in molecular de Broglie interferometry — •Michael Gring[1], Stefan Gerlich[1], Lucia Hackermüller[1,4], Klaus Hornberger[2], Hendrik Ulbricht[1], Marcel Müri[3], Jens Tüxen[3], Marcel Mayor[3], and Markus Arndt[1] — [1]Faculty of Physics, University of Vienna, Boltzmanngasse 5, A-1090 Wien, Austria — [2]Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians-Universität München, Theresienstrasse 37, 80333 München, Germany — [3]University of Basel, Department of Chemistry, St Johannsring 19, CH-4056 Basel, Switzerland — [4]Present address: Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55099 Mainz, Germany

We present recent matter wave interferometry results with perfluoroalkyl-functionalized azobenzene molecules. These long molecular chains are interesting for future decoherence and metrology experiments since they can be optically switched between two different conformers. We discuss the question under which conditions one can identify different molecular conformations using the Kapitza-Dirac-Talbot-Lau interference scheme that was recently developed in our group. We further examine the influence of state-dependent molecular properties such as the polarizability or dipole moment on the interference pattern and the experimental modifications required to reveal these properties also in various other molecular systems.

Q 45.7 Do 15:30 3G

Towards quantum optics with biomolecular clusters — •Philipp Haslinger, Markus Marksteiner, Hendrik Ulbricht, and Markus Arndt — Faculty of Physics, University of Vienna, Austria

We present recent progress towards matter wave experiments with large biomolecular clusters. All successful experiments on macromolecule interferometry so far, with fullerenes [Nature1999], fullerene derivates [PRL2003] and large perfluoroalkyl-functionalized azobenzenes [Nature2007] used effusive beam sources. In order to prepare experiments with molecules of biological interest, we have implemented a pulsed laser desorption source. The combination of UV laser desorption into an intense noble gas jet and single-photon ionization by a VUV excimer laser (157nm) allows us to observe intense neutral jets of amino acids, nucleotides and polypeptides. We recently discovered a new method for producing large and neutral amino acid-metal complexes, such as for instance Ca@Trp2...Ca@Trp30, with masses exceeding 6000 amu. The addition of alkaline Earth salts in the desorption process leads to the inclusion of at least one metal atom per complex and is sufficient to catalyze the cluster formation process. We discuss how interferometric deflectometry might help in obtaining additional information about the structure of such large molecular compounds.

Q 46: Ultrakurze Laserpulse (Erzeugung II / Anwendungen I)

Zeit: Donnerstag 14:00–16:15 Raum: 3H

Q 46.1 Do 14:00 3H

Passiv modengekoppelter Thulium-dotierter Faserlaser mit 3,45 nJ Pulsenergie — •Frithjof Haxsen, Martin Engelbrecht, Dieter Wandt und Dietmar Kracht — Laserzentrum Hannover e.V., Hollerithallee 8, 30419 Hannover

Es wird ein Thulium-dotierter modengekoppelter Faserlaser mit interner Dispersionskompensation vorgestellt. Das vorliegende System wurde in Ringresonatorkonfiguration aufgebaut, bei dem eine bei 793 nm gepumpte Thulium-dotierte Doppelkernfaser als Verstärkungsmedium eingesetzt wurde. Die durch nichtlineare Polarisationsdrehung generierten Pulse hatten eine Zentralwellenlänge von 1985 nm mit 17 nm Halbwertsbreite und eine Pulsenergie von 3,45 nJ bei einer Repetitionsrate von 41,4 MHz. Aufgrund der negativen Dispersion der Faserstrecke bei der Emissionswellenlänge wurde zu deren Kompensation ein Gitteraufbau verwendet, bei dem durch eine 4-f-Abbildung positive Dispersion realisiert wurde. Die erzeugten Pulse wiesen einen deutlichen Chirp auf. Die Pulsdauer betrug 1,26 ps und konnte extern auf 320 fs komprimiert werden. Sie lag damit 12 % über dem Bandbreitenlimit. Nach unserem Wissen ist dies die höchste Pulsenergie aus einem modengekoppelten Faseroszillator bei 2 μm Wellenlänge.

Q 46.2 Do 14:15 3H

Erbium-Faserlaser im positiven Dispersionsbereich mit Pulsenergien über 10 nJ — •Vincent Kuhn, Axel Rühl, Dieter Wandt und Dietmar Kracht — Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover

Das Ziel dieser Arbeit war die Übertragung der von Ytterbium-Faserlasern bekannten selbstähnlichen Pulsformung* – und deren Potential zur Pulsenergieskalierung – auf Erbium-Faseroszillatoren. Der dazu entwickelte Laser wurde ohne resonatorinterne Dispersionskontrolle aufgebaut und selbststartende Modenkopplung über nichtlineare Polarisationsdrehung realisiert. Die erzielten Pulsenergien lagen über 10 nJ und sind somit die, nach unserem Wissen, höchsten Pulsenergien die direkt aus einem Erbium-Faseroszillator gewonnen wurden. Die stark gechirpten Pulse ($C > 50$) konnten resonatorextern auf Pulsdauern unter 75 fs komprimiert werden. Die erreichten Spitzenleistungen lagen somit oberhalb von 135 kW.

Ein deutlicher Unterschied zwischen Yb und Er dotierten Faserlasern ist die wesentlich geringere maximale Dotierungskonzentration im Fall von Erbium. Dies erfordert den Einsatz einer deutlich längeren Verstärkerfaser und verhindert die Möglichkeit einer Entkopplung von Verstärkung und Pulsformung. Zudem spielt auch Intrapuls-Raman-Streuung eine beträchtliche Rolle in der Strukturgebung der Pulse. Dies führt zu einer Pulsformung deren Analogien und Unterschiede zur selbstähnlichen Pulsevolution in diesem Beitrag diskutiert werden.

* Ilday et al., Phys. Rev. Lett. **92**, 213902 (2004)

Q 46.3 Do 14:30 3H

Front-end of Petawatt Field Synthesizer (PFS) — •Izhar Ahmad, Antonia Popp, Sergei Trushin, Tie-jun Wang, Zsuzsanna Major, and Stefan Karsch — Max-Planck Institue for Quantum Optics, Garching, Germany

We are pursuing the development of a novel few-cycle ~5fs, phase stabilized light source with a peak power ranging from 0.5 to 1.0 Petawatt. It is based on an ultrabroadband Optical-Parametric-Chirped-Pulse Amplification (OPCPA) technique, synchronously pumped with a high-repetition rate (10Hz) diode pumped Yb:YAG laser operating at ~10 ps pulse duration as a driver.

The progress in the development of front end for this novel source will be presented. It involves seed generation for the pump source for optical synchronization based on soliton self stimulated emission in photonic crystal fibers, pulse compression of Ti:Sapphire amplifier using hybrid pulse compression technique and advancement towards ultrabroad band seed generation for OPCPA.

Q 46.4 Do 14:45 3H

Filamentation in air - poor man's sub 7 fs setup — •Bruno Schmidt, Waldemar Unrau, Adlo Mirabal, Ludger Wöste, and Torsten Siebert — Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

An optical setup for generation and measurement of few cycle pulses is presented. It comprises spectral broadening via single filamentation in air, standard chirp mirrors for dispersion compensation and a transient grating FROG as characterization. This cheep and robust arrangement enables measuring of pulses as short as 6.4 fs and FROG traces with bandwidths reaching from (370-950) nm for uncompressed supercontinuum.

Q 46.5 Do 15:00 3H

Octave wide tunable UV-pumped NOPA: pulse durations down to 20 fs and repetition rates up to 2 MHz — •Christian Homann, Christian Schriever, Peter Baum, and Eberhard Riedle — Lehrstuhl für BioMolekulare Optik, LMU München

For ultrafast spectroscopy, femtosecond laser pulses with wide tunability and high repetition rates are needed. Recently, amplified Yb-doped fiber systems became commercially available, delivering 10 μJ pulses at 1035 nm and 2 MHz repetition rate. We demonstrate frequency conversion with a noncollinear optical parametric amplifier (NOPA), which is pumped by the frequency tripled (345 nm) output of the fiber-amplifier system and is seeded by a smooth continuum generated in bulk sapphire. The 3ω light is generated with 15% conversion efficiency in a novel and extremely simple setup consisting of two BBO crystals only. The NOPA is tunable between 460 and 990 nm, thus spanning over one octave. The output pulses show smooth Gaussian shaped spectra and pedestal-free autocorrelation traces. Nearly Fourier-limited pulse durations down to 19.8 fs are achieved. The remaining green 2ω light from the frequency tripling setup is used to pump an additional, independently tunable NOPA with a tuning range of 600-970 nm. Together, the two NOPAs provide powerful sources for tunable two-color pump-probe spectroscopy. Interference experiments show that the two NOPA systems have a precisely locked relative phase, despite of being pumped by different harmonics with differing phase fluctuations. This directly proves that parametric amplification preserves the phase of the seed light.

Q 46.6 Do 15:15 3H

Optimierte Wavelet-basierte Algorithmen zur Phasenrekonstruktion ultrakurzer Lichtimpulse — •Jens Bethge und Günter Steinmeyer — Max-Born-Institut, Max-Born-Straße 2a, D-12489 Berlin

Die Rekonstruktion der spektralen Phase von ultrakurzen Lichtimpulsen ist der Schlüssel zu ihrer Charakterisierung. Bei einer SPIDER-Messung [1] muss dazu die Periode eines Fringemusters in einem Interferogramm ausgewertet werden. Es wurde gezeigt, dass neben dem üblichen Takeda-Algorithmus [2] auch Wavelet-basierte Algorithmen benutzt werden können, ohne dass auf eine hohe Aktualisierungsrate verzichtet werden muss [3]. Dabei wird eine Gabor-Wavelet Transformation verwendet nach deren Anwendung sich eine sehr genaue Frequenzanalyse direkt durchführen lässt. Wir haben die vorgeschlagene Methode optimiert. Sowohl in numerischen Versuchen als auch bei der Anwendung auf experimentelle Daten konnte dabei die höhere Zuverlässigkeit und Genauigkeit, besonders bei schlechtem Signal-zu-Rausch-Verhältnis, nachgewiesen werden.

[1] C. Iaconis and I.A. Walmsley, Opt. Lett. **23**, 792 (1998).
[2] M. Takeda *et al.*, J. Opt. Soc. Am. A **72**, 156 (1982).
[3] J. Bethge *et al.*, Opt. Express **15**, 14313 (2007).

Q 46.7 Do 15:30 3H

Ein linear optisches Verfahren zur Mesung der Carrier-Envelope Phase modengekoppelter Laser — •Christian Grebing[1], Karoly Osvay[1], Mihaly Görbe[2] und Günter Steinmeyer[1] — [1]Max-Born-Institut, Max-Born-Straße 2a, D-12489 Berlin — [2]Department of Optics and Quantum Electronics, University of Szeged, P.O.Box 406, H-6701, Szeged

Das f-$2f$ Interferometer hat sich als Standard zur Messung der Carrier-Envelope Phasenänderung (CEP) von aufeinanderfolgenden Laserpulsen etabliert. Es beruht auf einem nichtlinearen Interferometer in dem die Fundamentale und die Frequenzverdoppelte des Pulsspektrums überlagert werden. Dieses Verfahren erfordert oktavbreite Pulse hoher Spitzenleistung und ist somit nicht für beliebige modengekoppelte Laser anwendbar. Wir schlagen eine neue lineare interferometrische Methode vor, die es erlaubt, die CEP eines Pulszuges über die Sichtbarkeit des Fringe-Musters in einem Mach-Zehnder Interferometer zu messen, in dessen einen Arm ein zusätzlicher Ringresonator eingefügt wurde. Die daraus resultierende Überlagerung aufeinanderfolgender Pulse mit unterschiedlicher CEP beeinflußt die Interferenz im Mach-Zehnder Interferometer und erzeugt eine Modulation des Interferenzkontrasts in Abhängigkeit von der CEP, was wir sowohl durch Messungen an einem Ti:Saphir-Laser als auch durch numerische Simulationen bestätigen konnten [1]. Da kein nichtlinearer Konversionsschritt erforderlich ist, erlaubt diese Methode auch CEP-Messungen für schmalbandige modengekoppelte Laser und solche mit geringer Laserleistung.

[1] K. Osvay *et al.*, Opt. Lett. **32**, 3095-3097 (2007).

Q 46.8 Do 15:45 3H

Selbstreferenzierendes f-$2f$ Interferometer zur Phasenstabilisierung von Femtosekundenlasern — •Sebastian Koke, Christian Grebing, Bastian Manschwetus und Günter Steinmeyer — Max-Born-Institut, Max-Born-Straße 2a, D-12489 Berlin

Die Stabilisierung der sogenannten Carrier-Envelope Phase (CEP), d.h. der Phase zwischen dem Träger und der Einhüllenden eines ultrakurzen Laserpulses, ist eine wichtige Voraussetzung zur Erzeugung isolierter Attosekundenpulse sowie für die Untersuchung der CEP-Abhängigkeit verschiedenster Ionisierungsvorgänge. Für die Stabilisierung der CEP wird routinemäßig ein f-$2f$ Interferometer verwendet, bei dem man die Struktur des Modenkamms ausnutzt, um die Wiederholfrequenz gleicher CEP-Werte zu extrahieren [1]. Da jegliche Drifts und Störungen in den beiden Armen des Interferometers die Qualität der Stabilisierung verschlechtern, ist man bemüht, diese durch passive Stabiliserungsmaßnahmen zu reduzieren. Kürzlich ist es mittels einer aktiven Stabilisierung der optischen Weglänge in beiden Interferometerarmen gelungen, das Restrauschen der Phasenstabiliserung eines Lasersystems deutlich zu verringern [2]. In diesem Beitrag demonstrieren wir, dass schon durch die Wahl einer geeigneten Geometrie, in der beide Interferometerarme nahezu zusammenfallen, eine vergleichbare Reduktion des Restrauschens ohne aufwendige aktive Stabilisierung der optischen Weglänge erreicht werden kann.

[1] H. Telle *et al.*, Appl. Phys. B **69**, 327-332 (1999).
[2] E. Moon *et al.*, Opt. Express **14**, 9758-9763 (2006).

Q 46.9 Do 16:00 3H

High Harmonics Generation (HHG) from water droplets. — •Jan Henneberger, Nico Franke, Sebastian Jung, Christian Ott, and Christian Spielmann — Physikalisches Institut, Universität Würzburg, Am Hubland, 97074 Würzburg

We experimentally study the interaction of ultrashort intense laser radiation with water microdroplets. In order to do this we build up a droplet source in a vacuum chamber, which allows us to produce liquid droplets with 30 μm diameter. We observe the HHG spectrum generated by a two pulse scheme.

The HHG from molecules can be used to see fast nuclear dynamics in molecules. We exploit that the harmonic spectrum is temporally chirped. As a result each harmonic order is emitted at a different time and therefore it is possible to map frequency to a recollision time. In particular, by comparing the spectrum of two isotopes, information about the vibration dynamics can be obtained. We compare the high harmonic spectrum from H_2O and D_2O. First measurements of the spectrum of this isotopes will be presented.

Q 47: Quantengase (Bosonen II / Fermionen)

Zeit: Donnerstag 16:30–18:45 Raum: 1A

Q 47.1 Do 16:30 1A

Mean-field description of a decaying BEC — •Astrid Niederle, Eva-Maria Greafe, Hans Jürgen Korsch, Friederike Trimborn, and Dirk Witthaut — TU Kaiserslautern, Germany

A quantum system with decay can be effectively described by a non-Hermitian Hamiltonian with complex energy eigenvalues, whose imaginary parts describe the decay rate. In this talk we focus on a non-Hermitian, two-mode Bose-Hubbard Hamiltonian, which serves as a model for a Bose-Einstein-condensate in a double-well potential with decay from one of the two wells. We discuss the dynamics of operators, which is governed by a generalized Heisenberg-equation. Taking expectation values of the operators, we obtain a mean-field approximation. The resulting dynamics described by a generalized nonlinear Bloch equation is mainly influenced by the (up to four) fixed points, which can be repulsive or attractive depending on the system parameters. The mean-field dynamics is compared with the full N-particle quantum evolution.

Q 47.2 Do 16:45 1A

Single atom detection on a magnetic microchip — •Helmar Bender[1], Andreas Günther[1], Alexander Stibor[1], Sebastian Kraft[2], József Fortágh[1], and Claus Zimmermann[1] — [1]Physikalisches Institut der Universität Tübingen, Auf der Morgenstelle 14, D-72076 — [2]van der Waals-Zeeman Instituut, Universiteit van Amsterdam, Valckenierstraat 65, 1018 XE Amsterdam, The Netherlands

The possibility to detect small amounts of atoms on a magnetic microchip opens the door to a variety of interesting fundamental experiments in the field of ultracold quantum gases. Standard absorption imaging requires a minimum number of several hundred atoms. Thus novel detection methods with single atom sensitivity are currently developed. Here, we present a single atom detector which is implemented in our magnetic microchip setup. The detection scheme is based on optical ionization of single atoms and subsequent counting of the ions in a channeltron. We discuss the characterization of the detector as well as our latest experimental data with ultracold atoms on a magnetic microchip.

Q 47.3 Do 17:00 1A

Dropping Bose-Einstein condensates over long times and large distances — •Endre Kajari, Stefan Arnold, Michael Eckart, Reinhold Walser, and Wolfgang P. Schleich for the QUANTUS-Collaboration — Institute of Quantum Physics, Universität Ulm, D-89069 Ulm

Ultracold quantum gases have the potential to extend the limits of matter-wave interferometry beyond current precision standards. In particular, the QUANTUS project [1] aims for the creation of a Bose-Einstein condensate at the drop tower facility at the "Center of Applied Space Technology and Microgravity" (ZARM) in Bremen. Such an experiment permits an unperturbed free fall of a condensate for up to 10 s. In this talk we present our theoretical contributions [2] and provide three-dimensional numerical simulations of the time dependent Gross-Pitaevskii equation, including explicit time dependent trapping frequencies. Our results are compared with the scaling approach given in [3,4].

[1] A. Vogel et al., Appl. Phys. B **84**, 664 (2006).
[2] G. Nandi et al., Phys. Rev. A (to be published 2007).
[3] Yu. Kagan et al., Phys. Rev. A. **54**, R1753 (1996).
[4] Y. Castin and R. Dum, Phys. Rev. Lett. **77**, 5315 (1996).

Q 47.4 Do 17:15 1A

Environment-induced dynamics in Bose-Einstein condensates — •Alexej Schelle[1,2], Andreas Buchleitner[2], Benoît Grémaud[1], and Dominique Delande[1] — [1]Laboratoire Kastler Brossel, 4, place Jussieu, F-75252 PARIS, cedex 05 — [2]Institute of Physics, Department for Quantum Optics and Statistics, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

We develop a master equation theory for general Bose-Einstein condensates. Starting from first principles, we find that the condensate's dynamics in the presence of the non-condensed component can be described by a Lindblad master equation, which accounts for all possible two-particle interaction processes. As a first application, we study the process of condensate formation in a 3-dimensional harmonic trap.

Q 47.5 Do 17:30 1A

Fermion- and Spin-Counting in Strongly Correlated Systems — •Sibylle Braungardt[1], Aditi Sen[1], Ujjwal Sen[1], Roy J. Glauber[2], and Maciej Lewenstein[1] — [1]ICFO - Institut de Ciencies Fotoniques, Mediterranean Technology Park, 08860 Castelldefels (Barcelona), Spain — [2]Lyman Laboratory, Physics Department, Harvard University, 02138 Cambridge, MA, U.S.A.

We apply the atom counting theory to strongly correlated Fermi systems and spin models, which can be realized with ultracold atoms. The counting distributions are typically sub-Poissonian and remain smooth at quantum phase transitions, but their moments exhibit critical behavior, and characterize quantum statistical properties of the system. Moreover, more detailed characterizations are obtained with experimentally feasible spatially resolved counting distributions.

Q 47.6 Do 17:45 1A

Interspecies Feshbach resonances and scattering properties of the ultracold Fermi-Fermi mixture ^{6}Li and ^{40}K — •Andreas Trenkwalder[1], Eric Wille[1,2], Frederik Spiegelhalder[1], Gabriel Kerner[1], Devang Naik[1], Gerhard Hendl[1], Florian Schreck[1], Rudolf Grimm[1,2], Tobias Tiecke[3], Jook Walraven[3], Servaas Kokkelmans[4], Eite Tiesinga[5], and Paul Julienne[5] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Innsbruck, Austria — [2]Institut für Experimentalphysik und Forschungszentrum für Quantenphysik, Universität Innsbruck, Austria — [3]Van der Waals-Zeeman Institute of the University of Amsterdam, The Netherlands — [4]Eindhoven University of Technology, The Netherlands — [5]Joint Quantum Institute, National Institute of Standards and Technology and University of Maryland, Gaithersburg, USA

We present recent results on the observation of interspecies Feshbach resonances in the Fermi-Fermi mixture of ^{6}Li and ^{40}K. The mixture is stored in an optical dipole trap and is prepared in different combinations of spin states. At specific values of the magnetic field we observe enhanced atom loss which we can assign with the help of two theoretical models to *s*- or *p*-wave Feshbach resonances. The results from a simple model agree well with a full coupled channels analysis. The singlet and triplet scattering lengths are found to be 52.1(3) a_0 and 63.5(1) a_0 respectively. Our next step will be the formation of bosonic molecules at the identified Feshbach resonances leading towards the creation of a heteronuclear molecular BEC. Preprint: arXiv:0711.2916

Q 47.7 Do 18:00 1A

Dissipative dynamics of a rotating, strongly-interacting Fermi gas. — •Edmundo R. Sánchez Guajardo, Stefan Riedl, Christoph Kohstall, Alexander Altmeyer, Johannes Hecker Denschlag, and Rudi Grimm — Institut für Experimentalphysik, Technikerstrasse 25/4, A-6020 Innsbruck

We present our experiments on dissipative dynamics of a rotating ultracold gas of strongly interacting ^{6}Li atoms in a harmonic trap. In such a system both the superfluid core and the surrounding thermal gas are hydrodynamic, in contrast to weakly interacting BEC experiments where the thermal gas is collisionless. This leads to particularly long lifetimes of rotation of the thermal part, allowing for precise measurement of the angular momentum. We measure the lifetime of the angular momentum for different temperatures and trap anisotropies using collective oscillations. The measurements are in excellent agreement with the theoretical exponential decay previously predicted [Guéry-Odelin, 2000].

Q 47.8 Do 18:15 1A

Finite-Temperature Collective Dynamics of a strongly interacting Fermi Gas — •Christoph Kohstall[1], Stefan Riedl[1,2], Edmundo R. Sánchez Guajardo[1], Alexander Altmeyer[1,2], Johannes Hecker Denschlag[1], and Rudolf Grimm[1,2] — [1]Inst. of Experimental Physics and Center for Quantum Physics, Univ. Innsbruck, 6020 Innsbruck, Austria — [2]Inst. for Quantum Optics and Quantum Information, Acad. of Science, 6020 Innsbruck, Austria

Collective excitations are a powerful tool to investigate the dynamics of a strongly interacting fermionic quantum gas.

In a weakly interacting Bose gas hydrodynamic behavior coincides with superfluidity. According to BCS-theory superfluidity of fermions concurs with pairing. These two predictions are no more valid in the BEC-BCS crossover where interactions are strong; hydrodynamic behavior, superfluidity and pairing are established at different temperatures.

The focus of this talk is our experimental data on collective oscillations of an ultracold, strongly interacting gas of ^{6}Li atoms showing the transition from hydrodynamic to nearly collisionless behavior as a function of temperature. The results are in agreement with recent calculations that take into account Pauli blocking and pairing.

We find a novel feature of the scissors mode which might indicate the critical temperature for superfluidity.

In addition, radiofrequency spectra reveal the existence of atom pairs up to a temperature where the gas behaves nearly collisionless.

Q 47.9 Do 18:30 1A

Dynamics of a trapped spinor Fermi gas — Nils Bornemann, •Philipp Hyllus, and Luis Santos — Institut für Theoretische Physik, Leibniz-Universität Hannover, Appelstr. 2, 30167 Hannover

We investigate the spin dynamics of an atomic Fermi gas with a spin of $f \geq \frac{3}{2}$ in a harmonic trap. Spin-changing collisions, which induce a population tranfer between different spin components, are largely suppressed in the presence of a sufficiently large magnetic field due to the quadratic Zeeman effect.

We derive the corresponding Master equation, and neglecting coherences, we simulate the equivalent rate equation for the populations including the supressing effects of the quadratic Zeeman effect, and the trap anharmonicity. We will show that the interplay between anharmonicity and quadratic Zeeman effect leads to a resonant enhancement of the spin-changing collisions as a function of the applied magnetic field. This effect should have clearly observable consequences especially for fermions in deep optical lattices, since for bosons under the same conditions the resonances would be absent.

Q 48: Quanteninformation (Quantenkommunikation)

Zeit: Donnerstag 16:30–19:00 Raum: 1B

Q 48.1 Do 16:30 1B

Two Photon Interference of Resonance Fluorescence Photons — •S. Gerber, D. Rotter, F. Dubin, and M. Mukherjee — Institut für Experimentalphysik, Universität Innsbruck, Austria

We report on two photon interference measurements of resonance fluorescence photons from trapped ions. Two indistinguishable photons impinging at two input ports of a 50/50 beam splitter coalesce, i.e. they both are leaving the device in one of the output ports. This Hong-Ou-Mandel interference is quantified by measuring correlations between the two output channels. The visibility of the two-photon interference effect determines the degree of indistinguishability of the input photons.

In a first experiment, a single trapped ion is converted into a pseudo two-photon source. The single ion resonance fluorescence is split in two parts, individually coupled into optical fibers of different length and then recombined on a beam splitter. A two-photon interference is observed with a contrast reaching 83%. The spectral brightness of our two-photon source is quantified and shown to be comparable to parametric down conversion devices [1].

In a successive experiment two-photon interference between two ions located in two separate traps is measured with up to 87% contrast. Thus, two-photon interference is used as a building block for quantum network operations.

[1] F. Dubin, D. Rotter, M. Mukherjee, S. Gerber, R. Blatt, Phys. Rev. Lett. 99, 183001 (2007)

Q 48.2 Do 16:45 1B

Quantum Repeaters using Coherent-State Communication — •Peter van Loock — Optical Quantum Information Theory Group, Max Planck Research Group, Institute of Optics, Information and Photonics, Staudtstr. 7/B2, 91058 Erlangen, Germany

We investigate quantum repeater protocols based upon atomic qubit-entanglement distribution through optical coherent-state communication. Various measurement schemes for an optical mode entangled with two spatially separated atomic qubits are considered in order to nonlocally prepare conditional two-qubit entangled states. In particular, generalized measurements for unambiguous state discrimination enable one to completely eliminate spin-flip errors in the resulting qubit states, as they would occur in a homodyne-based scheme due to the finite overlap of the optical states in phase space [1]. As a result, by using weaker coherent states, high initial fidelities can still be achieved for larger repeater spacing, at the expense of lower entanglement generation rates. In this regime, the coherent-state-based protocols start resembling single-photon-based repeater schemes.

[1] P. van Loock, T. D. Ladd, K. Sanaka, F. Yamaguchi, Kae Nemoto, W. J. Munro, and Y. Yamamoto, Phys. Rev. Lett. **96**, 240501 (2006).

Q 48.3 Do 17:00 1B

Verbesserte Fehlerschwellen für das BB84 und 6-state Protokol — •Oliver Kern, Joseph M. Renes und Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt, 64289 Darmstadt, Germany

Es ist bekannt, dass lokale Randomisierung die Raten von Quantenkryptographie Protokollen welche Einwegkommunikation nutzen, verbessern kann. Ein noch größerer Vorteil kann für das BB84 Protokol erlangt werden, indem man eine Randomisierung mit strucktuierten (nicht zufälligen) Blockcodes verknüpft. Wir zeigen, dass ein solcher Vorteil auch für das 6-state Protokol erlangt werden kann. Es ist möglich, die beste untere Schranke für die Bitfehlerrate von 14.12% mit Randomisierung auf mindestens 14.57% mit dem verknüpften Verfahren zu erhöhen.

Q 48.4 Do 17:15 1B

Continuous-variable quantum key distribution with qudits — •Ulrich Seyfarth and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289, Darmstadt

A qudit generalization of the recently discussed two-state continuous-variable quantum key distribution protocol of Heid and Lütkenhaus [1] is presented. Secret key rates are evaluated for cases in which an eavesdropper can extract information by beam splitting attacks. Resulting key generation rates for direct and reverse reconciliation are compared.

[1] M. Heid and N. Lütkenhaus, Phys. Rev. A **73**, 052316 (2006).

Q 48.5 Do 17:30 1B

Measurement induced decoupling of Gaussian Noise for quantum communication — •Metin Sabuncu[1,2], Radim Filip[3], Gerd Leuchs[2], and Ulrik L. Andersen[1,2] — [1]Department of Physics, Technical University of Denmark — [2]IOIP, Max-Planck Forschungsgruppe, Universität Erlangen-Nürnberg, Germany — [3]Department of Optics, Palacky University, Czech Republic

Every communication link is affected by noise. In classical communication the noise does not have a very detrimental influence and can be removed. For quantum communication, however, the effect of this noise becomes much more devastating, normally preventing quantum information processing tasks from being realised. Therefore when performing quantum communication protocols it is crucial to have efficient noise erasing procedures that renders the protocols fault tolerant. We investigate a protocol used in quantum key distribution, where the information is encoded into conjugate continuous variables of a coherent state. We then consider a Gaussian noisy interaction with the environment and show that by performing environmental measurements it is possible to decouple the noise after some suitable measurement induced operations. Using this strategy, the quantum information content of conjugate variables can be ideally recovered independent of the amount of environmental excess noise provided that the state of the environment is fully accessible. We present an experiment in which coherent states are inflicted by Gaussian noise and we present different scenarios how to decouple the noise in the channel via measurement induced operations and compare it to the theory.

Q 48.6 Do 17:45 1B

Time-Bin Encoding for Narrow-Band Single Photons — •Nils Neubauer, Matthias Scholz, and Oliver Benson — Humboldt-Universität zu Berlin, Institut für Physik, AG Nanooptik, Hausvogteiplatz 5-7, 10117 Berlin

For long-range applications in quantum information processing (e.g., quantum key distribution QKD), time-bin encoding of single photons is the favorable choice since this scheme does not suffer from polarization degradation in optical fibers. In order to build larger quantum networks, coherent storage and retrieval of single photons in atomic ensembles has been suggested and realized, e.g., by using electromagnetically induced transparency in optically dense media. Therefore, the spectrum of these photons needs to match the narrow linewidth of atomic resonances.

We realized a scheme for time-bin encoding of narrow-band single photons. The setup consists of two unbalanced Michelson interferometers acting as encoding and decoding units. Using a relative arm length difference of 100 m each, a path delay of 500 ns can be implemented, suitable for single photons with a bandwidth of 10 MHz. It is intended to show QKD via the BB84 protocol with attenuated light pulses of this bandwidth.

Q 48.7 Do 18:00 1B

Eavesdropping in quantum cryptography with six mixed states — •Zahra Shadman, Hermann Kampermann, Tim Meyer, and Dagmar Bruss — Institut für Theoretische Physik III,Düsseldorf,Germany

For the case of the six state protocol in the presence of white noise (six mixed states) we express the optimal mutual information for both cases Alice/Bob and Alice/Eve in terms of the noise parameter and the quantum bit error rate. In comparison to the pure state case the crossing point of the two mutual information curves moves to a higher quantum bit error rate. We conclude that the six state protocol with mixed states is more robust against eavesdropping than for pure states.

Q 48.8 Do 18:15 1B

Optical Free-Space Quantum Key Distribution — •Sebastian Schreiner[1], Henning Weier[1], Martin Fürst[1], Tobias Schmitt-Manderbach[1], Christian Kurtsiefer[2], and Harald Weinfurter[1,3] — [1]Department für Physik der LMU München, Schellingstr 4/III, 80799 München — [2]Department of Physics, National University of Singapore, 2, Science Drive 3, Singapore 117542 — [3]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

The security of quantum key distribution, (QKD) is based on physical laws rather than assumptions about computational complexity: An adversary will necessarily disturb the communication by his quantum measurement. This leads to an error rate in the generated keys which allows to calculate an upper bound on the information eavesdropped. However, real implementations will be sensitive to side-channel attacks, i.e. to information losses due to distinguishabilities in other degrees of freedom, which an adversary can measure without causing errors.

Here we report on progress of our implementation of the BB84 protocol installed on top of two university buildings in downtown Munich. Using attenuated laser pulses in combination with decoy states we can establish a key over a distance of 500˜m. Our system is fully remote controlled and allows for continuous and fast QKD. Additionally it is fully characterized with respect to spectral, temporal and spatial side-channels and so can guarantee secure key exchange. Our experiments proof free-space QKD to be feasible, providing high key rates while still staying both robust and simple.

Q 48.9 Do 18:30 1B

Distillation of entangled state after a fading channel — •Ruifang Dong[1], Mikael Lassen[2], Christoph Marquardt[1], Radim Filip[1], Ulrik L. Andersen[2], and Gerd Leuchs[1] — [1]Institute for Optics, Information and Photonics,Max-Planck Researchgroup, University Erlangen-Nuernberg, Guenther-Scharowsky-Str. 1, 91058, Erlangen,Germany — [2]Department of Physics, Technical University of Denmark, Building 309, 2800 Lyngby, Denmark

We report on the experimental distillation of a continuous variable polarization entangled state which is affected by a fading channel. We produce a polarization entangled state by mixing two fiber-based polarization squeezing states at a beam splitter [1]. After the beam splitter, one part of the entangled beams is subject to a fading channel. Such channel may exhibit any kind of random distribution of the attenuation. In the experiment, to simulate the fading channel and implement the distillation, we insert a variable optical attenuator into one of the entangled beams and tap off a small portion of the attenuated beam for post selection [2], the joint measurement on the corrupted entangled beams is also made for verification. Then by setting various different attenuation levels, we achieve a series of data from tap measurements and verification measurements which are collected by A/D card into computer. Later, all the measured data can be mixed in the computer with certain distribution form and a destroyed entangled state after a certain fading channel is simulated. Based on such procedure, the distillation can be succeeded and a recovery of the original entangled state is obtained with an accessible success probability.

Q 48.10 Do 18:45 1B

Experimental aspects of deterministic secure quantum key distribution — •Nino Walenta[1], Dietmar Korn[1], Dirk Puhlmann[1], Timo Felbinger[1], Kim Boström[2], Holger Hoffmann[1], and Martin Ostermeyer[1] — [1]Universität Potsdam, Institut für Physik, 14469 Potsdam — [2]Universität Münster, 48149 Münster

Most common protocols for quantum key distribution (QKD) use non-deterministic algorithms to establish a shared key. But deterministic implementations can allow for higher net key transfer rates and eavesdropping detection rates. The Ping-Pong coding scheme by Boström and Felbinger [1] employs deterministic information encoding in entangled states with its characteristic quantum channel from Bob to Alice and back to Bob.

Based on a table-top implementation of this protocol [2] with polarization-entangled photons fundamental advantages as well as practical issues like transmission losses, photon storage and requirements for progress towards longer transmission distances are discussed and compared to non-deterministic protocols. Modifications of common protocols towards a deterministic quantum key distribution as in [3] are addressed.

[1] K. Boström, T. Felbinger. Phys. Rev. Lett. 89 187902 (2002)
[2] M. Ostermeyer, N. Walenta. arXiv:quant-ph/0703242v1
[3] M. Lucamarini, J. S. Shaari, M.R.B. Wahiddin. arXiv:0707.3913v1

Q 49: Ultrakurze Laserpulse (Anwendungen II)

Zeit: Donnerstag 16:30–19:15 Raum: 3H

Q 49.1 Do 16:30 3H

Exact description of self-focusing in highly nonlinear geometrical optics — •Larisa Tatarinova and Martin Garcia — University of Kassel, Kassel, Germany

Problem of intense light propagation in a media exhibiting highly nonliner responce is studied in the geometrical optic approximation. We demonstrate that for big number of modern experiments and applications this approximation is appropriate. Particularly, for propagation of 5 nJ femtosecond pulse in air, the obtained analytically self-focusing distance deviates from the numerical solution of the nonlinear Schrodinger equation as 0.4%. We construct analytical solutions for several types of nonlinearities. The obtained solutions turn out to be exact on the beam axis and provide a benchmark for numerical simulations, and replace the widely used empirical Marburger formula. We show how the hight order nonlinearities can lead to dramatic changes in the self-focusing behaviour, and present a way for their experimental determination.

Q 49.2 Do 16:45 3H

Enhancement of the X-ray yield by adaptive shaping of ultrashort laser pulses — •Steffen Linden, Martin Silies, Henrik Witte, and Helmut Zacharias — Physikalisches Institut, Westfälische Wilhelms-Universität Münster

A deformable mirror is implemented in a laser-based hard X-ray experiment in order to increase the hard X-ray yield. The imperfect wavefront from the Ti:Sapphire CPA laser system is spatially changed by means of a piezoelectric deformable mirror before th focusing optics of the laser-plasma experiment. The hard X-ray yield of the generation process is detected by an X-ray sensitive Schottky diode. This diode delivers the feedback signal for an evolutionary algorithm, that controls the piezovoltages of the deformable mirror. After a series of generations of the algorithm with an adjustable number of individuals (one individuum represents one mirror deformation) the $Fe - K_\alpha$ yield is enhanced significantly.

Q 49.3 Do 17:00 3H

Auswirkungen von zeitverzögerten und geformten fs Laserpulsen auf das Abtragsverhalten von Werkstoffen — •Markus Schomaker, Holger Lubatschowski und Alexander Heisterkamp — Laser Zentrum Hannover e.V., Hollerithalle 8, 30419 Hannover

Die laserinduzierte Strukturierung ist nicht nur für das Mikro- und Nanomachining von großer Bedeutung, sondern auch im Bereich der laserbasierten Zell- und Nanochirurgie sind definierte Strukturen für eine erfolgreiche Behandlung notwendig. Um solche Strukturen erzeugen zu können, sind Kenntnisse zur Wechselwirkung von Laserstrahlung und Material erforderlich. Ein tieferes Verständnis zum Ablationsprozess geben die durchgeführten Doppelpulsexperimente, bei denen gaußförmige fs- Doppelpulse mit unterschiedlicher, zeitlicher Verzögerung generiert werden. Dieses erfolgt durch das Aufsplitten eines Laserpulses in zwei Teilpulse und der anschließenden Leitung über verschieden lange Wegstrecken, bevor die beiden Teilpulse wieder überlagert werden. Durch das Fokussieren dieser Doppelpulse auf eine Probe können Abträge realisiert werden. Erfolgt das Auftreffen der Teilpulse zeitverzögert im Pikosekundenbereich, kommt es zu einer räumlichen Veränderung in den Abtragsdimensionen. Ebenfalls wird die Größe des Abtrags durch das Umwanden der Pulsform beeinflusst. Realisiert wird dieses durch das Einbringen einer Phasenplatte in den Strahlengang und einer Überlagerung der Teilpulse. Die erzielten Ergebnisse erlauben ein besseres Verständnis zur Puls- Materialwechselwirkung und geben Informationen zum gesamten Abtragsprozess.

Q 49.4 Do 17:15 3H

Adaptive Optik und deren Anwendung in biologischen Systemen — •Raoul-Amadeus Lorbeer, Holger Lubatschowski und Alexander Heisterkamp — Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover

Die Echtzeitanpassung von Teleskopsekundärspiegeln an atmosphärische Turbulenzen hat die terrestrische Astronomie revolutioniert. Durch kompaktere Systeme könnte diese Technik nun auch Einzug in die Mikroskopie und Lasermedizin halten. Ein geeignetes System stellen so genannte Spatial Light Modulators (SLMs) dar. Mit einem Flüssigkristall SLM lassen sich die Wellenfronten von Laserlicht gezielt manipulieren und zur Verbesserungen der optischen Eigenschaften bzw. der Verringerung möglicher Aberrationen in biologischen Systemen einsetzen.

Mögliche Anwendungsfelder sind daher zum einen die Augenheilkunde und zum anderen die Mikroskopie. Bei der Propagation des Lichtes durch Augenhornhaut, Augenlinse sowie Glaskörper werden diesem Aberrationen aufgeprägt. Um somit in der Augenheilkunde den Augenhintergrund genau abbilden und manipulieren zu können, ist es notwendig, die auftretenden Wellenfrontverkrümmungen zu korrigieren. Ebenso ist in der Mikroskopie beim Arbeiten mit hohen Numerischen Aperturen die detailgetreue Abbildung aus verschiedenen Probentiefen nicht mehr gewährleistet und eine Korrektur sinnvoll.

Aus diesen Gründen wurde ein Versuchsaufbau realisiert, mit dem sowohl die Messung von Aberrationen als auch deren Korrektur möglich ist.

Q 49.5 Do 17:30 3H

Laser-Gewebe-Wechselwirkungen von ultrakurzen Laserpulsen bei unterschiedlichen Pulsfolgefrequenzen — •Kai Kütemeyer, Judith Baumgart, Holger Lubatschowski und Alexander Heisterkamp — Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover

Oberhalb einer materialabhängigen Intensitätsschwelle erzeugt ein ultrakurzer Laserpuls in einem transparenten Medium einen optischen Durchbruch, der zu einem Abtrag des Materials führt. Für die Manipulation von einzelnen Zellorganellen in der Zellchirurgie ist die Minimierung der durch die Laserstrahlung eingebrachten Energie entscheidend, um die Vitalität der Zellen nach der Behandlung zu gewährleisten. Deshalb wird der Abtrag von einzelnen Zellorganellen im MHz Bereich mit Pulsenergien um 1 nJ unterhalb der Schwellenenergie für einen optischen Durchbruch durch kumulative chemische Effekte erzielt, die durch erzeugte freie Elektronen induziert werden. Zur Untersuchung dieser Mechanismen werden mit Hilfe eines akusto-optischen Modulators und eines mechanischen Shutters Pulszüge mit einer variablen Pulsfolgefrequenz zwischen 20 kHz und 4,5 MHz, einer Pulsdauer von 100 fs und einer Pulsenergie von einigen nJ erzeugt. Durch ein Objektiv mit einer hohen numerischen Apertur von 1,3 werden die Pulse auf die Probe fokussiert. In Abhängigkeit der Pulsenergie, der Pulsfolgefrequenz und der Anzahl der eingestrahlten Pulse wird die Schädigung in transparenten biologischen Proben und künstlichen Modellsubstanzen bewertet, um eine Optimierung der Parameter für die Manipulation innerhalb einzelner Zellen zu erreichen.

Q 49.6 Do 17:45 3H

Zwei-Farben-Pump-Abfrage-Messungen von Quantenpunktstrukturen mit einem MHz-OPA — •Marcel Schultze, Andy Steinmann, Guido Palmer und Uwe Morgner — Institut für Quantenoptik, Leibniz Universität Hannover

Da die zeitliche Auflösung von Pump-Abfrage-Messungen direkt mit der Pulsdauer der verwendeten Laserquelle korreliert, eignen sich Femtosekundenlaser hervorragend um z.B. einen direkten Einblick in die Ladungsträgerdynamik von Halbleiterstrukturen zu erlangen. Wir präsentieren die Messung der Relaxationsdynamik von Quantenpunktproben mit Hilfe einer Pump-Abfrage-Messung. Als Quelle dient ein optisch parametrischer Verstärker (OPA) mit MHz-Repetitionsrate. Im Vergleich zu kHz-Systemen ist dieser deutlich rauschärmer und ermöglicht durch die höheren Repetitionsraten eine Verbesserung des Signal-zu-Rausch-Verhältnisses. Dadurch lassen sich Transmissionsänderung bis herab zu 0,05 % messen. Ein passiv modengekoppelter Yb:KYW Oszillator mit Cavity-Dumping dient bei einer Zentralwellenlänge von 1040 nm als Pumpquelle für den OPA und wird gleichzeitig zur Anregung der Quantenpunktproben verwendet. Der durchstimmbare Idler des OPA-Systems wird im Wellenlängenbereich von 1100 nm bis 1300 nm für die zeitliche Abfrage der Exzitonenniveaus der Halbleiterstrukturen genutzt. Durch eine zusätzliche Kühlung der Probe mit Hilfe eines Stickstoffkryostaten konnte eine weitere Zunahme der Transmissionsänderung erreicht werden.

Q 49.7 Do 18:00 3H

Femtosekunden Wellenform-Synthesizer — •Stefan Rausch, Thomas Binhammer, Anne Harth und Uwe Morgner — Institut für Quantenoptik, Leibniz Universität Hannover

Die Formung der spektralen Phase ultrakurzer Laserpulse wird seit kurzem gezielt angewandt, um zeitliche Pulsprofile und -sequenzen auf Femtosekunden-Zeitskalen zu erzeugen. Durch eine zusätzliche Einflussnahme auf die spektrale Amplitude des Pulses eröffnen sich zahlreiche neue Möglichkeiten auf dem Gebiet der Femtosekunden-Pulsformung.

Wir präsentieren hier einen Pulsformer-Aufbau bestehend aus einem Titan:Saphir-Oszillator, einem SPIDER-Messsystem und einem LCD-Pulsformer, der die unabhängige Manipulation von spektraler Pulsphase und -amplitude erlaubt. Das über-oktavbreite Spektrum des Lasers unterstützt eine Fourier-limitierte Pulsdauer von 3.7 fs, was ihn zur idealen breitbandigen Lichtquelle für Pulsformungsexperimente macht. Mit diesem Aufbau ist es möglich, Pulse mit variablen spektralen Formen, Pulsdauern unterhalb des Fourier-Limits und andere anspruchsvolle zeitliche Pulsformen zu generieren. Einige dieser Ergebnisse werden hier präsentiert.

Um die totale Kontrolle über das E-Feld eines ultrakurzen Laserpulses zu erlangen, muss neben seiner spektralen Phase und Amplitude zusätzlich seine Träger-Einhüllende Phase beeinflusst werden, was über eine Phasenstabilisierung des Oszillators erreicht werden kann. Der dann realisierte Wellenform-Synthesizer erlaubt phasensensitive Experimente mit variablen Pulsformen im Bereich der kohärenten Kontrolle.

Q 49.8 Do 18:15 3H

Attosecond relative timing jitter from a two-branch femtosecond Er:fiber laser — •Alexander Sell[1], Florian Adler[1,2], Rupert Huber[1], and Alfred Leitenstorfer[1] — [1]Department of Physics, University of Konstanz, 78464 Konstanz, Germany — [2]JILA, University of Colorado, Boulder, Colorado 80309-0440, USA

We present the first direct measurement of the relative timing jitter between the parallel pulse trains of two erbium-doped fiber amplifiers which share the same femtosecond seed oscillator. The system is operated without active stabilization. Each amplifier branch provides independently tunable pulses in the near infrared (tuning range: 1.0 μm to 2.4 μm) with durations down to 12 fs, generated via four wave mixing in a highly nonlinear dispersion shifted bulk fiber. Employing an interferometric optical cross-correlator, the phase noise spectral density is measured with high sensitivity in a range from 1 Hz up to the Nyquist frequency of 24.5 MHz. The integrated timing jitter amounts to 11 attoseconds directly after the amplifier stages and 43 as after propagation through free-space optics and nonlinear fibers for frequency conversion. Multi-branch fiber lasers are thus promising seed sources for important applications such as phase stable, tunable difference frequency generation, field resolved spectroscopy or high-harmonic generation.

Q 49.9 Do 18:30 3H

***Strong field* control of molecular dynamics by *resonant shaped* ultrashort laser pulses** — •Matthias Wollenhaupt, Tim Bayer, and Thomas Baumert — Universität Kassel, Institut für Physik and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), Heinrich-Plett-Str. 40, D-34132 Kassel, Germany

Quantum control by tailored ultrashort light pulses is very successful to manipulate physical and chemical properties of matter. In many cases the underlying physical processes are not very well understood – particularly when *shaped resonant intense* pulses are applied. These pulses are of general importance because resonant control scenarios are the dominant pathways for pulses with ultra broad spectra. In this contribution the physical mechanism of strong field quantum control using tailored *resonant* pulses is investigated on small molecules [1-3]. Switching among different final electronic states is realized by selective population of dressed states **(SPODS)**. Our experiment is based on femtosecond pulse shaping and time-of-flight photoelectron spectroscopy. The spectrum of a femtosecond laser pulse is sinusoidally phase-modulated in frequency domain [4] to produce a sequence of pulses interacting with molecules in a beam. Our result show selectivity among different electronic states. Because SPODS is ultrafast our strategy might be operative in the presence of decoherence processes as well. [1] M. Wollenhaupt et al., Chem. Phys. Lett 419, 184 (2006) [2] M. Wollenhaupt and T. Baumert, J. Photochem. Photobiol. A 180, 248 (2006) [3] M. Wollenhaupt et al., Ann. Rev. Phys. Chem. 56, 25 (2005) [4] M. Wollenhaupt et al., Phys. Rev. A. 73, 063409 (2006)

Q 49.10 Do 18:45 3H

Ludwig-Maximilians-Universität, München, Deutschland — •Philipp von den Hoff, Dorothee Geppert, and Regina de Vivie-Riedle — Ludwig-Maximilians-Universität, München, Deutschland

An efficient approach to describe electron dynamics in molecules is developed which exploits quantum dynamics and quantum chemistry in a new way. The photodissociation of D_2^+, that can be controlled via the carrier-envelope phase of an ultrashort laser pulse, is chosen as a test system. In this system, the approach is checked against more rigorous theories as well as experiments which show excellent agreement. The electron dynamics is visualized in several ways including the phase information of the electronic wavefunction. The detailed analysis of the electron motion after different ionization events reveals the underlying complex dynamics which are hidden in the experiment. The interplay between the carrier-envelope phase and electron control is elucidated. The ansatz is based on the highly developed electronic structure theory and can be implemented quite easily. The method allows for a successive extension to multi-electron systems and simultaneously enables a quantum dynamical description of the nuclear motion.

Q 49.11 Do 19:00 3H

Strong-field control landscapes of coherent electronic excitation — •Tim Bayer, Matthias Wollenhaupt, and Thomas Baumert — Universität Kassel, Institut für Physik und CINSaT, Heinrich-Plett-Str. 40, D-34132 Kassel, Germany

We study physical mechanisms of resonant strong-field coherent control. To this end, time-of-flight photoelectron spectra from multiphoton ionization of potassium atoms with intense shaped femtosecond laser pulses are measured and discussed in terms of Selective Population of Dressed States (SPODS). Recently, it was shown [1,2] that pulse sequences and chirped pulses provide efficient yet complementary realizations of SPODS. Combining these two approaches thus leads to a physically motivated pulse parametrization that opens up search spaces of manageable size. The SPODS control topology of these reduced search spaces is mapped out experimentally and presented in the form of strong-field control landscapes. Having revealed the landscape topologies we apply the same pulse parametrization to an adaptive optimization procedure in order to optimize SPODS on one of the mapped parameter spaces. The concept of control trajectories is introduced and serves to visualize the temporal evolution of the optimization on the measured landscape surface. The question whether such optimization procedures under experimentally constrained conditions in fact end up at the global optimum or eventually become trapped by suboptimal local extrema [3] is addressed.

[1] M. Wollenhaupt *et al.*: PRA **73**, 2006 [2] M. Wollenhaupt *et al.*: APB **82**, 2006 [3] H. A. Rabitz *et al.*: PRA **74**, 2006

Q 50: Poster Ultrakalte Atome

Zeit: Donnerstag 16:30–19:00 Raum: Poster C2

Q 50.1 Do 16:30 Poster C2

Trapping and guiding neutral atoms using ultra-thin optical fibres. — •Guillem Sagué, Eugen Vetsch, Florian Warken, and Arno Rauschenbeutel — Institut für Physik, Staudingerweg 7, 55128 Mainz

We aim to optically trap and guide neutral atoms close to the surface of subwavelength-diameter optical fibres. For this purpose, we set up a two-colour surface trap which is based on light-induced dipole forces exerted on the atoms by a blue- and red-detuned evanescent light field [1], created by launching two co-propagating laser beams through the fibre. This results in a cylindrically symmetric trap around the fibre. It exhibits a trapping minimum about two hundred nanometers above the surface with expected radial trapping frequencies above 700 kHz. By launching a second, counter-propagating red-detuned laser beam through the fibre a red-detuned standing wave can be realized. This results in a periodic trapping potential along the fibre, thereby confining the atoms in all three dimensions.

[1] G. Sagué, E. Vetsch, W. Alt, D. Meschede, and A. Rauschenbeutel, Phys. Rev. Lett. **99**, 163602 (2007)

Q 50.2 Do 16:30 Poster C2

Optical Spectroscopy On Trapped Nanoparticles — •Alexander Kuhlicke, Stefan Schietinger, and Oliver Benson — AG Nano-Optik, Institut für Physik, Humboldt-Universität zu Berlin, Hausvogteiplatz 5-7, 10117 Berlin

Linear radio frequency ion traps, so-called Paul traps, became widely used tools for high-resolution spectroscopy because of the absent interaction between particles and supporting surfaces or other particles. With their help it was possible to build up quantum registers and implement first operations for quantum computing. Also trapping of micrometer-sized particles in larger traps was demonstrated. Until today not much work was done for trapping particles in the span between these two size regimes of few atoms and microscopic particles. We have narrowed the gap by trapping single nanoparticles with sizes down to 20 nm within a linear Paul trap. We observed Coulomb crystals within the trap and performed spectroscopy on single trapped dye-doped particles and N-V centers in nanodiamonds. Future experiments aim at the spectroscopy of single quantum emitters revealing their interaction with a mesoscopic environment.

Q 50.3 Do 16:30 Poster C2

Lasersystem zum Kühlen und Fangen von neutralem Quecksilber — •Patrick Villwock, Arne Schönhut, Mathias Sinther und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, AG Laser und Quantenoptik, Schlossgartenstr.7, 64289 Darmstadt

Kalte Quecksilberatome in einer magneto-optischen Falle bieten die Möglichkeit der Erzeugung translatorisch kalter Moleküle durch Photoassoziation, sowie deren Laserkühlung in den vibratorischen Grundzustand. Zusätzlich erlaubt es die Untersuchung eines neuen Zeitstandards. Quecksilber hat stabile bosonische und fermionische Isotope, deren natürliche Häufigkeit im zweistelligen Prozentbereich liegen. Die Sättigungsintensität des Kühlübergangs bei 253,7 nm beträgt 10,2 mW/cm^2 bei einer natürlichen Linienbreite von 1,27 MHz.

Die Strahlung bei dieser Wellenlänge kann durch zweimalige Frequenzverdoppelung erreicht werden. Als Basis dient ein Yb:YAG Scheibenlaser der am Rand seines Verstärkungsmaximums bei 1014,8 nm betrieben wird. Die erste Verdopplungsstufe bildet ein geheizter LBO innerhalb eines Überhöhungsresonators. Als zweite Verdopplungseinheit folgt ein kommerzieller Überhöhungsresonator mit einem temperaturstabilisierten BBO. UV-Leistungen über 200 mW können so erreicht werden.

Q 50.4 Do 16:30 Poster C2

Clock laser for an optical lattice clock with strontium — •Thomas Legero, Fritz Riehle, and Uwe Sterr — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Ultrastable lasers with high spectral purity are a key technology in optical frequency metrology. We report on a 698 nm master-slave diode laser setup to probe the 1S0 - 3P0 clock transition of strontium atoms confined in a 1D optical lattice. The master laser is an extended cavity diode laser in Littman configuration which is locked to a high finesse optical cavity by the Pound-Drever-Hall stabilization technique. The temperature-stabilized and vibration-insensitive cavity is made of a 100 mm long ULE spacer and shows a Finesse of 330 000. For probing the clock transition, the light from the injection locked slave laser is sent to the strontium atoms and to a femtosecond fiber-laser comb by two actively noise-cancelled optical fibers. We present the setup and the characteristics of the master-slave system and the performance of the fiber noise cancellation.

Q 50.5 Do 16:30 Poster C2

Vorbereitende Experimente zu einer magnetooptische Falle für Erbium — •Riad Bourouis, Benjamin Botermann und Martin Weitz — Universität Bonn, Institut für Angewandte Physik, 53115 Bonn, Deutschland

Wir zeigen, wie wir eine magnetooptische Falle für Erbium realisieren wollen. Die optischen Eigenschaften von Erbium werden präsentiert. Insbesondere erklären wir den Aufbau einer Erbium-Gasentladungszelle, mit deren Hilfe wir eine Spektroskopie zur Stabilisierung eines kommerzielles Lasersystem betreiben. Außerdem stellen wir Planung, Aufbau und Konzept eines Zeeman-Slowers vor. Dabei gehen wir speziell auf die Vereinbarkeit von theoretischer Vorarbeit und experimenteller Umsetzung ein. Wir berichten über aktuelle Fortschritte des Experiments.

Q 50.6 Do 16:30 Poster C2

Ion trap for efficient single ion-photon coupling — Robert Maiwald[1,2], •Markus Sondermann[1], Gerd Leuchs[1], James C. Bergquist[2], Dietrich Leibfried[2], Joe Britton[2], and David J. Wineland[2] — [1]Institut für Optik, Information und Photonik, Max Planck Forschungsgruppe, Universität Erlangen-Nürnberg, 91058 Erlangen, Germany — [2]National Institute of Standards and Technology, Boulder, CO 80305, USA

We present the design of an ion trap that allows for the localization of an ion in the focal point of a deep parabolic mirror. The trap consists of a single radio frequency (RF) electrode and two ground electrodes. The RF electrode and one of the ground electrodes are placed concentrically on the optical axis of a conducting parabolic mirror that establishes the second ground electrode. This geometry results in a trapping potential that follows the axial symmetry of parabolic mirrors. Furthermore, the trap design enables minimally invasive optical access to the ion from almost the entire solid angle. The latter property is essential for efficient coupling of single ions to single photons in free space.

The trap design can be adapted for other applications by replacing the mirror by a planar electrode. Using this more general design the ion can still be optically accessed from at least half to over 90% of the solid angle. First test results are presented.

Q 50.7 Do 16:30 Poster C2

Ultra-cold Strontium atoms in 1-D optical lattice for optical frequency metrology — •Joseph Sundar Raaj Vellore Winfred, Thomas Legero, Christian Lisdat, Fritz Riehle, and Uwe Sterr — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Recent advancement in optical frequency metrology promises to measure time with a fractional accuracy of 10^{-17}. Such precise measurement of time is very important in technological and scientific endeavors. With a narrow transition linewidth of about 1 mHz and the existence of the magic wavelength in the NIR region for optical traps leading to cancellation of AC stark shift of the clock transition, strontium is an attractive candidate for such an optical clock. We report preliminary results of our Strontium optical clock experiment. ^{88}Sr atoms are cooled down to ultra cold temperature regime($\sim 1\ \mu$K) and trapped in a 1-D optical lattice with a potential depth around 120 μK. Details of our experimental set up, characterization of atoms in the 1-D optical lattice with respect to different trap parameters and the status of spectroscopy of the magnetic field induced $^1S_0$-$^3P_0$ clock transition will be presented.

Q 50.8 Do 16:30 Poster C2

Chromium atoms in a very deep optical trap — •Jimmy Sebastian, Anoush Aghajani-Talesh, Markus Falkenau, Axel Griesmaier, and Tilman Pfau — 5. Physikalisches Institut, Universität

Stuttgart

We study the properties of a very deep (∼4mK) optical dipole trap for ultracold chromium atoms that is generated by a single 300W fibre laser at a wavelength of 1070nm. We load the dipole trap directly from a magneto optical trap. Due to the high intensity of the laser field, the atoms in the region of the dipole trap experience differential light shifts between ground state and excited state much larger than the line width of the cooling transition. Additionally, the shifts depend on the polarization of the dipole trap beam and on the magnetic states which strongly influences the cooling and loading mechanism in the trap.
We present spectroscopic measurements and calculations of the differential shifts and discuss strategies for optimal loading of optical traps in such a regime.

Q 50.9 Do 16:30 Poster C2

Ladedynamik optischer Dipolfallen bei Erdalkaliatomen — •Felix Vogt, Joseph Sundar Raaj Vellore Winfred, Uwe Sterr und Fritz Riehle — Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

Vorgestellt wird die experimentelle Untersuchung des Transfers von Atomen aus einer magnetooptischen Falle in eine optische Dipolfalle für die Erdalkaliatome ^{40}Ca und ^{88}Sr. Beide Elemente werden in einer zweistufigen magnetooptischen Falle auf ∼12 μK (Ca) und ∼1 μK (Sr) abgekühlt und in eine optische Dipolfalle umgeladen. Als Dipolfallenlaser dient für Ca ein 25 W Yb:YAG-Scheibenlaser (1030 nm) und für Sr ein 1,1 W Ti:Sa-Laser (813 nm). Das durch das Lichtfeld des Dipolfallenlasers erzeugte Potential des Grund- (^{1}S$_0$) und angeregten Zustands (^{3}P$_1$) ist attraktiv, weist jedoch, abhängig von der Wellenlänge des Dipolfallenlasers eine unterschiedliche Tiefe für die atomaren Zustände auf. Dies beeinflusst die Effizienz der Laserkühlung innerhalb der Dipolfalle und damit auch die Laderate. Wir beobachten ein dynamisches Gleichgewicht im Transfer der Atome zwischen Dipol- und magnetooptischer Falle, das durch ein Differentialgleichungsmodell gut beschrieben werden kann. Maximale Transferraten werden bei übereinstimmender Tiefe von Grund- und angeregtem Zustand erwartet. Der Einfluss des geometrischen Überlapps zwischen beiden Fallen auf die Laderate wird zusätzlich diskutiert und die optimalen Transferbedingungen für Ca und Sr miteinander verglichen.

Q 50.10 Do 16:30 Poster C2

Atom guiding in a photonic band gap fibre — •Stefan Vorrath, Sönke Möller, Kai Bongs, and Klaus Sengstock — Universität Hamburg, Institut für Laser-Physik, Hamburg, Germany

In our project we investigate a promising new kind of atomic waveguide based on a 2D photonic band gap fibre which provides nearly lossless guiding of light and atoms in the central hole over long distances. Our guiding mechanism is realized by capturing, compressing and cooling rubidium atoms from a dark spot MOT into the guiding trap composed of several watts of laser power at 1064nm. After optimizing the loading process of our trap we capture about 3 million atoms in front of the fibre. Our newest results will be presented.

Q 50.11 Do 16:30 Poster C2

Status of the Hamburg Cavity Cooling Experiment — •Julian Klinner, Malik Lindholdt, Matthias Wolke, and Andreas Hemmerich — Institut für Laserphysik, Universität Hamburg, Hamburg, Germany

We prepared a new experimental apparatus, which permits to trap a Bose-Einstein Condensate of rubidium atoms inside an optical cavity with 500.000 finesse and a mode volume greater than 0.1 cmm. The cavity displays a ratio between the scattering rate into the cavity mode and into all other modes well above 10 and a narrow bandwidth of a few kHz. We plan to explore cavity induced cooling mechanisms in the transition regime between thermal and quantum degenerate atomic dynamics. The poster presents the status of our experiments.

Q 50.12 Do 16:30 Poster C2

CO2-Laser Optical Dipole Trap for Fermionic Potassium Atoms — •Alexander Gatto, Christian Bolkart, Sylvi Händl, and Martin Weitz — Institut für Angewandte Physik, Rheinische Friedrich-Wilhelms-Universität Bonn, Wegelerstrasse 8, 53115 Bonn, Deutschland

All optical techniques for the cooling of atoms toward quantum degeneracy are especially attractive for fermions, since in contrast to most magnetic trap techniques no additional atomic species for sympathetic cooling are required here. We here report on ongoing work aiming at an all-optical preparation of a 40K Fermi gas in a CO2-laser dipole trap, which will be used for the study of strongly correlated Fermi gases in optical lattices. Initially, we load a magneto-optical trap of 40K atoms from a two-dimensional MOT. Subsequently, the atomic density is increased in a compressed MOT, for which the magnetic field gradient is ramped towards higher values. Our CO2-laser dipole trap realized by a single mid-infrared focussed beam is loaded from this ensemble of cold atoms, in which further cooling by means of evaporative cooling will be performed. The present status of the work will be reported.

Q 50.13 Do 16:30 Poster C2

Continuous loading of calcium atoms into an optical dipole trap — •Purbasha Halder, Chih-Yun Yang, Oliver Appel, Dirk Hansen, and Andreas Hemmerich — Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Alkaline-earth metals are interesting candidates for novel laser cooling schemes due to the presence of narrow intercombination lines in addition to strong principal fluorescence lines. We demonstrate an efficient scheme for continuously loading Ca atoms into a ground-state ($^1S_0$) optical dipole trap (ODT) at 532nm. The ODT is loaded from a MOT in the triplet metastable state ($^3P_2$), by spatially selective optical pumping. This is done by careful superposition of the dipole trap laser on a depumping laser at 430 nm.

With this setup we achieve a cold ensemble of 10^5 atoms at 40 μK and a phase space density of $4 \cdot (10^{-5})$. The loading and subsequent evaporation and cross-dimensional relaxation stages are well described by a simple model. We also point out that a comparable scheme could be employed to load a dipole trap with $^3P_0$ atoms.

We are now setting up a new dipole laser at 1064 nm. We will be trying out a crossed dipole trap with which we hope to achieve efficient evaporative cooling and eventually reach quantum degeneracy. Here, we present the latest developments and the current status of our experiment.

Q 50.14 Do 16:30 Poster C2

Development and Characterization of a Multiple Species Zeeman Slower — Ryan Olf, Edward Marti, Enrico Vogt, •Anton Öttl, and Dan Stamper-Kurn — Department of Physics, University of California, Berkeley, CA 94720

An increasing number of experiments cool and trap multiple atomic species both simultaneously and alternatively. Here we present a Zeeman slower design which is optimized for multiple species operation. Different sections of precision windings are targeted at individual species, with only marginally reduced performance than a slower designed for a single species only.

We have constructed a Zeeman slower that is optimized for Lithium and Rubidium atoms emerging from a dual species oven. A combined Lithium-Rubidium magneto-optical trap is loaded with the slowed atomic beam. We will review design and construction of the setup and characterize the dual species operation of our system.

Q 50.15 Do 16:30 Poster C2

Imaging ultracold atoms with nanometer resolution — •Tim Langen, Tatjana Gericke, Peter Würtz, Daniel Reitz, and Herwig Ott — Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz

We present our experimental setup for high resolution imaging of individual atoms in ultracold quantum gases. The apparatus combines scanning electron microscopy with a standard all-optical approach to Bose-Einstein condensation of ^{87}Rb. A condensate of up to 120000 atoms is produced inside a CO_2 laser dipole trap 13 mm below the tip of an electron microscope. The focused 6 keV electron beam scanning through the cloud of atoms is able to locally produce ions that are subsequently detected with a channeltron ion detector. This allows a precise reconstruction of the atoms' initial positions only limited by the width of the electron beam. We demonstrate the resolving power by imaging single sites of an optical lattice with a period of 604 nm.

Q 50.16 Do 16:30 Poster C2

Fringe-free imaging of BEC with spatially incoherent light — •Jochen Kronjäger[1], Lars Neumann[1], Christoph Becker[1], Kai Bongs[2], and Klaus Sengstock[1] — [1]Institut für Laser-Physik, Universität Hamburg — [2]Midlands Centre for Ultracold Atoms, University of Birmingham

Imaging techniques of cold atomic gases, e.g. alkali Bose-Einstein condensates, critically rely on one atomic absorption line with a width of a few MHz typically. Laser light from the same source used for e.g. Doppler cooling naturally provides the highly concentrated spectral power density needed for efficient absorption or phase contrast imaging. The drawback of using laser illumination in any application is interference fringes, originating from diffraction at optical apertures or dust particles and multiple reflections on optical surfaces in the light path.

We have developed and tested an approach to neutralize these unwanted artefacts which is based on laser light scattered from an opaque fluid. In a simplified view, random scattering destroys the spatial coherence of the beam, while preserving its spectral narrowness. A more refined approach based on the properties of laser speckle allows to quantitatively analyze our setup and demonstrates its fitness for the purpose of fringe reduction.

Q 50.17 Do 16:30 Poster C2

Methods for High-Resolution Preparation of Bose-Einstein Condensates with Spatial Light Modulators — •Simon Stellmer, Mathis Baumert, Christoph Becker, Parvis Soltan-Panahi, Jochen Kronjäger, Kai Bongs, and Klaus Sengstock — Institut für Laserphysik, Uni Hamburg, Germany

The use of Spatial Light Modulators (SLM) has developed into a common technique in the past years. The field of application ranges from biological use in the form of optical tweezers to optical manipulation of Bose-Einstein condensates. Splitting and transport of BECs [1] has been demonstrated, as well as the generation of oscillating solitons [2] and the observation of Josephson junctions in ultra-cold atoms [3].

Here we present a method to manipulate BECs with an extraordinary high spatial resolution, leading e.g. to the generation of solitons in Bose-Einstein condensates. We achieve the accuracy by imaging computer generated structures on a spatial light modulator onto the BEC.

Additional preparation methods are discussed regarding resolution and feasibility. We present holographic imaging in divergent laser beams allowing for an optical set-up with extremely high numerical aperture and therefore high resolution. Furthermore, we report on the possibilities of generating non-diffractive Bessel beams which may be employed in transport of atoms within quantum registers and atom guiding within photonic band gap fibres.

[1] V. Boyer *et al.*, Phys. Rev. A **73**, 031402 (2006)
[2] C. Becker *et al.*, to be published
[3] S. Levy *et al.*, Nature **449**, 579 (2007)

Q 50.18 Do 16:30 Poster C2

State-selective microwave potentials on atom chips — •Pascal Böhi[1,2], Max F. Riedel[1,2], Johannes Hoffrogge[1,2], Theodor W. Hänsch[1,2], and Philipp Treutlein[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München

We present the status of our experiment with microwave near-fields on atom chips. Microwave near-fields are a key ingredient for atom chip applications such as quantum information processing, entanglement of Bose-Einstein condensates, atom interferometry, the study of Josephson effects and chipbased atomic clocks. We have integrated miniaturized microwave guiding structures on our atom chip. The micrometersized structures allow to generate microwave near-fields with unusually strong gradients. Through microwave dressing of hyperfine states, these can be used to create state-selective double-well potentials.

Q 50.19 Do 16:30 Poster C2

An ultracold gas of Rydberg atoms — •Wendelin Sprenger, Christoph Hofmann, Janne Denskat, Christian Giese, Thomas Amthor, and Markus Reetz-Lamour — Physikalisches Institut Universität Freiburg, Hermann-Herder-Str.3, 79104 Freiburg

We report on the investigation of interaction phenomena in ultracold Rydberg gases. ^{87}Rb atoms are confined in a magneto-optical trap and excited into Rydberg levels via a two-photon process (780 nm and 480 nm). We present experimental details and results of the latest work. This includes coherent Rabi oscillations between ground and Rydberg state [1] and stimulated rapid adiabatic passage, transferring 90% of the gas into Rydberg states [2], ionization induced by van der interatomic forces, even for systems initially exhibiting repulsive v.d.W. interaction [3,4] and the understanding of the coherent dynamics of resonant energy transfer processes [5] . We also present a proposal for studying energy transport in the presence of exciton traps [6] and for structuring the Rydberg gas.

[1] M. Reetz-Lamour *et al.*, submitted
[2] J. Deiglmayr *et al.*, Opt. Comm. 264, 293 (2006)
[3] T. Amthor *et al.*, Phys. Rev. Lett. 98, 023004 (2007)
[4] T. Amthor *et al.*, Phys. Rev. A 76, 054702 (2007)
[5] S. Westermann *et al.*, Eur. Phys. J. D 40, 37 (2006)
[6] O. Mülken *et al.*, Phys. Rev. Lett. 99, 090601 (2007)

Q 50.20 Do 16:30 Poster C2

Apparatus for all optical probing of Rydberg states — •Harald Kübler, Tim Van Boxtel, Stefan Müller, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany

We present an apparatus for all optical probing of Rydberg states in a dense atomic sample, trapped in a crossed CO_2 laser trap. We implemented electrical field control which allows us to apply complex field configurations on the atoms.

The apparatus offers an excellent numeric aperture for the detection of Rydberg states via light (in contrast to detection via field ionization). For this we will use electromagnetically induced transparency on the usual 5S-5P absorption line via coherent coupling to a highly excited Rydberg state[1]. We present first Rydberg EIT experiments.

[1] A. K. Mohapatra, T. R. Jackson, C. S. Adams: Coherent optical detection of highly excited Rydberg states using electromagnetically induced transparency

Q 50.21 Do 16:30 Poster C2

State-Selective Transport of Single Caesium Atoms — •Leonid Förster, Michał Karski, Daniel Döring, Florian Grenz, Arne Härter, Wolfgang Alt, Jai-Min Choi, Artur Widera, and Dieter Meschede — Institute for Applied Physics, University of Bonn

The state-selective quantum transport of single neutral atoms in optical lattices offers a promising alternative to implement basic modules of advanced schemes in the context of quantum engineering. These range from the implementation of so called quantum walks, utilizing fundamental quantum effects involving spatial quantum interference to the preparation of so-called cluster states using coherent cold collisions as an inter-qubit interaction.

We investigate systems of single Caesium atoms stored, one by one, in a state-dependent one-dimensional optical lattice. It is formed by a superposition of two standing wave dipole traps with right- and left-handed circular polarisation respectively. They can be shifted with respect to each other. With an appropriate wave length, each of the two lattices couples to a different hyperfine state. Therefore, atoms prepared in these qubit states can be transported in opposite directions. Using microwave pulses in the presence of magnetic field gradients, the internal states can be separately manipulated.

We present the current state of the experimental realisation of a one-dimensional quantum transport for Caesium atoms, focussing on the experimental setup and the tools for the preparation and manipulation of individual qubit states and their spatial detection.

Q 50.22 Do 16:30 Poster C2

Measuring the coupling strength of single atoms to the field of a high-finesse optical resonator — •Tobias Kampschulte, Wolfgang Alt, Mkrtych Khudaverdyan, Karim Lenhard, Sebastian Reick, Karsten Schörner, and Dieter Meschede — Institut für Angewandte Physik, Wegelerstr. 8, D-53115 Bonn

Cavity QED experiments provide unique possibilities for studying atom-photon interactions at a fundamental level. In our experiment we investigate the coupling of a small number of neutral caesium atoms to the mode of a high-finesse optical cavity ($\mathcal{F} = 10^6$).

Using a number-triggered loading process we transfer a predetermined number of atoms, ranging from a single atom to several atoms, from a magneto-optical trap into a standing wave dipole trap. Subsequently, the atoms are transported into the center of the cavity mode with submicrometer precision using the dipole trap as an optical conveyor belt.

Of fundamental importance for the implementation of any controlled atom-cavity interaction is the knowledge of the atom-cavity coupling strength $g(\vec{r})$. It is equivalent to the energy splitting of the cavity mode when an atom is present. The splitting can be measured by taking a transmission spectrum of a weak probe laser beam going through the cavity. A different approach is the detection of the change of the atomic state induced by the probe laser when it is resonant with a mode of the coupled atom-cavity system.

The controlled and deterministic coupling of single atoms to the mode of a cavity is an important step towards cavity-enhanced atom-atom interaction, a basic ingredient of quantum information processing.

Q 50.23 Do 16:30 Poster C2

Manipulation of a quantum particle in a rapidly oscillating potential by phase hops — Armin Ridinger[1] and •Christoph Weiss[1,2] — [1]Laboratoire Kastler Brossel, École Normale Supérieure, Université Pierre et Marie-Curie-Paris 6, CNRS — [2]Institut für Physik, Universität Oldenburg

We show that the state and the energy of a quantum particle trapped by a rapidly oscillating potential can be significantly manipulated in a controlled fashion by instantaneously changing the phase of the potential (a phase hop). We demonstrate our results for the case of the ideal one-dimensional Paul-trap.

Q 50.24 Do 16:30 Poster C2

Spectroscopy of two-photon resonances in a single-atom-cavity system — •Alexander Kubanek, Ingrid Schuster, Andreas Fuhrmanek, Thomas Puppe, Pepijn Pinkse, Karim Murr, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Strong coupling of a single atom to a single mode of an optical cavity leads to an energy level structure consisting of a ladder of doublets, the lowest of which is known as the normal-mode splitting. Here we show additional resonances in the transmission spectrum stemming from multi-photon transitions to higher doublets, which exhibit a nonlinear response to a change of probe intensity. To explain the details of the spectra, we need to take into account the micromotion of the atom which is localized in the mode by means of an auxiliary intracavity dipole trap. For this reason, we perform Monte-Carlo simulations on the dynamics of a trapped atom in a driven cavity. We calculate atomic trajectories by combining the Langevin equation of motion for the atom's center of mass with the internal dynamics of a two-state atom coupled to a quantized mode. In this way, we are able to match theory and experiment. Additionally, we show that a classical treatment of the field following Maxwell's equations fails to reproduce the data, regardless of whether the atom is modelled as a harmonic oscillator or as a two-state particle. This shows that the observed nonlinearity cannot be attributed to saturation effects, but is of quantum origin.

Q 50.25 Do 16:30 Poster C2

A freely falling magneto-optical trap drop tower experiment — •Thorben Könemann[1], Hansjörg Dittus[1], Tim van Zoest[2], Ernst Maria Rasel[2], Wolfgang Ertmer[2], Wojciech Lewoczko-Adamczyk[3], Achim Peters[3], Anika Vogel[4], Kai Bongs[4], Klaus Sengstock[4], Endre Kajari[5], Reinhold Walser[5], and Wolfgang Peter Schleich[5] — [1]ZARM, University of Bremen — [2]IQO, Leibniz University of Hanover — [3]QOM, Humboldt-University of Berlin — [4]Institute of Laser-Physics, University of Hamburg — [5]Institute of Quantum Physics, University of Hamburg

We experimentally demonstrate the possibility of preparing ultracold atoms in the environment of weightlessness at the earth-bound short-term microgravity laboratory Drop Tower Bremen. Our approach is based on a freely falling magneto-optical trap (MOT) drop tower experiment performed within the ATKAT collaboration (Atom-Catapult) as a preliminary part of the QUANTUS pilot project (Quantum Systems in Weightlessness) pursuing a Bose-Einstein condensate (BEC) in microgravity at the drop tower. We give a complete account of the specific drop tower requirements and present the results of the realized freely falling MOT and further accomplished experiments during several drops.

Q 50.26 Do 16:30 Poster C2

An Internet Controlled BEC Experiment — •Nadine Meyer, Anika Vogel, Kai Bongs, and Klaus Sengstock — Institut für Laserphysik, Universität Hamburg, Germany

In our project we present the fascinating world of cold atoms and Bose-Einstein condensation to students all over the world. In the experiment all relevant parameters including laser locking, laser power monitoring are internet controllable. The setup has only little need of maintenance, as we use the laser system designed in our QUANTUS collaboration (talk Q22.7) and an atom chip for a compact setup. In addition to a theoretical introduction to the field, there are animations and simulations for the users to work on. The project is funded by the Multimedia Kontor Hamburg.

Q 51: Poster Ultrakalte Moleküle

Zeit: Donnerstag 16:30–19:00 Raum: Poster C2

Q 51.1 Do 16:30 Poster C2

Towards an ultracold gas of polar molecules — •Karin Mörtlbauer, Christian Glück, Jörg Lange, Johannes Deiglmayr, Anna Grochola, Roland Wester, and Matthias Weidemüller — Albert-Ludwigs Universität, Physikalisches Institut, Hermann-Herder-Str. 3, 79104 Freiburg i.Brsg., Germany

We recently demonstrated the formation of ultracold LiCs molecules by the trapping light of a double species magneto optical trap [1] and also achieved the active photoassociation of dipolar LiCs molecules in the same setup. In order to create a stable and large ensemble of ultracold LiCs molecules, we will form the molecules in an optical dipole trap [2] and transfer them into the absolute ro-vibrational ground state relying on a Raman-type relaxation scheme and radiative decay. Estimates for the transfer efficiency are derived and the current status of the experimental setup is described.

[1] S. D. Kraft *et al.*, J. Phys. B **39**, S993 (2006)
[2] M. Mudrich *et al.*, PRL **88**, 253001 (2002)

Q 51.2 Do 16:30 Poster C2

Photoassociation of ultracold atoms by shaped ultrashort pulses — •Simone Götz[1], Wenzel Salzmann[1], Terry Mullins[1], Magnus Albert[1], Judith Eng[1], Roland Wester[1], Matthias Weidemüller[1], Andrea Merli[2], Fransizka Sauer[2], Fabian Weise[2], Steffan Weber[2], Mateusz Plewicki[2], Ludger Wöste[2], and Albrecht Lindinger[2] — [1]Physikalisches Institut, Universität Freiburg, Herrmann-Herder-Str.3, 79104 Freiburg — [2]Institut für Physik, Freie Universität Berlin, Arnimallee 14, D-14195 Berlin

We present experiments on the photoassociation (PA) of ultracold atoms using shaped femtosecond laser pulses. In a pump-probe scheme, molecules are produced in am excited state from an ultracold gas of ^{85}Rb atoms, are ionized and mass selectively detected. Pump-pulses are shaped to suppress atomic losses from the trap [1] and address only bound molecular states. The molecular ion signal shows rich coherent interactions between the molecules and the electric field. Quantum dynamical simulations accompany the data, providing detailed insight into the process. Wavepacket motion is a requirement for proposed PA into ground states [2] and was not observed due to rapid wavepacket dispersion. We circumvent this by the use of picosecond pulses with a more suitable bandwidth that is closely matched to the free-bound Franck-Condon factors. A new pulse-shaper design allows high-resolution shaping of such pulses and thus application of coherent control techniques to the PA process in the perturbative domain.

[1] W. Salzmann et al., PRA 73, 023414 (2006)
[2] C. Koch et al., PRA 73, 043409 (2006)

Q 51.3 Do 16:30 Poster C2

Formation of Ultracold Ground State Molecules with a Single Short Laser Pulse — •Ruzin Aĝanoĝlu and Christiane P. Koch — Freie Universität zu Berlin, Institut für Theoretische Physik, Arnimallee 14, 14195 Berlin

Bringing ultracold systems and coherent control schemes together is a promising subject of current research. One method to combine ultracold and ultrafast is photoassociation where two colliding atoms are transferred to an electronically excited state coherently with a short laser pulse. Already after a single pulse, formation of ultracold molecules in their electronic ground state is also observed. This is due to the change of the initial scattering wavefunction which leads to molecules in very weakly bound levels of the electronic ground state.

Here we study the creation of ground state molecules with a single short laser pulse. Since the molecule formation is desired only in the electronic ground state, an excited state is chosen with a repulsive potential and the short laser pulse is blue detuned for excitation.The laser parameters can be chosen such that atoms far from each other are blown away while atoms very close to each other are kept and form molecules.

The initial thermal probability density of atoms is expected to be very small at short internuclear distances. However, it can be manipulated by changing the scattering properties of the atoms. In this work an optically induced Feshbach resonance is employed to modify the initial atomic distribution prior to photoassociation by a single short pulse.

Q 51.4 Do 16:30 Poster C2

The Efimov Molecule with short and finite range potentials — •Bettina Berg[1], Lev Plimak[1], Misha Ivanov[2] und Wolfgang P. Schleich[1] — [1]Institute of Quantum Physics, Ulm University, Germany — [2]NRC, Ottawa, Canada

The Efimov effect [1,2] has always been regarded somewhat of a mystery. As there is an evergrowing interest in this problem, a simple explanation of this effect utilizing only elementary quantum mechanics appears more than desirable. We investigate the so-called Efimov molecule formed by two heavy and one light particle in the Born-Oppenheimer limit, by applying an Ansatz from “Quantum Chemistry 101” and assuming that the light particle interacts with the heavy ones via a short-range potential. The resulting molecular term exhibits the typical $1/R^2$ behaviour of a Efimov potential [3]. An extention of our method to potentials of arbitrary radius is also discussed.

[1] V. N. Efimov, *Weakly Bound States of Three Resonantly-Interactiong Particles*, Sov. J. Nucl. Phys. 12, 589-595 (1971).

[2] T. Kraemer *et al.*, *Evidence for Efimov quantum states in an ultracold gas of caesium atoms*, Nature 440, 315-318 (16 March 2006), cond-mat/0512394.

[3] L. Plimak, B. Berg, M. Ivanov, W. Schleich, *Quantum Chemistry of the Efimov Molecule*, submitted.

Q 51.5 Do 16:30 Poster C2

Few-body physics with ultracold Cs atoms and molecules — •Steven Knoop[1], Martin Berninger[1], Francesca Ferlaino[1], Harald Schöbel[1], Michael Mark[1], Hanns-Christoph Nägerl[1], and Rudolf Grimm[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Innsbruck, Austria

Ultracold atomic gases are versatile systems to study few-body physics because of full control over the external and internal degrees of freedom and the magnetic tunability of the scattering properties using Feshbach resonances. Here we experimentally study three- and four-body physics by investigating ultracold (30-250 nK) atom-dimer and dimer-dimer collisions with Cs Feshbach molecules in various molecular states and Cs atoms in different hyperfine states. Resonant enhancement of the atom-dimer relaxation rate is observed in a system of three identical bosons and interpreted as being induced by a trimer state, possibly an Efimov state. A strong magnetic field dependence of the relaxation rate is also observed when the atoms are transferred to a different hyperfine sublevel [1]. For dimer-dimer collisions we have observed an unexpected temperature dependence and a suppression of the collisional loss rate [2].

[1] S. Knoop et al., in preparation [2] F. Ferlaino et al., in preparation

Q 51.6 Do 16:30 Poster C2

Ultracold Cesium Feshbach Molecules — •Martin Berninger[1], Steven Knoop[1], Francesca Ferlaino[1], Harald Schöbel[1], Michael Mark[1], Hanns-Christoph Nägerl[1], and Rudolf Grimm[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Innsbruck, Austria

We present our recent work on ultracold Cesium Feshbach molecules in an optical dipole trap. We have implemented a new crossed-beam laser trap, which traps atoms and molecules simultaneously. By scanning one laser beam the ellipticity can be dynamically tuned for an optimal trap configuration. We routinely prepare ultracold mixed atomic and molecular or pure molecular samples at temperatures down to 30 nK [1]. We selectively populate Feshbach molecules in various s-, d-, g- and even l-wave states [2]. We have experimentally demonstrated that the l-wave dimers can be stable against spontaneous decay on the timescale of one second well above the dissociation threshold [3]. We have recently implemented the technique of resonantly modulated magnetic field spectroscopy [4]. Transitions between the atomic continuum and dimer states, and vice versa, as well as dimer-dimer transitions can be driven. Our main motivation is to apply this technique to search for trimer and tetramer states, whose presence has been indicated by resonances in collisional loss measurements.

[1] F. Ferlaino et al., in preparation; [2] M. Mark et al., Phys. Rev. A 76, 042514 (2007); [3] S. Knoop et al., arXiv:0710.4052; [4] T. M. Hanna et al., Phys. Rev. A 75, 013606 (2007)

Q 52: Poster Materiewellenoptik

Zeit: Donnerstag 16:30–19:00 Raum: Poster C2

Q 52.1 Do 16:30 Poster C2

Berry phase in atom optics — •Polina V. Mironova, Maxim A. Efremov, and Wolfgang P. Schleich — Institut für Quantenphysik, Universität Ulm, Ulm, Germany

We suggest a scheme to observe the Berry phase using the atomic external degrees of freedom. We consider two consecutive interactions of an atom with a near-resonant standing light waves. An atom is scattered by a standing wave, which is formed by two red-detuned traveling light waves, $\Delta < 0$, with wave vectors $\mathbf{k}_1$ and $\mathbf{k}_2$, $|\mathbf{k}_1| = |\mathbf{k}_2| = k$, $\measuredangle(\mathbf{k}_1, \mathbf{k}_2) = 2\alpha$. Afterwards, the atom is scattered by a second standing wave, which is formed by two blue-detuned traveling light waves, $\Delta > 0$, with wave vectors $\mathbf{k'}_i/|\mathbf{k'}_i| = -\mathbf{k}_i/|\mathbf{k}_i|$, $i = 1, 2$. We assume that both interactions turn-on and turn-off adiabatically. Within the rotating wave approximation and the adiabatic approximation on the atomic center-of-mass motion we obtain that the final state of the atom differs from the initial state of the atom only by twice the familiar Berry phase, which depends on the atomic external degrees of freedom. The dynamical phase is cancelled out and the scattering picture is determined only by the atomic center-of-mass position.

Q 53: Poster Photonik

Zeit: Donnerstag 16:30–19:00 Raum: Poster C2

Q 53.1 Do 16:30 Poster C2

Fluoreszenzlebensdauer von Quantenpunkten und Laserfarbstoffen in Photonic-Crystal-Fasern — •Peter Keller und Fedor Mitschke — Universität Rostock, Institut für Physik, Experimentalphysik: Optik, 18051 Rostock

Photonic-Crystal-Fasern mit Hohlkern (HC-PCF) können für einige neue Anwendungen (z.B. Sensorik) mit Gasen oder Flüssigkeiten gefüllt werden [1]. In diesem Beitrag wird neben dem Fluoreszenzspektrum vor allem die Fluoreszenzlebensdauer von Quantenpunkten und Laserfarbstoffen untersucht, die in Lösungsmittel gelöst in den zentralen Kern, aber nicht in die Braggstruktur, einer HC-PCF eingebracht sind. Wir regen die befüllte Faser mit 250fs-Pulsen aus einem frequenzverdoppelten Ti:Sa-Laser an. Während die Laserfarbstoffe keinerlei verändertes Fluoreszenzverhalten zeigen, ist bei den Quantenpunkten zum Teil eine deutliche Verkürzung der Lebensdauer zu beobachten. Diese Verkürzung ist abhängig von der Pumpintensität und der Einwirkdauer.

[1] J. M. Fini, Meas. Sci. Technol. **15**, 1120 (2004)

Q 53.2 Do 16:30 Poster C2

Frequency Tripling and Interferometric Sensing with Ultra-Thin Optical Fibers — •Ulrich Wiedemann, Konstantin Karapetyan, Wolfgang Alt, and Dieter Meschede — Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, 53115 Bonn

We present the first results and the perspectives of our work devoted to investigation of ultra-thin optical fiber applications.

Our first goal is to achieve effective third harmonic generation (THG) using an ultra-thin fiber, which allows for light guidance over a large length while keeping the spot size small. In case of sub-wavelength fibers a significant portion of the power propagates outside the fiber, in the evanescent field. This high intensity light field in the space around the fiber is coupled to atoms with high third order nonlinearity to provide THG. To phase-match the fundamental and the frequency-tripled waves we compensate material dispersion with modal dispersion.

The second goal is to create an interferometric fiber sensor, in which the two legs of Mach-Zehnder scheme are represented by two different transverse fiber modes. One mode has a smaller evanescent field intensity than the other one, leading to different degree of influence of the surrounding medium on the optical path length. The two coherent modes are obtained and recombined using either non-adiabatic taper transition or long period fiber gratings.

For both experiments we are using standard single-mode fibers tapered down to diameters of about 500 nm at the length of 1–20 mm by flame-heating and stretching.

Q 53.3 Do 16:30 Poster C2

Einfluss von Belichtungsparametern bei schreibender Excimerlaserbelichtung auf die Indexmodifikation von PMMA — •Hauke Höppner, Sebastian Huber, Ortwin Siepmann, Volker Braun, Sabine Tiedeken, Ulrich Teubner und Hans Josef Brückner — FH OOW - Emden, Niedersachsen, Deutschland

Die Absorption von UV-Strahlung führt in PMMA unterhalb von ca. 260 nm zum Aufbrechen von Molekülbindungen und zur Erhöhung des optischen Brechungsindexes. Es ist zu beobachten, dass sich bei Erhöhung der Leistungsdichte das Absorptionsverhalten und die Form eines lokal erzeugten Indexprofils ändert. Dies ist insbesondere bei der Herstellung optischer Wellenleiter durch schreibende Excimerlaserbelichtung kritisch, da zur Reduzierung der Herstellungszeit mit hohen Leistungsdichten unterhalb der Ablationsschwelle gearbeitet wird. Der Einfluss von Belichtungsparametern wie Gesamtdosis und Leistungsdichte auf die Indexmodifikation und die Führungseigenschaften von optischen Wellenleitern wird dargestellt.

Q 53.4 Do 16:30 Poster C2

Design von Mikroresonatoren in photonischen Kristallen in Diamant — •Janine Riedrich-Möller, Roland Albrecht, Elke Neu und Christoph Becher — Universität des Saarlandes, Fachrichtung 7.3, Technische Physik, Campus E 2.6, 66123 Saarbrücken

Optisch aktive Farbzentren in Diamant sind vielversprechende Kandidaten für die Realisierung von Konzepten der Quanteninformationsverarbeitung. Für den Einsatz in Quantencomputern [1], sowie in der Quantenkryptographie [2] ist die Ankopplung des Farbzentrums an die Mode eines Resonators hoher Güte wünschenswert. Zur Realisierung dieser Ankopplung betrachten wir Mikroresonatoren in zweidimensionalen photonischen Kristallen in Diamantfilmen. Die zeitliche und räumliche Lokalisierung der Feldverteilung ist sowohl abhängig von dem Design eines solchen Mikroresonators wie auch von der Absorption des verwendeten Materials. Wir stellen Strategien zur Optimierung des Gütefaktors Q verschiedener Resonatorstrukturen anhand von Simulationen zur Lösung der Maxwell-Gleichungen im Zeit- und Frequenzraum (FDTD) vor. Zudem diskutieren wir den Einfluss von Verlusten im Material, sowie die mögliche experimentelle Realisierung von photonischen Kristallen in Diamant.

[1] Lim et al. Phys. Rev. A **73**, 012304 (2006)
[2] Beveratos et al. Phys. Rev. Lett. **89**,187901(2002)

Q 53.5 Do 16:30 Poster C2

Selective excitation of magnetic and electric resonances in single split-ring resonators with polarization tailored light — •Peter Banzer[1], Susanne Quabis[1], Ulf Peschel[1], Gerd Leuchs[1], Stefan Linden[2], Nils Feth[2], and Martin Wegener[3] — [1]Max Planck Research Group, Institute of Optics, Information and Photonics, Erlangen, Germany — [2]Institut für Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft, Karlsruhe, Germany — [3]Institut für Angewandte Physik and DFG-Center for Functional Nanostructures, Universität Karlsruhe, Karlsruhe, Germany

Metamaterials consist of building-blocks which can be seen as artificial atoms. Especially the magnetic response of these sub-structures is important if one wants to achieve extraordinary material properties like negative permeability. Therefore we investigate experimentally the pure magnetic coupling to the magnetic resonance of single splitring resonators (SRR) in the optical regime. Therefor we use strongly focused azimuthally polarized light. It provides an ideal polarization pattern on a sub-wavelength scale for studying the magnetic resonance behaviour of single SRRs. If a SRR is placed in the centre of the focal spot the pure longitudinal magnetic field component points perpendicular to the SRR plane. In the resonant case, the magnetic field can excite a magnetic dipole. By displacing the SRR in the focal spot, one can also couple to magnetic and electric resonances via transversal electric fields (for corresponding wavelengths). In the transmitted light, one can search for fingerprints of the excited magnetic dipole.

Q 53.6 Do 16:30 Poster C2

Spektroskopie und nichtlineare Optik in photonischen Hohlfasern — •Christoph Brenker, Jan Klärs, Frank Vewinger und Martin Weitz — Institut für Angewandte Physik, Wegelerstraße 8, 53115 Bonn

Photonische Hohlfasern erfahren in letzter Zeit ein wachsendes Interesse in der Spektroskopie [1] und der Untersuchung nichtlinearer Prozesse [2],[3]. Die kleine Strahltaille in der Faser von wenigen Mikrometern bei einer Wechselwirkungslänge von mehreren Metern ermöglicht eine sehr hohe Sensitivität. Für nichtlineare Prozesse bietet sie durch die Fokussierung über die gesamte Länge optimale Voraussetzungen.

Wir berichten über Ergebnisse zur Spektroskopie in hohlen photonischen Fasern, die mit Stickstoffdioxid gefüllt wurden. Auch wird über den Stand von Experimenten zur Erzeugung von Seitenbändern durch Vier-Wellen Mischung berichtet. Wir stellen Faserstrukturen vor, deren optimierte Dispersionsrelation eine Überhöhung von nichtlinearen Prozessen erwarten lässt.

[1] J.Henningsen, J.Hald and J.C.Petersen: Saturated absorption in acetylene and hydrogen in hollow-core photonic bandgap fibers, Optics Express 13,10475 (2005)

[2] P.S. Light, F.Benabid and F.Couny Electromagetically induced transparency in Rb-filled coated hollow-core photonic crystal fiber, Optics Letters 32,1323 (2007)

[3] S.O. Konorov, A.B.Fedotov and A.M. Zheltikov, Enhanced fourwave mixing in a hollow-core photonic-crystal fiber, Optics letters 28,1448 (2003)

Q 53.7 Do 16:30 Poster C2

Linear and nonlinear optics in curved space — •Sascha Batz, Henrike Trompeter, and Ulf Peschel — Max Planck Research Group of Optics, Information and Photonics, Günther-Scharowsky-Str. 1 / Bau 24, 91058 Erlangen

In the past nonlinear optics was restricted to homogenous Euclidean space. However, completely new effects occur if the curvature of space starts to play a role. In optics we can investigate related phenomena if we abandon one spatial dimension and restrict wave propagation to a two-dimensional manifold. Using the tools provided by the theory of general relativity we established a mathematical model for the propagation of light on a curved surface with arbitary curvature. Here we focus on surfaces with constant Gaussian curvature. A sphere with a film waveguide on it is an example for a space of constant positive curvature. Here already the linear wave propagation deviates from that in flat space. It is characterized by periodic refocusing caused by a quantization into discrete modes with constant wavenumber spacing. If the power is increased solitons appear as nonlinear extension of these discrete linear modes. They show a distinct stability behavior deviating considerably from that of their counterparts in flat space. The theoretical model developed to describe wave propagation on curved surfaces shows some interesting similarities with nonlinear systems e.g. dispersion management in optical fibers and solitons in trapped Bose-Einstein condensates. Symmetry transformations derived for wave propagation in curved space can likewise be applied to other systems, thus generating new solutions.

Q 53.8 Do 16:30 Poster C2

Präparation von photonischen Hohlkernfasern zum selektiven Befüllen mit Materialien hoher optischer Nichtlinearität — •Dirk Puhlmann[1], Markus Gregor[2] und Martin Ostermeyer[1] — [1]Institut für Physik, Universität Potsdam, Am Neuen Palais 10, 14469 Potsdam — [2]Institut für Physik, Humboldt-Universität zu Berlin, Hausvogteiplatz 5-7, 10117 Berlin

Photonische Hohlkernfasern können mit Materialien hoher optischer Nichtlinearität befüllt werden. Auf diese Art werden sie zu interessanten Lichtquellen für eine Reihe von Anwendungen. Es ist jedoch beim Befüllen des Faserkerns mit z.B. einer Flüssigkeit Sorgfalt geboten, um zu verhindern, daß die Löcher der Ummantelung mit befüllt werden und somit die lichtleitenden Eigenschaften der Faser stark modifiziert oder gar zerstört werden. Um dieses Problem zu lösen, haben wir einen alternativen Ansatz gewählt. Zunächst wurde ein Ende der Faser komplett (Kern und Ummantelung) mit einem positiv Fotolack befüllt. Daraufhin haben wir den Lack durch das andere, noch offene Ende der Faser belichtet. Da der geführte Mode in der photonischen Faser deutlich im Faserkern konzentriert ist, wird dabei nur der Lack belichtet, der den Kern verstopft. In der Folge kann der belichtete Lack mit Hilfe eines Entwicklers wieder "ausgewaschen" werden. Die Faser ist nun bereit mit der gewünschten Flüssigkeit hoher Nichtlinearität befüllt zu werden, da der Kern "frei" ist, die Löcher der Ummantelung jedoch noch durch den Lack besetzt sind. Die Probleme die bei dieser Technik auftreten sowie unsere Lösungsansätze werden präsentiert.

Q 53.9 Do 16:30 Poster C2

Optimierung eines nichtlinearen verstärkenden Schleifenspiegels zur Amplitudenregeneration phasenkodierter optischer Signale — •Tobias Röthlingshöfer[1], Klaus Sponsel[1], Kristian Cvecek[1], Christian Stephan[1], Georgy Onishchukov[1], Bernhard Schmauss[2] und Gerd Leuchs[1] — [1]Institut für Optik, Information und Photonik, Abteilung I, Universität Erlangen-Nürnberg — [2]Lehrstuhl für Hochfrequenztechnik, Universität Erlangen-Nürnberg

In der optischen Datenübertragung werden mehr und mehr phasenkodierte Modulationsformate eingesetzt. Durch nichtlineare Effekte in Übertragungsfasern, wie Selbstphasenmodulation, wird jedoch Amplitudenrauschen in nichtlineares Phasenrauschen umgewandelt und beeinträchtigt so besonders phasenkodierte Signale.

Es wird gezeigt, daß die Amplituden-Regeneration von phasenkodierten optischen Datenformaten, wie z.B. Differential Phase-Shift Keying" (DPSK), mit Hilfe eines modifizierten Faser-Sagnac Interferometer z.B. Nonlinear Amplifying Loop Mirror (NALM), möglich ist. Dadurch wird die Generation von nichtlinearem Phasenrauschen unterdrückt, ohne daß die Phasenkodierung der Daten zerstört wird.

Q 53.10 Do 16:30 Poster C2

Towards tunable high-Q whispering-gallery-mode resonators — •Michael Pöllinger, Danny O'Shea, Florian Warken, and Arno Rauschenbeutel — Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz

We present experimental results on the fabrication and characterization of tunable whispering-gallery-mode resonators. These so-called bottle resonators are highly prolate and exhibit an advantageous mode geometry and spectrum [1]. They are realized from glass fibers, which are flame heated and elongated to produce a 15 μm diameter waist. The resonator structure is then obtained by focused CO_2 laser heating. The resonators are spectrally characterized in a setup where light is coupled in and out by means of micron sized coupling fibers. Furthermore, this setup allows us to tune the resonance frequency by applying mechanical strain. Tuning over more than one free spectral range and quality factors in the $Q = 10^6$–10^7 range have been observed.
Our current efforts aim at enhancing Q. Therefore, we fabricate resonators from different ultra-pure commercial glass fibers, investigate the surface properties by TEM imaging and quantitatively investigate the spatial mode structure of the resonator. Achieving Q-factors in the 10^8–10^9 range together with the special features of the resonator would open interesting perspectives for cQED experiments and ultralow-power optical switches.
We acknowledge financial support by the DFG research unit 557.
[1] Y. Louyer, D. Meschede, and A. Rauschenbeutel, Phys. Rev. A 72, 031801(R) (2005).

Q 53.11 Do 16:30 Poster C2

Evaneszente Felder von ZnO Nanodrähten und Nano-Fasern — •Sandra Börner, Marcel Bremerich, Farzaneh Fattahi und Wolfgang Schade — Insitut für Physik und Physikalische Technologien, Leibnizstr. 4, 38678 Clausthal-Zellerfeld

Optische Fasern mit Durchmessern im Mikrometer-Bereich oder ATR-Elemente werden unter Ausnutzung einer evaneszenten Wechselwirkung mit umgebenden Medien, wie z.B. Gasen oder Flüssigkeiten, zur Detektion im nahen infraroten oder mittleren infraroten Spektralbereich genutzt. Nanodrähte oder -fasern bieten eine effiziente Alternative. Da sie in einer Dimension eine Ausdehnung im Nanometerbereich besitzen, sind sie kleiner als die üblich genutzten Wellenlängen. Ein großer Teil des Lichtes wird dadurch als evaneszentes Feld außerhalb der Strukturen geführt. Infolge dessen wird die Wechselwirkung mit dem umgebenden Medium erhöht. Die Wellenleitereigenschaften von ZnO Nanodrähten wurden simuliert und hinsichtlich ihrer evaneszenten Eigenschaften analysiert. Die theoretischen Resultate können mit Hilfe optischer Mikroskopie bestätigt werden. Zusätzlich wurden herkömmliche Quarz-Fasern durch systematisches Erhitzen und Ziehen bearbeitet, um eine Verjüngung in den nm-Bereich zu erreichen. Diese wurden hinsichtlich ihrer Transmissions- und Wellenleitungseigenschaften untersucht. In Zukunft sollen diese Erkenntnisse der Entwicklung und Verbesserung optischer Sensorsysteme dienen.

Q 54: Poster Laserentwicklung

Zeit: Donnerstag 16:30–19:00 Raum: Poster C2

Q 54.1 Do 16:30 Poster C2

Eine flexible, gepulste Lichtquelle auf Basis eines ns-Titan:Saphir Lasers — •Diana Wendland, Daniel Depenheuer, Thorsten Führer und Thomas Walther — TU Darmstadt, Institut für angewandte Physik, Laser- und Quantenoptik, Schlossgartenstr. 7, 64297 Darmstadt

Vorgestellt wird ein ns-Titan:Saphir Lasersystem, das als flexible Lichtquelle konzipiert ist. Durch die Verwendung eines kleinen Resonators konnten sehr kurze und konstante Buildup Zeiten erreicht werden. Dies ermöglicht es den Spektralbereich des Lasers nicht nur durch die Erzeugung höherer Harmonischer, sondern auch durch Summen- und Differenzfrequenzmischen mit dem Pumppuls stark zu erweitern. Dieser ist sowohl nach unten, als auch nach oben nur durch die Verfügbarkeit von Konversionskristallen beschränkt und ist Aufgrund des grossen Abstimmbereichs von Titan:Saphir nahezu lückenlos.

Q 54.2 Do 16:30 Poster C2

Ein schmalbandiger cw-Titan:Saphir Laser mit resonatorinterner Frequenzverdopplung — •Ulrich Jäger, Christoph Burandt und Thomas Walther — Laser- und Quantenoptik, Institut für Angewandte Physik, Technische Universität Darmstadt

Vorgestellt wird ein cw-Titan:Saphir Laser in Bow-Tie Konfiguration. Eine Durchstimmbarkeit von 816 nm bis 873 nm ist mittels eines Lyotfilters möglich. Durch zusätzliches injection-seeding wird ein schmalbandiger Betrieb bei 871,6 nm erreicht. Eine Frequenzverdopplung auf 435,8 nm wird resonatorintern mit einem BBO-Kristall realisiert. In der zweiten Harmonischen können Ausgangsleistungen von über 5 mW erreicht werden. Das System ist für spektroskopische Anwendungen an Quecksilber konzipiert. Berichtet wird über den aktuellen Entwicklungsstand.

Q 54.3 Do 16:30 Poster C2

Entwicklung eines regenerativen Ti:Saphir-Verstärkersystems auf 761 nm und 789 nm zum Nachweis von Hg in einer MOT — •Alexander Bertz, Andrea Golla und Thomas Walther — TU Darmstadt, Institut für angewandte Physik, Laser und Quantenoptik

Wir stellen ein regeneratives Ti:Saphir-Verstärkersystem vor, welches für die synchrone Emission von fourierlimitierten ns-Pulsen der Wellenlängen 761 nm und 789 nm ausgelegt ist. Durch resonatorexterne Frequenzkonversionsprozesse wird Strahlung der Wellenlängen 253,7 nm bzw. 197,3 nm erzeugt, die für den Photoionisationsnachweis von Hg-Dimeren in einer magneto-optischen Falle mittels eines linearen Time-of-Flight-Massenspektrometers verwendet werden soll.

Q 54.4 Do 16:30 Poster C2

Spektroskopie Pr-dotierter Oxide — •Nicky Thilmann, André Richter, Friedjof Tellkamp, Klaus Petermann und Günter Huber — Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Es wurden mittels Czochralski-Zucht Praseodym (Pr) dotierte oxidische Kristalle hergestellt und spektroskopisch untersucht. Die Granatkristalle $Y_3Ga_5O_{12}$ (YGG) und $Gd_3Ga_5O_{12}$ (GGG) weisen eine kubische Kristallstruktur auf und haben schon mit Nd als aktivem Ion effiziente Lasertätigkeit gezeigt. Daher erscheint die Nutzung dieser Wirtsmaterialien für diodengepumpte Pr-Laser aussichtsreich.

Der Peakabsorptionswirkungsquerschnitt liegt in der Größenordnung von mehren $10^{-20}\,\mathrm{cm}^2$ bei einer Wellenlänge von 450 nm. Die größten Emissionswirkungsquerschnitte betragen $1{\cdot}10^{-19}\,\mathrm{cm}^2$ bei einer Wellenlänge von 742 nm. Diskrete strahlende Übergänge unter Laserdiodenanregung in das $^3P_2$ - Niveau erfolgen im gesamten Spektralbreich von 485 nm bis 750 nm. Die Lebensdauer des $^3P_0$- Multipletts beträgt bei Raumtemperatur 24 μs. Um eine Abschätzung der Laserschwelle vornehmen zu können, werden die spektroskopischen Daten mit denen Pr-dotierter Fluoride verglichen. Ferner wird über die ersten spektroskopischen Daten von Pr:$GdScO_3$ berichtet.

Q 54.5 Do 16:30 Poster C2

Optimierung und Verbesserung eines ECDLs durch nichtlineare Stromnachführung und Einsatz eines LC-Segments — •Denise Stang, Thorsten Führer und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, AG Laser und Quantenoptik, Schlossgartenstr. 7, D-64289 Darmstadt

In der Spektroskopie und als Seed-Quelle für leistungsstarke Laser werden häufig ECDLs eingesetzt. Hierfür sind möglichst große modensprungfreie Abstimmbereiche und eine große Stabilität von Vorteil. Daher werden neben einer zuverlässigen Modensprung-Detektion Möglichkeiten zur Stabilisierung der Modenselektion benötigt. Damit während der Änderung der Wellenlänge stets die gleiche Mode dominiert, müssen die Modenabstände des internen und externen Resonators entsprechend geändert werden.

Dies wird im präsentierten Aufbau für den externen Resonator durch eine Längenänderung mittels Piezoaktoren, für den internen Resonator mittels einer Änderung des Laserdiodenstroms realisiert. Da die Ausdehnung der Piezoaktoren nichtlinear von der Spannung abhängt, wird der Strom ebenfalls nichtlinear nachgeführt und dadurch der Durchstimmbereich vergrößert. Ferner wird gezeigt, dass auch eine gezielte Modulation der rückgekoppelten Intensität in die Laserdiode anstelle der Änderung des Laserdiodenstroms ein modensprungfreies Durchstimmen ermöglicht. Diese Modulation wird aufgrund der polarisationsabhängigen Beugungseffizienz des Gitters durch einen Polarisationsrotator auf Flüssigkristallbasis erreicht.

Q 54.6 Do 16:30 Poster C2

Untersuchung von getrennt kontaktierten Trapezlaserdioden im externen Resonator — •Andreas Jechow und Ralf Menzel — Universität Potsdam, Institut für Physik, Photonik, Am Neuen Palais 10, 14469 Potsdam

Trapezlaserdioden zeigen bei etwa gleicher Effizienz gegenüber Breitstreifenlaserdioden deutlich verbesserte räumliche Strahlqualität und liefern optischen Ausgangsleistungen von mehreren Watt [1].

Mithilfe von externen Resonatoren ist es möglich auch die spektralen Eigenschaften des Trapezlasers weiter zu verbessern. Die dadurch erreichte schmalbandige spektrale Emission und ein weiter Durchstimmbereich erschließen nichtlineare Anwendungen wie Frequenzverdopplung.

Durch die getrennte Kontaktierung von Ridge und Trapezsektion ist eine zusätzliche Leistungssteigerung bei verringertem Materialstress möglich geworden.

[1] M.T. Kelemen, J. Weber, G. Kaufel, G. Bihlmann, R. Moritz, M. Mikulla, G. Weimann, “Tapered diode lasers at 976 nm with 8 W nearly diffraction limited output power”, Electronics Letters **41**, 1011-13 (2005)

Q 54.7 Do 16:30 Poster C2

Untersuchung der Auswirkung von Materialdispersion in spektral modengekoppelten Lasern (Fourier Domain Mode Locking - FDML) — •Benjamin Biedermann, Christoph Eigenwillig und Robert Huber — Lehrstuhl für BioMolekulare Optik, Fakultät für Physik, LMU München

Bei Fourier Domain Mode Locking handelt es sich um einen neuen Operationsmodus von Lasern, bei dem nicht die Amplitude, sondern die Frequenz synchron zur Lichtumlaufzeit moduliert wird [1]. Dies ermöglicht die Realisierung von schnell abstimmbaren Lasern, welche sich mit bis zu 300kHz über einen Bereich von 150nm im nahen Infraroten abstimmen lassen. Durch diese hohe Geschwindigkeit sind FDML-Laserquellen ideal für die optische Kohärenztomographie (OCT) geeignet. Die OCT stellt ein optisches Bildgebungsverfahren dar, welches mit einer räumlichen Auflösung von wenigen Mikrometern die dreidimensionale Darstellung von Brechzahlkontrasten erlaubt und damit für medizinische Anwendungen von Bedeutung ist [2]. Materialdispersion im Resonator ist ein Problem bei FDML-Laserquellen, da sie eine gleichzeitige, perfekte Synchronisation aller Frequenzkomponenten verhindert. Im Wellenlängenbereich um 1550nm werden FDML-Laser mit unterschiedlich großer Gesamtdispersion untersucht. Die Auswirkung von Dispersion auf Rauschen, instantane Kohärenzlänge und spektrale Bandbreite wird gezeigt. Die Eignung dieser Laserquellen für OCT wird untersucht.

1. Huber R. et al. Optics Express 14:3225-3237 (2006).
2. Huang D. et al. Science 254:1178-1181 (1991).

Q 54.8 Do 16:30 Poster C2

Enhanced Four-Wave Mixing in mercury isotopes, prepared by Stark-chirped rapid adiabatic passage — •Martin Oberst, Jens Klein, and Thomas Halfmann — Institute for Applied Physics, TU Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt, Germany

We demonstrate significant enhancement of four-wave mixing (FWM) in coherently driven mercury isotopes to generate vacuum-ultraviolet radiation at 125 nm. The enhancement is accomplished by preparation of the mercury atoms in a state of maximum coherence, i.e. maximum nonlinear-optical polarization, driven by Stark-chirped rapid adiabatic passage (SCRAP). In this technique a pump laser at 313 nm excites the two-photon transition between the ground state $6s^2\ ^1S_0$ and the target state $7s\ ^1S_0$ in mercury. A strong, off-resonant radiation field at 1064 nm generates dynamic Stark shifts. These Stark shifts induce a rapid adiabatic passage process on the two-photon transition. The maximum nonlinear-optical polarization induced by SCRAP permits efficient FWM of the pump laser and an additional probe laser at 626 nm. The efficiency is further enhanced, as the SCRAP process stimulates the *complete* set of different mercury isotopes to participate in the FWM-process. This enlarges the effective atomic density of the medium. Thus, we observe the generation of vacuum-ultraviolet radiation at 125 nm enhanced by more than one order of magnitude with respect to conventional frequency conversion. Parallel to the FWM-process, we monitored the evolution of the population in the medium by laser-induced fluorescence. These data demonstrate efficient coherent population transfer by SCRAP.

Q 54.9 Do 16:30 Poster C2

Nichtlineare parametrische Konversion zu RGB direkt aus einem gütegeschalteten Oszillator — •Tino Lang[1], Matthias Pospiech[2] und Uwe Morgner[2,3] — [1]Westsächsischen Hochschule Zwickau, Deutschland — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland — [3]Laserzentrum Hannover e.V.

Aktiv gütegeschaltete Lasersysteme bieten aufgrund hoher Pulsenergien die Möglichkeit der parametrischen Konversion in diverse Wellenlängenbereiche mit hoher Effizienz. Die zweite und dritte Harmonische wurde mit den 10 ns-Pulsen mit einer Pulsenergie von 0,3 mJ (40 kHz) und einer Wellenlänge von 1064 nm erzeugt. Durch die Verwendung periodisch gepolter Kristalle in Kombination mit einem signal-resonanten optisch parametrischen Oszillator konnte mit dem übrigen fundamentalem Laserlicht von 100 nJ für die Konversion zu 1,5 μm eine Effizienz von 75 % erreicht werden. Diese hohe Effizienz ermöglicht die anschließende Konversion zu Blau und Rot mit der zuvor generierten dritten Harmonischen und der restlichen Fundamentalen. Aufgrund numerischer Simulationen werden Leistung größer 1 W pro Farbe erwartet. Wir stellen die Ergebnisse und den Vergleich mit Simulationen vor.

Q 54.10 Do 16:30 Poster C2

Tunable mid-IR CW narrowband laser source for molecular spectroscopy — •Sergey Vasilyev[1], Alexander Nevsky[1], Stephan Schiller[1], Arnaud Grisard[2], Eric Lallier[2], David Faye[2], Zhaowei Zhang[3], Deyuan Shen[3], Andrew Clarkson[3], Morten Ibsen[3], Peter Geiser[4], Axel Bohman[4], Peter Kaspersen[4], and Juan Jiménez[5] — [1]Institute for Experimental Physics, Düsseldorf, Germany — [2]Thales Research and Technology, Palaiseau Cedex, France — [3]Optoelectronics Research Centre, University of Southampton, UK — [4]Norsk Elektro Optikk, Lørenskog, Norway — [5]University of Valladolid, Spain

The objective of our research project is the development of a widely tunable (5 - 15 μm) narrowband mid-IR laser source based on a nonlinear down conversion of 1.5 - 2.0 μm laser radiation using difference frequency generation (DFG) and optical parametric generation (OPO) in a Orientation-Patterned Gallium Arsenide (OP-GaAs) crystal. The OP-GaAs combines a high nonlinearity, wide transparency range, and high thermal conductivity with merits of a quasi-phase-matching technique. Recently a method was developed for fabrication of large-size OP-GaAs structures.

Tunable mid-IR source based on the DFG between a narrowband broadly tunable EDFA (10 W) and thulium doped fiber laser MOPA (1 W) has been developed. DFG output wavelength was tunable from 7.5 μm to 8.2 μm with pm precision. Mid-IR output power of 0.1 - 0.3 mW has been measured. Spectroscopic capabilities of the mid-IR source were tested by measuring of CH_4 absorption spectra.

Q 54.11 Do 16:30 Poster C2

Emissionsrauschen eines Festkörperlasers mit resonatorinterner Frequenzverdoppelung — •Oliver Back, René Hartke, Ernst Heumann, Günter Huber, Klaus Sengstock und Valeri Baev — Institut für Laserphysik, Universität Hamburg

Das Emissionsrauschen eines frequenzverdoppelten Festkörperlasers wird durch die Anregung der Summenfrequenz bei zwei- oder mehrmodigem Laserbetrieb verursacht [1]. Wir haben festgestellt, dass die Bedingung für die Entstehung des Rauschens eine partielle Entkopplung der verfügbaren Inversion für verschiedene Moden z.B. durch räumliche Inhomogenität in der Verstärkung ist. Es ist bekannt, dass eine Verringerung des Rauschens möglich ist, wenn die Effizienz der Summenfrequenzbildung gegenüber der Frequenzverdoppelung reduziert wird [2]. Eine andere Methode zur Unterdrückung des Rauschens beruht auf der Reduzierung der Modenentkopplung, z.B. durch die Verringerung des Modenabstandes [3]. Die numerische Modellierung eines Zweimodenlasers unter der Berücksichtigung der räumlichen Inhomogenität der Verstärkung hat unsere experimentellen Ergebnisse bestätigt. Die Steuerung des Emissionsrauschen eines frequenzverdoppelten Festkörperlasers kann sowohl mit der Effizienz der Summenfrequenzbildung als auch mit der Modenentkopplung effizient erfolgen.

[1] T.Baer, J. Opt. Soc. Am. B 3, 1175 (1986)
[2] C.Czeranowsky, V.Baev, G.Huber, Opt. Lett. 28, 2100 (2003)
[3] R.Hartke, V.Baev, K.Seger, O.Back, E.Heumann, G.Huber, M.Kühnelt, U.Steegmüller, Appl. Phys. Lett. (submitted)

Q 55: Poster Laseranwendungen

Zeit: Donnerstag 16:30–19:00 Raum: Poster C2

Q 55.1 Do 16:30 Poster C2

Absorption spectroscopy of isolated molecules using sub-wavelength diameter optical fibres — •Ariane Stiebeiner, Ruth García Fernández, and Arno Rauschenbeutel — Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz

Particles on the surface of sub-wavelength diameter air-clad fibres are strongly coupled to the pronounced evanescent field of the fibre guided modes. This makes such fibres a powerful tool for absorption spectroscopy of surface-adsorbed molecules, based upon the measurement of the reduction in fibre transmission. We have shown that the corresponding detection sensitivity for a given surface coverage of molecules can be orders of magnitude higher than for conventional techniques [1].

We present an improved setup for the detection of small numbers of isolated molecules at room temperature. The measurements are carried out on different species of organic molecules in a dry nitrogen atmosphere, thus permitting spectroscopy of molecules that are not stable under ambient conditions. Also, due to the absence of water in this atmosphere, reordering processes to monolayer islands or even a polycrystalline phase, which are possible for some molecular species, will be slowed down, enabling us to prepare and observe molecules on the fibre surface for extended periods of time.

[1] F. Warken et al., Opt. Express, 15, 11952-11958 (2007)

Q 55.2 Do 16:30 Poster C2

Laserspektroskopie an Farbzentren in CVD-Diamantfilmen — •David Steinmetz, Elke Neu und Christoph Becher — Universität des Saarlandes, Technische Physik, Campus E2.6, 66123 Saarbrücken

Eine zentrale Voraussetzung für die Realisierung verschiedener Konzepte in der Quanteninformationsverarbeitung ist die Verfügbarkeit von Einzelphotonenquellen, die photostabil sind und über eine schmale Linienbreite verfügen [1]. Als Einzelphotonenemitter eignen sich Farbzentren in künstlich hergestellten Diamanten, die sehr schwach an den umgebenden Kristall koppeln, was schmale Fluoreszenzlinien zur Folge hat. Ein Beispiel ist das aus einem Silizium-Atom und zwei Gitterfehlstellen aufgebaute Si-V Zentrum [2]. Farbzentren aus Übergangsmetallen wie Wolfram, Tantal oder Nickel sind weitere vielversprechende Möglichkeiten für Einzelphotonenemitter [3].
Die von uns untersuchten Farbzentren liegen in Diamantfilmen vor, die in einem so genannten *Chemical Vapor Deposition*-Verfahren (CVD) hergestellt werden. Die Farbzentren entstehen dabei im Wachstumsprozess der Filme oder durch Ionenimplantation. Sie lassen sich mit Hilfe konfokaler Laser-Fluoreszenzmikroskopie analysieren und zur Einzelphotonenemission anregen. Wir stellen Ergebnisse von temperaturabhängigen spektroskopischen Untersuchungen an verschiedenen Farbzentren vor und diskutieren deren Eignung als Einzelphotonenemitter.

[1] B. Lounis et al., Rep. Prog. Phys. **68**, 1129-1179 (2005)
[2] C. Wang et al., J. Phys. B **39**, 37-41 (2006)
[3] A. Zaitsev, Phys. Rev. B **61**, 12909-12922 (2000)

Q 55.3 Do 16:30 Poster C2

Spektroskopie an CVD-Diamantfilmen im ultravioletten, sichtbaren und nahinfraroten Spektralbereich — •Christian Hepp, David Steinmetz, Elke Neu und Christoph Becher — Universität des Saarlandes, Technische Physik, Campus E2.6, 66123 Saarbrücken

Aktuelle Forschung der Quanteninformationstechnologie beschäftigt sich mit dem Ankoppeln von Einzelphotonenemittern an Mikroresonatoren. Die von uns untersuchten Emitter sind Farbzentren in Diamantfilmen verschiedener Kristallitgrößen. Für dieses Materialsystem bietet sich die Realisierung von Mikroresonatoren in photonischen Kristallstrukturen an [1]. Die Güte dieser Mikroresonatoren hängt jedoch kritisch von den Absorptionsverlusten des Materials ab. Deshalb liegt ein besonderes Interesse unserer Forschung auf den Untersuchungen der Absorption in Diamantfilmen. Diese Absorption wird hauptsächlich durch sp^2-gebundenen Kohlenstoff in den Korngrenzen des Diamanten und die dadurch ermöglichten Übergänge innerhalb der Bandlücke verursacht [2]. Wir untersuchen die Transmissionseigenschaften von Diamantfilmen mit Hilfe von UV/Vis/NIR-Spektroskopie. Um Mehrfachreflexionen und den Einfluss der Oberflächenrauhigkeit zu berücksichtigen, wird das Mehrschichtsystem aus CVD-Diamant und Substrat mit Hilfe der Wellen-Transfer-Matrixmethode simuliert. Aus den Messdaten kann der Absorptionskoeffizient der Diamantfilme bestimmt und mit einem theoretischen Modell verglichen werden.

[1] C.F. Wang et al., Appl. Phys. Lett. **91**, 201112 (2007)
[2] P. Achatz et al., Appl. Phys. Lett. **88**, 101908 (2006)

Q 55.4 Do 16:30 Poster C2

Detection of NO isotopologues with a Quantum Cascade Laser based Faraday Modulation Spectroscopy — •X Sabana, Thomas Fritsch, Peter Hering, and Manfred Mürtz — Institut für Lasermedizin, 40225 Düsseldorf

The detection of ^{14}NO and ^{15}NO enables to analyse endogenous as well as exogenous sources. Faraday Modulation Spectroscopy (FAMOS) is a method used to detect NO with high sensitivity and without any cross-interferences.

FAMOS uses a Quantum Cascade Laser (QCL) because of its narrow linewidth and high optical output. It is also able to be frequency modulated up to about hundred MHz. This allows to improve the sensitivity of the detection using the double modulation technique. The double modulation technique is a combination of the laser frequency modulation and magnetic field frequency modulation with detection at the sum frequency.

The QCL used in our laboratory operates between 1839.9 cm^{-1} and 1851.9 cm^{-1} at a temperature between -30^oC and 30^oC and a maximum power of 27.4 mW. The laser power at the wavelength of the used NO transition is in the 1 mW range.

The NO transitions are in the frequency range of the QCL at 1842.94 cm^{-1} (^{14}NO) and 1841.76 cm^{-1} (^{15}NO) and the detection limits are 70 ppb (parts per billion) for ^{15}NO and 380 ppb for ^{14}NO with an integration time of 300 ms.

Because of its high selectivity, the FAMOS technique is an excellent method for measuring NO production from aqueous solutions.

Q 55.5 Do 16:30 Poster C2

Integrated Cavity Output Spectroscopy für die Atemgasanalytik — •Jón Mattis Hoffmann, Sven Thelen, Peter Hering und Manfred Mürtz — Institut für Lasermedizin, Heinrich-Heine-Universität, Düsseldorf, www.ilm.uni-duesseldorf.de/tracegas

Der Nachweis bestimmter Spurengase im Atem spielt in der Medizin eine immer größere Rolle. Für die quantitative Analyse von Spurengasen im ppb-Bereich ist die *Cavity Ring Down Spectroscopy* (CRDS) als empfindliches und spezifisches Messverfahren etabliert. Als eine Alternative wird in der Literatur die *Integrated Cavity Output Spectroscopy* (ICOS) diskutiert, die ebenfalls die Verlängerung des Absorptionsweges in einer Cavity ausnutzt, aber als robuster und leichter handhabbar gilt.

In diesem Beitrag soll die Anwendbarkeit von ICOS für die Atemgasanalyse im Wellenlängenbereich um 3 μm untersucht und mit der CRDS verglichen werden. Hierzu wird ein neues System aufgebaut, welches aus einer 56 cm langen Absorptionszelle mit zwei hochreflektierenden Spiegel sowie einem CO-Obertonlaser besteht. Der Laserstrahl wird in diesem System im Off-Axis-Verfahren in die Zelle eingekoppelt, wobei der Aufbau durch Simulationen unterstützt wird.

Q 55.6 Do 16:30 Poster C2

Absorptionsmessungen im Resonator eines Tm-dotierten Faserlasers von 1730 nm bis 2040 nm — •Matthias Höh[1], Benjamin Löhden[1], Klaus Sengstock[1], Valeri Baev[1] und Bera Pálsdóttir[2] — [1]Institut für Laserphysik, Universität Hamburg, Germany — [2]OFS Fitel, Brondby, Denmark

Die Nutzung Thulium-dotierter Silikatglasfasern mit höherer Dotierung und besserer Qualität konnte den Durchstimmbereich eines damit realisierten Thulium-Faserlasers um insgesamt 50% gegenüber früheren Experimenten [1] erweitern. Das Emissionsspektrum wird mit einer asphärischen Linse im Resonator zwischen 1730 nm und 2040 nm durchgestimmt. Der erweiterte Spektralbereich ermöglicht hochempfindliche Absorptionsmessungen wichtiger atmosphärischer Gase wie H_2O, H_2S, NH_3, HCl, HBr, NO, N_2O, CO, $^{12}CO_2$, $^{13}CO_2$, CH_4, die für Medizin, Prozesstechnik und Umweltanalyse von Relevanz sind. Dabei entspricht die Messempfindlichkeit einer Absorptionsweglänge von mehreren Kilometern bezogen auf konventionelle Messverfahren. Zur Aufnahme der Spektren wurde wahlweise ein Fourier-Spektrometer oder ein Gitterspektrometer mit Diodenzeile verwendet. Die nichtstationäre Modendynamik des Lasers bewirkt bei den Messungen mit dem Fourier Spektrometer einen Rauschuntergrund. Die Diodenzeile dagegen ermöglicht deutlich schnellere und rauscharme Aufnahmen.

[1]. A.Stark, L.Correia, M.Teichmann, S.Salewski, C.Larsen, V.M.Baev, P.E.Toschek, Opt. Commun., 215, 113 (2003)

Q 55.7 Do 16:30 Poster C2

Entwicklung eines ultra-temperaturstabilen Zerodur-Masterlasers — •Alexandra Dwenger, Anika Vogel, Kai Bongs und Klaus Sengstock — Institut für Laserphysik der Universität Hamburg, Germany

In unserem Projekt entwickeln wir ein neuartiges Laserkonzept, welches hohen Anforderungen hinsichtlich mechanischer Stabilität, Temperaturunempfindlichkeit, Größe und Gewicht genügen muss.

Das mobile und flexible Lasersystem ist mit seinen Abmessungen von 103 x 103 x 90 mm^3 ultraklein. Es muss Beschleunigungen bis zu 50 g standhalten, wie sie bei den Experimenten unserer QUANTUS-Kollaboration (Q 22.7) erreicht werden.

Um diese Eigenschaften zu gewährleisten sind alle Komponenten des Systems aus der Glaskeramik Zerodur gefertigt und mittels einer von uns entwickelten Klebetechnik justierbar.

Q 55.8 Do 16:30 Poster C2

Polarization dependent light transmission through single nanoscopic apertures — •Jochen Kindler née Mueller, Peter Banzer, Susanne Quabis, Ulf Peschel, and Gerd Leuchs — Max Planck Research Group of Optics, Information and Photonics, Günther-Scharowsky-Str. 1 / Bau 24, 91058 Erlangen

In the recent years the investigation of transmission through sub wavelength holes in thin metal films has intensified in order to gain a better understanding at a fundamental level. Much work has been published studying arrays of holes. In contrast, we experimentally study the transmission of a single aperture and compare our results to rigorous numerical calculation based on FDTD algorithm. We concentrate on investigating the influence of polarization distributions which are non-homogeneous on a scale of less than one wavelength. For this purpose we generate radially and azimuthally polarized beams at wavelengths of 775 nm and 532 nm which are focussed by a high numerical aperture microscope objective onto each aperture. As samples we use glass substrates covered with different metals (Ag, Pt, Cr) which are structured with apertures of different types and sizes. For holes as well as for annular rings with diameters smaller than the wavelength we find a strong polarization effect on the transmitted power. In this contribution, we will apply the concept of cylindrically symmetric waveguide Eigenmodes to our results. Furthermore, the FDTD model calculation reveals the excitation of surface plasmons to play an important role.

Q 55.9 Do 16:30 Poster C2

Polarization effects on metal edges — •Pavel Marchenko, Susanne Quabis, Ulf Peschel, and Gerd Leuchs — Max Planck Research Group, Insitute of Optics, Information and Photonics, University Erlangen-Nuremberg, Günther-Scharowsky-Str. 1 / Bau24, 91058 Erlangen

To image the intensity distribution of laser beams the so-called "knife-edge" method can be applied. The principle is to move the spot across differently oriented metal edges and reconstruct the intensity distribution by analyzing the slope of the photocurrents. But at nanoscale dimensions the modification of the electric field by the metal edge cannot be neglected, so in general the reconstruction of a strongly focused beam is not possible any more. However, understanding the mechanisms of how various parameters (wavelength, metal properties, input polarization) influence this field modification offer a way to overcome this problem.

In our experiment linearly, radially and azimuthally polarized beams at 532, 633 and 780 nm are focused by a high numerical aperture onto a sample. The sample is a p-i-n photodiode covered with metal objects consisting of an Zn/Au alloy with various mixing ratios. We move the spot over the metal edges and for each one record the photocurrent as a function of the position.

The measurements reveal "push" and "pull" effects the metal edge exerts on the field where the direction of the polarization vector plays an important role. Moreover, we can determine conditions where these effects compensate.

Q 56: Quanteninformation (Photonen und nichtklassisches Licht I)

Zeit: Freitag 11:00–13:00 Raum: 1A

Q 56.1 Fr 11:00 1A

Two-mode single-atom laser as a source of entangled light — •Martin Kiffner[1], M. Suhail Zubairy[1,2], Jörg Evers[1], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Institute for Quantum Studies and Department of Physics, Texas A&M University, College Station, Texas 77843, USA and Texas A&M University at Qatar, Education City, P. O. Box 23874, Doha, Qatar

Continuous variable entanglement is a key resource in many applications of quantum information and quantum computation theory. We theoretically investigate a single atom trapped inside a doubly resonant cavity as a source of entanglement in macroscopic light. The four-level gain medium atom interacts with two (nondegenerate) cavity modes on separate transitions, while the two other transitions are driven by control laser fields. Spontaneous decay of the atomic levels as well as cavity losses are included in our model. We employ an inequality [1] based on the correlation of the field operators as a sufficient criterion for the entanglement of the cavity field. It is shown that the considered two-mode single-atom laser gives rise to an entangled state of the cavity modes with a macroscopic number of photons over a wide range of control parameters and initial states of the cavity field [2].

[1] L.-M. Duan, G. Giedke, J. I. Cirac, and P. Zoller,

Phys. Rev. Lett. **84**, 2722 (2000).
[2] M. Kiffner, M. S. Zubairy, J. Evers, and C. H. Keitel, Phys. Rev. A **75**, 033816 (2007).

Q 56.2 Fr 11:15 1A

Aperture imaging beyond the classical resolution limit by using incoherent photons — •Christoph Thiel[1], Thierry Bastin[2], Joachim von Zanthier[1], and Girish S. Agarwal[3] — [1]Institut für Optik, Information und Photonik, Max- Planck-Forschungsgruppe, Universität Erlangen-Nürnberg, Germany — [2]Institut de Physique Nucléaire, Atomique et de Spectroscopie, Université de Liège, Belgium — [3]Department of Physics, Oklahoma State University, Stillwater, OK, USA

We propose a technique to image arbitrary objects, e.g. an aperture, with sub-wavelength resolution using incoherent light. The method employs two photons spontaneously emitted by two atoms acting as the light source of our setup. The photons irradiate an aperture and are subsequently detected by two detectors in the far field region. We demonstrate that for certain detector positions $\mathbf{r}_1$ and $\mathbf{r}_2$ the second order correlation function $G^{(2)}(\mathbf{r}_1, \mathbf{r}_2)$ offers full information of the aperture, even if of size $\lambda/2$. The result corresponds thus to a 2-fold increase in spatial resolution in comparison with the classical intensity pattern. Unlike in the classical case, the two photons can take different but indistinguishable quantum paths. Our method makes explicit use of the second order interferences between these paths and it is thereby able to obtain a resolution beyond the classical limit.

Q 56.3 Fr 11:30 1A

Realization of two indistinguishable Fourier-limited solid state single-photon sources — Robert Lettow[1], Ville Ahtee[2], Alois Renn[1], Erkki Ikonen[2], •Stephan Götzinger[1], and Vahid Sandoghdar[1] — [1]Laboratory of Physical Chemistry, ETH Zürich, CH-8093 Zürich, Switzerland — [2]Metrology Research Institute, Helsinki University of Technology , FI-02015 TKK, Finland

Single-photon sources comprise an important building block in many quantum information processing schemes. The feasibility of such sources has been demonstrated in various systems. Single photons have also already been successfully used for applications in quantum cryptography. However, complex schemes of quantum information processing require a large number of indistinguishable photons from independent sources.

We demonstrate indistinguishable Fourier-limited single-photon sources based on two single molecules [1]. High resolution laser spectroscopy and optical microscopy were combined to identify individual molecules in two independent microscopes. The Stark effect was exploited to shift the transition frequency of a given molecule and thus obtain single-photon sources with perfect spectral overlap. The solid-state aspect of our system offers many advantages including well defined polarization and a nearly indefinite measurement time using the same single emitters. Our experimental arrangement sets the ground for the realization of quantum interference experiments with two independent solid state single-photon sources.

[1] R. Lettow et al., Optics Express 15, 15842 (2007).

Q 56.4 Fr 11:45 1A

Gequetschtes Licht bei 1550 nm — •Sebastian Steinlechner, Jessica Dück, Stefan Gossler, Moritz Mehmet, Karsten Danzmann und Roman Schnabel — Max-Planck-Institut für Gravitationsphysik (AEI) und Institut für Gravitationsphysik, Leibniz Universität Hannover

Die Empfindlichkeit von Gravitationswellendetektoren der zweiten Generation wird durch thermisches Rauschen sowie durch Quantenrauschen des Lichtfeldes limitiert sein.

Empfindlichkeiten unter dem Quantenrauschen können durch den Einsatz von nichtklassischem (gequetschtem) Licht erreicht werden. Entsprechende Experimente mit gequetschtem Licht wurden erfolgreich durchgeführt und die Umsetzung für den Detektor GEO 600 befindet sich derzeit im Aufbau. Vielversprechender Ansatz zur Verminderung des thermischen Rauschens ist die Kühlung der Interferometer-Testmassen. Die bisher verwendeten Fused-Silica-Substrate besitzen hohe optische Qualität, zeigen jedoch bei niedrigen Temperaturen inakzeptable mechanische Verluste. Aussichtsreichster Kandidat für kryogene Testmassen ist Silizium, das jedoch bei der bisher verwendeten Laserwellenlänge von 1064 nm nicht transparent ist. Dagegen wird im Bereich von 1550 nm ein extrem niedriger Absorptionskoeffizient erwartet. Vorhandene Techniken für die Erzeugung von gequetschtem Licht werden auf 1550 nm übertragen, um zusammen mit Silizum-Testmassen die Grundlage für kommende, kryogene Detektoren zu bilden.

Wir stellen das Konzept und erste Ergebnisse einer Quetschlichtquelle bei 1550 nm vor.

Q 56.5 Fr 12:00 1A

An entangled-pair photon source for single-photon single-atom interaction — •Albrecht Haase, Nicolas Piro, Morgan Mitchell, and Jürgen Eschner — ICFO - Institut de Ciencies Fotoniques, 08660 Castelldefels (Barcelona), Spain

We present a narrow-bandwidth source of entangled photon pairs, which will allow us to address the transitions D3/2-P3/2 and D5/2-P3/2 in single 40Ca+ ions at 850 and 854 nm wavelength, respectively. The source has been designed to emit photons with a high spectral power density into the absorption window of the Calcium ions, which has a bandwidth of ˜20 MHz. We describe the setup and characterize the performance of the source. Its applications will be experiments towards the probabilistic entanglement of distantly trapped single atoms. As a first step we employ the temporal correlation of the photon pairs to study the triggered excitation of an ion. Additionally the source provides entanglement in the polarization degree of freedom of the photons, which we have observe with over 91% visibility. We propose schemes to transfer the entanglement to the internal states of the trapped ions.

Q 56.6 Fr 12:15 1A

Observation of polarization squeezing in PPKTP waveguides — Malte Avenhaus[1], Maria Chekhova[2], •Leonid Krivitsky[1], Gerd Leuchs[1], and Christine Silberhorn[1] — [1]University of Erlangen-Nurnberg, Institute for Optics Information and Photonics — [2]M.V. Lomonosov Moscow State University

We study the experimental configuration of generation of polarization-squeezed states based on interference effect involving two nonlinear crystals. Our experiment represents a generalization of the well developed method of polarization-entangled state generation at the single photon level for the case of high parametric gain. The high gain regime is achieved by using an efficient source based on periodically poled KTP crystal waveguide pumped by a femtosecond laser. We show that the effect of polarization entanglement observed at a single photon level transforms in observation of polarization squeezing at a high gain regime.

Q 56.7 Fr 12:30 1A

Spatial modes and spectral entanglement in PDC — •Andreas Eckstein, Andreas Christ, Thomas Lauckner, and Christine Siblerhorn — University Erlangen-Nuremberg, Max-Planck Research Group IOIP, Integrated Quantum Optics Group

We present the observation of a picosecond beating in a Hong-Ou-Mandel (HOM) type experiment. To study the HOM interference, we implemented a PDC process in a PPKTP waveguide, pumped by a picosecond laser at 404nm. Both signal and idler photons are fed into a balanced beamsplitter, and coincident photons from its output ports are detected. Instead of a gaussian HOM dip, we observe a gaussian-enveloped beating signature of coincidence events. Unlike the experiment in [1], our setup exhibits anti-bunching without spectrally restricting the detector response function.

We attribute this behavior the fact that our waveguide is multimoded in the pump regime. The superposition of spatial pump modes inside the waveguide is translated into a frequency correlation between signal and idler photons via modal dispersion. Owing to the broadband nature of the PDC-generated photons, we propose a definition for broadband mode entanglement and explore the feasibility of this anti-bunching effect as an entanglement witness.

[1] Hong, C. K., Ou, Z. Y., and Mandel, L. *Phys. Rev. Lett.* **59**(18), 2044*2046 (1987).

Q 56.8 Fr 12:45 1A

Photon pair generation in photonic crystal fibres — •Christoph Söller, Leyun Zang, Myeong Soo Kang, Philip Russell, and Christine Silberhorn — Max Planck Research Group IOIP, Günther-Scharowsky-Str. 1 / Bau 24, 91058 Erlangen

Spontaneous four-wave mixing in photonic crystal fibres (PCF) is a new promising approach to generate photon pairs for quantum information applications. Tailoring of the PCF microstructure allows the realisation of a wide variety of dispersion profiles and offers the prospect to control the spectral properties of the generated photons to a high degree. We are working on the implementation of a PCF source optimized

for quantum networks. By manufacturing appropriate fibres, we aim to realise a source that provides heralded single photon states without narrow bandpass filtering. The heralding signal photon is emitted at a wavelength in the Si-APD range to ensure efficient detection. The idler photon of the pair is generated at 1.55μm and can thus be transmitted with very low losses by telecom fibres. Spectral decorrelation of the pair photons ensures the indistinguishability of idler photons from different sources and permits quantum interference without narrow bandpass filters.

Q 57: Quanteneffekte (QED / Lichtstreuung)

Zeit: Freitag 11:00–13:00 Raum: 2D

Q 57.1 Fr 11:00 2D

Jaynes-Cummings Ladder in Quantum-Dot Microcavities — •Lukas Schneebeli, Mackillo Kira und Stephan Koch — Department of Physics and Materials Sciences Center, Philipps-University Marburg, Renthof 5, 35032 Marburg, Germany

The quantum-optical hierarchy problem for dots in microcavities in the strong-coupling regime is analyzed using a cluster-expansion approach [1]. Resonance fluorescence spectra are discussed for several excitation conditions.

[1] M. Kira, S.W. Koch/Progress in Quantum Electronics 30 (2006), 155-296

Q 57.2 Fr 11:15 2D

From a single-photon emitter to a single ion laser — •Helena G. Barros[1,2], François Dubin[1], Carlos Russo[1,2], Andreas Stute[1,2], Piet O. Schmidt[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universiät Innsbruck, Technikerstr. 25, A-6020 Innsbruck — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, A-6020 Innsbruck

A single atom interacting with a single mode of a cavity is the building block of a laser from a fundamental point of view. In this work, we study a single $^{40}Ca^+$ ion coupled to a high finesse optical resonator. In particular, we evaluate the statistical properties of emitted cavity photons for different regimes of operation.

In the experiment, a drive laser together with an optical cavity excites an off-resonant Raman transition that connects the $S_{1/2}$ and $D_{3/2}$ levels of the $^{40}Ca^+$ ion. Population gets transferred from $S_{1/2}$ to $D_{3/2}$ while emitting a photon into the cavity. The excitation cycle is closed by a recycling laser that brings the atomic population back to the initial state $S_{1/2}$ via resonant excitation of the $P_{1/2}$ state. The photons leave the cavity at a rate of 54 kHz and are sent to a Hanbury-Brown & Twiss setup, where photon-photon correlations are measured. For weak recycling laser intensity, the system is operating as a single-photon source. In this regime, we can tune the statistics of the photon arrival times from sub-Poissonian to super-Poissonian behaviour. For faster recycling rates, we observe a single-atom laser at threshold. Different criteria for lasing in such a system are discussed.

Q 57.3 Fr 11:30 2D

Non-perturbative vacuum-polarization effects in proton-laser collisions — •Antonino Di Piazza, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Merging of laser photons can occur due to the polarization of vacuum in the collision of a high-energy proton beam and an intense laser field [1]. The photon merging rate is calculated by exactly accounting for the laser field which involves a highly non-perturbative dependence on the laser field parameters, namely its intensity and frequency. It is shown that even non-perturbative vacuum-polarization effects could be in principle experimentally measured by combining proton accelerators presently available with the next generation of table-top petawatt lasers.

[1] A. Di Piazza, K. Z. Hatsagortsyan, and C. H. Keitel, Phys. Rev. Lett. (in press). See also arXiv:0708.0475 [hep-ph].

Q 57.4 Fr 11:45 2D

Slow light in inhomogeneous and transverse magnetic fields — •Leon Karpa and Martin Weitz — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn, Germany

Electromagnetically induced transparency allows for light transmission through dense atomic media by means of quantum interference of absorption amplitudes[1]. Media exhibiting electromagnetically induced transparency have interesting properties, such as very slow group velocities[2]. Associated with the slow light propagation are quasiparticles, so-called dark polaritons, which are mixtures of a photonic and an atomic contribution[3]. We have carried out experiments, where circularily polarized light traversing a rubidium gas cell under EIT conditions is deflected by an inhomogeneous magnetic field. The obtained results can be described in terms of dark state polaritons having a nonzero effective magnetic moment[4]. In subsequent experiments, electromagnetically induced transparency and slow light have also been observed with a transverse magnetic field orientation. Such a configuration can be used in further studies of the quasiparticle nature of slow light, as in a planned Aharonov-Casher experiment.

[1] See e.g.: E. Arimondo, Prog. Opt. **35**, 257 (1996).
[2] See e.g.: L. V. Hau et al. Nature (London) **397**, 594 (1999).
[3] M. Fleischhauer and M. D. Lukin, Phys. Rev. Lett. **84**, 5094 (2000).
[4] L. Karpa and M. Weitz, Nature Physics **2**, 332 (2006).

Q 57.5 Fr 12:00 2D

Nonlinear Effects in Pulse Propagation through Doppler-Broadened Closed-Loop Atomic Media — •Robert Fleischhaker and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg

Nonlinear effects in pulse propagation through a medium consisting of four-level double-Λ-type systems are studied theoretically. We apply three continous-wave driving fields and a pulsed probe field such that they form a closed interaction loop. Due to the closed loop and the finite frequency width of the probe pulses the multiphoton resonance condition cannot be fulfilled, such that a time-dependent analysis is required. By identifying the different underlying physical processes we determine the parts of the solution relevant to calculate the linear and nonlinear response of the system. We find that the system can exhibit a strong intensity dependent refractive index with small absorption over a range of several natural linewidths. For a realistic example we include Doppler and pressure broadening and calculate the nonlinear selfphase modulation in a gas cell with Sodium vapor and Argon buffer gas. We find that a selfphase modulation of π is achieved after a propagation of few centimeters through the medium while the absorption in the corresponding spectral range is small.

Q 57.6 Fr 12:15 2D

Lossless Negative Refraction in An Active Dense Gas of Atoms — •Jörg Evers, Peter P. Orth, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Heidelberg

Negative index materials promise far-reaching applications in a broad range of areas from sub-wavelength imaging to antenna design. Since current designs are passive, however, negative index materials suffer from losses, prohibiting applications in particular towards optical frequencies. Here we predict lossless negative refraction in an active, i.e. amplifying, dense gas of atoms [1]. External laser fields are used to tune the medium's electromagnetic response and an additional weak pumping field controls the absorption properties. We identify metastable Neon as a suitable experimental candidate at infrared frequencies. Our approach provides negative refraction without losses as required for applications and offers the unique opportunity to study the controlled transition to active negative index material.

[1] P. P. Orth, J. Evers, and C. H. Keitel, arXiv:0711.0303

Q 57.7 Fr 12:30 2D

Controlled Coupling of Counterpropagating Whispering-Gallery Modes by a Single Rayleigh Scatterer: A Classical Problem in a Quantum Optical Light — Andrea Mazzei[1], •Stephan Götzinger[2], Leonardo Menezes[1], Gert Zumofen[2], Oliver Benson[1], and Vahid Sandoghdar[2] — [1]Institut für Physik, Humboldt-Universität zu Berlin, 10117 Berlin, Germany — [2]Laboratory of Physical Chemistry, ETH Zürich, CH-8093 Zürich, Switzerland

It is well established that the radiative properties of atoms can be strongly modified by coupling them to resonators. A corner stone of such modifications is the change of the photonic density of states caused by the boundary conditions imposed by a cavity. We investigate the analogy between this quantum optical scenario and the classical phenomenon of Rayleigh scattering in the presence of a high-finesse cavity.

We present experiments where a single subwavelength scatterer is used to examine and control the backscattering induced coupling between counterpropagating high-Q modes of a microsphere resonator [1]. Our measurements reveal the standing wave character of the resulting symmetric and antisymmetric eigenmodes, their unbalanced intensity distributions, and the coherent nature of their coupling. We discuss our findings and the underlying classical physics in the framework common to quantum optics and provide a particularly intuitive explanation of the central processes.

[1] A. Mazzei et al., Phys. Rev. Lett. 99, 173603 (2007).

Q 57.8 Fr 12:45 2D

Improving High-Finesse Cavities: Corrections beyond the Paraxial Approximation — •Martin Zeppenfeld, Michael Motsch, Pepijn W.H. Pinkse, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

Increased atom-light interactions in a cavity due to many degenerate modes are of great interest for many experiments in quantum optics. While every second transverse mode of a confocal resonator is degenerate within the framework of the paraxial approximation, it is by no means to be expected that this remains the case when taking into account corrections to the paraxial approximation.

Spheroidal coordinates and the associated spheroidal wave functions can be used to construct a set of exact solutions to Maxwell's equations in free space which reduce to the Laguerre-Gaussian modes in the short wavelength limit. Using these solutions, we calculated first-order corrections to the resonance frequencies of modes in a two-mirror Fabry-Perot resonator. For a confocal resonator, the mode degeneracy is lifted. The calculations are supported by measurements with a high finesse cavity.

Q 58: Ultrakalte Atome (Einzelne Atome)

Zeit: Freitag 11:00–12:30 Raum: 3B

Gruppenbericht Q 58.1 Fr 11:00 3B

Quantum nonlinearity with one atom dressed by two photons — •Ingrid Schuster, Alexander Kubanek, Andreas Fuhrmanek, Thomas Puppe, Pepijn Pinkse, Karim Murr, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

The strong-coupling regime of cavity QED has proven to be a rich pond of optical phenomena at the level of single atoms and photons. We experimentally demonstrate that such a system exhibits a nonlinear intensity response when a single atom is made to interact not with one, but with two photons at the same time. This nonlinearity is explained by quantum mechanics and is expected to vanish in the limit of many intracavity atoms. It originates from the energy-level structure of the system, which consists of a ladder of doublets with anharmonic level splitting. The first doublet is visible in low-intensity spectroscopy, where it leads to the well-known vacuum-Rabi or normal-mode splitting. For stronger driving, we find a resonance stemming from excitation of the second doublet, at a frequency which is distinct from the normal modes because of the anharmonicity of the energy level spectrum. Since we access the resonance by driving a two-photon transition, we see a mainly quadratic response with respect to the probe intensity. Our experiment opens up new avenues for the controlled generation of multi-photon states.

Q 58.2 Fr 11:30 3B

Experimentelle Demonstration einer deterministischen Einzelionenquelle für die nm-genaue Implantation von Ionen in Festkörper — •Wolfgang Schnitzler, N. M. Linke, J. Eble, F. Schmidt-Kaler und K. Singer — Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, D-89069 Ulm

Wir haben mittels einer Ionenfalle eine universelle deterministische Einzelionenquelle realisiert [1]. In einer segmentierten linearen Falle werden zunächst kalte $^{40}Ca^+$ Ionenkristalle gefangen, anschließend deterministisch aus der Falle extrahiert und mit einer Erfolgsquote von über 90% auf einen 25cm entfernten Detektor geschossen. Die Streuung der kinetischen Energie der Ionen liegt dabei unter 0,1%. Auch das Laden und Extrahieren gemischter Kristalle wurde bereits erfolgreich durchgeführt. Für die nm-genaue Implantation planen wir, die räumliche Auflösung der extrahierten Ionen mittels einer elektrostatischen Einzellinse weiter zu optimieren. Diese können dann zur Implantation von P in Si oder zur Erzeugung von NV-Farbzentren in Diamant genutzt werden, welche optisch manipuliert werden können. Solche Systeme stellen Kandidaten zur Realisierung eines skalierbaren Festkörper-Quantencomputers dar [2,3]. Die elektrischen Eigenschaften von Halbleiterbauelementen können durch die deterministische Implantation einzelner Ionen ebenfalls verbessert werden [4].

[1] J. Meijer et. al., Appl. Phys. **A 83**, 321 (2006)
[2] B. Kane, Nature **393**, 133 (1998)
[3] F. Jelezko et. al., Phys. Rev. Lett. **93**, 130501 (2004)
[4] T. Shinada et. al., Nature **437**, 1128 (2005)

Q 58.3 Fr 11:45 3B

State-Selective Transport of Single Caesium Atoms — •Michał Karski, Leonid Förster, Daniel Döring, Florian Grenz, Arne Härter, Wolfgang Alt, Jai-Min Choi, Artur Widera, and Dieter Meschede — Institute for Applied Physics, University of Bonn

The state-selective quantum transport of single neutral atoms in optical lattices offers a promising alternative to implement basic modules of advanced schemes in the context of quantum engineering. These range from the implementation of so called quantum walks, utilizing fundamental quantum effects involving spatial quantum interference to the preparation of so-called cluster states using coherent cold collisions as an inter-qubit interaction.

We investigate systems of single Caesium atoms stored, one by one, in a state-dependent one-dimensional optical lattice. It is formed by a superposition of two standing wave dipole traps with right- and left-handed circular polarisation respectively. They can be shifted with respect to each other. With an appropriate wave length, each of the two lattices couples to a different hyperfine state. Therefore, atoms prepared in these qubit states can be transported in opposite directions. Using microwave pulses in the presence of magnetic field gradients, the internal states can be separately manipulated.

We present the current state of the experimental realisation of a one-dimensional quantum transport for Caesium atoms, focussing on the experimental setup and the tools for the preparation and manipulation of individual qubit states and their spatial detection.

Q 58.4 Fr 12:00 3B

Measuring the coupling strength of single atoms to the field of a high-finesse optical resonator — •Sebastian Reick, Wolfgang Alt, Tobias Kampschulte, Mkrtych Khudaverdyan, Karim Lenhard, Karsten Schörner, and Dieter Meschede — Institut für Angewandte Physik, Wegelerstr. 8, -53115 Bonn

The long-term goal of our experiment is the realisation of quantum information processing using neutral atoms. Since they are not coupled to each other or to the environment by a dipole force, which is an advantage in terms of coherence times, coherent interaction of two or more atoms has to be achieved by other means, e.g. by photon exchange.

In our experiment, we store atoms in a standing wave dipole trap, which can be utilised as an optical conveyor belt to move the atoms into the mode of a high-finesse optical resonator. We control the number of atoms loaded into the dipole trap and - with sub-micron precision - the transport distance. We aim at the realisation of coherent interaction between two atoms, placed both at the centre of the cavity field. The calculated parameters of our experimental setup $((g_{\max}, \kappa, \gamma) = 2\pi(18, 0.43, 2.61)\mathrm{MHz}, g^2/(2\kappa\gamma) = 146)$ show that we are in the strong coupling regime.

An important prerequisite for this experiment is the precise knowledge of the coupling strength between one atom and the cavity field g. Furthermore, g should be maximised and kept constant over the interaction time. We report on our results to measure the coupling strength between single atoms and the field of our high-finesse resonator.

Q 58.5 Fr 12:15 3B

Cold Atoms On Nanostructures — •Carsten Weiss[1,2], Reinhold Walser[1], Wolfgang P. Schleich[1], and József Fortágh[2] — [1]Institut für Quantenphysik, Universität Ulm — [2]Physikalisches Institut, Universität Tübingen

A single-walled carbon nanotube (SWCNT) mounted on a lithographically fabricated chip defines a nearly perfect mechanical nano-oscillator. At common temperatures of a cryogenically cooled chip surface it performs large classical oscillations. By exposing it to ultra-cold alkali atoms we want to study the elastic and inelastic scattering by the SWCNT. In particular, we will present simulations for the interaction between a nanotube and a polarizable ^{87}Rb atom.

[1] J. Fortágh, and C. Zimmermann, Rev. Mod. Phys.**79**, 235 (2007)
[2] R. A. Jishi *et al.*, Chem. Phys. Lett. **209**, 77 (1993)
[3] R. Fermani *et al.*, arXiv:quant-ph/0703155v2
[4] I. Wilson-Rae *et al.*, Phys. Rev. Lett. **92**, 75507 (2004)
[5] M. D. LaHaye *et al.*, Science **304**, 74 (2004)

Q 59: Transport in ultrakalten Gasen und Plasmen [gemeinsam mit A]

Zeit: Freitag 11:00–12:30 Raum: 3C

Hauptvortrag Q 59.1 Fr 11:00 3C

Nonlinear coherent transport of waves in disordered media — •Thomas Wellens[1] and Benoît Grémaud[2] — [1]Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3a, 79104 Freiburg — [2]Laboratoire Kastler Brossel, Université Pierre et Marie Curie, 4 place Jussieu, 75252 Paris Cedex 05

In general, transport of waves in disordered media cannot fully be described as a simple diffusion process, since wave interference effects lead to a reduction or even complete suppression of the diffusion constant (weak or strong localization) and the appearance of a coherent backscattering peak.

In this talk, I present a diagrammatic theory for treating the impact of nonlinearities on such disorder-induced localization phenomena [1]. The theory is applied to describe propagation of weakly interacting Bose-Einstein condensates in disordered potentials, on the one hand, and multiple scattering of light in nonlinear media, on the other one. In particular, the conditions under which nonlinear effects diminish or enhance the height of the coherent backscattering peak, and the consequences for the occurrence of Anderson localization of light and cold matter are discussed. Finally, I also talk about the possibility to incorporate quantum-mechanical many-body effects (for example multi-photon scattering processes from strongly driven two-level atoms), which generally lead to decoherence, thereby reducing the localization effects.

[1] T. Wellens and B. Grémaud, PRL (in press)

Q 59.2 Fr 11:30 3C

One-Dimensional Rydberg Gas in a Magnetoelectric Trap — •Bernd Hezel[1], Michael Mayle[2], Igor Lesanovsky[3], and Peter Schmelcher[1,2] — [1]Physikalisches Institut, Universität Heidelberg, 69120 Heidelberg, Germany — [2]Theoretische Chemie, Universität Heidelberg, 69120 Heidelberg, Germany — [3]Institut für Theoretische Physik, Universität Innsbruck, 6020 Innsbruck, Austria

We study the quantum properties of Rydberg atoms in a magnetic Ioffe-Pritchard trap superimposed by a homogeneous electric field. Trapped Rydberg atoms in long-lived electronic states can be created with *permanent* electric dipole moments of several hundred Debye. The resulting dipole-dipole interaction in conjunction with the radial confinement gives rise to an effectively one-dimensional ultracold Rydberg gas with a macroscopic interparticle distance. Analytical expressions for the electric dipole moment and the required linear density of Rydberg atoms can be derived.

Q 59.3 Fr 11:45 3C

Structural phase transitions in low-dimensional ion crystals — •Gabriele De Chiara[1], Shmuel Fishman[2], Tommaso Calarco[3], and Giovanna Morigi[1] — [1]Departament de Fisica, Universitat Autonoma de Barcelona, 08193 Bellaterra, Spain — [2]Physics Department, Technion, 32000 Haifa, Israel — [3]Institut für Quanteninformationsverarbeitung, Universität Ulm, D89069 Ulm, Germany

A chain of singly-charged particles, confined by a harmonic potential, exhibits a sudden transition to a zigzag configuration when the radial potential reaches a critical value, depending on the particle number. This structural change is a phase transition of second order, whose order parameter is the crystal displacement from the chain axis. We study analytically the transition using Landau theory and find full agreement with numerical predictions by J. Schiffer [Phys. Rev. Lett. 70, 818 (1993)] and Piacente et al. [Phys. Rev. B 69, 045324 (2004)]. Our theory allows us to determine analytically the system's behaviour at the transition point.

Q 59.4 Fr 12:00 3C

Damped Bloch Oscillations of Bose Einstein Condensates in disordered gradient fields — •Sascha Drenkelforth, Georg Kleine Büning, Johannes Will, Wolfgang Ertmer, and Jan Arlt — Institut für Quantenoptik, Universität Hannover, Welfengarten 1, 30167 Hannover

Optical lattices are excellent tools to probe the nature of quantum degenerate Bose gases and serve as an ideal testing ground for theories originating in solid state physics.

One of the most peculiar effects in the framework of periodic potentials is the well known Bloch Oscillation (BO) of quantum particles. Under the influence of a constant force they undergo an oscillatory motion instead of a linear acceleration.

We report on our investigations of damped BO in optical lattices. The addition of disorder to the prior perfect optical lattice leads to an dephasing and therefore to a damping of the BO [1]. The experimental results show increased damping with stronger disorder and a strong broadening of the quasimomentum distribution during the time evolution of the BO.

These results promise a better understanding of the role of disorder in quantum transport experiments.

[1] Schulte et al., cond-mat/0707.3131(2007)

Q 59.5 Fr 12:15 3C

Sympathetic Cooling of Ions using Laser-Cooled One-Component Plasmas — •Michael Bussmann[1], Ulrich Schramm[2], Peter Thirolf[1], Veli Kolhinen[1], Jerzy Szerypo[1], Juergen Neumayr[1], Michael Sewtz[1], and Dietrich Habs[1] — [1]Ludwig-Maximilians-Universitaet Muenchen, Am Coulombwall 1, 85748 Garching — [2]Forschungszentrum Dresden-Rossendorf, Bautzner Landstraße 128, 01328 Dresden

We present new simulation results on sympathetic cooling of ions for precision experiments. Using a laser-cooled one-component plasma of 10^5 $^{24}Mg^+$ ions it is possible to stop and sympathetically cool ions to mK temperatures. With the proposed cooling scheme fast and efficient cooling of rare nuclei for precision in-trap physics, e.g. subsequent mass measurements in Penning traps, becomes possible. In the talk we will give an overview of previous results before presenting new results on the stopping dynamics, especially the interplay of collective dynamics, plasma stability and recooling efficiency.

[1]Bussmann M. et al., European Physical Journal D 45(1) (2007) 129-132.

[2]Bussmann M. et al., Hyperfine Interactions 173(1-3) (2007) 27-34.

Q 60: Quantengase (Gemische / Tunneleffekte)

Zeit: Freitag 11:00–13:00 Raum: 3G/H

Q 60.1 Fr 11:00 3G/H

Interacting Rubidium and Caesium Atoms — •Claudia Weber, Michael Haas, Shincy John, Nicolas Spethmann, Lars Steffens, Artur Widera, and Dieter Meschede — Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, 53115 Bonn

In our experimental set up we magnetically trap a mixture of Rubidium and a few Caesium atoms simultaneously. We selectively cool only Rubidium atoms by a microwave field tuned to the Rubidium ground state hyperfine transition. Caesium is sympathetically cooled via elastic collisions with Rubidium. We are able to cool down the mixture to temperatures below 1μK. Analysing the dynamics of sympathetic cooling we have estimated a lower limit for the Rubidium-Caesium s-wave scattering length to 150 a_0. Our next step is to load the mixture in an optical dipole trap. Using an external homogeneous magnetic field we intend to tune the inter-species interaction. We will present our latest results.

Q 60.2 Fr 11:15 3G/H

Self-Trapping of Bosons and Fermions in Optical Lattices — •Dirk-Sören Lühmann[1], Kai Bongs[2,3], Klaus Sengstock[2], and Daniela Pfannkuche[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstr. 9, 20355 Hamburg, Germany — [2]Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Midlands Centre for Ultracold Atoms, School of Physics and Astronomy, University of Birmingham, Edgbaston, Birmingham B15 2TT, United Kingdom

The superfluid to Mott insulator transition is one of the paradigms of solid state physics that maps onto ultra cold atomic systems. The interaction between different kinds of atoms adds an additional degree of freedom to two-component atomic systems not present in the solid state counterpart.

We numerically investigate the enhanced localisation of bosonic 87Rb by fermionic 40K atoms in three-dimensional optical lattices and find a self-trapping of bosons and fermions. Due to the mutual interaction the fermion orbitals are substantially squeezed which results in a strong deformation of the bosonic effective potential. We show that orbital effects in attractively interacting atomic mixtures are non-negligible as they lead to a large shift of the critical point of the transition from a superfluid to a Mott-insulator, which is of direct relevance to recent experiments with 87Rb and 40K atoms.

Q 60.3 Fr 11:30 3G/H

Heteronuclear Feshbach resonances in a mixture of ultracold ^{87}Rb and ^{133}Cs atoms — •Andrea Prantner[1], Almar Lange[1], Karl Pilch[1], Gabriel Kerner[2], Francesca Ferlaino[1], Hanns-Christoph Nägerl[1], and Rudolf Grimm[1,2] — [1]Institut für Experimentalphysik, Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation,

In the last few years there has been a growing interest in the in the area of heteronuclear ultracold quantum gases and the production of heteronuclear molecules via Feshbach resonances. We present the first observation of heteronuclear Feshbach resonances in a mixture of ultracold ^{87}Rb and ^{133}Cs. We give an overview about our experimental setup and the procedure of sample preparation. One of the key ingredients to reach the ultracold limit is the implementation of simultaneous degenerate Raman sideband cooling on both species. This cooling technique allows us to get around 10^8 atoms, fully polarized in the lowest magnetic sublevel at a temperature of $\sim 1\mu K$ in a crossed dipole trap. We discuss the next steps towards double degeneracy and present our approach to produce ground state RbCs molecules starting from weakly bound Feshbach molecules.

Q 60.4 Fr 11:45 3G/H

Feshbach Resonances in a Lithium Rubidium Mixture — •Carsten Marzok, Benjamin Deh, Philippe W. Courteille, and Claus Zimmermann — Physikalisches Institut, Universität Tübingen, Auf der Morgenstelle 14, D-72076

Ultracold atomic gases are a versatile instrument allowing to study the rich field of many body physics with unprecedented control. Indeed the coupled dynamics is governed by few parameters only, namely temperature, masses of the constituents and the interactions between them. In ultracold gases these interactions are ruled by the s-wave scattering length. Control over this parameter is provided by magnetic Feshbach resonances. The physics involved can be enriched by choosing a mixture of different atomic species with different masses and different quantum statistics i.e. Bose-Fermi mixtures. The lithium-rubidium system is remarkable among these because of its large mass difference. In recent experiments we were able to detect two heteronuclear Feshbach resonances in the ^{6}Li-^{87}Rb system, that now make it possible to study the physics of this rich system in more detail. The characterization of these resonances and further experiments will be discussed in this presentation.

Q 60.5 Fr 12:00 3G/H

Do mixtures of bosonic and fermionic atoms adiabatically heat up in optical lattices? — •Marcus Cramer[1], Silke Ospelkaus[2], Christian Ospelkaus[2], Kai Bongs[2], Klaus Sengstock[2], and Jens Eisert[1] — [1]Blackett Laboratory, Imperial College London — [2]Institut für Laser-Physik, Universität Hamburg

Mixtures of bosonic and fermionic atoms in optical lattices provide a promising arena to study strongly correlated systems. In experiments realizing such mixtures in the quantum degenerate regime the temperature is a key parameter. We investigate the intrinsic heating and cooling effects due to an entropy-preserving raising of the optical lattice, identify the generic behavior valid for a wide range of parameters and discuss it quantitatively for the recent experiments with ^{87}Rb and ^{40}K atoms. In the absence of a lattice, we treat the bosons in the Hartree-Fock-Bogoliubov-Popov approximation, including the fermions in a self-consistent mean field interaction. In the presence of the full three-dimensional lattice, we use a strong coupling expansion. We find the temperature of the mixture in the lattice to be always higher than for the pure bosonic case, shedding light onto a key point in the analysis of recent experiments.

Q 60.6 Fr 12:15 3G/H

Heteronuclear Feshbach molecules in an ultracold Bose-Fermi Mixture — •Carsten Klempt, Thorsten Henninger, Oliver Topic, Lisa Kattner, Eberhard Tiemann, Wolfgang Ertmer, and Jan Arlt — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, D-30167 Hannover, Germany

Within the past decade, quantum degenerate bosonic and fermionic ensembles were investigated in detail. The use of Feshbach resonances now allows for precise control of the interactions in heteronuclear mixtures of two atomic species. Within our experiments, bosonic ^{87}Rb atoms are used to cool an ensemble of fermionic ^{40}K atoms to joint quantum degeneracy. This mixture provides the starting point for the detailed analysis and manipulation of the interactions.

Applying a homogeneous magnetic field up to 700G allows for the investigation of heteronuclear Feshbach resonances in this mixture. The measurement of these resonances is of great interest for the precise investigation of the molecular potential. We have been able to observe 28 resonances in ten different spin combinations. Together with results from molecular spectroscopy, this allowed for a large improvement of the interaction model. One of the observed resonances is used for the production of weakly bound heteronuclear Feshbach molecules. The collisional stability of these molecules can be enhanced significantly by removing residual Rb atoms.

We report on the production of ultracold Feshbach molecules and the ongoing steps towards a deexcitation of such molecules into deeply bound molecular states via a Stimulated Raman Adiabatic Passage.

Q 60.7 Fr 12:30 3G/H

Correlated Tunneling of Few Bosons in a 1-D Double Well — •Sascha Zöllner[1], Hans-Dieter Meyer[1], and Peter Schmelcher[1,2] — [1]Universitaet Heidelberg, Theoretische Chemie, Im Neuenheimer Feld 229, 69120 Heidelberg — [2]Universitaet Heidelberg, Physikalisches Institut, Philosophenweg 12, 69120 Heidelberg

This talk is about few-boson tunneling in a one-dimensional double-well trap, covering the full crossover from weak interactions to the fermionization limit of strong correlations. After reviewing the underlying mechanism of ground-state fermionization of trapped bosons, it will be shown how the tunneling of two atoms evolves from Rabi oscillations to correlated pair tunneling as we increase the interaction strength. The physics behind it will be analyzed, rounded off by an outlook on how many-body effects modify the picture and how the tunneling can be controlled via tilting the wells.

Q 60.8 Fr 12:45 3G/H

A coherent single atom shuttle between two Bose-Einstein condensates — •Uwe R. Fischer[1], Christian Iniotakis[2], and Anna Posazhennikova[3] — [1]Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen, Germany — [2]ETH Zürich, Institut für Theoretische Physik, CH-8093 Zürich, Switzerland — [3]Physikalisches Institut, Universität Bonn, D-53115 Bonn, Germany

We study an atomic quantum dot representing a single hyperfine "impurity" atom which is coherently coupled to two well-separated Bose-Einstein condensates, in the limit when the coupling between the dot and the condensates dominates the inter-condensate tunneling coupling. It is demonstrated that the quantum dot by itself can induce coherent oscillations of the particle imbalance between the condensates, which display a two-frequency behavior. For noninteracting condensates, we provide an approximate solution to the coupled nonlinear equations of motion which allows us to obtain these two frequencies analytically.

Q 61: Quanteninformation (Photonen und nichtklassisches Licht II)

Zeit: Freitag 14:00–15:30 Raum: 1A

Q 61.1 Fr 14:00 1A

Spectral decomposition of quantum light — •Wolfgang Mauerer and Christine Silberhorn — University Erlangen-Nuremberg, Max-Planck Research Group IOIP, Integrated Quantum Optics Group

A growing number of applications for quantum mechanics in both computation and communication has been devised during the last years. The experimental realisation is usually performed with optical technologies. Most concepts are well understood theoretically, but they are usually based on a single-mode description. This is not the case in reality, especially when fast pulsed sources are employed. Contributions from many spectral modes are unavoidable in such regimes and need to be accounted for by the models.

Following initial work presented in Ref. [1], we develop various techniques for the analysis of multi-mode states. Special emphasis is put on how to find simple and effective multi-mode descriptions for a number of recent experiments. We demonstrate that noise which has previously been accounted to experimental imperfections can emerge from spectral effects.

We also show how to derive the Bogoliubov transformations for quadratic nonlinear interactions (e.g., parametric downconversion) from a fully quantum mechanical spatio-spectral model. This is used as a basis for further structural analysis of multi-mode quantum states with various techniques, for instance Bloch-Messiah decomposition.

[1] P. P. Rohde, W. Mauerer, and Ch. Silberhorn, New Journal of Physics **9**, 91(2007)

Q 61.2 Fr 14:15 1A

Improved methods for Polarization squeezing with photonic crystal fibers — •Josip Milanovic[1], Alexander Huck[2], Joel Heersink[1], Christoph Marquardt[1], Ulrik L. Andersen[2], and Gerd Leuchs[1] — [1]Institute of Optics, Information and Photonics, Max-Planck Research Group, University of Erlangen-Nuremberg, Guenther-Scharowsky-Straße 1, 91058, Erlangen, Germany — [2]Department of Physics, Technical University of Denmark, Fysikvej, 2800, Kgs. Lyngby, Denmark

Squeezing or quantum noise reduction of optical states in glass fibers has been chronically afflicted by the large phase noise from Guided Acoustic Wave Brillouin Scattering (GAWBS). This excess noise is one of the main effects that decrease the purity of the quantum states. In previous experiments we have already shown that Photonic Crystal Fibers (PCFs) represent a promising new approach to reduce this noise.

At a squeezing level of -3.3 ± 0.3 dB at 810 nm the purity of the squeezed state was three times higher than in experiments with standard telecom fibers. A major problem is that the dispersion properties for different axes are not identical. Due to the different spectral evolution of the pulses in the PCFs the interference of squeezed pulses is very low which implies a large loss in the detectable squeezing. We present improved methods which can be used to increase and detect higher levels of polarization squeezing.

Q 61.3 Fr 14:30 1A

Modal Properties of Parametric Down-conversion in the High Gain Regime — •Kaisa Laiho, Malte Avenhaus, and Christine Silberhorn — Max Planck Junior Research Group, Günther-Scharowsky-Str. 1 / Bau 24, D-91058 Erlangen

Parametric down-conversion (PDC) is widely used in the low gain regime as a source of photon pairs. It is also a promising candidate for Non-Gaussian state engineering [1]. Recently, bright waveguided PDC sources have become available. In this high gain regime it is possible to generate pairs of pairs, which can be understood as quadrature squeezing in the continuous variable picture.

The photon pairs generated in the PDC process are spectrally correlated. Although we use a broadband, ultrafast pump, the phase-matching is a limiting factor. In order to be able to define the state as a broadband single mode squeezer, it needs to be decorrelated [2]. We have studied the spectral correlations in the ultrafast regime for a 10mm long type II PP-KTP waveguide and spectrally resolved the tilted correlation function. Our measured photon statistics indicate strong multimodal behaviour. To modify the spectral correlations we have cut down the waveguide to 2.5mm length and study the modal properties by spectral filtering. Ultimately, we aim at Non-Gaussian state preparation where it is crucial to drive the state towards single mode characteristics to ensure the purity.

[1] A. I. Lvovsky *et al.*, Phys. Rev. Lett. **87**, 050402 (2001)
[2] P. P. Rohde *et al.*, New J. Phys. **9**, 91 (2007)

Q 61.4 Fr 14:45 1A

Linear optics unleashed — •Konrad Kieling[1,2] and Jens Eisert[1,2] — [1]QOLS, Blackett Laboratory, Imperial College London, Prince Consort Road, London SW7 2BW, UK — [2]Institute for Mathematical Sciences, Imperial College London, Prince's Gate, London SW7 2PE, UK

Linear optical architectures for quantum information processing are based on single-photon sources, photon-number preserving optical elements, and photon (number resolving) detectors. Due to the allowed set of tools being narrowed down, specific problems can often be cast into a mathematical framework that allows for the assessment of possible state manipulation, measurement and preparation. The measurement based nature of optical gates and the issue of encoding qubits in a way to easily access them experimentally leads to a rich structure of problems. In this talk, we will discuss issues of resource consumption in optical state preparation, optimal success probabilities, and prescriptions of how to build linear optical quantum gates and measurement devices.

Q 61.5 Fr 15:00 1A

Is the role of beam-splitters in quantum optics any different from that in classical optics? — •Daniela Denot, Lev Plimak, and Wolfgang P. Schleich — Institute of Quantum Physics, Ulm University, 89069 Ulm, Germany

A statement is often made that the role of beam-splitters in quantum optics is fundamentally different from that in classical optics [1]. This statement is based on the paper by Mandel et al [2] showing that the action of a beam-splitter on a single-photon state is turning it into an entangled state of two modes. The question we ask if there exists an experimental proof of this statement. We show that the answer is negative for all photodetection measurements with two beams involving local oscillators. To prove this we devise a Gedanken-experiment where the joint photocurrent statistics of the two detectors is fully imitated in a measurement where the incident beam is detected directly. This statement is easily proven for arbitrary classical states of the incident beam while its validity for quantum states follows from the optical equivalence theorem by Sudarshan [3].

[1] G. S. Agarwal, a talk given at the Institute of Quantum Physics, Ulm, Sept. 2007, unpublished.

[2] C. K. Hong, Z. Y. Ou, and L. Mandel, Phys. Rev. Lett., 59(18), 2044, 1987.
[3] E. C. G. Sudarshan. Phys. Rev. Lett., 10(7), 277, 1963.

Q 61.6 Fr 15:15 1A

Experimental demonstration of anyonic statistics with multiphoton entanglement — •Witlef Wieczorek[1,2], Jiannis Pachos[3], Christian Schmid[1,2], Nikolai Kiesel[1,2], Reinhold Pohlner[1,2], and Harald Weinfurter[1,2] — [1]Max-Planck-Institut für Quantenoptik, D-85748 Garching — [2]Department für Physik, Ludwig-Maximilians-Universität München, D-80799 München — [3]School of Physics & Astronomy, University of Leeds, Leeds LS2 9JT, UK

Particles in nature appear as two distinct types according to their statistics: bosons and fermions. However, if one considers only two spatial dimensions statistical behaviour ranging from bosonic to fermionic is found. Particles exhibiting such a behaviour are called anyons. Our experimental demonstration of their statistics is based on a particular two-dimensional model: the toric code proposed by Kitaev [1]. There, anyons arise as excitations that are generated by local operations. We show that for this model anyonic behaviour is revealed for as little as four qubits. This allowed us to experimentally demonstrate anyonic statistics in a quantum simulation using four-photon entanglement [2].

[1] A.Y. Kitaev, Ann. Phys. (N.Y.) 303, 2-30 (2003).
[2] J.K. Pachos *et al.*, e-print arXiv: 0710.0895 (2007).

Q 62: Ultrakalte Atome (Fallen und Kühlung)

Zeit: Freitag 14:00–15:45 Raum: 3B

Q 62.1 Fr 14:00 3B

An intense clean source for cold Lithium — Tobias Tiecke, Antje Ludewig, •Sebastian Kraft, Steve Gensemer, and Jook Walraven — Van der Waals-Zeeman-Instituut, Universiteit van Amsterdam, The Netherlands

We experimentally investigate a novel atomic beam source for cold ^{6}Li. The source operates according to the 2D-MOT principle and is found to be very monochromatic and intense. Its longitudinal velocity is centered at 33m/s with a full-width at half maximum (FWHM) of 14 m/s, with no flux observed at higher velocities.

We measured the intensity of the source by loading a 3D MOT from the cold atomic beam. We report loading rates as high as 10^9s^{-1} resulting in up to a total of 10^{10} trapped atoms.

Q 62.2 Fr 14:15 3B

Speichereigenschaften einer planaren Mikrochip-Ionenfalle — •Christian Greve[1], Michael Kröner[2], Markus Debatin[1], Jochen Mikosch[1], Sebastian Trippel[1], Markus Reetz-Lamour[1], Peter Woias[2], Roland Wester[1] und Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Freiburg — [2]Institut für Mikrosystemtechnik, Universität Freiburg

Untersuchungen an hydratisierten Ionen ermöglichen tiefgreifende Einsichten in den Verlauf chemischer und biologischer Prozesse. Für derartige Experimente entwickeln wir eine planare transparente RF-Multipolfalle in Kombination mit einer gepulsten Ionenquelle. Die aus zwei gegenüberliegenden Chips mit kammartiger Elektrodenstruktur bestehende Ionenfalle hat bereits Lebensdauern von mehr als 10 s mit Argonionen ermöglicht. Der simulierte Verlauf des erzeugten effektiven Potentials stimmt dabei hervorragend mit einem analytischen Modell überein [1]. Für zeitnahes Testen neuer Fallendesigns lassen sich die Chips mit Photolithographie oder durch Laserablation strukturieren. Nach der Extraktion findet eine Analyse mit einem Wiley McLaren-artigen Flugzeitmassenspektrometer statt. Im Vortrag wird der aktuelle Stand des Experimentes insbesondere die Ionenquelle, ein verbessertes Fallendesign sowie die in der Extraktion erreichte Massenauflösung vorgestellt. Für die Zukunft ist unter anderem eine Tomographie der Ionendichte mittels Photodetachment [2] und die Kombination der Ionenfalle mit einer MOT geplant.

[1] M. Debatin et al., in prep.
[2] S. Trippel et al., PRL 97, 193003 (2006)

Q 62.3 Fr 14:30 3B

Trapping of rubidium atoms by ac electric fields — •Sophie Schlunk[1,2], Adela Marian[1], Wieland Schöllkopf[1], and Gerard Meijer[1] — [1]Fritz-Haber-Institut, Berlin, Germany — [2]FOM Institute for Plasma Physics Rijnhuizen, Nieuwegein, The Netherlands

We have demonstrated trapping of ultracold ground-state Rb atoms in a macroscopic ac electric trap [S. Schlunk et al., PRL 98, 223002 (2007)]. AC electric trapping has been previously demonstrated for polar molecules [H. L. Bethlem et al., PRA 74, 063403 (2006)], as well as for Sr atoms on a chip [T. Kishimoto et al., PRL 96, 123001 (2006)], and recently for Rb atoms in a three-phase electric trap [T. Rieger et al., PRL 99, 063001 (2007)]. AC traps for neutral particles operate analogously to Paul traps for ions. A potential energy surface is created with a saddle point at the trap center, resulting in attractive forces (focusing) in one direction and repulsive forces (defocusing) along the other two directions. Alternating between the two electric field configurations leads to dynamic confinement of the particles.

In the experiment, the Rb atoms are cooled in a standard MOT and loaded into a magnetic trap. The magnetically trapped cloud is then transferred into a second vacuum chamber housing the ac trap. Stable electric trapping is observed in a narrow range of switching frequencies around 60 Hz, in agreement with trajectory calculations. We have trapped about 2×10^5 atoms with lifetimes on the order of 9 s. Absorption images of the atom cloud taken at various phases of the ac switching cycle show different shapes reflecting the focusing and defocusing forces acting on the atoms.

Q 62.4 Fr 14:45 3B

Observation of a trapped cloud of electrons in a planar-cryogenic Penning trap — •Pavel Bushev[1,2], Stefan Stahl[2], Michael Hellwig[1,4], Michael Ferner[1], Riccardo Natali[3], Gerrit Marx[4], Günther Werth[2], and F. Schmidt-Kaler[1] — [1]Institut für Quanteninformationsverarbeitung,Universität Ulm, D-89069 Ulm — [2]Institut fürPhysik, Johannes Gutenberg-Universität Mainz, D-55099 Mainz — [3]Dipartimento di Fisica, Università degli Studidi Camerino, 62032 Camerino, Italy — [4]Institutfür Physik, Ernst Moritz Arndt-Universität Greifswald,D-17489 Greifswald

We have succeeded in trapping, cooling and detecting clouds of electrons by using a cryogenic planar Penning trap which is installed in a dilution refrigerator. The trap consists of concentric rings with a diameter of a few millimeters [1]. The operating temperature range is 50-100 mK, the magnetic field is about 1 Tesla. We observed a lifetime of trapped electrons of about 3 hours. In the planar geometry, a strong anharmonicity of the trapping potential prevents us from observing single electrons. The ways to diminish such anharmonicity and the current status of cryogenic electron trapping will be presented. The single electron will be used for an application in quantum computing [2]. Here the spin of an individually trapped electron represents a qubit, which can be coherently manipulated with pulses of a microwave field. Entanglement between electronic qubits is achieved by an electrical connection of the electrodes of separate traps.

[1] S. Stahl et. al., Eur. Phys. J. D. **32**, 139 (2005).
[2] G. Ciaramicioli et. al, Phys. Rev. Lett. **91**, 017901 (2003).

Q 62.5 Fr 15:00 3B

Atom cooling in a ring — •Andreas Ruschhaupt — Institut fuer Mathematische Physik, TU Braunschweig, Mendelssohnstr. 3, D-38106 Braunschweig

We propose a method to cool atoms in a ring. An atom diode -a laser device which can by passed by atoms in only one direction- is put in a ring in such a way that the velocity of the crossing atom is also decreased. In addition, the atom is trapped if its velocity is below a threshold velocity. In this manner, the atom or an atom cloud moving in the ring can be cooled and finally trapped after repeated passages of the atom diode.

Q 62.6 Fr 15:15 3B

Kompaktes und extrem robustes frequenzstabilisiertes Lasersystem für Experimente mit atomaren Quantengasen — •Max Schiemangk, André Wenzlawski, Wojciech Lewoczko-Adamczyk und Achim Peters — Humboldt-Universität zu Berlin, Institut für Physik, AG Quantenoptik und Metrologie, Hausvogtei-

platz 5-7, 10117 Berlin

Auf dem Weg zur Implementierung eines im Rahmen des DLR-Projekts QUANTUS geplanten Quantengasexperimentes im Weltraum haben wir eine miniaturisierte und mechanisch stabile Apparatur für Vorexperimente im Fallturm des ZARM in Bremen entwickelt. Bei einer Höhe von 110 m erreicht man dort eine Freifallzeit von ca. 4,5 s mit Restbeschleunigungen von ca. 10^{-6} g. Diese Zeit kann durch den Einsatz eines neu implementierten Katapults verdoppelt werden, wobei jedoch die Anfangsbeschleunigung von mehr als 30 g sehr hohe Ansprüche an den experimentellen Aufbau hinsichtlich mechanischer Stabilität stellt.

In diesem Vortrag wird ein ultrastabiler Master-Laser vorgestellt, der als Frequenzreferenz für das gesamte Experiment dient. Dieser basiert auf einem DFB-Diodenlaser und wird mittels Frequenzmodulationsspektroskopie auf einen atomaren Übergang in Rubidium stabilisiert. Das kompakte Design, die schnelle Regelelektronik sowie die Optimierung der atomaren Antwort auf Frequenzänderungen werden ausführlich diskutiert.

Q 62.7 Fr 15:30 3B

A high-flux atomic source for transportable experiments — •Tais Gorkhover, Ulrich Eismann, Alexander Senger, Malte Schmidt, and Achim Peters — Institut für Physik, Humboldt-Universität zu Berlin

We present a setup for a compact and robust vapor loaded MOT for Rubidium atoms suitable as an atomic source for transportable experiments as the FINAQS GAIN (Gravimetry Atom Interferometer) experiment at the HU-Berlin.

The design is based on a modified 2D-MOT with the two pairs of opposing trap-beams tilted towards the line of flight of the cold atoms allowing for longitudinal cooling of the atom beam. Using a moving molasses scheme the atoms can be launched with a narrow velocity distribution and low mean velocity. Our setup features large MOT-beam diameter and the possibility of three adjacent cooling stages which should allow for high fluxes ($> 10^{12}$ atoms/s) and a highly recapturable beam. We report on technical details of the setup and first characterisations.

Q 63: Quantengase (Wechselwirkungseffekte II / Spinorgase)

Zeit: Freitag 14:00–16:00 Raum: 3G/H

Q 63.1 Fr 14:00 3G/H

Metastable neon atoms in optical dipole traps: collisional properties of different internal states — •W.J. van Drunen[1], E.-M. Kriener[1], J. Schütz[1], N. Herschbach[1], W. Ertmer[2], and G. Birkl[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

After performing a detailed analysis of the collisional properties of metastable neon atoms ($^3P_2$, m=+2) in a magnetic trap [1], we implemented an optical trap for metastable neon for further investigations. This enables us to explore possibilities to manipulate interactions and extend our studies of interactions to states, which are not magnetically trappable.

As a result, we could demonstrate the first trapping of metastable neon ($^3P_0$) atoms. Measurements of the number decay of trapped atoms allows us to determine the rate coefficient for two-body loss of neon in the $^3P_0$ metastable state for both bosonic isotopes ^{20}Ne and ^{22}Ne. In addition to the requirements of our previous quantitative studies [1], a careful characterization of the optical trap is required as well.

[1] P. Spoden et al., Phys. Rev. Lett. **94**, 223201 (2005)

Q 63.2 Fr 14:15 3G/H

Cavity QED with a Bose-Einstein Condensate — •Ferdinand Brennecke, Tobias Donner, Stephan Ritter, Thomas Bourdel, Michael Köhl, Christine Guerlin, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zürich, Switzerland

Cavity quantum electrodynamics (cavity QED) studies the coherent interaction of light and matter inside a high-finesse resonator. One of the main challenges in present experiments within the optical regime of cavity QED is to achieve a deterministic coupling strength between atoms and light, which in particular requires high control over the atomic external degrees of freedom. Using a Bose-Einstein condensate (BEC), we enter a new regime of cavity QED where all atoms couple identically to the cavity field. Here we present a measurement of the energy spectrum of this strongly coupled system in the low excitation limit. Due to a collective coupling of several GHz we observe a significant coupling of the BEC to higher-order transverse cavity modes. The strong coupling even of a single atom to the cavity mode offers the possibility to detect and manipulate a minority component of atoms in a different hyperfine state embedded within a BEC. Besides its relevance to the field of quantum information processing, the presented system offers a variety of interesting phenomena expected in the many-body physics of quantum gases within a quantum optical lattice. In contrast to the case of optical lattice potentials provided by strong laser fields, here the light field itself becomes a dynamical quantity depending on the atomic distribution, which leads to substantial cavity-mediated long-range interactions between the atoms.

Q 63.3 Fr 14:30 3G/H

Dipole Oscillations of a Bose-Einstein Condensate in Presence of Defects and Disorder — •Mathias Albert, Nicolas Pavloff, Patricio Leboeuf, and Tobias Paul — Laboratoire de Physique Théorique et Modèles Statistiques, Universite Paris Sud

We study the influence of a weak defect or disorder potential on the dipole modes of a weakly interacting Bose Einstein condensate, confined in a harmonic cigar-shaped trap with a tight transverse confinement but a shallow axial trapping frequency in presence of an external defect or disorder potential. We show that for small-amplitude dipole oscillations the BEC-flow is superfluid and the dipole oscillations are almost undamped, but the external defect potential induces a small shift of the excitation frequency. We compute this frequency shifts by use of a perturbative approach, both in the low-density regime and in the Thomas-Fermi large-density regime and apply this approach -as a first test- to a single Gaussian-shaped barrier potential. Then, we consider the experimental relevant case of an optical speckle-potential where we find uncorrelated frequency shifts of the dipole mode with respect to the pure harmonic case. This behavior is confirmed by numerically solving the Gross-Pitaevskii equation. Finally, we derive a relation between the disorder correlation-function and the ensemble-averaged fluctuations of the frequency shift. This opens the perspective for experiments to obtain from the dipole-frequency fluctuations characteristic parameters of the disorder potential (e.g. correlation lengths).

Q 63.4 Fr 14:45 3G/H

Far-from-equilibrium dynamics of ultracold Bose gases — •Philipp Struck and Thomas Gasenzer — Institute for Theoretical Physics, University of Heidelberg, Philosophenweg 16, 69120 Heidelberg

The dynamical evolution of a Bose-Einstein condensate trapped in a one-dimensional optical lattice is investigated in the framework of the Bose-Hubbard model. Of special interest is the far-from equilibrium evolution of a strongly interacting gas. Using functional integral techniques, the dynamic equations are derived from the two-particle-irreducible effective action expanded in inverse powers of the field components. This approach reaches far beyond the Hartree-Bogoliubov mean-field theory and Quantum Boltzmann approaches. Within this framework we investigate various configurations of one-dimensional lattices of particular interest for present experiments. This includes dipole oscillations of a condensate damped by the thermal cloud and squeezing of particle number fluctuations below the classical limit.

Q 63.5 Fr 15:00 3G/H

Non-Abelian dynamics of ultracold atoms: From Schrödinger to Dirac. — •Michael Merkl, Frank Zimmer, and Patrik Öhberg — Heriot-Watt University, Edinburgh EH14 4AS, United Kingdom

In an atomic system a non-trivial gauge potential is induced with respect to the external motion of the atoms if two conditions are met. First, the considered atomic system should, during its time evolution, remain in space dependent eigenstates, so called dark-states. Secondly, if there are two degenerated dark-states, the resulting vector potential can be of a non-Abelian nature. These conditions can be fulfilled if one considers ultra-cold atoms with a tripod-type coupling scheme in the regime of electromagnetically induced transparency [1]. In the present talk we consider this tripod system in more detail. Hereby we distinguish the two limits of weak and strong non-Abelian dynamics. In the latter the dynamics of the atoms is described by an effective Dirac equation [2]. For both cases we consider the motion of the atoms with and without external trapping potentials and show that the corresponding wave-packet dynamics is highly non-trivial.

[1] J. Ruseckas, G. Juzeliūnas, P. Öhberg and M. Fleischhauer, Phys. Rev. Lett. 95, 010404 (2005)
[2] G. Juzeliūnas, J. Ruseckas, M. Lindberg, L. Santos and P. Öhberg, preprint

Q 63.6 Fr 15:15 3G/H

Fermi Gases with Arbitrary Spin — •Aristeu Lima[1] and Axel Pelster[2] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Fachbereich Physik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg, Germany

After the experimental realization of Bose-Einstein condensation in optical traps, where the spin degree of freedom of the bosonic atoms is no longer frozen, the question has arisen whether also fermionic atoms can be optically trapped. In fact, such a system has recently been experimentally realized with ^{173}Yb atoms [1]. Other promising examples of fermionic systems with a total angular moment F in the ground state which is larger than 1/2 are all alkali fermions (except ^{6}Li) and ^{53}Cr. Thus, now many interesting physical properties of spinor Fermi gases can be studied. Concerning the contact interaction, many pairing channels can occur. Furthermore, an additional dipole-dipole interaction, responsible for anisotropic superfluidity, plays a major role in ^{53}Cr, which has six valence electrons. Having these applications in mind, we calculate the ground-state energy of such systems perturbatively with respect to the two-particle interaction.

[1] T. Fukuhara et al. Phys. Rev. Lett. **98**, 030401 (2007)

Q 63.7 Fr 15:30 3G/H

Exact solution of strongly interacting quasi one-dimensional spinor bose gases — •Frank Deuretzbacher[1], Klaus Fredenhagen[2], Daniel Becker[1], Kai Bongs[3,4], Klaus Sengstock[3], and Daniela Pfannkuche[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Germany — [2]II. Institut für Theoretische Physik, Universität Hamburg, Germany — [3]Institut für Laserphysik, Universität Hamburg, Germany — [4]School of Physics and Astronomy, University of Birmingham, United Kingdom

One-dimensional systems of non-interacting fermions can be mapped to bosons with infinite δ-repulsion. This relationship has been found by Girardeau already in 1960 for spinless particles. We generalize Girardeau's mapping to bosons with spin. The surprising new result is that hard-core bosons with spin can be mapped to spinless non-interacting fermions *and* distinguishable spins.

Our mapping allows for exact calculations of spin densities and the energy spectrum. Another central result is that the momentum distribution depends on the symmetry of the spin wave function. States with completely symmetric spin wave functions have the typical momentum distribution of spinless bosons, whereas states with very antisymmetric spin wave functions have much broader and flatter momentum distributions which resemble the one of non-interacting fermions.

[1] F. Deuretzbacher, *et al.*, arXiv:0708.3039

Q 63.8 Fr 15:45 3G/H

Spontane Musterbildung in antiferromagnetischen Spinor-Bose-Einstein Kondensaten — •Jochen Kronjäger[1], Christoph Becker[1], Kai Bongs[2] und Klaus Sengstock[1] — [1]Institut für laser-Physik, Universität Hamburg — [2]Midlands Centre for Ultracold Atoms, University of Birmingham

Spontane Musterbildung ist ein verbreitetes Phänomen in räumlich ausgedehnten, nichtlinearen Medien. Die Musterbildung beruht oft auf der dynamischen Instabilität des homogenen Systems gegenüber räumlich oszillierenden Störungen, die exponentiell wachsen und schliesslich zu stabilen raum-zeitlichen Mustern sättigen.

Bose-Einstein Kondensate sind als nichtlineares Medium, in dem beispielsweise Solitonen auftreten, seit längerem bekannt. Auch neuere Arbeiten an Spinor-Kondensaten zielen auf räumliche Effekte ab. Nachgewiesen wurde z.B. bereits die spontane Bildung Spinpolarisierter Domänen in einem ferromagnetischen Spinor-Kondensat.

Unsere Messungen an elongierten $F = 2$ ^{87}Rb Spinor-Kondensaten zeigen erstmals die spontane Bildung von Domänen in einem *antiferromagnetisch* wechselwirkenden Spinor-System. Die Domänenbildung zeigt sich als regelmäßige Modulation des axialen Spins mit charakteristischer Wellenlänge. Induzierte Strukturbildung in einem gezielt angelegten Magnetfeld-Gradienten wird ebenfalls beobachtet, führt jedoch entgegen der Erwartung *nicht* zu regelmäßigen Mustern. Numerische und analytische Indizien unterstützen die Interpretation unserer Beobachtungen.