Quantum Optics and Photonics Division (Q)

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Overview of Invited Talks and Sessions

(lecture rooms A 001, A 310, A 320, E 001, E 214, E 415, F 128, F 342, and M 11; poster Lichthof)

Prize Talk

Q 9.1	Mo	16:30–17:00	A 320	**Highly excited atoms in cold environments: From antihydro- gen production to ultracold plasmas and Rydberg gases** — •Thomas Pohl

Invited talks of the symposium SYFC

See SYFC for the full program of the symposium.

SYFC 1.1	Mo	14:00–14:30	A 001	**Fundamental constants, gravitation and cosmology** — •Jean-Philippe Uzan
SYFC 1.2	Mo	14:30–15:00	A 001	**Molecular hydrogen in the lab and in the early universe; search for varying mu** — •Wim Ubachs
SYFC 1.3	Mo	15:00–15:30	A 001	**Stability of the proton-to-electron mass ratio tested with molecular spectroscopy using an optical link to frequency reference** — •Anne Amy-Klein, Alexander Shelkovnikov, Robert J. Butcher, Olivier Lopez, Christophe Daussy, Haifeng Jiang, Fabien Kéfélian, Giorgio Santarelli, Christian Chardonnet
SYFC 1.4	Mo	15:30–16:00	A 001	**Optical clocks with trapped ions and the search for variations of fundamental constants** — •Ekkehard Peik
SYFC 2.1	Mo	16:30–17:00	A 001	**Gravitational and cosmological probes of varying fundamental parameters** — •Thomas Dent
SYFC 2.2	Mo	17:00–17:30	A 001	**The astrophysical search for varying fundamental constants** — •Nils Prause
SYFC 2.3	Mo	17:30–17:45	A 001	**Variability of the proton-to-electron mass ratio on cosmological scales - quantification and handling of systematics** — •Martin Wendt
SYFC 2.4	Mo	17:45–18:00	A 001	**Towards Direct Frequency Comb Spectroscopy of Metal Ions** — •Boerge Hemmerling, Daniel Nigg, Ivan V. Sherstov, Piet O. Schmidt

Invited talks of the symposium SYDP

See SYDP for the full program of the symposium.

SYDP 1.1	Mo	16:30–17:00	F 107	**Experimental all-optical one-way quantum computing** — •Robert Prevedel
SYDP 1.2	Mo	17:00–17:30	F 107	**Benchmarks and statistics of entanglement dynamics** — •Markus Tiersch
SYDP 1.3	Mo	17:30–18:00	F 107	**Squeezed Light For Gravitational Wave Astronomy** — •Henning Vahlbruch
SYDP 1.4	Mo	18:00–18:30	F 107	**High-precision mass measurements with Penning traps** — •Sebastian George

Invited talks of the symposium SYDC

See SYDC for the full program of the symposium.

SYDC 1.1	Tu	14:00–14:30	E 415	**Environment-induced Decoherence of Quantum States: An Introduction** — •Heinz-Peter Breuer
SYDC 1.2	Tu	14:30–15:00	E 415	**Fighting Decoherence: Quantum Information Science with Trapped Ca^+ Ions** — T. Monz, K. Kim, A. Villar, P. Schindler, M. Chwalla, M. Riebe, C. F. Roos, H. Häffner, W. Hänsel, M. Hennrich, •R. Blatt
SYDC 1.3	Tu	15:00–15:30	E 415	**Decoherence phenomena in molecular systems: Localization of matter waves & stabilization of chiral configuration states** — •Klaus Hornberger
SYDC 1.4	Tu	15:30–16:00	E 415	**Decoherence of free electron waves and visualization of the transition from quantum- to classical-behaviour** — •Franz Hasselbach
SYDC 2.1	Tu	16:30–17:00	E 415	**Coherence and the loss of it in molecular photoionization** — •Uwe Hergenhahn
SYDC 2.2	Tu	17:00–17:30	E 415	**Decoherence in fermionic interferometers** — •Florian Marquardt
SYDC 2.3	Tu	17:30–18:00	E 415	**Quantum diffusion in gravitational waves backgrounds** — •Serge Reynaud, Brahim Lamine, Rémy Hervé, Astrid Lambrecht
SYDC 2.4	Tu	18:00–18:30	E 415	**Quantum coherence and decoherence in biological systems** — •Martin Plenio

Invited talks of the symposium SYLA

See SYLA for the full program of the symposium.

SYLA 1.1	We	14:00–14:30	E 415	**How the laser happend** — •Herbert Welling
SYLA 1.2	We	14:30–15:00	E 415	**The origin of the quantum theory of lasing** — •Fritz Haake
SYLA 1.3	We	15:00–15:30	E 415	**Lasers for precision measurements** — •Thomas Udem
SYLA 1.4	We	15:30–16:00	E 415	**Short, Ultra Short, Atto Short** — •Dietrich von der Linde
SYLA 2.1	We	16:30–17:00	E 415	**Our Daily Life with Semiconductor Lasers** — •Dieter Bimberg
SYLA 2.2	We	17:00–17:30	E 415	**Power to the Industry - the story of Laser upscaling** — •Reinhart Poprawe
SYLA 2.3	We	17:30–18:00	E 415	**The Outstanding Qualities of Fiber Lasers and Thin Disk Lasers** — •Adolf Giesen
SYLA 2.4	We	18:00–18:30	E 415	**Solid State Lasers:meeting the challenges of the 21st Century** — •Robert L. Byer

Invited talks of the symposium SYQS

See SYQS for the full program of the symposium.

SYQS 1.1	Th	10:30–11:00	E 415	**Theoretical studies on quantum control and spectroscopy of ultrafast photoreactions** — •Regina de Vivie-Riedle, Judith Voll, Artur Nenov, Tiago Buckup, Jürgen Hauer, Marcus Motzkus
SYQS 1.2	Th	11:00–11:30	E 415	**Quantum Control Spectroscopy: Understanding photobiology with coherently controlled matter waves** — •Tiago Buckup, Jürgen Hauer, Judith Voll, Regina Vivie-Riedle, Marcus Motzkus
SYQS 1.3	Th	11:30–12:00	E 415	**Development of strategies for the optimal control in complex systems** — •Roland Mitric
SYQS 1.4	Th	12:00–12:30	E 415	**Mechanistic laser pulse parameterizations** — •Tobias Brixner
SYQS 2.1	Th	14:00–14:30	E 415	**Efficient control of electron dynamics** — •Matthias Wollenhaupt
SYQS 2.2	Th	14:30–15:00	E 415	**Exploring wavepacket dynamics under strong laser fields** — •Leticia Gonzalez
SYQS 2.3	Th	15:00–15:30	E 415	**Quantum Control Spectroscopy in Ultracold Atomic and Molecular Gases** — •Matthias Weidemüller

Invited talks of the symposium SYSA

See SYSA for the full program of the symposium.

SYSA 1.1	Th	10:30–11:00	A 320	**Cavity EIT with single atoms** — •Stephan Ritter, Martin Mücke, Eden Figueroa, Jörg Bochmann, Carolin Hahn, Celso J. Villas-Boas, Gerhard Rempe

SYSA 1.2	Th	11:00–11:30	A 320	**Optical detection of single trapped atoms with less than one spontaneous emission** — Jürgen Volz, Roger Gehr, Guilhem Dubois, Jérôme Estève, •Jakob Reichel
SYSA 1.3	Th	11:30–12:00	A 320	**Substantial interaction between a singe atom and a focused light beam** — •Gleb Maslennikov, Syed Abdullah Aljunid, Brenda Chng, Florian Huber, Meng Khoon Tey, Timothy Liew, Valerio Scarani, Christian Kurtsiefer
SYSA 1.4	Th	12:00–12:30	A 320	**Exploring Quantum Physics with Single Neutral Atoms** — •Artur Widera
SYSA 2.1	Th	14:00–14:30	A 320	**Detecting single ultra cold atoms** — •Jörg Schmiedmayer
SYSA 2.2	Th	14:30–15:00	A 320	**Entanglement of two individual neutral atoms using Rydberg blockade** — •Tatjana Wilk, Alpha Gaëtan, Charles Evellin, Janik Wolters, Yevhen Miroshnychenko, Philippe Grangier, Antoine Browaeys

Sessions

Q 1.1–1.8	Mo	14:00–16:00	A 310	**Quantum Effects: Light Scattering and Propagation I / Interference and Correlations I**
Q 2.1–2.8	Mo	14:00–16:00	A 320	**Ultracold Atoms: Trapping and Cooling (with A)**
Q 3.1–3.8	Mo	14:00–16:00	E 001	**Quantum Gases: Bosons I**
Q 4.1–4.8	Mo	14:00–16:00	E 214	**Quantum Information: Concepts and Methods I**
Q 5.1–5.8	Mo	14:00–16:00	F 128	**Laser Development: Nonlinear Effects I**
Q 6.1–6.8	Mo	14:00–16:00	F 342	**Ultrashort Laser Pulses: Generation I**
Q 7.1–7.7	Mo	14:00–15:45	M 11	**Precision Measurements and Metrology I**
Q 8.1–8.9	Mo	16:30–19:00	A 310	**Quantum Effects: Interference and Correlations II / Entanglement and Decoherence I**
Q 9.1–9.9	Mo	16:30–19:00	A 320	**Ultracold Atoms: Rydberg Gases / Miscellaneous (with A)**
Q 10.1–10.10	Mo	16:30–19:00	E 001	**Quantum Gases: Bosons II**
Q 11.1–11.10	Mo	16:30–19:00	E 214	**Quantum Information: Concepts and Methods II**
Q 12.1–12.10	Mo	16:30–19:00	F 128	**Laser Development: Solid State Lasers I**
Q 13.1–13.10	Mo	16:30–19:00	F 342	**Ultrashort Laser Pulses: Generation II**
Q 14.1–14.8	Tu	14:00–16:15	A 310	**Precision Measurements and Metrology II**
Q 15.1–15.8	Tu	14:00–16:00	A 320	**Ultracold Atoms: Manipulation and Detection (with A)**
Q 16.1–16.8	Tu	14:00–16:15	E 001	**Quantum Gases: Interaction Effects I**
Q 17.1–17.8	Tu	14:00–16:30	E 214	**Quantum Information: Atoms and Ions I**
Q 18.1–18.8	Tu	14:00–16:00	F 128	**Laser Development: Solid State Lasers II**
Q 19.1–19.8	Tu	14:00–16:00	F 342	**Ultrashort Laser Pulses: Generation III**
Q 20.1–20.7	Tu	14:00–16:00	F 303	**Ultra Cold Atoms, Ions and BEC I (with A)**
Q 21.1–21.92	Tu	16:00–19:00	Lichthof	**Poster I**
Q 22.1–22.7	We	10:30–12:15	A 310	**Quantum Effects: Entanglement and Decoherence II**
Q 23.1–23.7	We	10:30–12:30	A 320	**Quantum Effects: Light Scattering and Propagation II / QED I**
Q 24.1–24.8	We	10:30–12:30	E 001	**Quantum Gases: Mixtures and Spinor Gases**
Q 25.1–25.8	We	10:30–12:30	E 214	**Quantum Information: Quantum Communication I**
Q 26.1–26.8	We	10:30–12:30	F 128	**Laser Development: Solid State Lasers III**
Q 27.1–27.8	We	10:30–12:30	F 342	**Ultrashort Laser Pulses: Applications I**
Q 28.1–28.8	We	10:30–12:30	F 303	**Ultra Cold Atoms, Ions and BEC II (with A)**
Q 29.1–29.9	We	14:00–16:15	A 310	**Precision Measurements and Metrology III**
Q 30.1–30.8	We	14:00–16:00	A 320	**Quantum Effects: QED II / Interference and Correlations III**
Q 31.1–31.8	We	14:00–16:00	E 001	**Quantum Gases: Interaction Effects II**
Q 32.1–32.8	We	14:00–16:00	E 214	**Quantum Information: Atoms and Ions II**
Q 33.1–33.8	We	14:00–16:00	F 128	**Laser Development: Semiconductor Lasers / Nonlinear Effects II**
Q 34.1–34.8	We	14:00–16:00	F 342	**Ultrashort Laser Pulses: Applications II**
Q 35.1–35.10	We	16:30–19:00	A 310	**Precision Measurements and Metrology IV**
Q 36.1–36.4	We	16:30–17:45	A 320	**Ultracold Atoms: Single Atoms (with A)**
Q 37.1–37.5	We	17:45–19:00	A 320	**Matterwave Optics I**
Q 38.1–38.10	We	16:30–19:00	E 001	**Quantum Gases: Bosons III / Lattices I**
Q 39.1–39.9	We	16:30–19:00	E 214	**Quantum Information: Atoms and Ions III**
Q 40.1–40.9	We	16:30–18:45	F 128	**Quantum Information: Quantum Computing**
Q 41.1–41.10	We	16:30–19:00	F 342	**Ultrashort Laser Pulses: Applications III**
Q 42.1–42.8	Th	10:30–12:30	A 310	**Precision Measurements and Metrology V**

Q 43.1–43.5	Th	10:30–12:00	E 001	**Ultracold Molecules (with MO)**
Q 44.1–44.8	Th	10:30–12:30	E 214	**Quantum Information: Concepts and Methods III**
Q 45.1–45.8	Th	10:30–12:30	F 303	**Ultra Cold Atoms, Ions and BEC III (with A)**
Q 46.1–46.3	Th	10:30–11:15	F 128	**Laser Development: Nonlinear Effects III**
Q 47.1–47.5	Th	11:15–12:30	F 128	**Photonics I**
Q 48.1–48.8	Th	10:30–12:30	F 342	**Ultrashort Laser Pulses: Miscellaneous**
Q 49.1–49.9	Th	14:00–16:15	A 310	**Precision Measurements and Metrology VI**
Q 50.1–50.4	Th	15:15–16:15	A 320	**Micromechanical Oscillators I**
Q 51.1–51.9	Th	14:00–16:15	E 001	**Quantum Gases: Fermions**
Q 52.1–52.9	Th	14:00–16:15	E 214	**Quantum Information: Concepts and Methods IV / Photons and Nonclassical Light I**
Q 53.1–53.9	Th	14:00–16:15	F 128	**Photonics II**
Q 54.1–54.9	Th	14:00–16:15	F 342	**Laser Applications: Optical Measurement Technology I**
Q 55.1–55.93	Th	16:00–19:00	Lichthof	**Poster II**
Q 56.1–56.7	Fr	10:30–12:15	A 310	**Quantum Information: Quantum Communication II**
Q 57.1–57.8	Fr	10:30–12:30	A 320	**Micromechanical Oscillators II**
Q 58.1–58.8	Fr	10:30–12:30	E 001	**Quantum Gases: Lattices II**
Q 59.1–59.8	Fr	10:30–12:45	E 214	**Quantum Information: Atoms and Ions IV / Photons and Nonclassical Light II**
Q 60.1–60.8	Fr	10:30–12:30	F 128	**Photonics III**
Q 61.1–61.6	Fr	10:30–12:00	F 342	**Ultrashort Laser Pulses: Applications IV**
Q 62.1–62.7	Fr	10:30–12:15	F 102	**Quantum Control (with MO)**
Q 63.1–63.7	Fr	14:00–16:00	A 310	**Quantum Effects: Entanglement and Decoherence III**
Q 64.1–64.8	Fr	14:00–16:00	A 320	**Matterwave Optics II**
Q 65.1–65.7	Fr	14:00–16:00	E 001	**Quantum Gases : Lattices III**
Q 66.1–66.8	Fr	14:00–16:00	E 214	**Quantum Information: Photons and Nonclassical Light III**
Q 67.1–67.7	Fr	14:00–15:45	F 128	**Photonics IV**
Q 68.1–68.6	Fr	14:00–15:30	F 342	**Laser Applications: Optical Measurement Technology II**
Q 69.1–69.7	Fr	14:00–15:45	F 303	**Ultra-Cold Atoms, Ions and BEC IV / Interaction with VUV and X-Ray Light II (with A)**

Mitgliederversammlung Fachverband Quantenoptik und Photonik

Mittwoch 13:30–14:00 A 310

- Bericht
- Wahl des Sprechers
- Verschiedenes

Sitzung des Deutschen Optischen Komitees

Dienstag 12:30 - 14:00 Raum lag bei Drucklegung nicht vor.

Q 1: Quantum Effects: Light Scattering and Propagation I / Interference and Correlations I

Time: Monday 14:00–16:00 Location: A 310

Q 1.1 Mo 14:00 A 310

Propagation of quantum fluctuations in EIT media — •Marc Bienert[1] and Pablo Barberis-Blostein[2] — [1]Theoretische Physik, Universität des Saarlandes, 66041 Saarbrücken — [2]Instituto de Investigaciones en Matemáticas Aplicadas y en Sistemas, Universidad Nacional Autónoma de México, 04510 México D.F., Mexico

We analyze the propagation of a pair of quantized fields inside a medium of three-level atoms in a Lambda configuration. We calculate the stationary quadrature noise spectrum of the field, in the case where the probe field is in a squeezed state and the atoms show electromagnetically induced transparency. We find an oscillatory transfer of the initial quantum properties between the probe and pump fields which is most strongly pronounced when both fields have comparable intensities. This implies that the quantum state measured after propagation can be completely different from the initial state, even though the mean values of the field are unaltered. We furthermore address the case where the two fields drive the Lambda system in two-photon resonance but detuned from the excited state and discuss the influence of the Doppler width on the propagation.

Q 1.2 Mo 14:15 A 310

Spinor Slow-Light with variable effective mass and anomalous localization — •Johannes Otterbach[1], Razmik Unanyan[1], Michael Fleischhauer[1], Julius Ruseckas[2], Viaceslav Kudriasov[2], and Gediminas Juzeliunas[2] — [1]Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Institute of Theoretical Physics and Astronomy, Vilnius University, 01108 Vilnius, Lithuania

Recently, systems showing an effective Dirac-like time evolution, such as graphene, have acquired a lot of interest. We here show how to create light-matter quasi-particles, so-called dark-state polaritons (DSP), obeying an effective Dirac equation in 1D. These spinor-like objects posses an effective "speed of light", given by the group velocity of slow-light, which can be externally controlled and be made many orders of magnitude smaller than the vacuum speed of light. Furthermore the mass of these spinor slow-light polaritons (SSP) is adjustable in size and sign on a small length scales. It has been shown that a 1D model of random mass Dirac particles shows unusual correlations. For a random mass with vanishing mean value there exists a zero energy (mid-gap) state which decays according to a power-law. We use the freedom of our SSPs to create a spatially randomly varying mass and thus observe the creation of such unusual mid-gap states and discuss a possible experimental implementation and its limitations.

Q 1.3 Mo 14:30 A 310

Photons Walking the Line: Quantum Walk with adjustable Coin Operations — •Andreas Schreiber[1], Katiuscia Cassemiro[1], Vaclav Potocek[2], Aurel Gabris[2], Peter J. Mosley[1], Erika Andersson[3], Igor Jex[2], and Christine Silberhorn[1] — [1]MPI for the Science of Light, IQO Group, Erlangen, Germany. — [2]Department of Physics, FNSPE, Czech Technical University in Prague, Praha, Czech Republic. — [3]SUPA, School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh, United Kingdom.

A major topic in the field of quantum information is the development and investigation of quantum algorithms. Recent works have shown that the quantum analogue of a well known model in natural science, namely random walks, constitute a universal platform for performing computation.

Towards this application we present the first robust implementation of a coined quantum walk over five steps using only passive optical elements. By employing a fiber network loop we keep the amount of required resources constant as the walker's position Hilbert space is increased. We observed a non-Gaussian distribution of the walker's final position, thus characterizing a faster spread of the photon wave-packet in comparison to the classical random walk. The walk is realized for different coin settings and initial states, which opens the way for the implementation of a quantum walk-based search algorithm.

Q 1.4 Mo 14:45 A 310

Phase dependent dynamics in a loop of microresonators — •Sandra Isabelle Schmid, Keyu Xia, and Jörg Evers — Max-Planck Institut für Kernphysik, Heidelberg, Germany

In recent years, chains of coupled microcavities have received considerable attention [1]. Here, we study arrays of microresonators which are arranged in a loop configuration [2]. This allows photons to travel along closed loop pathways and thereby gives rise to quantum interference between different evolution pathways in the microresonators [3]. As our model system, we consider three whispering gallery mode microresonators which are coupled via their evanescent fields. In addition, one of the resonators is coupled to a tapered fiber, and we use the transmitted and reflected light as observables. In particular, we study the interplay of the different pathways a photon can take in scattering from the input to an output mode of the fiber. We show that due to the loop configuration, the optical properties of the resonator structure become dependent on the phases of the complex coupling constants describing the coupling of the different resonators. Finally, possible applications are discussed.

[1] M. A. Popovic et al., Optics Express **14**, 3 (2006); M. Hammer, Opt. Quantum Electron., **40**, 821 (2008)
[2] M. A. Popovic et al., Conference on lasers and electro optics, **1-9**, 1600 (2008)
[3] M. Mahmoudi and J. Evers, Phys. Rev. A **74**, 063827 (2006)

Q 1.5 Mo 15:00 A 310

Photon crystallization in driven dissipative arrays of nonlinear optical resonators — •Michael Hartmann — Technische Universität München, Physik Department, 85748 Garching, Germany

Possibilities to observe strong correlations of interacting polaritons have received considerable attention in recent years [1]. Early works have mostly addressed equilibrium phenomena that have previously been observed in other realizations. For polaritons, it is however experimentally more feasible to study driven dissipative systems. I will discuss the steady states of such systems and their characteristic correlations. Interestingly, these show spatial density-density correlations, which indicate that the polaritons crystallize despite being injected by a coherent light source and damped by the environment.

[1] Hartmann, Brandão and Plenio, Laser & Photon. Rev. **2**, 527556 (2008).

Q 1.6 Mo 15:15 A 310

Photon-number selective group delay in cavity induced transparency — •Gor Nikoghosyan and Michael Fleischhauer — Department of Physics and research center OPTIMAS, University of Kaiserslautern, Germany

Electromagnetically induced transparency (EIT) is an interference effect that results in a dramatic reduction of the group velocity of a propagating weak probe pulse accompanied by vanishing absorption. The group velocity of the probe depends on the intensity of a coupling field which has to be strong and thus it is usually a classical laser beam. In the present work we propose a scheme where the coupling field is substituted by a quantized cavity field. The adiabatic transfer of probe photons to the cavity mode modifies the refractive index of medium in a similar manner as the coupling field does in the case of ordinary EIT. We show that our system can be used to generate and control quantum pulses of light with very high accuracy. In particular it can be used to spatially separate the single photon from higher photon-number components of a few photon probe pulse and thus to create an optical Fock-state filter or a deterministic single-photon source.

Q 1.7 Mo 15:30 A 310

Phase-controlled pulse propagation in media with cross coupling of electric and magnetic probe field component — •Robert Fleischhaker and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Recently, quantum optical systems interacting with both the electric and the magnetic component of a probe beam have received considerable interest as a candidate for materials with a negative index of refraction [1]. In addition to a large medium density, a cross coupling of electric and magnetic field component was proposed to enhance the inherently weak magnetic response of the medium [2].

Here, we discuss light propagation dynamics in media with such a cross coupling independent of negative refraction and at much lower densities [3]. First, we derive and solve the wave equations for a probe pulse for general medium response coefficients. Then, we apply these results to a specific atomic example system in which cross couplings are induced by additional control fields. We show that the cross-couplings render the propagation dynamics sensitive to the relative phase of the additional fields, and this phase dependence enables one to control the pulse during its propagation through the medium. Our results demonstrate that the magnetic field component of a probe beam can crucially influence the system dynamics already at experimentally accessible parameter ranges in dilute vapors.

[1] J. Kästel et al., Phys. Rev. Lett. **99**, 073602 (2007)
[2] J. B. Pendry, Science **306**, 1353 (2004)
[3] R. Fleischhaker and J. Evers, Phys. Rev. A **80**, 063816 (2009)

Q 1.8 Mo 15:45 A 310

Thermalisierung eines zweidimensionalen Photonengases in einem optischen Hoch-Finesse-Resonator — •Jan Klärs, Frank Vewinger und Martin Weitz — Institut für Angewandte Physik der Universität Bonn, Weglerstraße 8, D-53115 Bonn

Bose-Einstein-Kondensation, die makroskopische Besetzung des energetischen Grundzustands in einem Bose-Gas unterhalb einer kritischen Temperatur, wurde in verschiedenen physikalischen Systemen realisiert. Obwohl die Plank'sche Hohlraumstrahlung das vielleicht bekannteste Bose-Gas ist, stellt sie einen Ausnahmefall dar, da sie keine Bose-Einstein-Kondensation bei niedrigen Temperaturen zeigt. Anstatt den energetisch niedrigsten Zustand zu besetzen, gehen die Photonen stattdessen in den Wänden verloren, da für sie keine Teilchenzahlerhaltung gilt (verschwindendes chemisches Potential).

Wir berichten hier von der Realisierung eines zweidimensionalen Photonengases in einem optischen Hoch-Finesse-Mikroresonator, das eine thermische Besetzung transversaler Moden bei gleichzeitig frei einstellbarem chemischen Potential zeigt. Die Thermalisierung wird durch mehrfache resonante Streuung der Photonen an Farbstoffmolekülen innerhalb des Resonators erreicht, dessen Geometrie zusätzlich für eine nicht-verschwindende (effektive) Photonenmasse und ein Fallenpotential sorgt - notwendige Vorraussetzungen für eine Bose-Einstein-Kondensation von Photonen. Als ein Beispiel für die ungewöhnlichen Systemeigenschaften zeigen wir, dass der Thermalierungsprozess zu einer Minimierung der potentiellen Energie der Photonen und damit zu einer Konzentrierung im Mittelpunkt des Fallenpotentials führt.

Q 2: Ultracold Atoms: Trapping and Cooling (with A)

Time: Monday 14:00–16:00 Location: A 320

Q 2.1 Mo 14:00 A 320

Shortcut to adiabaticity: fast optimal frictionless atom cooling in harmonic traps — •Andreas Ruschhaupt — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany

A method is proposed to cool down atoms in a harmonic trap as in a perfectly slow adiabatic expansion but in a much shorter time. This is achieved by designing the time dependence of the trap frequency, the harmonic trap may even become an expulsive parabolic potential in some time interval. The resulting cooling times have no fundamental lower bound and are shorter than previous minimal times using optimal-control bang-bang methods and real frequencies.

Ref.: [1] Xi Chen, A. Ruschhaupt, S. Schmidt, A. del Campo, D. Guery-Odelin and J. G. Muga, arXiv:0910.0709v1 [quant-ph]
[2] J. G. Muga, Xi Chen, A. Ruschhaupt and D. Guery-Odelin, J. Phys. B: At. Mol. Opt. Phys. 42 (2009) 241001 (FTC)

Q 2.2 Mo 14:15 A 320

Fiber-pigtailed atoms — •Daniel Reitz, Rudolf Mitsch, Melanie Müller, Eugen Vetsch, Samuel T. Dawkins, and Arno Rauschenbeutel — QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz

We present our recent results on trapping laser-cooled cesium atoms around a subwavelength-diameter optical nanofiber. The atoms are localized in the evanescent field in a 1d optical lattice, created by blue- and a red-detuned laser beams, launched through the fiber. We detect the atoms by measuring the absorption of a weak resonant probe beam, sent through the fiber, which couples to the atoms via the evanescent field. Remarkably, the ensemble of 2000 trapped atoms is optically dense. Furthermore, we demonstrate a fiber-based optical conveyor belt. For this purpose, the two counter-propagating red-detuned beams are mutally detuned, thereby setting the optical lattice in motion and transporting the atoms along the fiber. Finally, we demonstrate an interferometric measurement of the optical phase shift due to the atomic ensemble. Our technique opens the route towards the direct integration of laser-cooled atomic ensembles within fiber networks, an important prerequisite for large scale quantum communication schemes. Moreover, it is ideally suited to the realization of hybrid quantum systems that combine atoms with, e.g., solid state quantum devices.

Financial support by the ESF (EURYI Award) and the Volkswagen Foundation (Lichtenberg Professorship) is gratefully acknowledged.

Q 2.3 Mo 14:30 A 320

Laser cooling of a magnetically guided ultra cold atom beam — •Anoush Aghajani-Talesh, Markus Falkenau, Valentin Volchkov, Axel Griesmaier, and Tilman Pfau — Universität Stuttgart, 5. Physikalisches Institut

We report on the transverse laser cooling of a magnetically guided beam of ultra cold chromium atoms. Radial compression by a tapering of the guide is employed to adiabatically heat the beam. Subsequently, heat is extracted from the atom beam by a two-dimensional optical molasses perpendicular to it, resulting in a significant increase of atomic phase space density. A magnetic offset field is applied to prevent optical pumping to untrapped states. Our results demonstrate that by a suitable choice of the magnetic offset field, the cooling beam intensity and detuning, atom losses and longitudinal heating can be avoided. Final temperatures below 65 μK have been achieved, corresponding to an increase of phase space density in the guided beam by more than a factor of 30. We discuss the resulting implications for the loading of a optical dipole trap from the beam [1].

[1] A Aghajani-Talesh, M Falkenau, A Griesmaier, and T Pfau. A proposal for continuous loading of an optical dipole trap with magnetically guided ultra cold atoms. *J. Phys. B.* **42** 245302 (2009).

Q 2.4 Mo 14:45 A 320

A miniaturized microwave guide for electrons — •Johannes Hoffrogge and Peter Hommelhoff — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching bei München

We are currently setting up an experiment aiming at guiding electrons in an AC quadrupole guide. The use of miniaturized trapping structures allows for an exceptional tight confinement in the transverse direction. In combination with a single atom tip as electron source, electron injection near the transverse ground state of motion may become feasible. This would lead to a well-defined motional quantum system with potential applications in, e.g. electron interferometry. While ion traps are driven at radiofrequencies, the stable confinement of electrons demands operation at microwave frequencies because of their much higher charge to mass ratio. This can be accomplished by the combination of the electrode layout of a microfabricated planar Paul trap with that of a microwave transmission line on a planar substrate. In stark contrast to the case of ion traps, for a guide with a length comparable to the wavelength of the driving field, the microwave guiding properties of the trap structure become important. Here, we show results of a detailed microwave analysis of a planar five wire structure driven at 1 GHz. As another important element of the experiment, an optimized incoupling structure for a smooth transition from the field free region to the trapping field will be dicussed. We also present experimental results of a first realization with trap frequencies around 100 MHz and radial trap dimensions of several hundred micrometers.

Q 2.5 Mo 15:00 A 320

Stopping particles of arbitrary velocities with an accelerated wall — •Sönke Schmidt[1], J. Gonzalo Muga[2], and Andreas Ruschhaupt[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany — [2]Departamento de Quimica Fisica, UPV-EHU, Bilbao, Spain

We propose a method to stop a pulse of particles with different velocities by making them collide with an accelerated wall with trajectory proportional to the square root of time. We discuss the ideal one-dimensional case. Then we generalize the model to three dimensions and different geometries of the potential wall to give a more realistic description. Finally we show the efficiency of the method.

Q 2.6 Mo 15:15 A 320

Kalte neutrale Quecksilberatome in einer MOT — •Sebastian Siol, Patrick Villwock, Mathias Sinther und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, AG Laser und Quantenoptik, Schlossgartenstr. 7, 64289 Darmstadt

Quecksilber hat fünf stabile bosonische und zwei stabile fermionische Isotope, die sich fangen und kühlen lassen. Die fermionischen Isotope eignen sich zur Untersuchung eines neuen optischen Zeitstandards. Zusätzlich bietet eine magneto-optische Falle die Möglichkeit durch Photoassoziation translatorisch kalte Hg-Dimere herzustellen und in den vibratorischen Grundzustand zu kühlen.

Die Sättigungsintensität des Kühlübergangs bei 253,7 nm beträgt 10,2 mW/cm^2, bei einer natürlichen Linienbreite von 1,27 MHz. Durch die zweistufige externe Frequenzverdopplung eines Yb:YAG Scheibenlasers bei 1014,9 nm kann eine UV-Leistung von bis zu 280 mW bereitgestellt werden. Zur Frequenzstabilisierung des Lasers wird ein entsprechendes Fehlersignal durch dopplerfreie Sättigungsspektroskopie in Kombination mit Frequenzmodulationsspektroskopie generiert. Es wurden Atomzahlen von bis zu (3,2±0,3)x10^6 erreicht. Bei einem mittleren Wolkenradius von (250±18) μm entspricht dies einer Atomdichte von (4,8±1,4)x10^{10} Atome/cm^3.

Neben der experimentellen Realisierung der magneto-optischen Falle werden die jüngsten Ergebnisse sowie interessante Anwendungsmöglichkeiten diskutiert.

Q 2.7 Mo 15:30 A 320

Manipulation of atoms with optical tweezers — •Lukas Brandt, Cecilia Muldoon, Tobias Thiele, Jian Dong, and Axel Kuhn — University of Oxford, Clarendon Laboratory, Parks Road, Oxford OX1 3PU, UK

In many implementations of quantum information processing schemes, the control of individual qubits relies on the ability to arbitrarily manipulate, address and couple individual information carriers, like single atoms or single photons. Here, we report on a novel dipole-trapping experiment that will ultimately allow to trap single neutral atoms in separate dipole traps and to displace them individually.

In order to reach a high degree of control on single atoms, we are implementing a scheme that enables us to trap ^{87}Rb atoms in an array of individual optical dipole-traps. These dipole-traps are created by imaging the surface of a digital light-modulator. The light-modulator is a digital micro-mirror device (DMD) whose surface consists of 1024 x 768 micro-mirrors. The micro-mirrors can be individually switched. By switching the micro-mirrors, the dipole-trap array can be dynamically rearranged. The DMD is imaged by an isoplanatic optical system [1], which is diffraction limited with a numerical aperture of NA=0.5 and thus is able to focus the light to a submicron spot size.

Recently we have observed trapping of atoms in separate dipole traps. This is the first step towards an array of trapped individual atoms.

[1] E. Brainis et. al., Optics Communication 282, 465 (2009)

Q 2.8 Mo 15:45 A 320

Laser cooling of atoms by collisional redistribution of radiation — •Anne Sass, Ulrich Vogl, and Martin Weitz — Institut für Angewandte Physik der Universität Bonn, Wegelerstraße 8, D-53115 Bonn

The general idea that optical radiation may cool matter was put forward by Pringsheim already in 1929. Doppler cooling of dilute atomic gases is an extremely successful application of this concept, and more recently anti-Stokes fluorescence cooling in multilevel systems has been explored. We experimentally demonstrate cooling of an atomic gas by collisional redistribution of fluorescence, a technique based on the atomic two level system, using rubidium atoms subject to 200 bar of argon gas pressure. The frequent collisions in the ultradense gas transiently shift a far red detuned laser beam into resonance, while spontaneous decay occurs close to the unperturbed atomic resonance frequency. During each excitation cycle, a kinetic energy of order of the thermal energy $k_{\mathrm{B}}T$ is extracted from the dense atomic sample. We presently achieve cooling in a heated gas from an initial temperature of 410 °C down to −120 °C temperature in the laser beam focus. The cooled gas has a density of more than 10 orders of magnitude above the typical values in Doppler cooling experiments. Future prospects of the demonstrated technique can include cryocoolers and the study of homogeneous nucleation in saturated vapour.

Q 3: Quantum Gases: Bosons I

Time: Monday 14:00–16:00 Location: E 001

Q 3.1 Mo 14:00 E 001

Matter Wave Turbulence: Beyond Kinetic Scaling — •Boris Nowak, Christian Scheppach, and Thomas Gasenzer — Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg

Turbulent scaling phenomena in an ultracold Bose gas far away from thermal equilibrium are studied theoretically. These phenomena are characterized in terms of universal scaling of correlation functions like the momentum distribution of particles. It is shown that certain scaling exponents derived within the Kolmogorov-Zakharov theory of wave turbulence are not necessarily found in the full dynamical theory considered here. Despite this, our results indicate that the Kolmogorov picture remains useful even in the strong turbulence regime at long wavelengths. Power-laws with anomalously large exponents recently found for the momentum dependence of the density in the long-wavelength limit could be experimentally accessible in ultracold atomic gases. Possible avenues to study such dynamical critical phenomena in experiments with ultracold gases are explored.

Q 3.2 Mo 14:15 E 001

Anderson Localization of Solitons — Krzysztof Sacha[1,2], •Cord A. Müller[2,3], Dominique Delande[2], and Jakub Zakrzewski[1] — [1]Uniwersytet Jagielloński, Kraków, Poland — [2]Laboratoire Kastler-Brossel, Paris, France — [3]Physikalisches Institut, Universität Bayreuth, Germany

At low temperature, a quasi-one-dimensional ensemble of atoms with an attractive interaction forms a bright soliton. When exposed to a weak and smooth external potential, the shape of the soliton is hardly modified, but its center-of-mass motion is affected. We show that in a spatially correlated disordered potential, the quantum motion of a bright soliton displays Anderson localization. The localization length can be much larger than the soliton size and could be observed experimentally.

[1] K. Sacha et al., PRL 103, 210402 (2009)

Q 3.3 Mo 14:30 E 001

Quasi-relativistic physics with ultra-cold gases — Julius Ruseckas[1], Gediminas Juzeliunas[1], Michael Merkl[2], Frank Zimmer[2], Patrik Öhberg[2], Markus Lindberg[3], Andreas Jacob[4], and •Luis Santos[4] — [1]Institute of Theoretical Physics and Astronomy of Vilnius University, A. Gostauto 12, Vilnius 01108, Lithuania — [2]School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh EH14 4AS, United Kingdom — [3]Department of Physics, Abo Akademi University, Abo FIN-20500, Finland — [4]Institute of Theoretical Physics, Leibniz University of Hannover, Appelstr. 2 D-30169, Hannover, Germany

Although cold gases are typically neutral, artificial electromagnetism may be induced by rotation, hopping-engineering in lattices and particular laser arrangements (as recently realized at NIST). We focus on the latter, discussing how spin-orbit coupling (SOC) may be induced in cold atoms, leading to a Dirac point and quasi-relativistic physics, in spite of the extremely low velocities. After discussing some quasi-relativistic consequences (as atomic Veselago super-lensing), we comment on the nonlinear properties of spinor condensates with SOC, which under proper conditions are described by a nonlinear Dirac equation, which present self-localized solutions, resembling chiral confinement in high-energy physics. We analyze 1D self-confined condensates, which present an intriguing sinusoidal dependence with the interaction strength. In addition, we show that the interplay between SOC and non-linearity may allow for self-localized condensates in 2D and 3D, which are fundamentally unstable in standard condensates.

Q 3.4 Mo 14:45 E 001

Process-chain approach to the Bose-Hubbard model — •Niklas Teichmann, Dennis Hinrichs, and Martin Holthaus — Institut für Physik, Carl von Ossietzky Universität, D-26111 Oldenburg, Germany

We carry out a perturbative analysis, of high order in the tunneling parameter, of the ground state of the homogeneous Bose-Hubbard model in the Mott insulator state[1]. This is done within a diagrammatic process-chain approach, derived from Kato's representation of the many-body perturbation series, which can be implemented numerically in a straightforward manner. We compute ground-state energies, atom-atom correlation functions, density-density correlations, and occupation number fluctuations, for one-, two-, and three-dimensional lattices with arbitrary integer filling. In addition, the process-chain approach is employed for calculating the boundary between the Mott insulator phase and the superfluid phase with very high accuracy. We find a surprising scaling relation, that maps critical hopping parameters for different filling factors onto each other [2].

[1] N. Teichmann, D. Hinrichs, M. Holthaus and A. Eckardt, Phys. Rev. B **79**, 224515 (2009).

[2] N. Teichmann and D. Hinrichs, EPJ B **71**, 219 (2009).

Q 3.5 Mo 15:00 E 001

Emergence of Levy distribution in many-body quantum systems — •Alexey V. Ponomarev, Sergey Denisov, and Peter Hanggi — Institute of Physics, University of Ausgburg, Germany

Levy distribution is known to describe a whole range of complex phenomena: classical chaotic transport, processes of subrecoil laser cooling, fluctuations of stock market indices, time series of single molecule blinking events, bursting activity of small neuronal networks, to name a few. The appearance of Levy distribution in a system output is a strong indicator of a long-range correlation "skeleton" which conducts system intrinsic dynamics.

Using two complimentary approaches, the canonical and the grand-canonical formalisms, we discovered that the momentum distribution of N strongly interacting (hard-core) bosons at finite temperatures confined on a one-dimensional optical lattice obeys the Levy distribution. The tunable Levy spline reproduces momentum distributions up to one recoil momentum. Our finding allows for calibration of complex quantum many-body states by using a unique scaling exponent.

[1] A. V. Ponomarev, S. Denisov and P. Hanggi, arXiv:0907.4328.

Q 3.6 Mo 15:15 E 001

Quantum Kinetic Theory of Superfluid Internal Convection — •Lukas Gilz and James R. Anglin — TU Kaiserslautern, Kaiserslautern, Germany

When a superfluid is heated locally one observes a superfluid current from colder to hotter regions, while the normal fluid flow is directed in the opposite direction. This 'internal convection' is modeled well by Landau's phenomenological two fluid model. We obtain a more fundamental description of internal convection by extending standard Quantum Kinetic Theory to include two reservoirs of different temperatures. We find that internal convection is caused by non-resonant scattering events that do not conserve momentum.

Q 3.7 Mo 15:30 E 001

Local and non-local relaxation of a 1D Bose gas with finite interactions — •Dominik Muth, Bernd Schmidt, and Michael Fleischhauer — Fachbereich Physik und Forschugszentrum OPTIMAS, Technische Universität Kaiserslautern

Simulating the dynamics of interacting quantum many-body systems is one of the computationally hardest problems in physics. One of the open questions is, whether integrable models, which have an infinite number of conserved quantities, relax (say, after a quench in the interaction strength) to a state that can be locally fully described by a grand canonical ensemble, defined only by temperature and chemical potential, or whether other quantities have to be taken into account in the Gibbs state. We investigate this question in the case of a 1D Bose gas with repulsive delta-type interactions, as found in recent experiments using ultra-cold gases. Dynamical simulations (employing a matrix-product-states description) of a quench yields both local and non-local correlations. They indicate, that indeed the stationary state for local quantities is identical to the grand canonical one. The same method is applied to the regime of strong attractive interactions. Here experiments have shown, that the system, instead of collapsing into the ground state, remains in a highly excited, metastable state. The properties and process of the formation of this so called super Tonks-Girardeau gas will be explored.

Q 3.8 Mo 15:45 E 001

Finding stationary states of the Gross-Pitaevskii equation: A numerical approach — •Parimah Kazemi — Universität Ulm, Institut für Quantenphysik, D-89069 Ulm, DE

The Gross-Pitaevskii equation is the starting point for studying many systems of Bose-Einstein condensates and superfluidity. In this work, we present a new method for the direct minimization of the Gross-Pitaevskii (GP) energy with or without rotation. The minimizers of the Gross-Pitaevskii energy correspond to stationary states. Our minimization is based on a gradient descent method using a new approach to enforce the normalization constraint. The new method is implemented in both finite difference and finite element in two and three dimensional settings and used to compute various complex configurations including those with vortices of rotating Bose-Einstein condensates. The new gradient method shows better numerical performances compared to classical gradient methods, especially when high rotation rates and complex trapping potential are considered

Q 4: Quantum Information: Concepts and Methods I

Time: Monday 14:00–16:00 Location: E 214

Q 4.1 Mo 14:00 E 214

A novel number operator-annihilation operator uncertainty relation and its use for entanglement detection — •Iñigo Urizar Lanz[1] and Geza Toth[1,2,3] — [1]Theoretical Physics, The University of the Basque Country, E-48080 Bilbao, Spain — [2]IKERBASQUE, Basque Foundation for Science, E-48011 Bilbao, Spain — [3]Research Institute for Solid State Physics and Optics, H-1525 Budapest, Hungary

We consider the number operator-annihilation operator uncertainty as a well behaved alternative of the number-phase uncertainty relation, and examine its properties. We find a formulation in which the bound on the product of uncertainties depends on the expectation value of the particle number. Thus, while the bound is not a constant, it is a quantity that can be easily controlled in many systems. The uncertainty relation is approximately saturated by number-phase intelligent states. It allows us to define amplitude squeezing, connecting coherent states to Fock states, without a reference to a phase operator. We consider using the uncertainty relation for entanglement detection.

Q 4.2 Mo 14:15 E 214

All reversible dynamics in maximally non-local theories are trivial — David Gross[1], •Markus Mueller[2], Roger Collbeck[3], and Oscar Dahlsten[3] — [1]Leibniz-Universitaet Hannover — [2]TU Berlin — [3]ETH Zuerich

A remarkable feature of quantum theory is non-locality (i.e. the presence of correlations which violate Bell inequalities). However, quantum correlations are not maximally non-local, and it is natural to ask whether there are compelling reasons for rejecting theories in which stronger violations are possible. To shed light on this question, we consider post-quantum theories in which maximally non-local states (non-local boxes) occur. It has previously been conjectured that the set of dynamical transformations possible in such theories is severely limited. We settle the question affirmatively in the case of reversible dynamics, by completely characterizing all such transformations allowed in this setting. We find that the dynamical group is trivial, in the sense that it is generated solely by local operations and permutations of systems. In particular, no correlations can ever be created; non-local boxes cannot be prepared from product states (in other words, no analogues of entangling unitary operations exist), and classical computers can efficiently simulate all such processes.

Q 4.3 Mo 14:30 E 214

Almost compatible observables in quantum tests of contextuality — Otfried Gühne[1,2], •Matthias Kleinmann[1], Adán Cabello[4], Jan-Ake Larsson[5], Gerhard Kirchmair[1,3], Florian Zähringer[1,3], Rene Gerritsma[1,3], Rainer Blatt[1,3], and Christian Roos[1,3] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Innsbruck, Austria — [2]Institut für Theoretische Physik, Universität Innsbruck, Austria — [3]Institut für Experimentalphysik, Universität Innsbruck, Austria — [4]Departamento de Física Aplicada II, Universidad de Sevilla, Spain — [5]Institutionen för Systemteknik och Matematiska Institutionen, Linköpings Universitet, Sweden

The Kochen-Specker-Theorem proves that in a hidden variable description of a quantum system, the value of a particular property (observable) depends on the context in which the value is to be revealed. The conflict here is between the hidden variable approach and the theory of quantum mechanics.

In order to establish this conflict as the inability to employ a hidden variable description of an actual experiment, it has been suggested to extend the notion of non-contextuality to sequential measurements of compatible observables. However, in an experimental implementation the requirement of perfect compatibility cannot be reached. We show that this “compatibility loophole” can be addressed and that a recent experiment using tapped ions [G. Kirchmair *et al.*, Nature (London) **460**, 494 (2009)] then excludes a large class of non-contextual hidden variable models.

Q 4.4 Mo 14:45 E 214

Quantum state tomography via compressed sensing — •David Gross[1], Yi-Kai Liu[2], Steve Flammia[3], Stephen Becker[4], and Jens Eisert[5] — [1]Leibniz-Universitaet Hannover — [2]California Institute of Technology — [3]Perimeter Institute for Theoretical Physics — [4]California Institute of Technology — [5]Universitaet Potsdam

We establish novel methods for quantum state and process tomography based on compressed sensing. Our protocols require only simple Pauli measurements, and use fast classical post-processing based on convex optimization. Using these techniques, it is possible to reconstruct an unknown density matrix of rank r using $O(rd \log d)$ measurement settings, a significant improvement over standard methods that require d^2 settings. The protocols are stable against noise, and extend to states which are approximately low-rank. The acquired data can be used to certify that the state is indeed close to a low-rank one, so no *a priori* assumptions are needed.

At the same time, new mathematical methods for analyzing the problem of low-rank matrix recovery have been obtained. The methods are both considerably simpler, and more general than previous approaches. It is shown that an unknown $d \times d$ matrix of rank r can be efficiently reconstructed given knowledge of only $O(dr \log^2 d)$ randomly sampled expansion coefficients with respect to any given matrix basis.

Q 4.5 Mo 15:00 E 214

Convex Polytopes and Quantum States — •colin wilmott, hermann kampermann, and dagmar bruss — Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, Düsseldorf

A *convex polytope* is defined as the convex hull of a finite non-empty set of vectors. We present a theorem of Rado (1952) which characterizes the convex hull of the collection of all permutations of a given real d-tuple in terms of the Hardy-Littlewood-Pólya spectral order relation $\prec$. We give a necessary and sufficient condition to construct a d-dimensional convex polytope which utilizes Rado's original $(d-1)$-dimensional characterization, and we describe how the resulting polytope may be placed in a quantum mechanical framework.

Q 4.6 Mo 15:15 E 214

Mapping between Kitaev's quantum double and the Levin-Wen spin net — •Zoltan Kadar[1], Annalisa Marzuoli[2], and Mario Rasetti[1,3] — [1]ISI Foundation, Torino, Italy — [2]University of Pavia, Italy — [3]Politecnico di Torino, Italy

Duality in lattice gauge theory is an equivalence of different descriptions of states living on the lattice. Kitaev's model is the description in terms of the (gauge) group algebra basis, the Levin-Wen spin net is that in the Fourier (a.k.a. spin network) basis. The construction is explicit for the ground state, whereas matching excitations is an open problem.

Q 4.7 Mo 15:30 E 214

Factorization with Gauss Sums — •Sabine Wölk and Wolfgang Schleich — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

Gauss sums manifest themeselves in many different physical phenomena. Therefore, the theoretical suggestion to factorize numbers with the help of the truncated Gauss sum led to many different realizations, such as the factorization with NMR, cold atoms, BEC, ultrashort laserpulses and classical light interferometry.

In the meantime, many questions such as "What happens, if we use rational numbers instead of integers as arguments of the truncated Gauss sum?" or "Is it possible to calculate Gauss sums efficient with the help of entanglement" turned up. In our talk, we will give a short overview of the topic of factorization with Gauss sums and try to answer sum of theses questions.

Q 4.8 Mo 15:45 E 214

Asymptotic dynamics of quantum systems under random unitary evolution — •Jaroslav Novotny[1,2], Gernot Alber[1], and Igor Jex[2] — [1]TU Darmstadt, Germany — [2]CTU in Prague, Czech Republic

We investigate the asymptotic dynamics of quantum systems resulting from large numbers of iterations of randomly applied unitary quantum operations. Despite the fact that in general the evolution superoperator of such random unitary operations cannot be diagonalized it is shown that the resulting iterated asymptotic dynamics is described by a diagonalizable superoperator. As a consequence it turns out that typically the resulting iterated asymptotic dynamics is governed by a low dimensional attractor space which is determined completely by the unitary transformations involved and which is independent of the probability distributions with which these unitary transformations are selected.

Based on this general approach analytical results are presented for the asymptotic dynamics of large qubit networks whose nodes are coupled by randomly applied controlled rotations.

Q 5: Laser Development: Nonlinear Effects I

Time: Monday 14:00–16:00 Location: F 128

Q 5.1 Mo 14:00 F 128

Ein frequenzverdoppeltes Lasersystem bei 511 nm zur Erzeugung von Antiwasserstoff — •Stefan Böttner, Andreas Müllers und Jochen Walz — Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, D-55128 Mainz, Germany

Das ATRAP Experiment am Antiproton Decelerator (AD) des CERN produziert Antiwasserstoff für zukünftige Tests der CPT Invarianz. Über eine Drei-Teilchen-Rekombination von zwei Positronen und einem Antiproton entsteht Antiwasserstoff. Die Atome sind allerdings zu heiß um sie zu speichern. Eine Möglichkeit, kältere Atome zu erhalten, ist der doppelte Ladungsaustausch. Hierbei wechselwirkt Rydberg-angeregtes Cäsium mit Positronen, wobei Positronium entsteht, das dann mit Antiprotonen Antiwasserstoff bildet.

Die Anregung von Cäsium erfolgt zweistufig. Der erste Übergang von $6S_{1/2}$ zu $6P_{3/2}$ wird mit einer 852 nm Laserdiode realisiert. Der zweite Anregungsschritt bei 511 nm erfolgt durch ein Lasersystem bestehend aus einem MOPA Aufbau bei einer Wellenlänge von 1022 nm und einer anschließenden Frequenzverdopplung in einem kompakten Resonator. Im Unterschied zur Bow-Tie-Geometrie wurden die Spiegel des langen Arms durch ein Prisma ersetzt, was den Strahlweg stark verkürzt und damit die Stabilität erhöht.

Bisher konnte eine Leistung von 125 mW bei 511 nm erreicht werden. Dies erlaubte in der Strahlzeit in 2009 die Erzeugung von Rydberg Cäsium innerhalb des 1 T Magnetfeldes der Falle. Durch weitere

Optimierungen der Konversionseffizienz des Resonators wird noch eine Erhöhung der harmonischen Leistung erwartet.

Q 5.2 Mo 14:15 F 128

Aufbau eines gepulsten $Ba(NO_3)_2$-Raman-Lasers zur Erzeugung schmalbandiger Laseremission bei 1599 nm — Hanjo Rhee[1], •Oliver Lux[1] und Alexander A. Kaminskii[2] — [1]Institut für Optik und Atomare Physik, TU Berlin, Deutschland — [2]Shubnikov Institute of Crystallography, Russian Academy of Sciences, Moscow, Russia

Der nichtlineare Effekt der stimulierten Raman-Streuung (SRS) bietet die Möglichkeit zur Erzeugung neuer Laserwellenlängen. Dabei ist der Spektralbereich zwischen 1570 und 1613 nm interessant für die CO_2-Detektion mittels Differential Absorption LIDAR (DIAL). Es wurden mehr als 80 verschiedene organische und anorganische Kristalle hinsichtlich ihrer Eignung als Raman-aktive Materialien für die Frequenzumsetzung in diesen Spektralbereich untersucht. Die Größe der induzierten diskreten Frequenzverschiebungen ist materialabhängig, wobei neben der SRS weitere nichtlineare Prozesse zweiter und dritter Ordnung eine Rolle spielen.
Weiterhin wurde ein externer Raman-Laser aufgebaut, der von einem gütegeschalteten Nd:YAG-Oszillator-Verstärker-System bei 1064 nm gepumpt wird. Als Raman-aktives Material dient hier ein Bariumnitratkristall ($Ba(NO_3)_2$), welcher ausgehend von der Pumpwellenlänge Frequenzverschiebungen im Abstand von etwa 1047 cm^{-1} erzeugt. Das Design des Raman-Lasers ist zu Gunsten einer effizienten Verstärkung der Stokes-Raman-Streuung dritter Ordung sowie einer hohen Schmalbandigkeit optimiert worden. Damit gelingt eine Laseremission bei 1599 nm mit hoher Pulsenergie und geringer spektraler Breite.

Q 5.3 Mo 14:30 F 128

Vier-Wellen-Mischen in Quecksilber mit Mehrphotonen-Resonanzen — •Daniel Kolbe, Martin Scheid, Andreas Koglbauer, Ruth Steinborn, Sven Richter und Jochen Walz — Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz

Im Zusammenhang mit Experimenten an Anti-Wasserstoff ist eine kohärente kontinuierliche Lichtquelle beim 1S–2P Kühlübergang (Lyman-α) wichtig. Diese Wellenlänge im Vakuum-Ultravioletten (VUV) kann durch Vier-Wellen-Mischen (VWM) mit drei unterschiedlichen Fundamentalstrahlen in Quecksilberdampf erreicht werden. Durch die Wahl von Wellenlängen in der Nähe von Resonanzen in Quecksilber lässt sich der nichtlineare Koeffizient, und damit die Lyman-α Leistung, steigern. Im Speziellen wird die Summenfrequenz zweier Laser genau auf eine Zweiphotonenresonanz abgestimmt. Es wird gezeigt, dass durch das zusätzliche Ausnutzen der intermediären Einphotonenresonanz, neben einer Änderung der nichtlinearen Suszeptibilität, vorallem eine Änderung der Phasenanpassung beobachtet werden kann. Damit wurde es möglich durch das Erweitern des VWM-Prozesses auf ein dreifach einphotonenresonantes Schema eine Steigerung der VUV Leistung um vier Größenordnungen zu erreichen.

Q 5.4 Mo 14:45 F 128

Lyman-α-Erzeugung in einem Überhöhungsresonator — •Sven Richter, Daniel Kolbe, Martin Scheid, Andreas Koglbauer, Ruth Steinborn, Andreas Müllers, Stefan Böttner und Jochen Walz — Institut für Physik, Johannes Gutenberg Universität Mainz, 55099 Mainz

Zur effektiven Kühlung von Antiwasserstoff wird kontinuierliche Lyman-α-Strahlung bei einer Wellenlänge von 121,56 nm benötigt.

Diese Lyman-α-Strahlung wird in einem Vier-Wellen-Misch-Prozesses erzeugt. Dazu werden drei fundamentale Laserstrahlen ausgewählter Frequenzen in ein nichtlineares Medium eingestrahlt, und durch Summenfrequenzmischen die benötigte Wellenlänge erreicht. Als Medium wird Quecksilberdampf verwendet, der innerhalb einer speziellen Dampfzelle erzeugt wird. Da der Vier-Wellen-Misch-Prozess als nichtlinearer Prozess dritter Ordnung sehr ineffizient ist sind bisherige kontinuierliche Lyman-α-Quellen nur im nW-Bereich möglich gewesen. Wegen der direkten Proportionalität der Lyman-α-Leistung zu den Fundamentalleistungen, soll das gleichzeitige Überhöhen aller drei Fundamentalstrahlen in einem Resonator die Ausgangsleistung deutlich steigern.

Um die Dampfzelle erfolgreich in den Resonator einzubinden, muss die Kontamination der Optiken durch Quecksilber vermieden werden, da dieses die Überhöhung empfindlich stört. Hierbei hat die Reinheit des Quecksilbers und die Geometrie der Dampfzelle eine zentrale Bedeutung. Deren Aufbau und der aktuelle Stand experimenteller Ergebnisse werden vorgestellt.

Q 5.5 Mo 15:00 F 128

Second Harmonic Generation in a Whispering Gallery Mode Resonator — •Josef Fürst[1,2], Dmitry Strekalov[3], Dominique Elser[1,2], Mikael Lassen[1,4], Ulrik L. Andersen[1,4], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max-Planck-Institut für die Physik des Lichts, Erlangen, Deutschland — [2]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, Erlangen, Deutschland — [3]Jet Propulsion Laboratory, California lnstitute of Technology, Pasadena, USA — [4]Department of Physics, Technical University of Denmark, Kgs. Lyngby, Dänemark

We present second harmonic generation(SHG) in a z-cut Lithium Niobate whispering gallery mode (WGM) resonator. Our WGM resonator has Q-factors of Q=10^7 for 1064 nm and 532 nm. Therefore nonlinear processes become efficient for very low optical powers. We apply non-critical temperature phase matching. We observed 9% conversion efficiency at 30 micro-Watts continuous wave input power for the SHG process. Additionally, we found a self-limiting effect at high pump power and over-coupled resonator. We will explore this effect further and aim for investigating dynamcial effects in the second order response of media, such as self pulsing and chaos.

Q 5.6 Mo 15:15 F 128

Effiziente Frequenzverdopplung im Einfachdurchgang eines kontinuierlich betriebenen Nd:YVO_4-Hochleistungslaser bei 1342 nm in MgO:PPLN — •Florian Lenhardt[1], Achim Nebel[2], Ralf Knappe[2], Thorsten Bauer[3], Jürgen Bartschke[3] und Johannes A. L'huillier[1] — [1]Photonik-Zentrum Kaiserslautern e.V., Kohlenhofstraße 10, 67663 Kaiserslautern — [2]Lumera Laser GmbH, Opelstraße 10, 67661 Kaiserslautern — [3]Xiton Photonics GmbH, Kohlenhofstraße 10, 67663 Kaiserslautern

Für kompakte Lichtquellen im roten Spektralbereich finden sich wichtige Anwendungen in der Spektroskopie, Display-Technologie und als Pumpquelle für cw-OPOs oder Cr:LiSaF-Laser. Ein Weg diesen Spektralbereich zu erreichen ist die Frequenzverdopplung von Nd-dotierten Festkörperlasern. Aufgrund des Fehlens von Lasern bei $1,3\ \mu m$ mit hohen Ausgangsleistungen, war es bisher nicht möglich effiziente Frequenzverdopplung im Einfachdurchgang zu erreichen. Dadurch war es nötig die Frequenzkonversion resonatorintern oder in einem externen Überhöhungsresonator zu erzielen. Beides erhöht die Komplexität des Aufbaus und verringert die Stabilität. Ein von uns kürzlich realisiertes Hochleistungslasersystem bei 1342 nm mit exzellenter Strahlqualität ermöglichte effiziente externe Verdopplung in einem langen MgO:PPLN-Kristall im Einfachdurchgang. Es wurde eine Leistung von $9,5$ W bei 671 nm in einem beugungsbegrenzten Strahl bei einer Effizienz von 46 % erreicht. Soweit uns bekannt wurde mit diesem Aufbau die höchste bisher veröffentlichte Ausgangsleistung bei 671 nm durch externe Frequenzverdopplung kontinuierlicher Strahlung realisiert.

Q 5.7 Mo 15:30 F 128

Highly Efficient Generation of the Second and Fourth Harmonic of Nd:YAG Laser Light — •Rajat Marwah[1], Sandra Mebben[1], Christian Kolleck[1,2], Jörg Neumann[1,2], and Dietmar Kracht[1,2] — [1]Laser Zentrum Hannover e.V., Hollerithallee 8, D-30419 Hannover, Germany — [2]Centre for Quantum-Engineering and Space-Time Research-Quest, Welfengarten 1, D-30167 Hannover, Germany

We present our results for various frequency conversion systems developed during the technology preparation program for the Martian Organic Molecular Analyzer laser of the joint ESA/NASA ExoMars Mission. A regular fiber-coupled passively Q-switched and linearly polarized Nd:YAG laser was used. The design of the harmonic generation stages is compact, with combined length of second and fourth harmonic generation stages down to 20 mm. The frequency conversion is highly efficient yielding $>$ 80 % efficiency of conversion from 1064 nm to 532 nm using KTP and $>$ 40 % efficiency from 532 nm to 266 nm using BBO. To the best of our knowledge, this is the highest efficiency achieved yet for a Q-switched system using BBO in single pass configuration. In the best case, M* of the UV beam was measured to be ~1.3 in the worse axis. The system has been shown to work with repetition rates up to 80 Hz.

An oscillator directly pumped with a diode stack with elliptical beam profile was also used for comparison, and although the 1064 nm beam had an M2 of ~3 in the worse axis, still high efficiencies (up to 80 % for 532 nm and ~30 % for 266 nm) could be obtained.

Q 5.8 Mo 15:45 F 128

Dauerstrich optisch parametrischer Oszillator zur direkten

Erzeugung durchstimmbarer Terahertz-Strahlung* — •Jens Kiessling, Rosita Sowade, Ingo Breunig und Karsten Buse — Physikalisches Institut der Universität Bonn, Wegelerstraße 8, 53115 Bonn, Deutschland

Wir demonstrieren einen durchstimmbaren optisch parametrischen Oszillator, basierend auf periodisch gepoltem Lithiumniobat, welcher kontinuierliche Terahertzstrahlung mit Leistungen im μW-Bereich erzeugt. Hierzu werden kaskadierte nichtlineare Prozesse ausgenutzt: das resonante nahinfrarote Signallicht des primären parametrischen Prozesses agiert selbst als Pumplicht für sekundäre, ebenfalls phasenangepasste optisch parametrische Oszillationen, deren Idlerwellen antiparallel zum Pumplicht laufen und im Terahertzbereich liegen. Die ferninfrarote Strahlung ist durchstimmbar von 1,2 bis 1,7 THz, besitzt nahezu Gauß'sches Strahlprofil und ist linear polarisiert.

* Unterstützt von der Deutschen Forschungsgemeinschaft und der Deutschen Telekom AG

Q 6: Ultrashort Laser Pulses: Generation I

Time: Monday 14:00–16:00 Location: F 342

Q 6.1 Mo 14:00 F 342

Regenerativer Ytterbium-KYW Verstärker mit kombinierten Verstärkungsspektren — •Alexander Büttner[1], Udo Bünting[2], Dieter Wandt[1,3], Dietmar Kracht[1,3] und Jörg Neumann[1,3] — [1]Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover — [2]Lumera Laser GmbH, Opelstr. 10, 67661 Kaiserslautern — [3]Centre for Quantum-Engineering and Space-Time Research - Quest, Welfengarten 1, 30167 Hannover

Wir präsentieren einen regenerativen Yb:KYW Ultrakurzpuls-Verstärker mit kombinierten Verstärkungsspektren. Als Seedquelle wird ein Yb-Faserlasersystem mit einer Pulsdauer von etwa 70 ps und einer Pulsenergie von 8 nJ verwendet. Der regenerative Verstärker ist als Doppelkristall-Aufbau realisiert, so dass die kristallooptischen Achsen Nm und Np des aktiven Mediums Yb:KYW innerhalb des Verstärkerresonators kombiniert werden. Die resonatorinterne Dispersion des Verstärkerresonators wurde mittels gechirpter Spiegel so weit kompensiert, dass sich auch bei einer Änderung der Anzahl der Resonatorumläufe zur Anpassung der Pulsenergie eine nahezu konstante Pulsdauer ergibt. Bei einer Wiederholfrequenz von 20 kHz wurde eine Pulsenergie von 250 μJ aus dem regenerativen Verstärker extrahiert. Die entsprechende komprimierte Pulsdauer betrug 196 fs. Bei einer Änderung der Pulsenergie von 10 bis 250 μJ variierte die komprimierte Pulsdauer auch ohne Nachjustage des Kompressors aufgrund der Nulldispersion des Resonators nur in einem Bereich von 180 bis 196 fs.

Q 6.2 Mo 14:15 F 342

Compact laser source for tunable sub 50 fs pulses with 44 MHz repetition rate and several 10 mW of average power in the range of 900 nm to 1300 nm. — •Bernd Metzger, Felix Hoos, Andy Steinmann, and Harald Giessen — 4th Physics Institute, University of Stuttgart, Germany

In the last decades it has become important for research to generate tunable ultrashort laser pulses. We developed a new cost-effective Yb:KGW laser source, which emits laser pulses between 200 fs and 300 fs and, depending on pulse duration, between 4 W and 4.5 W average power at 1025 nm. With this laser source we were able to generate ultrashort white light laser pulses in tapered fibers, which span a spectrum over 1000 nm with average output powers of 2.5 W. These pulses were characterized by XFROG (cross-correlation frequency-resolved optical gating). We compressed different spectral parts of the supercontinuum pulses using a simple SF10 prism sequence. We achieved pulse durations in the range of 25 fs to 50 fs with central wavelengths from 915 nm to 1200 nm and output powers ranging from 17 mW to 175 mW.

Q 6.3 Mo 14:30 F 342

Quasisynchron gepumpter Titan:Saphir-Oszillator mit oktavbreitem Spektrum — •Michael Jackstadt, Stefan Rausch, Thomas Binhammer, Guido Palmer und Uwe Morgner — Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland

Wir präsentieren einen quasi-synchron gepumpten Titan:Saphir-Laseroszillator, der von einem frequenzverdoppelten Ytterbium:KLuW-Scheibenlaser gepumpt wird. Bei 515 nm stehen ca. 8 Watt Pumpleistung bei einer Puls-Wiederhohlrate von 34,7 MHz und Pulslänge von 500 fs zur Verfügung. Der Ti:Saphir-Oszillator ist für eine Puls-Repetitionsrate von 69,4 MHz, was der doppelten Pumpfrequenz entspricht, ausgelegt. Eine Feineinstellung der Resonatorlänge kann über einen manuellen oder piezobetriebenen Verschiebetisch erfolgen. Normalerweise müssen solche, per Kerrlinse modengekoppelte, Laser durch eine externe Störung gestartet werden. Durch das quasisynchrone Pumpen zeigt der Laser nun ein selbststartendes Verhalten in einem Bereich, der einer Verstimmung der beiden Resonatoren um etwa ±100 Hz entspricht.

Eine echte Selbstsynchronisation der Pulswiederholraten von Scheibenlaser und Ti:Saphir-Laser wurde auch beobachtet - jedoch nur in sehr kleinen Verstimmungsbereichen und nicht immer reproduzierbar.

Weiterhin konnte die Träger-Einhüllenden-Frequenz des Systems mithilfe eines f-zu-2f-Interferometers gemessen und stabilisiert werden. Aufgrund des oktavbreiten Spektrums des Ti:Saphir-Oszillators konnte die Stabilisierung ohne externe spektrale Verbreiterung realisiert werden.

Q 6.4 Mo 14:45 F 342

Passively mode-locked Yb:YCOB laser with sub-50-fs pulse duration — •Akira Yoshida[1,2], Andreas Schmidt[1], Valentin Petrov[1], Uwe Griebner[1], Christian Fiebig[3], Katrin Paschke[3], and Götz Ebert[3] — [1]Max-Born-Institut for Nonlinear Optics and Short Pulse Spectroscopy, Berlin — [2]Institute of Laser Engineering, Osaka University, Japan — [3]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Berlin, Germany

Yb-doped $YCa_4O(BO_3)_3$ or YCOB is an acentric crystal interesting for ultrashort pulse generation and self-frequency doubling lasers. Mode-locking of Yb:YCOB has been reported only in one short communication with the modest result of 210 fs pulse duration [1]. Femtosecond mode-locking is investigated for Yb:YCOB pumped by a two-section distributed Bragg-reflector tapered diode-laser at 976 nm. The shortest pulse duration of 69 fs with an average output power of 58 mW were obtained with a Y-cut Yb:YCOB sample for the E//Z polarization. The output spectral bandwidth was 26.7 nm (FWHM) centered at 1050 nm, corresponding to a time-bandwidth product of 0.49. After external compression pulse durations as short as 49 fs were achieved, yielding a time-bandwidth product of 0.36. The obtained pulse durations with Yb:YCOB are among the shortest pulses demonstrated with mode-locked Yb lasers. Shorter pulses with a duration of 47 fs have been reported only once before, with $Yb:CaGdAlO_4$ [2].

[1] G. J. Valentine et al., Electron. Lett. **36**, 1621 (2000).
[2] Y. Zaouter et al., Opt. Lett. **31**, 119 (2006).

Q 6.5 Mo 15:00 F 342

Modengekoppelter zwei-Kristall Yb:KYW Oszillator mit Cavity-Dumping im positiven Dispersionregime — •Guido Palmer[1], Anna Lena Lindemann[1], Marcel Schultze[1], Martin Siegel[1], Moritz Emons[1] und Uwe Morgner[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [2]Laser Zentrum Hannover, Germany

Femtosekundenpulse mit Mikrojoule-Pulsenergien bei MHz-Repetitionsraten sind für eine Vielzahl von Anwendungen in Industrie und Forschung von großem Interesse. Im Bereich bis zu 10 Mikrojoule sind modengekoppelte Laseroszillatoren, die auf Bulk-Kristallen basieren und im positiven Dispersionsbereich (Chirped-Pulse-Oscillator, CPO) betrieben werden, hervorragend zur Erzeugung von sub-400-fs-Pulsen geeignet. Die hohe Auskopplung wird dabei z.B. mit Hilfe der Cavity-Dumping-Methode realisiert. Dabei sind die hohen Verstärkungen im Bulk-Kristall sowie die gechirpten Pulse Grundlage für eine hohe Auskoppeleffizienz beim Dumping. Zuvor konnten mit dieser Technik bereits Mikrojoule-Pulse bei 370 fs Pulsdauer mit einem auf Yb:KYW basierenden CPO bei einer Repetitionsrate von 1 MHz demonstriert werden. Wir stellen ein CPO-System vor, das im Gegensatz zum vorherigen Laser mit zwei Yb:KYW Kristallen betrieben wird und Pulsdauern unter 300 fs bei Ausgangsleistungen von über

2 W generiert. Neben der externen Kompression der Pulse von Piko- auf Femtosekunden Pulsdauer wird auf die Untersuchungen weiterer wichtiger Lasereigenschaften eingegangen.

Q 6.6 Mo 15:15 F 342

Yb:Lu_2O_3-Scheibenlaser mit 120 W in 800-fs-Pulsen und 301 W im cw-Betrieb — •Christian Kränkel[1,2], Cyrill Baer[1], Oliver H. Heckl[1], Clara J. Saraceno[1], Kolja Beil[2], Rigo Peters[2], Matthias Golling[1], Thomas Südmeyer[1], Klaus Petermann[2], Günter Huber[2] und Ursula Keller[1] — [1]Institut für Quantenelektronik, ETH Zürich, Schweiz — [2]Institut für Laser-Physik, Universität Hamburg, Deutschland

Im Dauerstrichbetrieb konnten wir die Ausgangsleistung von Yb:Lu_2O_3 und anderen Sesquioxiden unter Beibehaltung der hohen optisch-optischen Effizienz von nahezu 75% auf bis zu 301 W skalieren. Basierend auf diesen Ergebnissen realisierten wir den ersten SESAM-modengekoppelten Scheibenlaser mit mehr als 100 W mittlerer Ausgangsleistung. Bis zu 120 W in 796-fs-Pulsen bei einer Pulswiederholrate von 58 MHz und einer Pulsenergie von 2,1 μJ wurden erzielt. Bei etwas niedrigerer Ausgangsleistung von 103 W wies der Laser eine hohe optisch-optische Effizienz von 42% auf. Da dieses Material bereits die Erzeugung von 329-fs-Pulsen im Scheibenlaser zuließ, sind wir zuversichtlich, auch im >100 W-Regime in Zukunft kürzere Pulse zu erzeugen. Für noch kürzere Pulsdauern stehen bereits alternative Materialien wie Yb:YCOB und Yb:$LuScO_3$ zur Verfügung.

Q 6.7 Mo 15:30 F 342

Erzeugung von 1,3 μJ, 8,8 fs Pulsen mit einem OPCPA System bei 143 kHz Wiederholrate — •Marcel Schultze[1], Thomas Binhammer[2], Andy Steinmann[1], Guido Palmer[1], Moritz Emons[1] und Uwe Morgner[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland — [2]VENTEON Laser Technologies GmbH, Garbsen, Deutschland

Wir präsentieren ein nichtkollineares OPCPA System, welches Pulse mit 1,3 μJ Energie und 8,8 fs Dauer bei einer Repetitionsrate von 143 kHz generiert. Das System basiert auf einem breitbandigen Titan:Saphir Oszillator, der sowohl den Seed als auch die Pumpe für den parametrischen Prozess bereitstellt. Es werden die spektralen Anteile bei 1030 nm separiert, in einem regenerativen Scheibenverstärker mit Yb:YAG als Gewinnmedium verstärkt, und anschließend in einem LBO Kristall frequenzverdoppelt. Das restliche breitbandige Spektrum des Ti:Saphir Oszillators dient als Signalstrahl für den parametrischen Prozess. Die zeitliche und spektrale Charakterisierung der verstärkten Pulse wird mit interferometrischen Autokorrelations- und SPIDER-Messungen realisiert. Mit einer Pulsspitzenleistung von nahezu 130 MW in Kombination mit der hohen Wiederholrate von 143 kHz ist dieses kompakte System hervorragend für zukünftige Experimente im Bereich der Licht-Materie Wechselwirkung, wie z.B. die Erzeugung hoher harmonischer Strahlung, geeignet.

Q 6.8 Mo 15:45 F 342

Temporal Pulse Control and the Coherent Addition of Laser Pulses at a Multi-10-TW Diode Pumped Yb:Glass Laser. — •Marco Hornung, Ragnar Boedefeld, Alexander Kessler, Matthias Schnepp, Rico Wachs, Sebastian Keppler, Alexander Saevert, Joachim Hein, and Malte C. Kaluza — Institut für Optik und Quantenelektronik, FSU Jena, 07743 Jena, Deutschland

We present a detailed characterization of the dispersion management in the diode-pumped Yb:Glass CPA laser system Polaris, in order to minimize the pulse duration and to maximize the peak intensity. A novel method for the alignment routine of a tiled grating compressor is described as well as a controlling method for the coherent addition of multi-10-TW laser pulses. The parallel alignment of the gratings is accomplished by observing the far-field of a tunable cw-laser. The coherent addition of two beam-parts is monitored by a spectrally resolved far-field measurement and demonstrated with two beam-parts generated by using a tiled grating compressor. These techniques are easy to implement in any setup, cost effective and directly and intuitive to analyze. Using our alignment procedure for the tiled-grating compressor we achieve nearly diffraction limited far-field profiles of the laser pulses and an almost bandwidth limited pulse duration. With the Polaris system we reproducibly generate peak intensities in excess of 8×10^{19} W/cm^2 which characterizes Polaris as a powerful tool for high-intensity laser-matter interaction experiments.

Q 7: Precision Measurements and Metrology I

Time: Monday 14:00–15:45 Location: M 11

Q 7.1 Mo 14:00 M 11

How to determine the blackbody shift in Sr optical lattice clocks — •Thomas Middelmann, Christian Lisdat, Stephan Falke, Joseph Sundar Raaj Vellore Winfred, Fritz Riehle, and Uwe Sterr — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Optical clocks have surpassed ^{133}Cs microwave clocks in stability and systematic uncertainty. The $^1S_0-{}^3P_0$ clock transition of ^{88}Sr and ^{87}Sr is investigated as atomic reference in an optical lattice clock. Currently the largest contribution to the uncertainty of $1\cdot10^{-16}$ is due to the ac Stark effect from ambient blackbody radiation. In good approximation the blackbody shift is proportional to the differential static polarizability of the two clock states and to the fourth power of the environmental temperature.

To reduce the uncertainty of the blackbody shift we prepare to measure the differential static polarizability in a dc electric field. Moreover, we want to reduce the blackbody shift itself by a low temperature environment. Trapped in a horizontal 1-D optical lattice the strontium atoms will be transported into a dc electric field or a liquid nitrogen cooled environment respectively. It is necessary to move the interference pattern together with the focus position to ensure invariant trap depth. This is achieved by moving the lattice optics, which are on opposite sides of the vacuum system, with two air bearing stages. The current status of the experiment will be presented in the talk.

The work is supported by the Centre for Quantum Engineering and Space-Time Research (QUEST) and the ERA-NET Plus Programme.

Q 7.2 Mo 14:15 M 11

A compact source of ultracold Yb for an optical lattice clock — •Charbel Abou-Jaoudeh, Cristian Bruni, and Axel Görlitz — Institut für Experimentalphysik, HHU Düsseldorf, 40225 Düsseldorf

Neutral ytterbium (Yb) is an interesting candidate for the realization of an optical clock at a wavelength of 578 nm. In the fermionic isotopes, the corresponding transition $^1S_0 \rightarrow {}^3P_0$ has a natural linewidth of a few tens of mHz. The use of bosonic istopes (e. g. ^{174}Yb) in an optical lattice clock is also possible if well-controlled magnetic fields are used to enable the otherwise forbidden direct optical excitation of the clock transition.

Here we report on the development of a transportable source of ultracold Yb atoms for an optical lattice clock. All laser systems in the compact apparatus are diode-based. We have already implemented the first cooling stage using blue laser diodes at 399 nm and realized a magnetooptical trap with more than 10^7 atoms. Successful transfer of bosonic ^{174}Yb and fermionic ^{171}Yb into the second stage magnetooptical trap operating on the narrow $6^1S_0 \rightarrow 6^3P_1$ at 556 nm and further cooling of the atoms to temperatures of a few 100 μK has also been achieved. The next step will be to load the atoms into a 3D optical lattice at the magic wavelength of 759 nm which is formed in a folded linear resonator inside the vacuum chamber. The special design of the lattice setup allows for a large-volume optical lattice with a diameter of 150 μm and a potential depth of 100 μK if 200 mW of radiation from a tapered diode laser are coupled into the resonator.

Q 7.3 Mo 14:30 M 11

Development of a sub-Hz laser system for optical clocks — •Christian Hagemann[1], Thomas Kessler[1], Uwe Sterr[1], Fritz Riehle[1], Michael J. Martin[2], and Jun Ye[2] — [1]Physikalisch-Technische Bundesanstalt and Centre for Quantum Engineering and Space-Time Research QUEST, Bundesallee 100, 38116 Braunschweig, Germany — [2]JILA, NIST and University of Colorado, 440 UCB, Boulder, CO 80309-0440, USA

Today's best optical clocks are outperforming the best primary Cs frequency standards. The short-term performance of such clocks is limited by the frequency stability of the lasers that are used to interrogate the atomic or ionic quantum transition used as the pendulum of the atomic clock. In such setups a interrogation laser is locked to a high performance cavity for frequency stabilization.

In the QUEST framework we are developing a novel single-crystal silicon cavity operated at a temperature of 120 K aiming at achieving a stabilized laser linewidth well below 1 Hz. In this talk we present the design of the silicon cavity and current setup, comprising the cryostat as well as the laser system. Possible noise sources limiting the frequency stability such as mechanical vibrations, temperature drifts and thermal noise will be discussed.

Q 7.4 Mo 14:45 M 11

Octave-Spanning Frequency Comb Generation in a Microresonator — Pascal Del'Haye[1], •Tobias Herr[1], Emanuel Gavartin[2], Ronald Holzwarth[1], and Tobias Kippenberg[1,2] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]École Polytechnique Fédérale de Lausanne, CH 1015, Lausanne, Switzerland

We demonstrate for the first time the generation of an octave-spanning optical frequency comb via four-wave mixing in a fused silica microresonator. The microresonator is resonantly pumped via a tapered optical fiber with an amplified tunable diode laser (continuous-wave) at a pump power of 2.5 Watt. The generated frequency combs extend from 990 nm to 2170 nm, covering more than a full octave and are continuously tunable over more than 1 THz by changing the pump laser frequency. Octave spanning frequency combs directly generated in a monolithic microresonator are an important step towards fully self-referenced optical frequency combs on a chip.

Q 7.5 Mo 15:00 M 11

Optical single-ion clock using quantum logic — •Olaf Mandel, Ivan V. Sherstov, and Piet O. Schmidt — QUEST Inst. for Exp. Quantum Metrology, PTB Braunschweig and Leibniz Univ. of Hannover, Germany

We present the status of a recently started project to build a transportable optical clock based on a single aluminum ion. $^{27}Al^+$ has been chosen as the clock ion since it has a narrow (8 mHz) clock transition at 267 nm which exhibits no electric quadrupole shift and a low sensitivity to black-body radiation. The design goals for the frequency standard are an inaccuracy of 10^{-17} or better and relative stability of 10^{-15} in one second.

The $^{27}Al^+$ "clock ion" will be trapped together with a $^{40}Ca^+$ ion which will act as a "logic ion" and is used for sympathetic cooling and internal state detection of the clock ion. After interrogating the $^{27}Al^+$ ion with the clock laser, its internal quantum state will be transferred to the logic ion with techniques developed for quantum information processing. The result of the clock interrogation can then be read out via the $^{40}Ca^+$ ion (see also [1]).

Clock comparison beyond a fractional uncertainty of 10^{-16} is only possible via dedicated optical fibers or by direct comparison of two physically close standards. As a consequence, we plan to build a portable system that allows us to travel to other sites and perform frequency measurements at the 10^{-17} level or below.

[1] C.-W. Chou *et al.*, arXiv:0911.4527v1 [quant-ph] (2009)

Q 7.6 Mo 15:15 M 11

Entanglement and precision measurements with states of a fluctuating number of particles — •Philipp Hyllus[1], Augusto Smerzi[1], and Luca Pezze[2] — [1]BEC-CNR-INFM and Dipartimento di Fisica, Università di Trento, I-38050 Povo, Italy — [2]Laboratoire Charles Fabry, Institut d'Optique, 2 Avenue Fresnel, 91127 Palaiseau - France

For linear interferometers operating with states with a fluctuating number of particles, we define the shot-noise limit and the ultimate limit allowed by quantum mechanics, the so-called Heisenberg limit, taking into account properly the number m of single measurement runs that a phase-estimation experiment consists of. We discuss the relation between sub shot-noise sensitivity and entanglement of the particles and generalize the spin-squeezing parameter of [D.J. Wineland, *et al.*, *Phys. Rev. A* **50**, 67 (1994)] to the case of non-fixed N.

Q 7.7 Mo 15:30 M 11

High precision cold atom gyroscope — •Christian Schubert, Sven Abend, Peter Berg, Timo Denker, Michael Gilowski, Gunnar Tackmann, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover

Due to its high potential, matter wave interferometry has been investigated as a tool for high precision inertial measurements for years. The research topic of the CASI project (Cold Atom Sagnac Interferometer) is a gyroscope using laser cooled Rubidium atoms and aiming for a sensitivity of a few 10^{-9} rad/s/Hz$^{1/2}$ for 10^8 atoms per shot. The atomic ensemble is launched in a pulsed mode onto a flat parabola with a forward drift velocity of 2,79 m/s leading to an interrogation time of over 50 ms. Via coherent beamsplitting using Raman transitions, the atomic trajectories forming the interferometer paths can enclose an area of several mm^2. In this talk we discuss the influence of the main noise sources which limit the sensitivity of our quantum sensor. Particularly, contributions affecting the beam splitting process as well as the detection will be considered. Furthermore, the lastest interferometry measurements will be presented. This work is supported by the DFG, QUEST, and IQS.

Q 8: Quantum Effects: Interference and Correlations II / Entanglement and Decoherence I

Time: Monday 16:30–19:00 Location: A 310

Group Report Q 8.1 Mo 16:30 A 310

Quantum optics with single molecules: photon-photon interactions — •Stephan Goetzinger, Jaesuk Hwang, Robert Lettow, Martin Pototschnig, Alois Renn, Yves Rezus, Gert Zumofen, and Vahid Sandoghdar — Laboratory of Physical Chemistry and optETH, ETH Zurich, CH-8093 Zurich, Switzerland

In this talk we shall review our quantum optical experiments with single molecules at cryogenic temperatures with emphasis on interacting photons. In the first experiment, we show that photons can be efficiently coupled to a single emitter without the need for a microresonator [1], resulting in a strong extinction of a weak laser beam. We achieved stimulated emission from a single molecule and demonstrated that it can act as an optical transistor [2]. In a further experiment we exploited the fact that single molecules serve as independent frequency-tunable single photon sources with a flux of more than one million photons per second [3]. By tuning the frequencies and spectral widths of two individual remote molecules, we explored various aspects of two-photon interference [4].

[1] G. Wrigge et. al., Nature Physics 4, 60 (2008). [2] J. Hwang et al., Nature 460, 76 (2009). [3] R. Lettow et al., Optics Express 15, 15842 (2007). [4] R. Lettow et al., arXiv:0911.3031v1 [quant-ph], (2009).

Q 8.2 Mo 17:00 A 310

Superradiance from Nuclear Spins in Single Quantum Dots and NV-Centers — Eric Kessler[1], J. Ignacio Cirac[1], Susanne Yelin[2], Mikhail D. Lukin[3], and •Geza Giedke[1] — [1]Max-Planck Institut für Quantenoptik, 85748 Garching, Deutschland — [2]University of Connecticut, Storrs, CT 06269, USA — [3]Harvard University, Cambridge, MA 02138, USA

We show that superradiant optical emission can be observed from the polarized nuclear spin ensemble of a single quantum dot or NV center. The superradiant light is emitted under optical pumping conditions and would be observable in quantum dots at nuclear polarizations already demonstrated in the lab.

Q 8.3 Mo 17:15 A 310

Absorption of single photons by a single ion — •Lukas Slodicka[1], Gabriel Hetet[1], Sebastian Gerber[1], Markus Hennrich[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, A-6020 Innsbruck, Austria — [2]Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, A-6020 Innsbruck, Austria

A single trapped ion is an ideal system to investigate the most essential physical processes in atom-photon interfaces.

Here, we report on absorption spectroscopy experiments with a single trapped $^{138}Ba^+$ ion. We focus a weak and narrowband Gaussian light beam onto an optically cooled ion using a high numerical aperture lens. Single ion absorption was observed and peak absorption of up to 3% was measured, close to the limit set by the size of solid angle covered by the input lens. Furthermore, we observe electromagnetically induced transparency by tuning a dressing beam over a two photon resonance in a three level lambda system. A 50% inhibition of the absorption due to population trapping was measured.

Our results are first important steps towards realizing an efficient quantum network using single atoms and single photons in free space.

Q 8.4 Mo 17:30 A 310

Using coherently backscattered light from two atoms to measure the photon statistics of dipole-dipole interactions — •Vyacheslav Shatokhin[1,2], Sergei Kilin[2], and Andreas Buchleitner[1] — [1]Albert Ludwigs University of Freiburg, Freiburg, Germany — [2]B.I.Stepanov Institute of Physics, Minsk, Belarus

We discuss properties of the second-order temporal intensity correlation function of laser light coherently backscattered from two isotropic atoms in the helicity preserving polarization channel. We show that this function exhibits photon antibunching, and hence, it can be used as a measure of the photon statistics of resonant dipole-dipole interactions.

Q 8.5 Mo 17:45 A 310

Ramsey Interferometry of Ion Coulomb Crystals in Spin-Dependent Potentials — •Jens Domagoj Baltrusch[1,2], Gabriele De Chiara[2], Tommaso Calarco[3], Shmuel Fishman[4], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, Germany — [2]Grup d'Òptica, Universitat Autònoma de Barcelona, Spain — [3]Institut für Quanteninformationsverarbeitung, Universität Ulm, Germany — [4]Department of Physics, Technion, Haifa, Israel

Ions confined in a harmonic, but highly anisotropic potential crystallize in a linear chain at sufficient low temperatures. By lowering the ratio between the radial and axial trapping frequency below a critical value, the system passes through a second order phase transition from a linear to a zig-zag configuration. By coupling the internal and the motional degrees of freedom, it is possible to measure the statistical properties of the crystal via a Ramsey type of experiment. One example is given by the autocorrelation function of the crystal which is connected to the visibility of the Ramsey signal [G. De Chiara et al. PRA 78, 043414 (2008)]. We present prospects to extend this model for ion crystals subjected to spin-dependent potentials.

Q 8.6 Mo 18:00 A 310

Quantum entanglement in dense multiparticle samples — •Mihai Macovei, Joerg Evers, and Christoph H. Keitel — Max-Planck-Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany

The existence of entanglement in multi-particle samples is an important fundamental problem. Here, we discuss the pairwise entanglement of atoms randomly extracted from a laser-driven dense multi-particle sample [1]. Our model includes a control laser field as well as quantum dissipation due to spontaneous emission. We find that the dipole-dipole interaction between the particles shifts the laser-qubit resonance frequency and consequently modifies the quantum entanglement. By means of an appropriate tuning of the laser frequency, one can optimize the entanglement in this system. For large ensembles, the maximum entanglement occurs near the laser parameters where the steady-state sample exhibits phase transition phenomena.

[1] M. Macovei, J. Evers, C. H. Keitel, arXiv:0911.1223v1 [quant-ph].

Q 8.7 Mo 18:15 A 310

Single spontaneous emission inducing motional coherence of atoms — •Jiri Tomkovic[1], Michael Schreiber[1], Joachim Welte[1], Jörg Schmiedmayer[2], and Markus K. Oberthaler[1] — [1]Kirchhoff-Institut für Physik, Im Neuenheimer Feld 227, Heidelberg — [2]Atominstitut der österreichischen Universitäten, Stadionallee 2, 1020 Wien

Spontaneous emission of a photon leads to a momentum transfer to the emitting atom resulting in an incoherent momentum distribution of an atomic ensemble. In case the atoms are 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 8.8 Mo 18:30 A 310

Towards electron-electron entanglement in Penning traps — •Lucas Lamata[1], Diego Porras[1], Juan Ignacio Cirac[1], Joshua Goldman[2], and Gerald Gabrielse[2] — [1]Max-Planck-Institut fuer Quantenoptik, Hans-Kopfermann-Strasse 1, D-85748 Garching, Germany — [2]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

Entanglement of isolated elementary particles other than photons has not yet been achieved. We show how building blocks demonstrated with one trapped electron might be used to make a model system and method for entangling two electrons. Applications are then considered, including two-qubit gates and more precise quantum metrology protocols.

Q 8.9 Mo 18:45 A 310

Two interacting atoms in a cavity: Entanglement vs decoherence — •Emerson Sadurní[1,2], Thomas Seligman[2,3], and Mauricio Torres[2] — [1]Institut fuer Quantenphysik, Ulm Universitaet — [2]Instituto de Ciencias Físicas, UNAM. México — [3]Centro Internacional de Ciencias, UNAM, México

We address the problem of two interacting atoms of different species inside a cavity and find the explicit solutions of the corresponding eigenvalue problem. Closed expressions for concurrence and purity as a function of time when the cavity is prepared in a number state are found. The behavior in the concurrence-purity plane is discussed.

Q 9: Ultracold Atoms: Rydberg Gases / Miscellaneous (with A)

Time: Monday 16:30–19:00 Location: A 320

Prize Talk Q 9.1 Mo 16:30 A 320

Highly excited atoms in cold environments: From antihydrogen production to ultracold plasmas and Rydberg gases — •Thomas Pohl — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden — Laureate of the Gustav-Hertz-Prize

The production of cold antihydrogen atoms at CERN marks a major development in AMO as well particle physics, as it holds great promise for high precession-spectroscopy tests of CPT invariance and for investigating matter-antimatter gravity. Since they form in highly excited states, successful cooling and trapping of antihydrogen atoms relies on the special properties of Rydberg atoms and how they form in the strong magnetic fields of anti-matter plasma traps.

Here, I will report on recent progress in understanding the formation of Rydberg atoms in antihydrogen traps as well as in ultracold neutral plasmas, as produced from laser-cooled atomic gases. This also includes fundamental questions concerning the nature of recombination processes in ultracold, so-called strongly coupled systems and is important for pushing the temperature limits of Rydberg plasmas. Controlling the temperature in ultracold plasmas and Rydberg gases is shown to open up a diverse range of interesting phenomena, such as dynamical crystallization processes in the classical as well as in the quantum domain.

Q 9.2 Mo 17:00 A 320

Coherent population trapping with controlled interparticle interactions — •Georg Günter[1], Hanna Schempp[1], Christian Giese[1], Sebastian Saliba[1], Christoph Hofmann[1], Brett D. DePaola[1], Sevilay Sevincli[2], Thomas Pohl[2], Thomas Amthor[1], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg — [2]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, 01187 Dresden

Coherent population trapping (CPT) and the related phenomenon of a "dark resonance" is a paradigm for quantum interference. Intense studies of this phenomenon have led to intriguing effects like electromagnetically induced transparency, lasing without inversion, adiabatic population transfer and subrecoil cooling. Whereas CPT is generally described within a single-atom framework, the situation becomes more involved when interparticle interactions have to be considered. To address this question, we investigate CPT in a strongly interacting, ultracold Rydberg-gas. In our experiment we tune the interaction strength by choosing the Rydberg state and control interactions effects using the ground state density. Even in the blockade regime we observe a resonance with sub-natural linewidth at the single-particle resonance frequency despite the strong van der Waals interactions among Rydberg atoms. Due to the correlations among the atoms the experimental observations cannot be explained within a meanfield model. A theoretical model that includes interparticle correlations is presented and nicely reproduces the observed features.

Q 9.3 Mo 17:15 A 320

Semiclassical analysis of Rydberg molecules — •Gordana Palavestric, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

In cold gases ultra-long range Rydberg molecules have been predicted theoretically [1] and recently observed experimentally [2]. The molecular binding can be described with a Fermi pseudo-potential and the Born-Oppenheimer approximation. We present a semiclassical model to describe the interaction. The electron of the highly excited Rydberg atom is scattered at the ground state atom. The transferred momentum causes a force on the neutral atom. We solve the classical equations of motion and investigate the initial condition for the bound dynamics of the “Rydberg molecule”.

[1] C. H. Green, A. S. Dickinson, H. R. Sadeghpour, Phys. Rev. Lett. **85**, 2458 (2000).
[2] V. Bendkowsky, B. Butscher, J. Nipper, J. P. Shaffer, R. Löw and T. Pfau, Nature **458**, 1005 (2009).

Q 9.4 Mo 17:30 A 320

Strongly interacting Rydberg atoms in a one-dimensional lattice — •Hendrik Weimer and Hans Peter Büchler — Institut für Theoretische Physik III, Universität Stuttgart

We analyze the ground state properties of a one-dimensional lattice system, where Rydberg excitations are created by laser driving. In the classical limit the ground state is characterized by comensurate crystals with fractional exciations. We show that quantum fluctuations lead to a melting of the crystalline phases that is governed by condensation of the excitations. We compare the critical exponents obtained within perturbation theory to mean-field predictions for a homogeneous gas [1,2].

[1] H. Weimer, et al., Phys. Rev. Lett. **101**, 250601 (2008).
[2] R. Löw et al., Phys. Rev. A **80**, 033422 (2009).

Q 9.5 Mo 17:45 A 320

Antiblockade of Rydberg excitation in an ultracold gas — •Christoph S. Hofmann[1], Thomas Amthor[1], Christian Giese[2], Georg Günter[1], Hanna Schempp[1], Nele Müller[1], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg — [2]Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

The long-range character of strong Rydberg–Rydberg interactions gives rise to phenomena such as the interaction-induced blockade of Rydberg excitation. The opposite effect, the so-called antiblockade of excitation has recently been proposed for a three-level two-photon Rydberg excitation scheme, in which an Autler-Townes splitting is induced by strong coupling laser at the lower transition [1]. When the coupling energy matches the interaction energy of the long-range Rydberg interactions, the otherwise blocked excitation of close pairs becomes possible. We present the first experimental observation of the antiblockade in an ultracold Rydberg gas [2]. To reveal this effect we use time-resolved ionization detection. In this way we monitor the distribution of excited-pair distances, which allows us to clearly observe additional excitation (antiblockade) of pairs at small distances out of a random arrangement of atoms. A model based on a pair interaction Hamiltonian is presented which nicely reproduces our experimental observations and allows to analyze the distribution of nearest neighbor distances.

[1] C. Ates et al., Phys. Rev. Lett 98, 023002 (2007)
[2] T. Amthor et al., arXiv:0909.0837v1

Q 9.6 Mo 18:00 A 320

Occupation statistics of a Bose-Einstein condensate in a driven double-well potential — •Moritz Hiller[1], Katrina Smith-Mannschott[2,3], Maya Chuchem[4], Tsampikos Kottos[2], and Doron Cohen[4] — [1]Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]Department of Physics, Wesleyan University, CT, USA — [3]MPI für Dynamik und Selbstorganisation, Bunsenstraße 10, 37073 Göttingen — [4]Department of Physics, Ben-Gurion University, Beer-Sheva, Israel

We consider the occupation statistics $P_t(n)$ of a Bose-Einstein condensate consisting of N particles loaded in a double-well trap with inter-site coupling K. Two dynamical scenarios are investigated: a) wave-packet dynamics and b) linear variation of the bias between the on-site energies of the two wells. In the latter case, we resolve three different behaviors as we increase the driving rate for intermediate values of the inter-atomic interaction $K/N < U < NK$: quantum adiabatic, diabatic, and sudden regime. We find that during the adiabatic to diabatic crossover, many-body Landau-Zener transitions play a dominant role, resulting in oscillations of the second moment of the occupation statistics. In contrast, the crossover to the sudden regime is characterized by a broad distribution $P_{t\to\infty}(n)$ which is reflected in a global maximum of its second moment.

Q 9.7 Mo 18:15 A 320

Spectral origin of decaying Bloch oscillations — •Hannah Venzl, Moritz Hiller, and Andreas Buchleitner — Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

We study Bloch oscillations of ultra-cold bosonic atoms in tilted optical lattices. Our analysis is based on the Bose-Hubbard Hamiltonian amended by a static field term. For comparable values of the control parameters, namely the inter-atomic interaction, the inter-site hopping amplitude, and the static field, the system displays chaotic level statistics. In this regime, the Bloch oscillations exhibit an irreversible, fast decay. We discuss how the corresponding decay rate can be obtained from the spectral properties of the Bose-Hubbard Hamiltonian.

Q 9.8 Mo 18:30 A 320

Probing a Bose-Hubbard system with a scattering particle — •Stefan Hunn[1], Moritz Hiller[1], Tsampikos Kottos[2,3], Doron Cohen[4], and Andreas Buchleitner[1] — [1]Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]Department of Physics, Wesleyan University, CT, USA — [3]MPI für Dynamik und Selbstorganisation, Bunsenstrasse 10, 37073 Göttingen — [4]Department of Physics, Ben-Gurion University, Beer-Sheva, Israel

We consider a probe particle in a tight-binding geometry with two leads attached to a central site that is coupled to a Bose-Hubbard system consisting of two or three wells. We find that the characteristic properties of the target's underlying phase-space structure are reflected in the scattering signal. Hence, this scattering setup constitutes a non-destructive method to measure the properties of a Bose-Einstein condensate confined on an optical lattice. We focus on the parameter regime where the corresponding classical dynamics is chaotic and follow a three-fold approach to the scattering process: Besides the quantum mechanical scattering theory we employ an improved random matrix model and propose a time-dependent, semi-classical formulation of the scattering process where the Bose-Hubbard Hamiltonian is treated in the mean-field (Gross-Pitaevskii) limit.

Q 9.9 Mo 18:45 A 320

Connecting ultra hot with ultra cold: geometric phases in cold atoms — •Michael Merkl[1], Patrik Öhberg[1], Luis Santos[2], and Gediminas Juzeliunas[3] — [1]Heriot-Watt University Edinburgh — [2]Universität Hannover — [3]Vilnius University

Ultra-cold atoms have turned out to be an ideal playground for testing quantum physics. Recently analogies between ultra-cold systems and high energy physics have attracted a great interest. For kinetic energies below the photon recoil limit, the internal electronic states can be said to follow the optical field and hence a Berry phase emerges in the atom's centre of mass Schrödinger equation. Moreover, for a degenerate manifold of electronic states the geometric phase describes transitions within this pseudo-spin Hilbert space, which can also give rise to non-Abelian effects. In this work we show how a wide range of phenomena like Josephson effects, mass currents and soliton like objects in the presence of geometric gauge potentials can occur. These techniques can also be used to mimic aspects of relativistic quantum mechanics with cold atoms.

Q 10: Quantum Gases: Bosons II

Time: Monday 16:30–19:00 Location: E 001

Q 10.1 Mo 16:30 E 001

Towards an all-optical ^{87}Rb BEC for atom interferometry — •Maic Zaiser, Jonas Hartwig, Dennis Schlippert, Vyacheslav Lebedev, and Ernst Maria Rasel — Leibniz Universität Hannover - Institut für Quantenoptik;

We present studies of loading and evaporative cooling of pre-cooled ^{87}Rb atoms in a crossed optical dipole trap (ODT) formed by a Thulium-doped fiber laser at 2 μm wavelength and 50 W output power. The atomic source for loading the ODT consists of a two-stage design, where a three dimensional magneto-optical trap (3D MOT) is loaded by a 2D MOT. With this setup, we reach very quick loading (less than 500 ms) with high initial atom numbers and phase space densities in the ODT, a prerequisite for successful evaporative cooling to BEC with high atom numbers.

This work is motivated by the ultra-low temperatures feasible in BEC, thus potentially improving the accuracy of matter wave interferometers for precision measurements, such as e.g. a quantum test of the equivalence principle. Optical dipole traps make a fast production of BEC possible allowing for a high repetition rate in an interferometer. Additionally, dipole traps are able to trap all m_F-substates, especially $m_F = 0$, being insensitive to magnetic fields in first order.

Q 10.2 Mo 16:45 E 001

Bose-Einstein condensation of an alkaline earth element: ^{40}Ca — •Sebastian Kraft, Felix Vogt, Oliver Appel, Fritz Riehle, and Uwe Sterr — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

We have achieved Bose-Einstein condensation of ^{40}Ca [1], the first for an alkaline earth element. Due to the large ground state s-wave scattering length and associated large three body losses an optimized loading and cooling scheme was necessary to condense about $2 \cdot 10^4$ atoms. Our cooling scheme consisting of a two-stage magneto-optical trap and subsequent forced evaporation in a crossed dipole trap at magical wavelength allows to reach degeneracy within less than 3 s. Here we present the optimized route to BEC and discuss future applications.

[1] S. Kraft, F. Vogt, O. Appel, F. Riehle, and U. Sterr, Phys. Rev. Lett. **103**, 130401 (2009).

Q 10.3 Mo 17:00 E 001

Bose-Einstein condensation of strontium — •Simon Stellmer[1,2], Meng Khoon Tey[1], Bo Huang[1,2], Rudolf Grimm[1,2], and Schreck Florian[1] — [1]Institut für Quantenoptik und Quanteninformation, 6020 Innsbruck, Austria — [2]Universität Innsbruck, 6020 Innsbruck, Austria

We report on the attainment of Bose-Einstein condensation with ultracold strontium atoms. We use the ^{84}Sr isotope, which has a low natural abundance but offers excellent scattering properties for evaporative cooling. Accumulation in a metastable state using a magnetic-trap, narrowline cooling, and straightforward evaporative cooling in an optical trap lead to pure condensates containing 1.5×10^5 atoms. This puts ^{84}Sr in a prime position for experiments on quantum-degenerate gases involving atomic two-electron systems.

Furthermore, we report on recent advances towards a degenerate Fermi gas of ^{87}Sr. Ideas of future experiments related to quantum simulation and ultracold SrRb molecules will also be discussed in the talk.

Q 10.4 Mo 17:15 E 001

Bose-Einstein condensates in micro-optical potentials — •Thomas Lauber, Johannes Küber, Oliver Wille, Martin Hasch, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

The goal of our experiments is to study the coherence properties of Bose-Einstein condensates in micro-optical potentials. We use an 'all-optical' BEC of rubidium, which we prepare in a crossed dipole trap, generated by a 1070nm fiber laser. The atoms are loaded directly from a magneto-optical trap and are evaporatevly cooled to quantum degeneracy in the dipole trap by simply ramping down the laser power.

We create the optical micro-potentials by using microfabricated lenses illuminated with off-resonant laser light, either red- or blue-detuned. We implement various types of lenses, including microlens arrays, cylindrical lens arrays and a ring shaped lens. These lenses allow the creation of potentials that can be used as beam splitters, wave guides or mirrors for atoms on a sub-millimeter scale. The ring lens for example suggests the implentation of a one-dimensional geometry with periodic boundary conditions. As a tool to move the atoms along the waveguides, we use Bragg scattering to split or transfer the BEC in different momentum states.

We are going to report on the current status of our experiments.

Q 10.5 Mo 17:30 E 001

Landau-Zener dynamics between pairwise coupled 1d-tubes — •Yu-Ao Chen[1,2], Stefan Trotzky[1], Ute Schnorrberger[1], Sebastian Huber[3], Ehud Altman[3], and Immanuel Bloch[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, Schellingstasse 4, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany — [3]Department of Condensed Matter Physics, The Weizmann Institute of Science, Rehovot, 76100, Israel

Non-equilibrium dynamics attracted a lot of recent interest. The departure from standard statistical mechanics is studied in a large variety of systems, at the heart of which lies the very fundamental setup of two levels undergoing an anti-crossing, knowing as the famous Landau-Zener (LZ) problem. Non-interacting atoms in a double well with tunable energy difference provide a generic two-mode system to study the dynamics of a LZ sweep. We experimentally realize a generalized LZ problem in an array of pairwise coupled tubes with interacting ultracold ^{87}Rb atoms in an optical superlattice potential. We investigate the impact of interactions and dimensionality on the sweep fidelity for sweeps in the ground state and in the excited state. The results show that interactions in the tubes improve the fidelity for sweeps in the ground state. For sweeps in the excited state we find relaxation of the system which can be explained in terms of one-dimensional low-energy excitations along the tubes, providing an intrinsic bath for thermalization.

Q 10.6 Mo 17:45 E 001

Cold Atoms in Minibands: Bloch-Zener Oscillations and Band Spectroscopy — •Sebastian Kling, Tobias Salger, Christopher Grossert, and Martin Weitz — Institut für Angewandte Physik, Wegelerstr.8 , 53115 Bonn, Germany

We report on experiments with an atomic ^{87}Rb condensate in a biharmonic optical lattice potential. The biharmonic potential is realized with a combination of a standing wave lattice potential of $\lambda/2$ spatial periodicity and a lattice of $\lambda/4$ periodicity generated by the dispersion of multiphoton Raman transitions. Such lattices allow for realizing a tunable miniband structure for the condensate. Minibands are formed in the band structure if the second band gap is larger than the first one. In this special case the conventional single band approximation for the dynamics is not valid any more and instead a multiband analysis is required. We have investigated experimentally the dynamics of the minibands by observing Bloch-Zener-Oscillations in momentum space. We have furthermore coherently split atomic wavepackets by tunneling at the bandgaps and observed an interference signal after subsequent recombining. This band interference allows for a novel bandgap spectroscopy.

Q 10.7 Mo 18:00 E 001

Emergence of semifluxons in 0-π-0 junctions as a topological state change — •Reinhold Walser[1], Michael Grupp[2], Wolfgang Schleich[2], Oliver Crasser[2], Reinhold Kleiner[3], and Edward Goldobin[3] — [1]Institut für Angewandte Physik, TU Darmstadt — [2]Institut für Quantenphysik, Universität Ulm — [3]Physikalisches Institut, Universität Tübingen

By continuously increasing the spatial extend of the π-region in a long 0-π-0 Josephson junction, one can dynamically induce the appearance of semifluxons starting with a flat-phase state. Thus, we can control the topological nature of a quantum system with an external parameter. This interesting topological quantum state is related to ordinary quantized magnetic flux in superconductors or vortices in superfluid systems, however it has accrued only π-phase winding. In here, we present a generic, analytical model of the phenomenon and demonstrate its implementation in the context of ultra-cold matter waves using optical junctions.

Q 10.8 Mo 18:15 E 001

Exact Quantum Dynamics of a Bosonic Josephson Junction — •Kaspar Sakmann, Alexej I. Streltsov, Ofir E. Alon, and Loerenz S. Cederbaum — Theoretische Chemie, Physikalisch-Chemisches Institut, Universität Heidelberg, Deutschland

The quantum dynamics of a one-dimensional bosonic Josephson junction is studied by solving the time-dependent many-boson Schrödinger equation numerically exactly. Already for weak interparticle interactions and on short time scales, the commonly employed mean-field and many-body methods are found to deviate substantially from the exact dynamics. The system exhibits rich many-body dynamics such as enhanced tunneling and a novel equilibration phenomenon of the junction depending on the interaction, which is attributed to a quick loss of coherence.

Q 10.9 Mo 18:30 E 001

Cold and hot finite quantum systems in contact: energy flow and temperature equilibration — •Alexey V. Ponomarev, Sergey Denisov, and Peter Hanggi — Institute of Physics, University of Augsburg, Germany

Relaxation toward the canonical state is commonly attributed to a situation where a small system of interest is coupled to a huge one (the Universe, a heat bath, etc). Here we focus on the case of two identical quantum systems composed of a finite number of bosons. Both the systems are initially prepared in Gibbs states at different temperatures, $\rho_A(T_A)$ and $\rho_B(T_B)$, and isolated from the external environment. Then the systems are brought into a thermal contact.

We demonstrate that the energy starts to flow from a "hot" system to a "cold" one until the system energies equilibrate. There are two possible distinguishable relaxation regimes. In the first regime, each of the systems evolves toward the state characterized by the arithmetic average of their initial density matrices, $\rho_A(T_A)/2 + \rho_B(T_B)/2$. The second regime substantiates what we would expect from the equilibration of two big, classical bodies: (i) both the quantum systems relax to the thermal (Boltzmann) states with equal temperatures; and (ii) the relaxation process has a quasistatic character, i. e. each system passes through a chain of intermediate thermal (Boltzmann) states. With that, we show for the first time that a non-equilibrium thermodynamic process can be reproduced within an isolated finite bipartite quantum system.

Q 10.10 Mo 18:45 E 001

Single Cs Atoms Interacting with an Ultracold Rb Cloud — •Nicolas Spethmann, Wolfgang Alt, Shincy John, Oskar Fetsch, Claudia Weber, Artur Widera, and Dieter Meschede — Institut für Angewandte Physik, 53115 Bonn, Deutschland

While single Cs atoms can be coherently controlled to a high degree, in these systems coherent interactions are still challenging to obtain. In contrast, in quantum gases coherent interactions naturally emerge whereas manipulation and detection with single particle control is still not routinely performed.

We aim on combining the advantages of both methods by controlled immersion of single and few Cs atoms in an ultracold cloud of Rb atoms. We trap single and few Cs atoms in a high-gradient magneto-optical trap (MOT) and observe the loading dynamics through fluorescence detection. A Rb ensemble is cooled in a magnetic trap and then transferred to a crossed dipole trap at the position of the Cs MOT. In this purely optical trap the Rb can be further cooled to quantum degeneracy. By transferring the Rb to a magnetic field insensitive state, it is possible to switch on the single atom MOT without affecting the Rb cloud. We will report on the status of using the single atoms to probe the Rb cloud in various temperature regimes.

Q 11: Quantum Information: Concepts and Methods II

Time: Monday 16:30–19:00 Location: E 214

Q 11.1 Mo 16:30 E 214

Practical methods for witnessing genuine multi-qubit entanglement in the vicinity of symmetric states — •Geza Toth[1,2,3], Witlef Wieczorek[4,5], Roland Krischek[4,5], Nikolai Kiesel[4,5,6], Patrick Michelberger[4,5], and Harald Weinfurter[4,5] — [1]Theoretical Physics, The University of the Basque Country, E-48080 Bilbao, Spain — [2]IKERBASQUE, Basque Foundation for Science, E-48011 Bilbao, Spain — [3]Research Institute for Solid State Physics and Optics, H-1525 Budapest, Hungary — [4]Max-Planck-Institut für Quantenoptik, D-85748 Garching, Germany — [5]Fakultät für Physik, Ludwig-Maximilians-Universität, D-80799 Garching, Germany — [6]Institute for Quantum Optics and Quantum Information (IQOQI), A-1090 Vienna, Austria

We present general numerical methods to construct witness operators for entanglement detection and for the estimation of the fidelity. Our methods are applied to detecting entanglement in the vicinity of a six-qubit Dicke state with three excitations and also to further entangled symmetric states. All our witnesses are designed to keep the measurement effort small thus they are useful in many-qubit experiments. We present also general results on the efficient local decomposition of permutationally invariant operators, which makes it possible to measure projectors to symmetric states efficiently.

Q 11.2 Mo 16:45 E 214

Separability criteria for genuine multiparticle entanglement — •Otfried Gühne[1] and Michael Seevinck[2] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, A-6020 Innsbruck, Austria — [2]Institute of History and Foundations of Science, Utrecht University, P.O Box 80.010, 3508 TA Utrecht, Netherlands

The characterization of genuine multiparticle correlations is an important problem in the field of quantum information theory. However, no systematic way to derive multiparticle entanglement criteria is known.

In this talk, we present a method to derive separability criteria for the different classes of multiparticle entanglement, especially genuine multiparticle entanglement. The resulting criteria are necessary and sufficient for certain families of states. Further, the criteria are superior to all known entanglement criteria for many other families; also they allow the detection of bound entanglement. We next demonstrate that they are easily implementable in experiments and discuss applications to the decoherence of multiparticle entangled states.

Q 11.3 Mo 17:00 E 214

Accuracy of the lower bound approximation for three-qubit concurrence — •Michael Siomau[1] and Stephan Fritzsche[2,3] — [1]Max-Planck-Institut fuer Kernphysik, Postfach 103980, D-69117 Heidelberg, Germany — [2]Department of Physical Sciences, P.O.Box 3000, Fin-90014 University of Oulu, Finland — [3]Frankfurt Institute for Advanced Studies, D-60438 Frankfurt am Main, Germany

A proper measure for the entanglement of a mixed state is the convex roof extension to the concurrence. Unfortunately, however, the computational complexity of this entanglement measure increases with the rank r of a given density matrix with as r^3 [1]. Certain approximations, such as the lower bound approximation for the concurrence [2], can significantly simplify the computations. We here investigate on particular examples the relation between the accuracy of the lower bound approximation and the rank of the density matrix. We show that for a density matrix $r < 4$ the lower bound for the concurrence can describe the entanglement of the state for all times. For density matrices with higher rank, in contrast, the lower bound approximation can be applied only to describe the dynamics of quasi-pure states.

[1] F. Mintert *et al.*, Phys. Rep. **415**, 207 (2005).
[2] M. Li, S.-M. Fei, Z.-X. Wang, J. Phys. A **42**, 145303 (2009).

Q 11.4 Mo 17:15 E 214

Structure factors and entanglement witnesses — •Hermann Kampermann[1], Philipp Krammer[2], Dagmar Bruss[1], Reinhold A. Bertlmann[2], Leong Chuang Kwek[3], and Chiara Macchiavello[4] — [1]Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf — [2]Faculty of Physics, University of Vienna, Austria — [3]Centre for Quantum Technologies, National University of Singapore, Singapore — [4]Dipartimento di Fisica "A. Volta", University of Pavia, Italy

We construct multi-qubit entanglement witnesses whose expectation value has a direct link to the static structure factor, and thus to diffractive properties. These “collective” witness operators are composed of two-point correlation operators. The general construction of these witnesses allows to detect different classes of multi-partite entangled states like Dicke states. The robustness of the entanglement detection with respect to noise is discussed.

Q 11.5 Mo 17:30 E 214

Estimates for the three-tangle from incomplete information — •Andreas Osterloh[1] and Philipp Hyllus[2] — [1]FB Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany. — [2]BEC-INFM, Dipartimento di Fisica, Università di Trento, Via Sommarive 14, I-38050 Povo, Italy.

We investigate the lower bound obtained from experimental data of a quantum state ρ, as proposed independently by Gühne et al. and Eisert et al. [1] and apply it to mixed states of three qubits. The measure we consider is the convex-roof extension of the three-tangle [2]. Our findings highlight an intimate relation to lower bounds obtained recently from so-called characteristic curves of a given entanglement measure [3]. For an unstructured admixture to a GHZ state the non-vanishing lower bound is obtained if the GHZ-fidelity of the produced states is larger than 3/4, which reproduces the result obtained from witnesses. We apply the bounds to estimate the three-tangle present in recently performed experiments aimed at producing a three-qubit GHZ state.

[1] O. Gühne, M. Reimpell, and R.F. Werner, PRL **98**, 110502 (2007); J. Eisert, F.G.S.L. Brandão, and K. Audenaert, NJP **9**, 46 (2007).
[2] V. Coffman, J. Kundu, and W.K. Wootters, PRA **61**, 052306 (2000).
[3] A. Osterloh, J. Siewert, and A. Uhlmann, Phys. Rev. A **77**, 032310 (2008).

Q 11.6 Mo 17:45 E 214

Mutually unbiased bases generated by a single unitary operator — •Kedar Ranade[1], Oliver Kern[2], and Ulrich Seyfarth[2] — [1]Institut für Quantenphysik, Universität Ulm — [2]Institut für Angewandte Physik, Technische Universität Darmstadt

In this talk, we discuss a method for constructing unitary operators which generate mutually unbiased bases on Hilbert spaces $\mathcal{H} = \mathbb{C}^d$ for d being a power-of-two dimension (i. e. $d = 2^m$, $m \in \mathbb{N}$). Such operators U have order $d+1$, and the columns of U, U^2, ..., $U^{d+1} = 1$ define mutually unbiased bases. The construction is based on finding a maximal commuting unitary operator basis of the matrix algebra associated to the Hilbert space and a Clifford group unitary transformation which maps the equivalence classes of a partition of this operator basis onto another. We explicitly construct unitary operators which generate mutually unbiased bases in all dimensions $d = 2^m$ for $m \leq 22$.

Q 11.7 Mo 18:00 E 214

Simple adaptive measurement strategies for estimation of d-dimensional quantum states — •Christof Happ and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm

Adaptive methods improve the quality of state reconstruction when estimating unknown pure d-level-states (qu$d$its), of which only a limited amount of copies is available. Using information from previous measurements, the adaption steps construct measurement bases for further measurements, which improve the estimation quality more than further measurements with fixed or random measurement bases. We present adaptive strategies for arbitrary finite dimensions d and discuss Monte-Carlo simulation results for complete reconstruction of the quantum state.

Q 11.8 Mo 18:15 E 214

Entanglement between Atoms in a Diatomic Molecule — •Nathan Harshman[1,2] and William Flynn[1] — [1]Department of Physics, American University, Washington, DC, USA — [2]Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

Entanglement between atoms in an idealized diatomic molecule in one-dimension is investigated. Trapped and free molecules and homonuclear and heteronuclear molecules are considered. The entanglement between the atoms for coherent states, number states, and superpositions of number states can be calculated analytically from the position wave function in atomic coordinates. Entanglement between atoms occurs in the ground state and other coherent states unless the molecular frequency and the trap frequency are the same. In number states, the exact functional dependence of entanglement depends in a complicated way on the ratio of the frequencies and the ratio of the masses. Generally, states with high numbers, large frequency differences, and equal masses have increased entanglement. While the interatomic entanglement can be quite large even in the coherent states, the covariance in position observables can be entirely explained by a classical model with appropriately chosen statistical uncertainty.

Q 11.9 Mo 18:30 E 214

Anderson Localization in Disordered Quantum Walks — •Volkher Scholz, Albert Werner, and Andre Ahlbrecht — Institut für Theoretische Physik, Leibniz Universität Hannover

We study a Spin-$\frac{1}{2}$-particle moving in a one dimensional lattice subjected to disorder induced by a random space dependent coin. The discrete time evolution is given by a family of random unitary quantum walk operators, where the shift operation is assumed to be non-random. Each coin is an independent identically distributed random variable with values in the group of two dimensional unitary matrices. We find that if the probability distribution of the coins is absolutely continuous with respect to the Haar measure, then the system exhibits localization. That is, every initially localized particle remains on average and up to exponential corrections in a finite region of space for all times.

Q 11.10 Mo 18:45 E 214

Area laws for thermal free fermions — •Holger Bernigau and Jens Eisert — University of Potsdam, 14476 Potsdam, Germany

Physical interactions in quantum many-body systems are typically local: Individual constituents interact mainly with their few nearest neighbors. This locality of interactions is inherited by a decay of correlation functions, but also reflected by scaling laws of correlation or entanglement measures: They satisfy an "area law" if the they merely grow like the boundary area of the subregion, and not like its volume, in sharp contrast with an expected extensive behavior. In this talk, we will investigate the scaling of the mutual information for thermal states of free fermionic lattice systems, and will discuss an exact formula for the asymptotic scaling, including all prefactors. Ideas of Toeplitz determinants applied to thermal states will be mentioned. We will finally briefly discuss implications of such results to the simulatability of such quantum systems.

Q 12: Laser Development: Solid State Lasers I

Time: Monday 16:30–19:00 Location: F 128

Q 12.1 Mo 16:30 F 128

Simulation und Fertigung von integrierten Faserschmelzkopplern mit hoher Transmission des Pump- und Signallichtes — Katharina Hausmann, •Thomas Theeg, Hakan Sayinc, Matthias Hildebrandt, Jörg Neumann und Dietmar Kracht — Laser Zentrum Hannover e.V., Hollerithallee 8, D-30149 Hannover

Für Faserlaser und -verstärker werden Schmelzkoppler für die justagefreie und verlustarme Pumplichtkopplung in Doppelkernfasern verwendet. Zumeist werden hierfür Faserbündel aus sechs oder mehr Pumpfasern und einer Faser mit Signaldurchführung getapert und anschließend mit der gewünschten (aktiven) Doppelkernfaser verspleißt. Dies ermöglicht eine effiziente Pumplichtkopplung mit Transmissionswerten von über 90 %. Jedoch können die Transmissionsverluste der Signalstrahlung durch eine fehlerhafte Modenfeldanpassung bis zu 20 % betragen. Besonders für einen Verstärkerbetrieb mit gegenläufiger Pumpstrahlung sind geringe Transmissionsverluste für die Signalstrahlung notwendig. Dies kann durch seitliches Einkoppeln der Pumpstrahlung in eine Doppelkernfaser realisiert werden. Hierfür wird die Pumpfaser vorgetapert und seitlich mit der Signalfaser verschmolzen.

In diesem Beitrag werden Schmelzkoppler mit bis zu vier Pumpfasern mit 125 μm Durchmesser mit Einkoppeleffizienzen bei 25 W Leistung pro Port von bis zu 95 % präsentiert. Die verwendete Doppelkernfaser mit einem Kerndurchmesser von 30 μm und einem Pumpkerndurchmesser von 250 μm zeigte eine Transmission der Signalstrahlung von über 97 %.

Q 12.2 Mo 16:45 F 128

Einkristalliner Yb^{3+}:(Gd,Lu)$_2$O$_3$-Wellenleiterlaser bei 976,8 nm — •Henning Kühn, Sebastian Heinrich, Andreas Kahn, Klaus Petermann und Günter Huber — Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, D-22761 Hamburg

Wir berichten über einen Yb^{3+}-dotierten Sesquioxid-Rippenwellenleiterlaser basierend auf einer gitterangepassten Yb^{3+}(3%):(Gd,Lu)$_2$O$_3$-Schicht, die epitaktisch mit Pulsed Laser Deposition (PLD) auf einem Y_2O_3-Substrat aufgewachsen wurde. Mittels Argon-Ionenätzen wurden Rippenwellenleiter strukturiert und Wellenleitung nachgewiesen. Unter Pumpen mit einem Ti^{3+}:Al_2O_3-Laser bei 905 nm wurde Laseremission bei 976,8 nm beobachtet [1]. In Bezug auf die eingestrahlte Leistung wurden eine Laserschwelle von 17 mW und aufgrund der noch recht hohen Verluste ein differentieller Wirkungsgrad von bisher 6,7% erzielt. Bei einer einfallenden Pumpleistung von 200 mW wurde eine maximale Ausgangsleistung von 12 mW erreicht. [1] H. Kühn et al., Optics Letters 34 (18), 2718-2720 (2009)

Q 12.3 Mo 17:00 F 128

Tapering fibers with complex shape — •Sebastian Pricking and Harald Giessen — 4. Physikalisches Institut, Universität Stuttgart

We present a model which allows us to accurately simulate the fabrication process of complex-shaped tapered fibers. The range of possible profiles is only limited by the properties of the heat source used to shape the fiber. The model takes into account the motion of the heat source relative to the fiber as well as its temperature distribution. Our measurements and corresponding finite element method (FEM) simulations have shown a strong dependency of the temperature distribution along the fiber axis on the actual diameter of the fiber. The inclusion of this relation in the model proved to be crucial for the accuracy of the results. Our model has been verified experimentally by fabricating tapered fibers with a sinusoidally modulated waist. A comparison to the profile predicted by our model reveals an excellent agreement.

Q 12.4 Mo 17:15 F 128

Hocheffiziente Femtosekunden-Laser geschriebene Kanal-Wellenleiterlaser in Yb:YAG-Kristallen — •Thomas Calmano, Jörg Siebenmorgen, Klaus Petermann und Günter Huber — Universität Hamburg, Institut für Laser-Physik, Luruper Chaussee 149, 22761 Hamburg

Aufgrund eines nichtlinearen Absorptionsprozesses ist eine Volumenstrukturierung dielektrischer Materialien mit fs-Laserpulsen im μm-Bereich möglich. In Yb-dotierten und undotierten YAG-Kristallen wurde die kristalline Struktur im Fokus des fs-Lasers zerstört. Durch Verfahren der Probe unter dem Fokus des fs-Lasers wurden Spuren aus zerstörtem Material hergestellt. Aufgrund des elasto-optischen Effekts bewirken diese Spuren eine lokale spannungsinduzierte Erhöhung des Brechungsindexes im umgebenen Material um $\Delta n \approx 10^{-3}$. In diesen Bereichen konnte Wellenleitung gezeigt werden. Durch Schreiben zweier paralleler Spuren in einem Abstand von 25 μm wurden im Bereich zwischen den Spuren Wellenleiter mit Verlusten von ca. 1,2 dB/cm hergestellt. Lasertätigkeit der Wellenleiter war über die Rückkopplung an den Endflächen aufgrund der Fresnel-Reflexion von $R \approx 9$ % möglich. Dies entspricht einem Auskoppelgrad von 99 %. Mit Yb(7%):YAG wurde eine maximale Ausgangsleistung von 775 mW bei 1,21 W eingekoppelter Pumpleistung und einer Schwellpumpleistung von 163 mW erreicht. Der differentielle Wirkungsgrad von $\eta_s = 74$ % bezüglich eingekoppelter Pumpleistung und $\eta_{se} = 66$ % bezüglich einfallender Pumpleistung ist der höchste Wirkungsgrad, der bisher in fs-Laser geschriebenen Wellenleiterlasern erzielt wurde.

Q 12.5 Mo 17:30 F 128

Ein leistungsstarker Ytterbium-Faserverstärker bei 1091 nm für eine Lyman-α-Quelle — •Ruth Steinborn, Martin Scheid, Daniel Kolbe, Andreas Müllers, Andreas Koglbauer, Stefan Boettner, Sven Richter und Jochen Walz — Institut für Physik, Universität Mainz, D-55099 Mainz

Als Teil eines Kühllasersystems für Anti-Wasserstoff wird ein stabiler, leistungsstarker und kontinuierlicher Laser bei einer Wellenlänge von 1091 nm benötigt [1].

Zu diesem Zweck wird das Licht einer gitterstabilisierten Laserdiode in einer Ytterbium-dotierten Faser verstärkt. Um dieses Faserverstärkersystem unter dem Gesichtspunkt maximaler Ausgangsleistung bei möglichst hoher ASE-Unterdrückung (Amplified Spontaneous Emission) zu optimieren, wurden unterschiedliche Fasern getestet und der Einfluss der Faserlänge untersucht.

Mit dem aufgebauten System kann bei einstufiger Verstärkung eine stabile Ausgangsleistung von 3 W bei einer ASE-Unterdrückung von 40 dB erreicht werden.

[1] M. Scheid, D. Kolbe, F. Markert, T. W. Hänsch, and J. Walz, Optics Express, Vol. 17, No. 14, 11274 (2009)

Q 12.6 Mo 17:45 F 128

Femtosekunden-Laser geschriebener Nd:YAG Wellenleiter mit Cr^{4+}:YAG Dünnschicht als gütegeschalteter Laser — •Friedjof Tellkamp, Thomas Calmano, Jörg Siebenmorgen, Klaus Petermann und Günter Huber — Universität Hamburg, Institut für Laser-Physik, Luruper Chaussee 149, 22761 Hamburg

Mit Laserpulsen einer Pulsdauer von 140 fs und einer Wellenlänge von 775 nm wurden in einem 9 mm langen Nd(1 at.%):YAG Kristall ca. 300 μm unter die Oberfläche spannunginduzierte Wellenleiter geschrieben.

Auf eine der Endflächen des Kristalls wurde eine ca. 5 μm dünne Schicht aus Cr^{4+}:YAG mittels Pulsed Laser Deposition auf einen Nd:YAG Wellenleiterlaser aufgetragen. Die Dotierung der Dünnschicht beträgt 10 at.% Chrom. Als Ladungskompensation zum Erhalt von vierwertigem Chrom wurde Magnesium beigemischt. Die Deposition der Schicht fand bei Raumtemperatur und einem Druck von 2×10^{-3} mbar in einer Sauerstoffatmosphäre statt. Für den Ablationsprozess wurde ein KrF-Excimerlaser mit 800 mJ Pulsenergie und einer Wiederholrate von 40 Hz verwendet.

Der Wellenleiter mit dem aufgebrachten sättigbaren Absorber wurde mit einem Ti:Saphir-Laser bei 808 nm gepumpt und auf Lasertätigkeit hin untersucht. Hierbei zeigte der Laser eine schnelle Modulation von ca. 1 MHz bei Pulsbreiten von etwa 100 ns.

Q 12.7 Mo 18:00 F 128

Design von aktiven Großkernfasern mit hoher Modendiskriminierung — Florian Jansen[1], Martin Baumgartl[1,2], •Hans-Jürgen Otto[1], Cesar Jauregui[1], Jens Limpert[1,2] und Andreas Tünnermann[1,2,3] — [1]Friedrich-Schiller-Universität Jena, Institut für Angewandte Physik, Albert-Einstein-Str. 15, 07745 Jena — [2]Helmholtz-Institut Jena, Max-Wien-Platz 1, 07743 Jena — [3]Fraunhofer Institut für Angewandte Optik und Feinmechanik, Albert-Einstein-Str. 7, 07745 Jena

Die wachsende Ausgangsleistung von Faserlasern erfordert eine Vergrößerung der Kernfläche zur Vermeidung nichtlinearer Effekte. Hierfür haben sich aktive Großkernfasern mit photonischer Kristallstruktur etabliert, welche jedoch keinen strikten Einmodenbetrieb besitzen. Durch Moden höherer Ordnung (HOM) wird die Strahlqualität und Strahllagestabilität verschlechtert. Mit einem angepassten Design der photonischen Struktur für aktive Großkernfasern lassen sich dennoch eine gute Strahlqualität und große Modenfelddurchmesser erreichen. Für verschiedene hexagonale Designs wird der Einfluss der Brechzahlabsenkung des Kerns, hervorgerufen durch die aktive Dotierung des Kernbereichs, untersucht. Für einen Propagationsverlust von 1dB/m bei einem Modenfelddurchmesser von 50μm wird bei einem angepassten Design für die 1. HOM ein Verlust von 100dB/m erreicht. Die experimentelle Bewertung eines solchen Faserdesigns ist mit Hilfe räumlich aufgelöster Spektroskopie (S^2) möglich.

Q 12.8 Mo 18:15 F 128

Einkristalline Seltenerd-dotierte Sesquioxid Rippenwellenleiter — •Sebastian Heinrich, Andreas Kahn, Henning Kühn, Friedjof Tellkamp, Klaus Petermann und Günter Huber — Universität Hamburg, Institut für Laser-Physik, Luruper Chaussee 149 22761 Hamburg

Die Wellenleitergeometrie ist vielversprechend im Hinblick auf die Entwicklung kompakter Lasersysteme. Infolge der hervorragenden thermomechanischen und optischen Eigenschaften stellen Seltenerd-dotierte Sesquioxid-Wellenleiter schmale Emissionslinien, eine hohe Frequenzstabilität und hohe optische Verstärkung in Aussicht. Mit dem Pulsed Laser Deposition-Verfahren wurden auf Y_2O_3-Substrate gitterangepasste Seltenerd-dotierte (Gd,Lu)$_2$O$_3$-Schichten hergestellt.

Spektroskopische Untersuchungen zeigten, dass die Emissionsspektren, bis auf eine geringe Verbreiterung, gut mit den Spektren von Er:Y_2O_3-Volumenkristallen übereinstimmen. In einem 0,6at.% Erbium-dotierten Wellenleiter konnte bei einer Wellenlänge von 1535 nm eine Verstärkung von 5,9 dB/cm gemessen werden. Die optische Verstärkung in Erbium-dotierten $(Gd,Lu)_2O_3$-Schichten reichte nicht aus, um die Wellenleitungsverluste von typischerweise einigen dB/cm auszugleichen. Dagegen konnte in einem Neodym-dotierten $(Gd,Lu)_2O_3$-Rippenwellenleiter Lasertätigkeit mit einem differentiellen Wirkungsgrad von 0,5% nachgewiesen werden [1]. Diskutiert werden verschiedene Verfahren, um die Wellenleitungsverluste zu reduzieren und so die Effizienz der Rippenwellenleiterlaser zu erhöhen. [1] A. Kahn et al., Opt. Express 17, 4412 (2009)

Q 12.9 Mo 18:30 F 128

Komplett faserbasierte regenerative Verstärkung von 40 ps Pulsen mit niedriger Pulsenergie von einer gewinngeschalteten Laserdiode — •Sebastian Kanzelmeyer, Matthias Hildebrandt, Thomas Theeg, Maik Frede, Jörg Neumann und Dietmar Kracht — Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover

Es wird die komplett faserbasierte AOM gesteuerte regenerative Verstärkung von Pulsen einer gewinngeschalteten Laserdiode mit 40 ps Pulsdauer und 28 pJ Pulsenergie vorgestellt. Durch dieses Konzept konnte auch bei niedriger Pulswiederholrate und der damit verbundenen sehr niedrigen mittleren Leistung eine Verstärkung von über 37 dB bei gleichzeitig guter ASE Unterdrückung erzielt werden.

Q 12.10 Mo 18:45 F 128

Leistungsskalierung Er:Yb-kodotierter Faserverstärker durch Injektion eines Hilfssignals bei 1,0 μm — •Vincent Kuhn[1,2], Peter Wessels[1,2], Jörg Neumann[1,2] und Dietmar Kracht[1,2] — [1]Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover — [2]QUEST – Centre for Quantum Engineering and Space-Time Research, Welfengarten 1, 30167 Hannover

In unserem Beitrag wird ein bei 976 nm gepumpter Er:Yb-kodotierter Faserverstärker in Doppelkerngeometrie vorgestellt, in den gleichzeitig einfrequente Signale bei 1556 nm und 1064 nm injiziert wurden. Die hierdurch erreichte Unterdrückung parasitärer Laserprozesse bei 1,0 μm Wellenlänge erlaubte das Erreichen einer stabilen und pumpleistungsbegrenzten Ausgangsleistung von 8,7 W bei 1556 nm und einer zugehörigen – und insbesondere für Er:Yb-kodotierte Systeme sehr hohen – Signalverstärkung von > 22 dB. Die optisch-zu-optische Effizienz bei 1556 nm wurde durch das bei 1064 nm injizierte Signal nicht verringert. Als Unterdrückungsmechanismus für parasitäre Laserprozesse um 1,0 μm dient die mit Hilfe des bei 1064 nm injizierten Signals erreichte Verstärkungssättigung. Dies bedeutet, dass die Verhinderung parasitärer Laserprozesse direkt durch den Übergang von Klein- zu Großsignalverstärkung erfolgt, anstatt durch, wie sonst üblich, wellenlängenselektive Verluste oder starke Injektionsignale und somit geringe Verstärkungsfaktoren. Abschließend werden in unserem Beitrag Möglichkeiten zur Leistungsskalierung, bzw. der Übertragung des Konzepts auf Hochleistungfaserverstärker im Bereich von 100 W Ausgangsleistung diskutiert.

Q 13: Ultrashort Laser Pulses: Generation II

Time: Monday 16:30–19:00 Location: F 342

Q 13.1 Mo 16:30 F 342

Optimierung des LIBS-Signals an Metallen durch Femtosekunden Doppelpulse — •Jutta Mildner[1], Lars Englert[1], Waldemar Wessel[2], Alexander Horn[1], Angelika Brueckner-Foit[2], Matthias Wollenhaupt[1] und Thomas Baumert[1] — [1]Universität Kassel, Institut für Physik und CINSaT, Heinrich-Plett-Str. 40, D-34132 Kassel, Germany — [2]Universität Kassel, Institut für Werkstofftechnik - Qualität und Zuverlässigkeit, Mönchebergstr. 3, D-34125 Kassel, Germany

Die verschiedenen Anregungsprozesse im Festkörper skalieren auf einer Femtosekunden bzw. Pikosekunden Zeitskala und sind zeitlich voneinander getrennt [1]. Ablationsprozesse bewegen sich hingegen auf einer längeren Zeitskala [2] und finden erst nach der fs-Anregung statt. Daher kann die Dynamik dieser Prozesse durch die Anwendung zeitlich geformter fs-Laserstrahlung gezielt angesprochen werden. In unseren Untersuchungen wurden Femtosekunden Doppelpuls-Experimente an Metallen mittels Laserinduzierter Breakdown-Spektroskopie (LIBS) durchgeführt. Der Einfluss der Verzögerungszeit und der Intensitätsverhältnisse zwischen den beiden Laserpulsen auf das LIBS-Signal und auf die Ablationsstrukturen werden diskutiert. Auf diese Weise soll die spektrochemische Sensitivität von fs-LIBS erhöht werden, während die hohe räumliche Auflösung [3] erhalten bleibt.

[1] B. Rethfeld *et al.*, Appl. Phys. A **79**, 767–769 (2004)
[2] Y. P. Raizer, Soviet Physics Uspekhi **8**, 650–673 (1966)
[3] A. Assion *et al.*, Appl. Phys. B **77**, 391–397 (2003)

Q 13.2 Mo 16:45 F 342

Energy-resolved measurements of laser-triggered electron pulses from ultrasharp metal tips — •Markus Schenk, Michael Krüger, and Peter Hommelhoff — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching bei München, Germany

For quantum optics experiments with free electrons a spatially and temporally well-controlled electron source is of high interest. Focusing few-cycle pulses of a Titanium:Sapphire-oscillator onto a sharp metal tip triggers electron emission on short timescales. Here we show that different processes occur and can be favored by properly choosing parameters such as laser intensity and static electric field[1]. We perform energy resolved measurements. At low static fields we observe pure over-the-barrier multi-photon photoemission. For higher static fields (narrower tunneling barrier) electrons from below the barrier can tunnel out of the tip after absorption of one or two photons (photo-field emission). At higher laser intensities electrons with energies corresponding to the absorption of up to 7 photons are observed (above-threshold-photoemission). This talk will give an overview about these observed processes.

[1] see also contributions by Michael Krüger et al. and Hanno Kaupp et al.

Q 13.3 Mo 17:00 F 342

Propagation of ultrashort UV pulses in a nonlinear dispersive self-defocusing gas: A route to an effective compression scheme? — •Christian Koehler[1], Luc Berge[2], and Stefan Skupin[1,3] — [1]Max-Planck-Institute for the Physics of Complex Systems, 01187 Dresden, Germany — [2]CEA-DAM, DIF, F-91297 Arpajon, France — [3]Friedrich-Schiller-University, Institute of Condensed Matter Theory and Solid State Optics, 07743 Jena, Germany

Compression of UV femtosecond laser pulses in xenon gas is studied numerically. Due to temporal modulational instability (MI), occurring in the normal dispersion regime with large negative Kerr index, $\sim$100 fs pulses are compressed by a factor up to eight to singly peaked wave-forms with unchanged shape over meters of propagation range. A detailed discussion of the compression mechanism is given for the (1+1)-dimensional waveguided case and a combination of MI theory and variational techniques is used to identify suitable parameters for compression in bulk (3+1)-dimensional configuration. Furthermore, a comparison between models with and without dispersive nonlinearity exhibits qualitative agreement, leading to the conclusion that even in the case of strong nonlinear dispersion the classical NLS equation captures the basic physical ingredients for this self-compression mechanism. Since in bulk configuration these ultrashort structures naturally evolve without any guiding devices, our findings give rise to a very simple and effective compressor for ultrashort pulses in the UV range.

Q 13.4 Mo 17:15 F 342

High Order Harmonic Enhancement Mediated by the Carrier-Envelope Phase — •J. Biegert[1,6], D. Faccio[1,2], C. Serrat[1,3], J.M. Cela[4], A. Farres[4], and P. Di Trapani[2,5] — [1]ICFO-Institut de Ciènces Fotòniques, Mediterranean Technology Park, 08860 Castelldefels, Barcelona, Spain — [2]CNISM and Dept. of Physics and Mathematics, Università dell'Insubria, IT-22100 Como, Italy — [3]DTDI Universitat de Vic, 08500 Vic, Barcelona, Spain — [4]CASE Barcelona Supercomputing Center, 08034 Barcelona, Spain — [5]Virtual Institute for Nonlinear Optics, Centro di Cultura Scientifica Alessandro Volta, 22100 Como, Italy — [6]ICREA Institució Catalana de Recerca i Estudis Avançats, 08010 Barcelona, Spain

A two decade enhancement in the conversion efficiency of high harmonic generation is observed and interpreted as the consequence of nonlinearly induced modulation in the phase mismatch between the generating dipole and the propagated harmonics.

We propose a novel technique to improve the efficiency of HHG with few-cycle pulses by controlling their Carrier-Envelope-Phase (CEP) so as to achieve a periodic modulation of the pump peak intensity along with propagation. We have performed numerical simulations based on a three dimensional propagation model in cylindrical coordinates using the nonadiabatic Strong Field Approximation (SFA) to calculate the atomic response. The harmonic grows linearly and after some propagation reaches a value roughly two orders of magnitude higher than the non-modulated, phase-mismatched case.

Q 13.5 Mo 17:30 F 342

Tm:KLu(WO$_4$)$_2$ laser mode-locked by a single-walled carbon nanotube saturable absorber — •Andreas Schmidt[1], Günter Steinmeyer[1], Valentin Petrov[1], Uwe Griebner[1], Won Bae Cho[2], Sun Young Choi[2], Jong Hyuk Yim[2], Soonil Lee[2], and Fabian Rotermund[2] — [1]Max Born Institute, Berlin, Germany — [2]Ajou University, Suwon, South Korea

Mode-locked solid-state lasers in the 2-μm spectral range are of great interest for various applications. Numerous Tm^{3+}-doped materials showed high efficiency and output powers in the CW and Q-switched regimes. So far only active mode-locking has been demonstrated with bulk Tm-lasers, and passive mode-locking using a SESAM has been shown solely in a Tm:Ho - codoped KY(WO$_4$)$_2$ laser operating around 2.05 μm [1]. Here, we demonstrate a passively mode-locked Tm:KLu(WO$_4$)$_2$ laser using a transmittive single-walled carbon nanotube saturable absorber (SWCNT-SA). The nonlinear dynamics of the SWCNT-SA were investigated by the pump-probe technique at 1.92 μm. The recovery time of the SWCNT-SA was estimated to be $\approx$1.2 ps. The laser yields picosecond pulses with maximum average output powers of 240 mW generated near 1.94 μm. The RF spectrum at the fundamental beat note of 126 MHz showed no spurious modulations and a noise floor that was approximately 60 dB below the signal. This high signal-to-noise ratio confirms stable single-pulse mode-locking without Q-switching instabilities.

[1] A. A. Lagatsky et. al., Opt. Lett. **34**, (2009) 2587.

Q 13.6 Mo 17:45 F 342

High peak and average power few-cycle OPCPA system — •Stefan Demmler[1], Jan Rothhardt[1], Steffen Hädrich[1], Enrico Seise[1], Franz Tavella[2], Arik Willner[2], Stefan Düsterer[2], Holger Schlarb[2], Josef Feldhaus[2], Jens Limpert[1,3], Jörg Rossbach[2], and Andreas Tünnermann[1,3] — [1]Friedrich Schiller University, Institute of Applied Physics, Jena, Germany — [2]Deutsches Elektronensynchrotron DESY, Hamburg, Germany — [3]Helmholtz Institute, Jena, Germany

Processes initiated by coherent XUV radiation have found interesting applications. Such photons are typically yielded via high harmonic generation, which suffers from low conversion efficiency. To increase the photon count, high repitition rate driver systems are required. The combination of parametric and chirped pulse amplification seems to be to date the only technique to amplify sub 10fs pulses to highest average powers. To further increase the average power of OPCPA systems, the pump power needs to be increased. This can easily be done by fiber CPA systems. We report on an OPCPA system, which uses two stage OPA and reaches 5.7GW peak power with sub 10fs pulses at a repitition rate of 96kHz (6.7W average power). The peak power of this system could be further enhanced by compressing the pulses to their transform limit, which is not trivial. A technique to obtain FT limited pulses is the multiphoton intrapulse interference phase scan method, which has been used to compress 12fs pulses from a Ti:Sa oscillator to 1% of their FT limit. We show the flexibility for implementation in a few-cycle OPCPA system with peak powers >10GW.

Q 13.7 Mo 18:00 F 342

Modelocked Integrated External-Cavity Surface Emitting Laser (MIXSEL) with output power up to 660 mW and repetition rate up to 10 GHz — •Thomas Südmeyer, Benjamin Rudin, Valentin J. Wittwer, Deran J. H. C. Maas, Yohan Barbarin, Matthias Golling, and Ursula Keller — Department of Physics, ETH Zurich, Switzerland.

Modelocked semiconductor disk lasers (also called VECSELs) achieve higher average output power and shorter pulses than any other ultrafast semiconductor laser technology. However, a modelocked VECSEL contains two separate semiconductor elements in a folded cavity, which is a challenge for cost-efficient high volume fabrication, as well as for reaching high repetition rates. Modelocked integrated external-cavity surface emitting lasers (MIXSELs) are a novel type of ultrafast semiconductor lasers. They combine gain and absorber in one semiconductor structure, enabling modelocking in a simple straight cavity and the possibility of a quasi-monolithic design. Here we present a substantially improved MIXSEL. We developed QD saturable absorber with low saturation energy, which allow for an antiresonant design. This relaxes the demands on the growth accuracy and avoids narrow resonances in the dispersion. Wafer removal technology enabled us to achieve 660 mW in 23 ps pulses for a heat sink temperature of 10°C. A higher pulse repetition rate of 10 GHz was achieved at lower output power of 200 mW. In both cases the output power was pump limited. Such performance is highly attractive for large-scale application such as optical clocking.

Q 13.8 Mo 18:15 F 342

Sub-20 fs pulse shaping in the UV by an acousto-optical programmable dispersive filter (AOPDF) — •Rafael Probst, Nils Krebs, and Eberhard Riedle — Lehrstuhl für BioMolekulare Optik, LMU München

Ultrashort laser pulses of controlled complex pulse shape are of high interest in innovative fields of research like coherent control of molecular dynamics and 2D spectroscopy. Until recently, direct shaping of femtosecond light pulses was restricted to the visible and IR regime. We apply a newly available very compact (8 x 8 x 4 cm^3) acousto-optic pulse shaper (Dazzler^{TM}) that offers full control over the spectral amplitude and phase at wavelengths deep into the UV (240 - 420 nm). The primary broadband UV pulses are generated by frequency doubling of a NOPA. We characterize the shaped pulses by ZAP-SPIDER, X-FROG and difference frequency cross correlation with visible 13 fs pulses. We demonstrate that intrinsic problems of spatial chirp can be solved through a specially designed optical beam path that properly takes into account aspects of geometric as well as Gaussian optics. This allows us to generate nearly transform limited pulses as short as 16.8 fs at 320 nm and 19.5 fs at 260 nm. Within a temporal shaping window of up to 3 ps we demonstrate full control over the amplitude and phase of the pulses by generating arbitrary pulse shapes, e.g., square pulses and complex pulse sequences. The subpulses were manipulated individually in intensity, temporal delay, chirp, relative phase and central wavelength, demonstrating the remarkable possibilities of the setup.

Q 13.9 Mo 18:30 F 342

Kryogener Doppelpass-Verstärker mit μJ-Pulsenergien — •Nils Pfullmann[1,2], Martin Siegel[1,2], Carsten Clever[1,2] und Uwe Morgner[1,2,3] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Centre for Quantum Engineering and Space-Time Research (QUEST) — [3]Laserzentrum Hannover (LZH)

Zur Erzeugung von hoher harmonischer Strahlung werden aktuell quasi ausschließlich Verstärkersysteme mit Pulsenergien im mJ-Bereich eingesetzt. Diese haben typischerweise eine Pulswiederholrate im Bereich einiger kHz.

Der hier präsentierte Nachverstärker basiert auf einer Kombination eines Seed-Ti:Saphir-Oszillators mit μJ-Pulsenergien und einem kryogen gekühltem Nachverstärker. Mit dem System ist es möglich, Pulse mit einer Pulsenergie von bis zu 1,9 μJ (1,6 μJ komprimiert), einem Fourierlimit von 100 fs (komprimierte Pulsdauer 207 fs) und einer Pulswiederholrate von 1 MHz zu erzeugen.

Ein einfaches analytisches Modell zeigt eine sehr gute Übereinstimmung mit den experimentellen Daten und erlaubt die Extrapolation des Systems zu noch höheren Pulsenergien.

Mit dem System eröffnen sich vielfältige experimentelle Möglichkeiten im Bereich der Starkfeldphysik, wie z.B. die Erzeugung von harmonischer Strahlung mit Megahertz- Repetitionsraten.

Q 13.10 Mo 18:45 F 342

100 kHz infrared pulse generation up to 5300 nm with novel optical parametric amplifiers — •Maximilian Bradler, Christian Homann, and Eberhard Riedle — Lehrstuhl für BioMolekulare Optik, LMU München

Few-cycle pulses in the Mid-Infrared are interesting for many applications such as time-resolved vibrational spectroscopy or high-field science. The most common approach to produce tunable MIR pulses is difference frequency mixing, e.g., of the NIR signal and idler of an optical parametric amplifier (OPA). However, this requires a compromise between the achievable bandwidth and corresponding pulse length below 100 fs and the overall conversion efficiency, which is typically in the 1 % range. Especially for 100 kHz systems with their limited pulse energy infrared pulse generation asks for new principles to access wavelengths above 3 mum.

Here we present a hybrid approach that yields ultrashort CEP stable MIR pulses up to 5 μm directly as the output of an OPA. We first preamplify selected parts of a supercontinuum generated in YAG in BBO. As pump we use the second harmonic of the laser source. In a second stage we further amplify these pulses in $LiNbO_3$ pumped by the remaining light after SHG. This directly renders idler pulses in the desired wavelength range from 2 to 5 μm. This concept was enhanced by chirp and energy management for the output of the first amplification stage to significantly increase the infrared output.

Q 14: Precision Measurements and Metrology II

Time: Tuesday 14:00–16:15 Location: A 310

Group Report Q 14.1 Tu 14:00 A 310

Dissemination of reference frequencies via optical telecommunication fiber — •Gesine Grosche[1], Osama Terra[1], Katharina Predehl[1,2], Andre Pape[3], Jan Friebe[3], Matthias Riedmann[3], Temmo Wübbena[3], Janis Alnis[2], Ronald Holzwarth[2], Thomas Legero[1], Burghard Lipphardt[1], Thomas Udem[2], Ernst Rasel[3,4], Uwe Sterr[1,4], and Harald Schnatz[1,4] — [1]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig — [2]Max-Planck-Institut für Quantenoptik (MPQ), Garching — [3]Institut für Quantenoptik (IQ), LUH, Hannover — [4]QUEST, Hannover/ Braunschweig

Optical frequency references have achieved an unprecedented accuracy better than 10^{-16}[1]. They are a formidable tool for precision experiments, since frequency is by far the most precisely measurable quantity. Many of these experiments require the comparison of frequencies between different sites. We present the current status of our frequency dissemination work using optical fibers. We achieved a relative accuracy of 10^{-19} for an optical frequency transmission over 146 km [2,3]. With a reference frequency delivered by fiber from PTB, Braunschweig, to IQ, Hannover, we optimised optical clock lasers on-line [4] and performed a remote frequency measurement of the Mg clock transition. Now a German-wide fiber network (IQ, MPQ, PTB...) is being implemented [5], and we explore how to distribute frequencies to many users simultaneously [6]. [1] Chou *et al.* arXiv:0911.4527v1 (2009) [2] Grosche *et al.* Opt. Lett. **34**, 2270 (2009) [3] Terra *et al.* Appl. Phys. B **97**, 541 (2009) [4] Pape *et al.* arXiv 0908.4238 (2009) [5] Predehl *et al.* CLEO (2009) [6] Grosche, DPMA 10 2008 062 139 (2008)

Q 14.2 Tu 14:30 A 310

Opto-mechanische Kopplung in einem Michelson-Sagnac Interferometer — •Henning Kaufer, Kazuhiro Yamamoto, Tobias Westphal, Daniel Friedrich und Roman Schnabel —
Institut für Gravitationsphysik, Leibniz Universität Hannover und
Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut)
Callinstrasse 38
D-30167 Hannover

Opto-mechanische Kopplung - der Austausch von Impuls zwischen Licht einem mechanischen Oszillator - sorgt für einen quantenmechanischen Rauschbeitrag bei einer Positionsmessung, das sogenannte Strahlungsdruckrauschen. Es übertrifft bei geringen Frequenzen das weiße Schrotrauschen, konnte bisher jedoch nicht experimentell nachgewiesen werden. Wir stellen einen neuen Ansatz für den Nachweis von Strahlungsdruckrauschen vor: Eine leichte ($m \approx 100$ ng) Siliziumnitrid-Membran hoher Güte (10^6) wird als Koppler in einem Michelson-Sagnac Interferometer verwendet. Diese Interfermometertopoglogie gestattet es, die Genauigkeit des Experiments durch Power- und Signal-recycling zu verbessern. Erste Ergebnisse und Berechnungen weisen auf eine notwendige Absenkung der Membrantemperatur auf ca 1 K hin, um thermisches Rauschen zu reduzieren und Strahlungsdruckrauschen zu messen. Die Absorption von SiN bei 1064 nm und hohen Lichtleistungen wird in diesem Zusammenhang bedeutend. Derzeit ist die Empfindlichkeit des Experiments durch das Intenstitätsrauschen des Lasers begrenzt.

Q 14.3 Tu 14:45 A 310

Konzepte für diffraktive Optiken mit geringem thermischen Rauschen — •Stefanie Kroker, Frank Brückner, Ernst-Bernhard Kley und Andreas Tünnermann — Institut für Angewandte Physik, Friedrich-Schiller-Universität Jena

Thermisches Rauschen ist ein bedeutender limitierender Faktor sowohl für die Sensitivität von optischen Hochpräzisionsmessungen wie z.B. der Gravitationswellendetektion als auch für die Frequenzstabilität von Einfrequenz-Lasern. Für ein geringes thermisches Rauschen sind optische Komponenten (z.B. Spiegel) mit niedrigen mechanischen Verlusten notwendig. Dielektrische Schichtstapel liefern dabei einen Hauptbeitrag zum Verlust des Systems. Konzepte auf der Basis resonanter Wellenleitergitter können Lösungen für dieses Problem bieten. Hierbei ermöglicht schon eine auf dem Substrat befindliche dünne mikrostrukturierte Schicht eines höherbrechenden Materials hohe Reflektivitäten. Silizium eignet sich auf Grund des geringen mechanischen Verlustes sehr gut als Material für diese Komponenten. Rein monolithische siliziumbasierte Strukturen mit einem Reflektivität nahe 100% wurden realisiert. Die Herstellung ist hierbei allerdings äußerst anspruchsvoll. Alternativ dazu sollen nun diamantbasierte Gitterkonzepte theoretisch untersucht werden. Diamant wird hierbei sowohl als Substratmaterial in Kombination mit Silizium (als höherbrechende Wellenleiterschicht) als auch als niedrigbrechende Zwischenschicht in Betracht gezogen. Unsere Simulationen umfassen neben der Spiegelfunktion auch reflektiv diffraktive Strahlteiler und Resonatorkoppler, die zukünftig transmittive Optiken in den Messaufbauten ersetzen sollen.

Q 14.4 Tu 15:00 A 310

Interferometry based high-precision dilatometry — •Eugen Stoppel[1,3], Martin Gohlke[1,2], Thilo Schuldt[2,3], Dennis Weise[1], Ulrich Johann[1], and Claus Braxmaier[3] — [1]EADS Astrium — [2]Humboldt-Universität zu Berlin — [3]HTWG Konstanz

In the scope of the gravitational wave detector LISA (Laser Interferometer Space Antenna), EADS Astrium in collaboration with the Humboldt-University Berlin and the University of Applied Sciences Konstanz (HTWG) developed a heterodyne interferometer, combined with technique of the so-called differential wavefront sensing for angle measurements. Based on the heterodyne interferometer, an optical dilatometer for high-accuracy and high-resolution measurement of the linear coefficient of thermal expansion (CTE) was realized.

With the first setup a CTE below 0.1×10^{-6} $1/K$ can be measured. In a new design all main parts are made of ultra stable glass ceramic instead of aluminum, in order to bring the noise performance to the theoretical limit of 10^{-9} $1/K$.

In this presentation, the dilatometer and first results of the measurements will be presented.

Q 14.5 Tu 15:15 A 310

Waveguide gratings as highly reflective mirrors without dielectric coatings — •Daniel Friedrich[1], Frank Brückner[2], Michael Britzger[1], Stefanie Kroker[2], Ernst-Bernhard Kley[2], Andreas Tünnermann[2], Karsten Danzmann[1], and Roman Schnabel[1] — [1]Institut für Gravitationsphysik, Leibniz Universität Hannover und Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) Callinstrasse 38 D-30167 Hannover — [2]Institut für Angewandte Physik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1 D-07743 Jena

Thermal noise in multilayer optical coatings may not only limit the sensitivity of future gravitational wave detectors in their most sensitive frequency band but is also a major impediment for experiments that aim to reach the standard quantum limit or to cool mechanical systems to their quantum ground state.

This talk will give an overview about the progress of waveguide gratings as highly reflective mirrors without multilayer coatings. The best result so far includes a monolithic mirror with a measured reflectivity of 99.8% for normal incidence.

Q 14.6 Tu 15:30 A 310

Frequency dissemination using a wide-area telecommunication fiber link — •Osama Terra[1], Gesine Grosche[1], Katharina Predehl[2], Ronald Holzwarth[2], and Harald Schnatz[1] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig,Germany — [2]Max Planck Institute for Quantum optics, Garching, Germany

Optical frequency standards can reach a relative uncertainty below 10^{-16} and an instability of $10^{-15}/(\tau^{1/2}/s)$. For the dissemination of such a stable frequency, an optical fiber link provides a promising technique which avoids degradation of frequency stability and accuracy when used with a system that compensates temperature fluctuations and acoustic perturbations of the optical fiber. We have investigated the performance of a 146 km telecommunication fiber link to transfer such stable frequencies. We have transferred the stability of a clock laser at PTB to a telecommunication laser at $\lambda = 1542nm$ and measured its stability at the remote end of the fiber. The comparison performed at PTB between the local and the remote signal showed a relative uncertainty below 1×10^{-19} and an instability of $\sigma_y(\tau) = 3.3 \times 10^{-15}/(\tau/s)$, limited by the time delay introduced by the link. We are currently establishing a $900km$ fiber link between PTB and MPQ. The transmitted signal has to be amplified several times to maintain the required power level and SNR. Bidirectional EDFAs that amplify the signal typically every $100km$ are used at the moment. We additionally studied the performance of Brillouin amplifiers to bridge larger distances in one step.

Q 14.7 Tu 15:45 A 310

Continuous-wave squeezed states at 1550 nm — •Moritz Mehmet, Tobias Eberle, Sebastian Steinlechner, Henning Vahlbruch, Karsten Danzmann, and Roman Schnabel — Institut für Gravitationsphysik, Leibniz Universität Hannover und Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstrasse 38, 30167 Hannover

It seems likely that the potential to enhance the sensitivity of quantum noise limited interferometers will make squeezed-light-injection a standard tool in future Gravitational Wave (GW) detector technology. One means to reduce the inherent noise floor of future detectors could be the use of new materials for optical components. For example, silicon constitutes an excellent test mass material with a high mechanical quality making it superior to the currently used fused silica components. This change would entail the replacement of the presently used laser by lasers operating at 1550 nm at which silicon shows very low optical loss. Besides the issue of how lasers at 1550 nm can be turned into reliable laser sources for future GW interferometers, research has to be undertaken on how to engineer the respective squeezed states.

Here, we report on the generation of cw squeezed vacuum states at a wavelength of 1550 nm with a non-classical noise reduction of 6.4 dB. These squeezed vacuum states were injected into the dark port of a Sagnac interferometer. A reduction of the interferometer shot noise by approximately 4.5 dB was observed and the enhancement of the signal-to-noise ratio for a phase modulation signal generated within the interferometer could be demonstrated.

Q 14.8 Tu 16:00 A 310

Remote characterization of ultrastable optical frequencies via a 73 km long telecommunication fiber link — •Andre Pape[1], Jan Friebe[1], Osama Terra[2], Matthias Riedmann[1], Temmo Wübbena[1], André Kulosa[1], Sana Amairi[1], Hrishikesh Kelkar[1], Ernst-Maria Rasel[1], Wolfgang Ertmer[1], Katharina Predehl[2], Thorsten Feldmann[2], Thomas Legero[2], Burghard Lipphardt[2], Gesine Grosche[2], and Harald Schnatz[2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Dissemination and remote comparison of ultrastable optical frequencies is an important research field, since the complexity of optical clocks does not allow for transportation today. We implemented a 73 km long optical telecommunication fiber link between the Physikalisch-Technische Bundesanstalt (PTB, Braunschweig) and the Institute of Quantum Optics (IQ, Hannover). We report on a remote characterization of ultrastable lasers on the 10^{-15} level in fractions of a second.

We additionally used this fiber link to characterize the magnesium optical frequency standard at the IQ against an ultrastable optical frequency, a hydrogen maser and a Cs fountain clock at PTB and report on an improved frequency measurement. The Mg optical frequency standard is based on cold free falling ensembles of neutral Mg atoms interrogated on the narrow ${}^1S_0 \rightarrow {}^3P_1$ intercombination transition using the Ramsey-Bordé interferometer scheme with subsequent detection using a MOT in the metastable ${}^3P_J \rightarrow {}^3D_{J'}$ system.

Q 15: Ultracold Atoms: Manipulation and Detection (with A)

Time: Tuesday 14:00–16:00 Location: A 320

Q 15.1 Tu 14:00 A 320

Interactions of atoms with spatially dispersive solids — •Harald Haakh[1], Carsten Henkel[1], and Baruch Horovitz[2] — [1]Universität Potsdam, Germany — [2]Ben Gurion University of the Negev, Beer Sheva, Israel

We discuss the coupling of atoms and ions to solid surfaces, in particular superconductors and metals. This is relevant for the anomalous heating in miniaturized ion traps and for spin flip rates of magnetic traps implemented on microchips, which determine the trap stability. Our approach is based on the surface response of spatially dispersive media, relevant for vortex lattices in type-II superconductors and the anomalous skin effect. We identify in particular the relevance of the scattering mean free path of the carriers in the solid, as compared to the distance of observation by the atom. Different boundary conditions for the current density (specular vs. diffuse) are generalized to the relevant parameter regime (non-retarded transverse response).

Q 15.2 Tu 14:15 A 320

A new Experiment for the investigation of ultra-cold Potassium Rubidium Mixtures — •Georg Kleine Büning, Johannes Will, Jan Peise, Wolfgang Ertmer, and Jan Arlt — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

We present an experimental apparatus, which will allow us to investigate mixtures of ^{87}Rb with the bosonic isotopes of potassium ^{39}K or ^{41}K, and also enable the use of Feshbach-resonances.

In the experiment the desired isotopes are collected in a magneto-optical trap from the background vapour. A magnetic quadrupole trap is used to transport the pre-cooled atoms mechanically into a glass cell with better vacuum. There the atoms are transferred into a novel hybrid optical and magnetic trap. Subsequently sympathetic cooling will be used to bring the desired isotopes of rubidium and potassium to quantum degeneracy. Finally a magnetic field can be tuned to the Feshbach resonances to manipulate the interaction strength.

Particular attention will be given to the design of the novel hybrid trap, which recently allowed for the realisation of a BEC of about 10^6 ^{87}Rb atoms.

Q 15.3 Tu 14:30 A 320

Evaporative cooling in a magnetic trap strongly distorted by gravitation — •Matthias Wolke, Julian Klinner, and Andreas Hemmerich — Universität Hamburg

Due to experimental constraints our cigar-shaped magnetic trap has to operate with its weak confinement along the direction of gravity. We present the first Bose-Einstein-Condensate via RF-induced evaporative cooling in this scenario. Differences between this setup and the conventional setup with its weak trapping axis in the horizontal direction are discussed. In our setup different Zeeman-species display a macroscopic difference in gravitational sag. We present data, which show that this has significant impact on the evaporation efficiency.

Q 15.4 Tu 14:45 A 320

Collective atom-cavity effects with cold Ytterbium gases. — Matteo Cristiani[1], Hannes Gothe[1], Tristan Valenzuela[1], and •Jürgen Eschner[1,2] — [1]ICFO - Institut de Ciencies Fotoniques, Mediterranean Technology Park, 08860 Castelldefels (Barcelona), Spain — [2]FR Experimentalphysik, Universität des Saarlandes, Campus E2.6, 66123 Saarbrücken

We report results from an experiment aiming at collective dynamics of a cold atomic ensemble coupled to the mode of an ultra-high finesse Fabry-Perot cavity. In our experiment we cool and trap $\approx 10^6$ Yb atoms in a MOT using the ${}^1S_0 \rightarrow {}^1P_1$ transition at 399 nm. The cloud temperature is $T = 2$ mK. Around the cloud position we have set up a high finesse cavity with length $L = 4.74$ cm, linewidth $\kappa = 2\pi \times 60$ kHz and finesse $\mathcal{F} = 55000$. We study the action of the atomic cloud on the cavity mode and observe a behaviour which indicates the presence of strong collective atom-photon coupling. The effects of the cavity mode on the atomic dynamics (cavity cooling and self-organization) are under investigation.

Q 15.5 Tu 15:00 A 320

Matter Wave Scattering from Ultracold Atoms in an Optical Lattice — Scott N. Sanders[1,2], •Florian Mintert[3], and Eric J. Heller[1] — [1]Physics Department, Harvard University — [2]Massachusetts Institute of Technology — [3]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

We study matter wave scattering from an ultracold, many body atomic system trapped in an optical lattice. The angular cross section of the target lattice for a matter wave is determined and is demonstrated to have a strong dependence on the many body phase, superfluid or Mott insulator. Analytical approaches are employed deep in the superfluid and Mott insulator regimes, while intermediate points in the phase transition are treated numerically. Matter wave scattering offers a convenient method for non-destructively probing the quantum many body phase transition of atoms in an optical lattice.

Q 15.6 Tu 15:15 A 320

Towards phase damping of two independent condensates via an optical high finesse cavity — •Simone Bux, Christine Gnahm, Gordon Krenz, Claus Zimmermann, and Philippe A.W. Courteille — Physikalisches Institut Tübingen, Auf der Morgenstelle 14, 72076 Tübingen

Optical ring cavities have been proposed for novel optical cooling schemes for atoms and molecules known as "cavity-cooling" [1,2]. However, they also play an important role in the quest for controllable damping mechanisms working even for superfluids, whose prominent feature is the absence of friction. Our goal is to experimentally prove the viability of a cavity-based damping scheme predicted to lead to the unification of independently grown Bose-Einstein condensates (BEC) [3]. For this purpose, we create in our experiment two BECs of Rb87 in two different hyperfine states. The states are coherently driven on a microwave-radiofrequency two-photon transition and additionally coupled by a Raman transition, which is stimulated by a high-finesse ring cavity. This scheme induces an irreversible cycling in the atomic excitation and, due to the cavity-mediated coupling to the external degrees of freedom, a synchronization of the condensates' de Broglie phases. We will present the model and the state of the art of our experiment.

[1] V. Vuletic and S. Chu, Phys. Rev. Lett. 84, 3787 (2000)

[2] P. Horak, S. M. Barnett, and H. Ritsch, Phys. Rev. A 61, 033609 (2000)

[3] D. Jaksch, S. A. Gardiner, K. Schulze, J. I. Cirac, and P. Zoller, Phys. Rev. Lett. 86, 4733 (2001)

Q 15.7 Tu 15:30 A 320

Dissipative manipulation of an ultracold quantum gas — •Andreas Vogler[1,2], Peter Würtz[1], Tatjana Gericke[1], Tobias Weber[1,2], Fabian Etzold[1], Frank Markert[1], and Herwig Ott[1,2] — [1]Institut für Physik, Johannes-Gutenberg Universität, Mainz — [2]Fachbereich Physik, Technische Universität Kaiserslautern

We present an experimental investigation of dissipative effects, affecting a cloud of ultracold Rb-atoms.

In our experiment we ionize atoms of an atomic ensemble by electron-impact ionization, using a tightly focussed electron-beam. The ions are extracted by means of electrostatic optics and subsequently detected. This allows us to probe density distributions with high spatial resolution. Furthermore, the electron-beam is a versatile tool capable of applying particle dissipation on the atomic ensemble. We can vary the atomic losses on individual positions by controlling the dwell time. By choosing the correct scan-pattern we are able to perturb the atomic cloud either on distinct places or homogeneously.

The temporal analysis of the detected ions allows us to determine cross-sections of electron-atom scattering as well as observe signatures of cold ion-atom collisions. We propose this dissipative manipulation technique to study many-body effects, e.g., local and non-local particle-particle correlations.

Q 15.8 Tu 15:45 A 320

A New Apparatus for Cavity QED Experiments in the Strong Coupling Regime — •Markus Koch, Christian Sames, Matthias Apel, Max Balbach, Alexander Kubanek, Alexei Ourjoumtsev, Pepijn Pinkse, Karim Murr, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, D-85748 Garching, Germany

The ability to trap single atoms in high-finesse cavities in the strong coupling regime has stimulated the field of cavity QED, leading to the observation of many long predicted effects such as the normal-mode splitting, two-photon resonances or cavity cooling. We present the status of a new apparatus to continue this line of research.

It features an asymmetric cavity, which significantly enhances the photon flux from the cavity. In addition, coned mirrors provide transverse optical access to the trapped atom. Finally, a piezo motor allows to adjust the length of the cavity macroscopically, thus enabling to study cavity QED effects over a broad range of cavity parameters.

First measurements of the normal modes as well as of the intensity response of the system are presented. We observe considerably increased storage times compared to previous experiments, mandatory for further investigations, e.g. nonlinear optics at the single-particle level.

Q 16: Quantum Gases: Interaction Effects I

Time: Tuesday 14:00–16:15 Location: E 001

Group Report Q 16.1 Tu 14:00 E 001

Giant coherence times in trapped atomic gases — Christian Deutsch[1], Fernando Ramirez-Martinez[2], Clement Lacroute[2], Friedemann Reinhard[1], Tobias Schneider[1], Jean-Noel Fuchs[3], Frederic Piechon[3], Franck Laloe[3], Jakob Reichel[1], and •Peter Rosenbusch[2] — [1]LKB, Ecole Normale Supérieure, Paris — [2]LNE-SYRTE, Observatoire de Paris — [3]LPS, Université Paris-Sud, Orsay

We present an atom chip experiment designed to operate a microwave clock using magnetically trapped atoms. The project builds on the demonstration experiment [Phys. Rev. Lett., vol. 92, 203005 (2004)] but aims at an improved clock stability of 10^{-13} at 1 s, 10 times better than commercial clocks. We give results on the contrast of Ramsey fringes recorded in the thermal regime, where atoms can be treated as independent particles following different trajectories. The predicted dephasing time for 10^5 atoms, based on the known collisional shift, the second order Zeeman shift and their partial compensation is around 1.5 s [Appl. Phys. B, vol. 95, 227 (2009)]. Here we present experimental data where the fringe contrast remains bigger than 75% up to 5 s of Ramsey free evolution time, equivalent to a 15 s 1/e-time, which is 10 times longer than predicted. This, to our knowledge is a new record in neutral atom experiments. First simulations indicate that the identical spin rotation effect, known to be at the origin of spin waves [Phys. Rev. Lett., vol. 102, 215301 (2009)], here leads to a synchronisation of the atom phases.

Q 16.2 Tu 14:30 E 001

Atom chip based generation of entanglement for quantum metrology — •Max Fabian Riedel[1,2], Pascal Böhi[1,2], Yun Li[3,4], Theodor Wolfgang Hänsch[1,2], Alice Sinatra[3], and Philipp Treutlein[1,2] — [1]Ludwig-Maximilians-Universität, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [3]Laboratoire Kastler-Brossel, ENS, 75005 Paris, France — [4]State Key Laboratory of Precision Spectroscopy, East China Normal University, Shanghai 200062, China

Entanglement-based technologies, such as quantum information processing, quantum simulations, and quantum metrology have the potential to revolutionize our way of computing and measuring, and help clarify the puzzling concept of entanglement itself. Ultracold atoms on atom chips are attractive for their implementation, as they provide control over quantum systems in compact, robust, and scalable setups. A severe limitation of atom chips, however, is that techniques to control atomic interactions and thus to generate entanglement have not

been experimentally available so far.

In this talk we present experiments where we generate multi-particle entanglement on an atom chip by controlling elastic collisional interactions with a state-dependent microwave near-field potential. We employ this technique to generate spin-squeezed states of a two-component Bose-Einstein condensate and show that they are useful for quantum metrology. Our data show good agreement with a dynamical multi-mode simulation and allow us to reconstruct the Wigner function of the spin-squeezed condensate.

Q 16.3 Tu 14:45 E 001

Multi-isotope trapping of metastable neon — •Jan Schütz, Thomas Feldker, Holger John, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

We investigate the interactions of laser cooled metastable neon (Ne*) in the $^3P_2$ state in a magneto-optical trap (MOT) and magnetic trap. Recent modifications of our setup enable us to trap all two-isotope combinations of bosonic ^{20}Ne, bosonic ^{22}Ne, and fermionic ^{21}Ne.

The most remarkable feature of Ne* is its extraordinary high internal energy which exceeds half of its ionization energy. This, on the one hand, leads to extremely high two-body losses due to Penning ionization but, on the other hand, allows for very sensitive detection of ions and metastables using electron multipliers. This serves as a direct probe for inelastic collisions and should enable us to gain a close insight into the inter-isotopic collision processes.

One objective is to determine the inter-isotopic collision cross sections which, if favorable, could open up new possibilities to create quantum degenerate bosonic or fermionic Ne*. Another goal is to create a dense, cold, spin-polarized sample of fermionic ^{21}Ne since reduction of the ion production would present a direct observation of Pauli blocking. We report on the status of the experiment.

Q 16.4 Tu 15:00 E 001

Phase separation in a thermal mixture of ultracold atoms — •Frank Münchow, Florian Baumer, Cristian Bruni, Simon Hübner, and Axel Görlitz — Institut für Experimentalphysik, HHU Düsseldorf, Germany

A fundamental question that arises if two gases of atoms are trapped in the same trap is whether the two species mix or phase separation occurs. Generally, a condition for phase separation in a thermal mixture is that the interspecies interaction energy is extremely large and exceeds the thermal energy. Therefore, interaction-driven phase separation has not been observed in ultracold atom experiments, so far. Here, we report on our recent results on mixtures of ultracold Yb and Rb in a hybrid trap consisting of a bichromatic optical potential superimposed on a magnetic trap. For a specific combination of isotopes, namely ^{174}Yb and ^{87}Rb, we have observed an almost complete spatial separation of thermal clouds of ^{174}Yb and ^{87}Rb at temperatures in the low μK regime. In the particular trapping geometry, the presence of an ultracold ^{87}Rb cloud ($\approx 10^7$ atoms) leads to a strong repulsive interaction potential for the $\approx 10^5$ ^{174}Yb atoms which are repelled from the trap center. The phase separation implies intrinsically large repulsive interspecies interaction for the specific isotopic mixture and indicates an interspecies scattering length greater than $10000\,a_0$.

Q 16.5 Tu 15:15 E 001

Parameterizing the influence of Feshbach resonances for photoassociation and in the context of the Bose-Hubbard model of ultracold atoms in optical lattices. — •Philipp-Immanuel Schneider — AG Moderne Optik, Institut für Physik, Humboldt-Universität zu Berlin, Newtonstraße 15, 12489 Berlin

Ultracold atoms interacting in the presence of a Feshbach resonance (FR) have a vast range of applications from the creation of strong correlations in ultracold gases to the formation of dipolar ultracold molecules. Here we present an extension of the Bose-Hubbard (BH) model for ultracold atoms in optical lattices interacting with large scattering lengths as they appear in FRs. We show by an exact numerical treatment that the BH Hamiltonian can reproduce the two-particle spectrum for arbitrary large scattering lengths only by replacing the original interaction parameter U. The optimal value of this parameter can be well approximated by an analytic expression. Furthermore, we study the enhancement of photoassociation in the presence of an FR. We find that one can describe the transition rate of the complex photoassociation process by only two parameters, the maximal transition rate and the position of vanishing transition rate. It is shown that the latter determines the maximal enhancement of the transition rate.

Q 16.6 Tu 15:30 E 001

Multi-layer stacks of dipolar Bose-Einstein condensates — •Andrej Junginger, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Multi-layer stacks of dipolar Bose-Einstein condensates are investigated variationally using a Gaussian trial wave function for each condensate. The individual condensates arranged in harmonic traps only interact via the long-range dipole-dipole interaction while there is an additional attractive contact interaction present in each condensate.

The stationary states of the stack are calculated minimizing the mean-field energy and the dynamics of the system are obtained applying a time-dependent variational principle. Introducing canonical variables this system is equivalent to a many-body Hamiltonian system with particle interaction. The energy exchange between the condensates in an excited stack is analyzed.

Q 16.7 Tu 15:45 E 001

Far-From-Equilibrium Dynamics of Ultracold Fermi Gases — •Matthias Kronenwett[1], Thomas Gasenzer[1], Michael Foss-Feig[2], and Ana Maria Rey[2] — [1]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg — [2]JILA, University of Colorado, Boulder CO-80309, USA

We study the dynamics of ultracold Fermi gases far from thermal equilibrium. We employ a functional-integral approach based on the Schwinger-Keldysh closed time path integral 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 N, where N is the number of atomic hyperfine states. 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. We present results on the dynamics of a 1D Fermi gas initially prepared far away from equilibrium. We also demonstrate how this formalism is specially suited to describe far-from-equilibrium dynamics in a Kondo lattice of ultracold fermionic alkaline-earth atoms.

Q 16.8 Tu 16:00 E 001

Delocalization of a disordered bosonic system by repulsive interactions — •Benjamin Deissler[1], Matteo Zaccanti[1], Giacomo Roati[1], Chiara D'Errico[1], Marco Fattori[1,2], Michele Modugno[1], Giovanni Modugno[1], and Massimo Inguscio[1] — [1]LENS and Dipartimento di Fisica, Università di Firenze, and CNR-INFM, 50019 Sesto Fiorentino, Italy — [2]Museo Storico della Fisica e Centro Studi e Ricerche 'E. Fermi', 00184 Roma, Italy

Anderson localization of ultracold atoms in disordered optical lattices, i.e. the transition from extended to exponentially localized states, was recently demonstrated for non-interacting samples. With the addition of atomic interactions, such a system becomes more complicated and is more difficult to describe theoretically. The effects of the disorder are expected to be gradually suppressed by repulsive interactions, and the possibility of different quantum phases arises. We employ a Bose-Einstein condensate of potassium, where the interaction can be tuned from negligible to large values via a Feshbach resonance and use a quasi-periodic lattice potential as a model of a controllable disordered system. This allows us to study the interplay of disorder and repulsive interactions in detail. We characterize the entire delocalization crossover through the study of the average local shape of the wavefunction, the spatial correlations, and the phase coherence. Three different regimes are identified and compared with theoretical expectations: an exponentially localized Anderson glass, the formation of locally coherent fragments, as well as a coherent, extended state.

Q 17: Quantum Information: Atoms and Ions I

Time: Tuesday 14:00–16:30 Location: E 214

Group Report Q 17.1 Tu 14:00 E 214

Coherent spectroscopy involving Rydberg states in microcells — •Thomas Baluktsian[1], Bernhard Huber[1], Harald Kübler[1], Andreas Kölle[1], Christian Urban[1], James P. Shaffer[2], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Germany — [2]Homer L. Dodge Department Of Physics And Astronomy, University of Oklahoma, USA

Micron sized glass cells filled with atomic vapor are promising candidates for quantum devices based on the Rydberg blockade. Due to the strong interaction between two Rydberg atoms, only one Rydberg excitation is possible within a certain volume characterized by the blockade radius (typically few microns), that is determined by the laser bandwidth and the interaction strength. This effect also provides a nonlinearity that is an essential tool for proposals to entangle mesoscopic ensembles and to realize single photon sources. In order to probe coherent dynamics it is necessary for the excitation times to be shorter than typical dephasing timescales. This can be realized by utilizing a bandwidth limited pulsed laser system which allows for the creation of high enough Rabi-frequencies. We report on the first coherent Rydberg excitation in a homemade 2D rubidium vapor cell with a thickness of 1 μm including investigation of effects due to confinement in the vapor cell [1]. Furthermore EIT measurements on rubidium vapor in micron sized channels show that coherent dynamics and narrow linewidths are possible. First measurements with a pulsed laser system showed evidence of coherent dynamics on the ns-timescale.

[1] H. Kübler et al., accepted by Nature Photonics, arXiv:0908.0275

Group Report Q 17.2 Tu 14:30 E 214

Scalable Architecture for Quantum Information Processing with Neutral Atoms — •Jens Kruse, Malte Schlosser, Peter Schauss, Benedikt Baumgarten, Sascha Tichelmann, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

Ultra-cold atoms in two-dimensional dipole trap arrays represent highly controllable and scalable systems for quantum information processing with long coherence times. In our experiment, we use sets of optical micro-potentials created by micro-fabricated lens arrays as the architecture for a scalable quantum processor. Advanced schemes for atom detection allow us to observe single atoms with high efficiency and reliability in a site-selective and state-specific fashion.

We report on a series of important advances: For flexible architectures, we implement a spatial light modulator in front of a microlens array as a pixel-addressable intensity modulator for the realization of arbitrary trapping configurations. We demonstrate the initialization and coherent manipulation of small ensembles of ^{85}Rb atoms at separatly addressable sites by applying coherent Raman coupling between hyperfine ground states. We also present an experimental scheme compensating for the differential lightshift induced by the trapping light. This "magic-wavelength" behavior synchronizes the coherent evolution and results in an increase of the spectroscopic resolution and a strong suppression of dephasing. The scheme is extendable to all alkali elements where no standard "magic-wavelength" is available and opens new avenues in metrology and quantum computing.

Q 17.3 Tu 15:00 E 214

Lossless qubit state detection of single neutral atoms — •Joerg Bochmann, Martin Mücke, Christoph Guhl, Carolin Hahn, Stephan Ritter, David Moehring, and Gerhard Rempe — MPI für Quantenoptik, Garching, Germany

Trapped neutral atoms are among the most promising resources for quantum information science. In a single trapped atom, the quantum bit (qubit) is typically encoded in or mapped onto atomic hyperfine states. However, hyperfine qubit read-out has proven remarkably difficult for neutral atoms. Existing protocols do not obtain an answer in every read-out attempt or suffer from loss of the atom during detection. We introduce a state detection scheme based on cavity-enhanced fluorescence. It makes use of the Purcell effect to establish a controlled coupling between qubit and environment. In an experiment with a single trapped Rubidium atom, we achieve a hyperfine state detection fidelity of 99.4% in 85 μs while a result is obtained in every read-out attempt. Most important, the qubit can be interrogated many hundred times without loss of the atom. This presents an essential advancement for the speed and scalability of quantum information protocols based on neutral atoms. Our scheme can be generalized to all systems in which the qubit is optically accessible.

Q 17.4 Tu 15:15 E 214

Loading atoms into a blue-box trap from a dark MOT: towards long lived quantum memory — •Fan Yang[1], Huan Nguyen[1], Torsten Mandel[1], Maximilian Plenert[1], Alexander Göbel[1], Shuai Chen[2], Zhen-Sheng Yuan[1,2], and Jian-Wei Pan[1,2] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg, Germany — [2]Hefei National Laboratory for Physical Sciences at Microscale and Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China

Quantum memories are fundamental ingredients for quantum information processing systems. Of key importance is the requirement of long-lived quantum memories in a long-distance quantum communication network composed of atomic ensembles and linear optical elements. We discuss the various decoherence mechanisms existing in a cold-atomic-ensemble based quantum memory. Solutions to maintain the coherence of the stored quantum state are proposed accordingly. Cold atoms confined in a blue detuned optical dipole trap are expected to extend the lifetime of quantum memory to the order of several hundred milliseconds. We report here the preliminary experimental results of loading cold atoms of 87Rb from a dark magneto-optical trap into a blue-box trap which will serve as a medium for long-lived quantum memories. High optical depth is observed and expected to boost the retrieve efficiency of a quantum memory and meanwhile offers more chances for studying quantum simulation.

Q 17.5 Tu 15:30 E 214

Multipartite W states for chains of atoms conveyed through an optical cavity — •Denis Gonta[1] and Stephan Fritzsche[2,3] — [1]Max-Planck-Institut für Kernphysik, Postfach 103980, D-69029 Heidelberg — [2]Department of Physical Sciences, P.O Box 3000, Fin-9014, University of Oulu, Finland — [3]GSI Helmholtzzentrum für Schwerionenforschung, D-64291 Darmstadt

Optical cavities provide a perspective tool to produce the interaction between neutral atoms which are coupled simultaneously to the same cavity mode. An excellent control of the atomic motion is essential for such interaction and can be realized especially by using optical lattices (conveyor belts), which have recently been utilized in various setups of cavity QED. The combination of such a lattice with the cavity QED setup, however, make it necessary to analyze how the velocity and the spacing between the atoms in the chain will affect the formation of entanglement.

In this contribution, we propose a scheme to generate the entangled W_N state between the qubits associated with N three-level atoms in the Λ-type configuration. The atoms are supposed to be equally separated from each other and conveyed through the cavity by means of an optical lattice. This scheme works in a completely deterministic way and is robust with respect to small oscillations in the atomic motion as caused by the thermal motion of atoms in the optical lattice [1].

[1] D. Gonta and S. Fritzsche, J. Phys. B **42**, 145508 (2009).

Q 17.6 Tu 15:45 E 214

Coherent Transport of Atomic Quantum States in a Scalable Shift Register — •Malte Schlosser, Jens Kruse, Andre Lengwenus, Sascha Tichelmann, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

The coherent control of the internal and external quantum states of ultra-cold neutral atoms represents an important experimental approach towards quantum information processing. An attractive architecture is given by physically independent qubits arranged in a scalable quantum register. In our experiment we obtain a suitable system of two-dimensional periodic potentials employing microfabricated lens arrays. While coherent storage and single-site adressability, offering the direct manipulation of individual qubits, are inherent for this design one has to implement techniques to connect distinct traps in order to perform two qubit operations. A natural way is to precisely control

interaction by actively arranging the positions of individual qubits. We present the controlled coherent transport of two-dimensional arrays of small ensembles of ^{85}Rb atoms. The scalable shift register is an all optical device which offers precise control of the position of trapped neutral atoms. The shift operation is based on consecutive loading, moving and reloading of two independently controllable arrays of traps. We show the scalability of our architecture and of the transport process by demonstrating the repeated hand-over of atoms from trap to trap. We investigate the processes of transport and reloading in detail and demonstrate the conservation of coherence during transport.

Q 17.7 Tu 16:00 E 214

Digital Coherent and Dissipative Quantum Simulations with Rydberg Atoms — •Hendrik Weimer[1], Markus Müller[2], Igor Lesanovsky[3], Peter Zoller[2], and Hans Peter Büchler[1] — [1]Institut für Theoretische Physik III, Universität Stuttgart — [2]Institut für Theoretische Physik, Universität Innsbruck, und Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaften, Innsbruck — [3]School of Physics and Astronomy, The University of Nottingham

A universal quantum simulator is a controlled quantum device which efficiently reproduces the dynamics of any other many particle quantum system with short range interactions. Based on a recent proposal for a many-body gate using strong interactions between Rydberg atoms [1], we present an implementation of a digital quantum simulator in an optical lattice with large lattice spacing [2]. Special focus is on the efficient simulation of Hamiltonians with local many-body interactions, including exotic spin models such as Kitaev's toric code, string nets, and lattice gauge theories. In addition, we show that the formalism also provides the simulation of dissipative terms taking the Lindblad form with many-body jump operators. These dissipative terms allow for the efficient ground state cooling and state preparation.

[1] M. Müller et al., Phys. Rev. Lett. **102**, 170502 (2009).
[2] H. Weimer et al., arXiv:0907.1657 (2009).

Q 17.8 Tu 16:15 E 214

Generation of macroscopic singlet states in atomic ensembles — •Geza Toth[1,2,3] and Morgan W. Mitchell[4] — [1]Theoretical Physics, The University of the Basque Country, E-48080 Bilbao, Spain — [2]IKERBASQUE, Basque Foundation for Science, E-48011 Bilbao, Spain — [3]Research Institute for Solid State Physics and Optics, H-1525 Budapest, Hungary — [4]ICFO, Institut de Ciencies Fotoniques, Mediterranean Technology Park, E-08860 Castelldefels (Barcelona), Spain

We study squeezing of the spin uncertainties by quantum non-demolition (QND) measurement in non-polarized spin ensembles. Unlike the case of polarized ensembles, the QND measurements can be performed with negligible back-action, which allows, in principle, perfect spin squeezing as quantified by [G. Toth et al., Phys. Rev. Lett. 99, 250405 (2007)]. The generated spin states approach many-body singlet states, and contain a macroscopic number of entangled particles, even when individual spin is large. We introduce the Gaussian treatment of unpolarized spin states and use it to estimate the achievable spin squeezing for realistic experimental parameters. Our proposal might have applications for quantum memories storing information in decoherence free subspaces.

Q 18: Laser Development: Solid State Lasers II

Time: Tuesday 14:00–16:00 Location: F 128

Q 18.1 Tu 14:00 F 128

Numerical investigation of a pulsed loop oscillator injection seeded via gain gratings — •Robert Elsner, Roland Ullmann, and Martin Ostermeyer — Institute for Physics and Astronomy, University of Potsdam, Karl-Liebknecht-Str. 24/25, 14476 Potsdam, Germany

We present a model of a pulsed loop oscillator that is coupled to a seed laser via gain grating inside a Nd:YAG rod. Such a loop oscillator emits short pulses due to a passive Q-switch realized by the transient diffraction efficiency of the gain grating. Because the gain grating's position is not fixed it can compensate for fluctuations of the resonator length and thus should be applicable for frequency stabilization. Thus the scheme has the potential for spectrally stable pulsed operation without the need for any active stabilization circuit when coupled to a frequency stable master. A set of nonlinear wave equations, their respective boundary conditions and rate equations are used for the numerical model. Numerical calculations are presented and options to reach a spectrally resolved solution within such a model are discussed.

[1] M. J. Damzen et al., Opt. Lett. 20, 1704- (1995)
[2] P. Sillard et al., IEEE J. Quantum Electron. 34, 465*472 (1998)

Q 18.2 Tu 14:15 F 128

Untersuchung des Modensprungverhaltens eines longitudinal gepumpten, passiv gütegeschalteten Nd:YAG-Lasers — •Thomas Hülsenbusch[1], Tino Lang[1], Mathias Ernst[1], Sandra Mebben[1], Rajat Marwah[1], Christian Kolleck[1,2], Jörg Neumann[1,2] und Dietmar Kracht[1,2] — [1]Laser Zentrum Hannover e.V., Hollerithallee 8, D-30419 Hannover, Germany — [2]Centre for Quantum-Engineering and Space-Time Research - Quest, Welfengarten 1, D-30167 Hannover, Germany

Für spektroskopische Messverfahren, wie zum Beispiel der Ramanspektroskopie, aber auch für die Erzeugung von freien Ionen oder Molekülen in der Massenspektrometrie haben sich in den letzten Jahren Lasersysteme mit möglichst kurzen Wellenlängen als vorteilhaft erwiesen. Passiv gütegeschaltete Laser eignen sich dabei aufgrund ihrer hohen Pulsenergien im mJ-Bereich bei gleichzeitig kurzen Pulslängen von wenigen ns zur nichtlinearen Frequenzvervielfachung in den grünen bzw. ultravioletten Spektralbereich. Ein Nachteil dieser Lasersysteme ist jedoch, dass aufgrund von Modensprüngen starke Energiefluktuationen auftreten können, die durch die anschließende Frequenzvervielfachung entsprechend verstärkt werden. Wir präsentieren und diskutieren die Ergebnisse umfangreicher Messungen bezüglich des Modensprungverhaltens eines passiv gütegeschalten Nd:YAG Laseroszillators, in Abhängigkeit von diversen Parametern, wie zum Beispiel der Resonatorlänge, der Kristalltemperatur, sowie für unterschiedliche Auskoppelgrade des Oszillators, Anfangstransmissionen des sättigbaren Absorbers und Pumpstrahlfokussierungen.

Q 18.3 Tu 14:30 F 128

Laser emission saturation in a small mode volume organic microcavity — •Robert Brückner, Martin Teich, Markas Sudzius, Hartmut Fröb, Vadim Lyssenko, and Karl Leo — Institut für Angewandte Photophysik, George-Bähr-Str. 1, 01069 Dresden, Germany

We investigate a high finesse organic microcavity (MC) (21 layer DBR of TiO_2 and SiO_2, $\frac{\lambda}{2}$-layer of Alq_3 doped with 2wt% DCM) under different pumping conditions using femtosecond pulses. We show that lasing saturation occurs in a small mode volume organic microcavity due to the limited number of excitable molecules per mode. On the one hand, a pumping wavelength of 400 nm is used to excite Alq_3 molecules with a subsequent transfer of the energy to DCM molecules via Förster-transfer. On the other hand, we pump the laser dye DCM directly to its absorption band (around 500 nm). In this case, a saturation of the output power is observed due to the finite number of DCM molecules in the mode volume. In contrast, the saturation of the output power occurs at much higher excitation levels if Alq_3 is pumped since the number of molecules is 50 times larger. A modified set of rate equations is applied to obtain a theoretical description of the lasing dynamics. These equations provide a basis to describe the occurence of saturation at high excitation levels in dependence of the excitation pulse width, the number of excited molecules in the mode volume, and the spontaneous emission factor β.

Q 18.4 Tu 14:45 F 128

Photoleitfähigkeit Yb-dotierter Lasermaterialien bei hohen Inversionsdichten und ihr Einfluss auf hoch Yb-dotierte Scheibenlaser — •Ulrike Wolters, Susanne T. Fredrich-Thornton, Klaus Petermann und Günter Huber — Institut für Laser-Physik, Universität Hamburg

Ytterbium lässt als dreiwertiges, aktives Ion in oxidischen Lasermaterialien aufgrund seines einfachen Energieniveauschemas keine internen Verlustprozesse wie Kreuzrelaxation oder Upconversion erwarten.

Dennoch sind in Photoleitfähigkeitsmessungen freie Ladungsträger in Yb-dotierten Einkristallen nachgewiesen worden, die bei Bestrahlung mit der Pumpwellenlänge von 940 nm erzeugt werden. Die gemessene Photoleitfähigkeit zeigt eine nichtlineare Abhängigkeit von der Dichte angeregter Ionen, sodass als Ursache ein Upconversionmechanismus angenommen wird, der Ladungsträger in ein stromführendes Band anhebt.

Es wird die Rolle von transienten sowie durch geeignete Kodotierung stabilisierten Yb^{2+}-Ionen in Hinblick auf die Photoleitfähigkeit Yb-dotierter Kristalle diskutiert.

Die Existenz eines Upconversionprozesses legt Auswirkungen auf den Laserbetrieb bei hohen Inversionsdichten nahe. Die tatsächlich beobachteten Verluste in Yb-dotierten Scheibenlasern zeigen ähnliche Abhängigkeiten von Anregungsdichte und Dotierungskonzentration wie die Photoleitfähigkeit. Diese Ergebnisse lassen darauf schließen, dass eine Korrelation beider Phänomene vorliegt.

Q 18.5 Tu 15:00 F 128

Diodengepumpter und wellenlängenstabilisierter Ho:YAG Hochleistungslaser — •Samir Lamrini[1,2], Philipp Koopmann[1], Karsten Scholle[1], Peter Fuhrberg[1] und Martin Hofmann[2] — [1]LISA laser products OHG, Max-Planck-Straße 1, 37191 Katlenburg — [2]Lehrstuhl für Photonik und Terahertztechnologie, Ruhr-Universität Bochum, Universitätsstraße 150, 44810 Bochum

Gepulste Lasersysteme im Wellenlängenbereich um 2100 nm sind aufgrund ihrer Eigenschaften vielfältig einsetzbar, z. B. in der Medizin oder Messtechnik. Desweiteren dienen gepulste Ho:YAG Laser zur Anregung von optisch parametrischen Oszillatoren für die nichtlineare Frequenzkonversion in den mittelinfraroten Wellenlängenbereich. Konventionelle Pulslaser um 2100 nm basieren auf blitzlampengepumpten kodotierten Kristallen (z.B. Cr,Tm,Ho:YAG), deren Gesamteffizienz jedoch auf Grund der notwendigen Energiemigrations- und des Thulium-Kreuzrelaxationsprozesses sehr gering ist. Wir präsentieren einen Ho:YAG Hochleistungslaser, der erstmalig mithilfe eines GaSb-basierten Laserdiodenstacks resonant gepumpt wird. Dabei wurde eine maximale Ausgangsleistung von 46 W und ein differentieller Wirkungsgrad von 62 % erzielt. Desweiteren wurde mithilfe eines Volumen Bragg Gitters als Auskoppler die Laserwellenlänge auf 2096 nm stabilisiert. Mit dem stabilisierten Laser wurden eine maximale Ausgangsleistung von 15 W und ein differentieller Wirkungsgrad von 37 % erreicht. Mithilfe eines akusto-optischen Modulators wurden Experimente zur Güteschaltung durchgeführt. Die erzielten Pulsenergien und -längen betrugen 6,2 mJ und 180 ns bei einer Pulswiederholrate von 250 Hz.

Q 18.6 Tu 15:15 F 128

Passiv modengekoppelte, 888 nm gepumpte Nd:YVO$_4$ Hochleistungsoszillatoren — •Christoph Schäfer, Richard Wallenstein und Johannes A. L'huillier — Photonik-Zentrum Kaiserslautern e.V., 67661 Kaiserslautern

Lasersysteme, die Pikosekunden-Impulse mit hoher Impulsenergie emittieren, haben sich in den letzten Jahren als Präzisionswerkzeug auf dem Gebiet der Laser-Mikromaterialbearbeitung etabliert. Die Basiskomponente derartiger Laserstrahlquellen bilden dabei häufig passiv modengekoppelte Nd:YVO$_4$ Masteroszillatoren. Ein kompakter und effizienter Nd:YVO$_4$ Hochleistungsoszillator basierend auf einer optimierten optischen Anregung des verwendeten Lasermaterials bei 888 nm wurde bereits realisiert. Wir demonstrieren durch ein optimiertes Resonatordesign in einer sogenannten „Gain-at-the-End"– Konfiguration, dass durch den Einfluss des Spatial-Hole-Burning (SHB) eine signifikante Reduzierung der zeitlichen Impulsdauer 888 nm gepumpter Nd:YVO$_4$ Oszillatoren möglich ist. Die experimentellen Ergebnisse bestätigen, dass die zeitliche sowie spektrale Breite der emittierten ps-Laserimpulse dabei im wesentlichen durch die Stärke des SHB bestimmt wird, welches die spektrale Verstärkungsdispersion des aktiven Mediums teilweise kompensiert. Ein Einfluss der Länge des aktiven Mediums auf den impulsverkürzenden SHB-Mechanismus wurde nachgewiesen. Als Ergebnis des optimierten Laserdesigns präsentieren wir einen passiv modengekoppelten, TEM$_{00}$, 100 MHz Hochleistungsoszillator mit einer mittleren Ausgangsleistung von 32 W und einer zeitlichen Impulsdauer von 14 ps.

Q 18.7 Tu 15:30 F 128

Multiple active mirror concept for high energy short-pulse lasers — •Markus Loeser, Franziska Kroll, Fabian Röser, Mathias Siebold, Ulrich Schramm, and Roland Sauerbrey — Forschungszentrum Dresden-Rossendorf e.V., Dresden,Germany

Ytterbium-doped gain media are preferably utilized in high-energy, diode-pumped lasers due to their comparably long fluorescence lifetime, absence of excited state absorption, and quenching effects. Despite exhibiting a low quantum defect, thermal lensing and stress birefringence within the amplifying medium limits the maximum repetition rate of large aperture lasers. Furthermore, the quasi-three-level scheme of Yb^{3+} leads to re-absorption losses at room temperature especially when operating at low fluences. Here, we present a novel approach combining longitudinal cooling of a disk-laser design with the energy storage capability of a rod amplifier. Therefore, a multiple active mirror amplifier is presented for improved optical-to-optical conversion efficiency and reduced thermally induced aberrations at high repetition rates. Multi-passing both pump and extraction beams through the gain medium, which is well known from thin-disk lasers, also reduces the re-absorption losses. However, energy scaling of a single thin-disk design is limited by parasitic lasing due to a high aspect ratio between longitudinal and transverse gain. We also introduce simulation results on a multiple active mirror short-pulse amplifier employing various Ytterbium-doped gain media such as Yb:YAG, Yb:CaF$_2$, Yb:glass, and Yb:silica. Furthermore, time resolved measurements of thermally induced aberrations at pulse-pumped operation are illustrated.

Q 18.8 Tu 15:45 F 128

A cryogenic Ti:sapphire single-pass amplifier for short pulses at high repetition rates — •Andreas Vernaleken[1], Akira Ozawa[1], Torsten Mans[2], Peter Russbueldt[2], Theodor W. Hänsch[1], Peter Hommelhoff[1], and Thomas Udem[1] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Fraunhofer-Institut für Lasertechnik, Aachen

Our group has demonstrated a phase-stable, cryogenically cooled Ti:sapphire single-pass amplifier [1]. We will review these initial experiments at pump powers of up to 18W. As the achievable gain in our experiments was ultimately limited by the available pump power, we are currently investigating the feasibility of using the frequency-doubled output of a recently developed pulsed Yb:YAG Innoslab high power amplifier [2] (500MHz repetition rate, 700fs pulse duration, 400W average power) at a wavelength of 515nm as a quasi-cw pump laser for our single-pass amplifier. To this end, we optimized both the length and the doping level of the Ti:sapphire crystal for the expected pump power (several tens of Watts) according to a numerical model [3]. We will present first results of our investigations with this new pulsed high power pump laser and discuss possible applications such as high harmonic generation and other highly non-linear effects at repetition rates on the order of 100MHz.

[1] Ozawa et al., New J. Phys. **11**, 083029 (2009)
[2] Russbueldt et al., Opt. Express **17**, 12230 (2009)
[3] Ozawa et al., in preparation

Q 19: Ultrashort Laser Pulses: Generation III

Time: Tuesday 14:00–16:00 Location: F 342

Q 19.1 Tu 14:00 F 342

Anforderungen für das kohärente Kombinieren von faserverstärkten ultrakurzen Laserpulsen — •Arno Klenke[1], Enrico Seise[1], Steffen Hädrich[1], Jens Limpert[1,2] und Andreas Tünnermann[1,2] — [1]Friedrich-Schiller Universität Jena, Institut für angewandte Physik, Albert-Einstein-Str. 15, 07745 Jena — [2]Helmholtz Institut, Jena

Als Skalierungskonzept von Laseroszillatoren bzw. -verstärkern im cw- und gütegeschalteten Betrieb sind verschiedene Verfahren zum aktiven als auch zum passiven, kohärenten und inkohärenten Kombinieren bekannt. Das kohärente Kombinieren verstärkter ultrakurzer Pulse stellt neue Anforderungen an die Stabilisierung des Aufbaus. Darüber hinaus erfordert die spektrale Bandbreite der Pulse die Berücksichtigung der auftretenden Dispersion in den einzelnen Kanälen.

Als Realisierungsmöglichkeit soll das polarisationsabhängige Kombinieren von ultrakurzen Pulsen vorgestellt werden. Eine aktive Stabilisierung erfolgt hierbei durch den Abgleich der optischen Weglänge der Kanäle mittels eines piezoelektrisch verschiebbaren Spiegels. Dabei dient ein Hänsch-Couillaud Detektor in Verbindung mit einem PID-Regler als Steuerung.

Das Verfahren soll bei der kohärenten Kombinierung von Ultrakurzpuls-Faserverstärkern Anwendung finden. Mit Hilfe von Simulationen wurden die in diesem Fall bestehenden Anforderungen bezüglich Dispersion, Nichtlinearitäten und Stabilität der einzelnen Verstärkerkanälen bestimmt. Der Vortrag zeigt die Ergebnisse dieser Simulationen und einiger experimenteller Untersuchungen.

Q 19.2 Tu 14:15 F 342

Pulsdynamik in einem fs Thulium-Faserlaser — •Frithjof Haxsen[1,2], Dieter Wandt[1,2], Uwe Morgner[1,2,3], Dietmar Kracht[1,2] und Jörg Neumann[1,2] — [1]Laser Zentrum Hannover, Hannover, Deutschland — [2]Centre for Quantum-Engineering and Space-Time Research - QUEST, Hannover, Deutschland — [3]Leibniz Universität Hannover, Hannover, Deutschland

Thulium-dotierte Fasern eignen sich dank ihrer großen Verstärkungsbandbreite hervorragend zur Erzeugung ultrakurzer Pulse im Bereich von etwa 2 μm Emissionswellenlänge. Durch den signifikanten Einfluss von Dispersion und Nichtlinearitäten spielt die Pulsdynamik bei fs-Faserlasern eine wesentliche Rolle. Wir stellen Untersuchungen der Pulsdynamik in einem passiv modengekoppelten Thulium-Faserlaser mit variabler resonatorinterner Dispersionskompensation und spektralem Filter vor. Mit dem vorgestellten System konnten Pulse mit einer Energie von über 4 nJ erzeugt werden, die sich resonatorextern auf eine Dauer von unter 220 fs komprimieren ließen. Die resonatorinterne Pulsdynamik ließ sich dem „Stretched-Pulse“-Betrieb zuordnen. Die numerische Reproduktion der Ausgangscharakteristik des Lasers auf Basis der experimentellen Ergebnisse ermöglichte ein detailliertes Verständnis der zeitlichen und spektralen Entwicklung innerhalb des Resonators.

Q 19.3 Tu 14:30 F 342

Pulsenergie Skalierung in gänzlich normal dispersiven Faserlasern durch Reduktion der Repetitionsrate — •Hakan Sayinc[1], Dirk Mortag[1], Oliver Prochnow[1], Michael Schultz[1], Dieter Wandt[1], Dietmar Kracht[1,2] und Jörg Neumann[1,2] — [1]Laser Zentrum Hannover e.V., Hollerithallee 8, 30149 Hannover, Deutschland — [2]Zentrum für Quanten Engineering und Raum Zeit Forschung (QUEST), Welfengarten 1, 30167 Hannover, Deutschland

In diesem Beitrag demonstrieren wir die Energieskalierung passiv modengekoppelter gänzlich normal dispersiver Ytterbium Faserlaser durch Reduktion der Repetitionsrate. Durch Einsetzen von Standard Fasern mit einer Länge von bis zu 75 m wurde die Wiederholfrequenz von 22.7 auf 2.4 MHz reduziert. Die Pulsenergie konnte damit von 7 auf 34.5 nJ vergrößert werden.

Q 19.4 Tu 14:45 F 342

Nichtlineare Kompression von fs Pulsen auf eine Pulsdauer unter 8 optische Zyklen in mikrostrukturierten Fasern — •Hakan Sayinc[1], Oliver Prochnow[1], Dieter Wandt[1], Dietmar Kracht[1,2] und Jörg Neumann[1,2] — [1]Laser Zentrum Hannover e.V., Hollerithallee 8, 30149 Hannover, Deutschland — [2]Zentrum für Quanten Engineering und Raum Zeit Forschung (QUEST), Welfengarten 1, 30167 Hannover, Deutschland

In diesem Beitrag präsentieren wir Untersuchungen zur nichtlinearen Kompression von 186 fs Pulsen auf unter 8 optische Zyklen in mikrostrukturierten Fasern im Wellenlängenbereich um 1 mikrometer. Bei einer mittleren Leistung von 86 mW betrugen die Pulsdauern direkt nach der mikrostrukturierten Faser 25 fs. Dies entsprach einer Pulsenergie von 2.6 nJ und einer Pulsspitzenleistung von 100 kW. Eine externe Kompression mit Gittern war hierzu nicht notwendig.

Q 19.5 Tu 15:00 F 342

Optical synchronization of femtosecond fiber lasers using a saturable absorber — •Till Walbaum, Petra Gross, and Carsten Fallnich — Institute for Applied Physics, University of Münster, Corrensstr. 2, 48149 Münster

Synchronizing the repetition frequency of pulsed lasers is of interest for data transmission and for pump-and-probe experiments. Furthermore, transfering stability from one laser to another can be useful for frequency metrology, allowing measurements at different locations using the same frequency comb. Due to their fast response time, opical methods should be superior to electronic means.

We set up two separate Erbium fiber lasers in a master-slave-configuration, each mode-locked via nonlinear polarization rotation. Synchronization is achieved using a shared saturable absorber mirror in a free space section. Numerical simulations are used to investigate the interplay of the externally pumped SAM and the NPR-mode-locking mechanism.

In the experiment, depending on the position of intracavity polarization controllers in the slave laser, locking ranges of up to 411 Hz can be achieved. We show that, using a stabilized master laser, stability of the repetition rate can be transfered to the slave laser, and that the difference of the carrier envelope offset frequencies can be measured and changed by detuning the length of the slave laser in locked state.

Q 19.6 Tu 15:15 F 342

Passiv modengekoppelter Ytterbium-Faser-Oszillator mit hoher Pulsenergie bei einer Repetitionsrate von 2 MHz — •Christian Hapke[1], Dirk Mortag[1], Dieter Wandt[1,2], Uwe Morgner[1,2,3], Dietmar Kracht[1,2] und Jörg Neumann[1,2] — [1]Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover, Germany — [2]Centre for Quantum-Engineering and Space-Time Research - QUEST, Welfengarten 1, 30167 Hannover, Germany — [3]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Die Verwendung eines Faseroszillators mit geringer Repetitionsrate ist besonders für die Erzeugung von hohen Pulsenergien in Verstärkersystemen von Interesse, da auf der einen Seite auf einen optischen Modulator zur Reduzierung der Repetitionsrate verzichtet werden kann und im Fall von sehr langen Oszillatorpulsen sogar zusätzlich auf einen Pulsstrecker. In diesem Beitrag stellen wir einen passiv modengekoppelten normaldispersiven Ytterbium-Faserlaser ohne Dispersionskompensation mit einer Repetitionsrate von 2,09 MHz vor. Der Resonator besteht aus einer etwa 95 m langen einmodigen Faser mit einem Modenfelddurchmesser von 10 μm. Die Modenkopplung wurde durch nichtlineare Polarisationsdrehung erreicht. Zur Rückführung der spektralen und zeitlichen Änderungen des Pulses während des Resonatorumlaufs wurde ein doppelbrechendes spektrales Filter eingesetzt. Der Oszillator emittierte stark gechirpte Pulse mit einer Pulsdauer von 100 ps und einer Zentralwellenlänge von 1031 nm. Die Pulse konnten extern mit einer Gitteranordnung auf 1,07 ps komprimiert werden.

Q 19.7 Tu 15:30 F 342

Ytterbium-dotierter Femtosekunden-Faser-Oszillator mit einer mittleren Ausgangsleistung von 1,5 W — •Dirk Mortag[1], Dieter Wandt[1,2], Uwe Morgner[1,2,3], Dietmar Kracht[1,2] und Jörg Neumann[1,2] — [1]Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover, Germany — [2]Centre for Quantum-Engineering and Space-Time Research - QUEST, Welfengarten 1, 30167 Hannover, Germany — [3]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

In diesem Beitrag präsentieren wir einen passiv modengekoppelten Ytterbium-dotierten Faserlaser ohne Dispersionskompensation. Die zeitliche Streckung sowie die spektrale Verbreiterung der Pulse in der normaldispersiven Faserstrecke werden durch Einsatz eines doppelbrechenden Filters aus Quarz ausgeglichen. Eine aktive Doppelmantelfaser mit einem einmodigen Signalkern in Kombination mit einer mehrmodigen fasergekoppelten Pumpdiode führt zu einer erhöhten mittleren Leistung im Vergleich zu kerngepumpten Kurzpuls-Faser-Oszillatoren. Der Laser emittiert Pulsenergien von über 30 nJ bei einer Repetitionsrate von 48 MHz und einer mittleren Leistung von mehr als 1,5 W. Die Pulse können mit einem externen Gitterkompressor auf eine Dauer von 139 fs komprimiert werden. Die Zentralwellenlänge liegt bei etwa 1040 nm.

Q 19.8 Tu 15:45 F 342

Mode-locking maps of passively mode-locked Erbium fiber lasers — •Tim Hellwig, Till Walbaum, Petra Gross, and Carsten Fallnich — Institut für Angewandte Physik, Westfälische Wilhelms-Universität Münster, Deutschland

Passive mode-locking by nonlinear polarization rotation provides the shortest pulses from fiber lasers up to date. Full characterization of the polarization dependence of the mode-locking behaviour could lead to a better understanding of the mode-locking mechanism and should improve the application of fiber lasers as turn-key ultrashort pulsed sources.

We utilize a real-time, all-fiber division-of-amplitude polarimeter to monitor the intracavity polarization of an Erbium fiber laser taking advantage of a calibration scheme with intracavity polarization controllers. For the first time to the best of our knowledge, fully automated scans covering the whole Poincaré sphere were performed, leading to the observation of mode-locking regimes which differ in output power and pulse duration. Mode-locking is identified on-line using two-photon absorption in a photodiode and can be distinguished from hybrid operation modes. Dependence of the mode-locking maps on laser parameters (e.g. spectral filtering or dispersion) as well as on environmental influences is expected and subject of current investigations.

Q 20: Ultra Cold Atoms, Ions and BEC I (with A)

Time: Tuesday 14:00–16:00 Location: F 303

Invited Talk Q 20.1 Tu 14:00 F 303

Probing weakly bound molecules with nonresonant light — •Mikhail Lemeshko and Bretislav Friedrich — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, D-14195 Berlin, Germany

We show that weakly-bound molecules, such as those created via Feshbach resonances or photoassociation of ultracold atoms, can be accurately probed by "shaking" in a pulsed nonresonant laser field. The technique relies on the ability to impart a tunable value of angular momentum to the weakly bound molecule such that the centrifugal term concomitant with it expels the molecule's vibrational level from the potential and thus causes the molecule to dissociate. The laser intensity needed to impart a preordained value of the angular momentum varies characteristically with the internuclear distance. It is this characteristic dependence that can be used to map out the probability density of the vibrational state from which the molecule was forced to dissociate. A highly accurate long-range molecular potential can then be retrieved by inverting the vibrational probability density. This route to an accurate potential, independent of spectroscopy or scattering, complements what can be learned from either. We illustrate the technique's machinery by examining Feshbach molecules of acute interest, Rb2 and KRb. In addition, we discuss the possibilities to control the molecular size, the positions of Feshbach resonances, and the photoassociation probability using cw laser fields, and note that the laser field of an optical dipole trap may dissociate some of the most weakly bound molecules via the "shaking" mechanism.

Q 20.2 Tu 14:30 F 303

Bragg Spectroscopy of Ultracold Bosons in an Optical Lattice — •Ulf Bissbort, Yongqiang Li, and Walter Hofstetter — Institut für Theoretische Physik, Goethe Universität Frankfurt

In recent experiments [1,2] it has become possible to probe an interacting atomic gas of ultracold atoms in an optical lattice using Bragg spectroscopy, allowing energy and momentum to be resolved independently within the same measurement. We simulate these experiments under realistic conditions using the time-dependent bosonic Gutzwiller method, which, in contrast to Gross-Pitaevskii theory, captures depletion effects and becomes exact in both the non-interacting and strongly interacting limit. Furthermore, in contrast to static mean-field theory, it is capable of describing correlated excitations, such as Goldstone modes, and is numerically efficient, allowing simulations for all experimentally feasible time scales. In the limit of weak interactions Bogoliubov theory (including trap effects) is recovered, whereas in the case of strong interactions close to the Mott insulating border, a gapped amplitude mode is found to dominate, which has not yet been observed in experiments.

[1] P. Ernst et al., arXiv:0908.4242 (2009).
[2] D. Clément et al., Phys. Rev. Lett. **102**, 155301 (2009).

Q 20.3 Tu 14:45 F 303

Lattice-Ramp Induced Dynamics in an Interacting Bose-Bose Mixture at Zero and Finite Temperature — •Julia Wernsdorfer[1], Michiel Snoek[2], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik , Goethe-Universität, Max-von-Laue-Str. 1, 60438 Frankfurt am Main, Deutschland — [2]Instituut voor Theoretische Fysica, Universiteit van Amsterdam, 1018 XE Amsterdam, Netherlands

In this work we model recent experiments [1] on an interacting 87Rb-41K bosonic gas in an optical lattice at zero and finite temperature. In particular we investigate the dynamics induced by the lattice-ramp up, which is an unavoidable step in the experimental procedure. Using the Gutzwiller mean-field method we examine whether the induced dynamics brings the system out of thermal equilibirum. We explain the experimentally observed oscillations in the visibility by relating them to the issue of adiabaticity [2].

[1] J. Catani, L. De Sarlo, G. Barontini, F. Minardi, and M. Inguscio, *Degenerate Bose-Bose mixture in a three-dimensional optical lattice*, Phys. Rev. A **77**, 011603 (R) (2008)
[2] J. Wernsdorfer, M. Snoek, and W. Hofstetter, *Lattice-Ramp Induced Dynamics in an Interacting Bose-Bose Mixture*, arXiv:0911.0697v1 (2009)

Q 20.4 Tu 15:00 F 303

Injection Locking of a Trapped Ion Phonon Laser — •Valentin Batteiger[1], Sebastian Knünz[1], Maximilian Herrmann[1], Guido Saathoff[1], Theodor W. Hänsch[1], Thomas Udem[1], and Kerry Vahala[2] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]California Institute of Technology, Pasadena, CA, USA

A single trapped ion is addressed by two laser beams, one tuned below, one above an atomic resonance. This opto-mechanical system can perform stable self-sustained oscillations, which we describe in close analogy to optical lasers [1]. We show the basic operation principle and present injection locking of the ion's motion to an externally controlled signal. Reference: [1] K. Vahala et al., Nature Physics 5, 682 (2009).

Q 20.5 Tu 15:15 F 303

Correlation versus commensurability effects for finite bosonic systems in one-dimensional lattices — •Ioannis Brouzos — Zentrum fuer Optische Quantentechnologien, Luruper Chaussee 149, 22761 Hamburg, Germany

We investigate few-boson systems in finite one-dimensional multiwell traps covering the full interaction crossover from uncorrelated to fermionised particles. Our treatment of the ground state properties is based on a numerically exact multi-configurational time-dependent method. For commensurate filling we trace the fingerprints of localisation, as the interaction strength increases, in several observables like local and non-local densities, fluctuations and momentum distribution. In addition for filling factor larger than one we observe on-site repulsion effects and other features of the physics beyond the Bose-Hubbard model regime approaching the Tonks-Girardau limit. The presence of an incommensurate fraction of particles induces partial delocalisation and spatial modulations of the profiles, taking into account the finite size of the system.

Q 20.6 Tu 15:30 F 303

Cooling into the spin-nematic state for a spin-1 Bose gas in an optical lattice — •Ming-Chiang Chung — National Center for Theoretical Sciences, Hsinchu, Taiwan

The possibility of adiabatically cooling a spin-1 polar Bose gas to a spin-nematic phase is theoretically discussed. The relation between the order parameter of the final spin-nematic phase and the starting temperature of the spinor Bose gas is obtained both using the mean-field approach for high temperature and spin-wave approach for low temperature. We find that there exists a good possibility to reach the spin-nematic ordering starting with spinor antiferromagnetic Bose gases.

Q 20.7 Tu 15:45 F 303

The Efimov effect in heteronuclear systems — •Kerstin Helfrich and Hans-Werner Hammer — Helmholtz-Institut für Strahlen- und Kernphysik and Bethe Center for Theoretical Physics, Universität Bonn, 53115 Bonn, Germany

Ultracold quantum gases with large scattering length show resonant enhancement of three-body loss rates when an Efimov trimer is at the scattering threshold. We calculate the three-body loss rates in heteronuclear mixtures of atoms for the case of large scattering length between the unlike atoms. Using zero-range interactions, we present results from the numerical solution of the integral equations for the recombination amplitude in momentum space and extract expressions for the recombination rate constants. Moreover, we calculate the relative positions of loss features for different sign of the scattering length and a first comparison with available experimental data is shown.

Q 21: Poster I

Time: Tuesday 16:00–19:00 Location: Lichthof

Q 21.1 Tu 16:00 Lichthof

Excitation spectrum of Bose-Einstein condensates in correlated disorder — •Christopher Gaul and Cord A. Müller — Physikalisches Institut, Universität Bayreuth, Deutschland

We consider a Bose-Einstein condensate in a speckle disorder potential. By a saddlepoint expansion of the Gross-Pitaevskii energy functional around the disordered groundstate [1], we compute the effective dispersion relation of Bogoliubov excitations perturbatively for weak disorder. Analytical predictions for the mean free path, the speed of sound and the density of states are derived for any dimension and the entire parameter space of healing length, disorder correlation length, and excitation wavelength. Notably, the speed of sound turns out to be reduced by correlated disorder [2]. We confirm our prediction in 1D by numerical simulations.

[1] Gaul and Müller, Europhys. Lett., 83, 10006 (2008)
[2] Gaul et al. PRA 80, 053620 (2009)

Q 21.2 Tu 16:00 Lichthof

Matter Wave Turbulence — •Boris Nowak, Christian Scheppach, and Thomas Gasenzer — Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg

Turbulence phenomena are studied in an ultracold Bose gas away from thermal equilibrium analytically and numerically. In the framework of functional quantum field theory turbulence fixed points of the dynamical evolution can be characterized analytically in terms of universal scaling exponents of correlation functions. It is shown that certain scaling exponents derived within the Kolmogorov theory of wave turbulence are not necessary found in the full dynamical theory considered here. Our results indicate, however, that the Kolmogorov picture remains useful even in the strong turbulence regime at long wavelengths. To explore possibilities for accessing this strong turbulence regime at low momenta in experiments with ultracold atomic gases, we study the dynamics numerically by means of c-field methods.

Q 21.3 Tu 16:00 Lichthof

Second Josephson oscillations — •Martin P. Strzys and James R. Anglin — Technische Universität Kaiserslautern, FB Physik, 67663 Kaiserslautern, Germany

A four-mode Bose-Hubbard model with two highly differing tunneling rates is considered as a model for two quantum systems in thermal contact. In addition to coherent particle exchange a novel slow second Josephson mode, which is not predicted by linear Bogoliubov theory, can be identified by a series of Holstein-Primakoff transformations. This energy exchange mode can be interpreted as heat exchange between the subsystems, is in close analogy to second sound in liquid helium, and may shed light on the emergence of thermodynamics in mesoscopic systems.

Q 21.4 Tu 16:00 Lichthof

Dynamics of cold Bose gases: effects of incoherent scattering — •Luis Rico-Pérez and James R. Anglin — Technische Universität Kaiserslautern, Germany

The correct description of the dynamics of a Bose gas at low temperatures is of extreme importance in the study of trapped BECs. Although some previous theoretical treatments can bring some light on the behavior of the non-condensed fraction of the gas, the condensation process and other interesting non-equilibrium phenomena, a global - and simple - formalism describing all of these is still necessary. We develop a formalism for the evolution of a cold and dilute Bose gas based in S-wave scattering calculations. In the Wigner representation and under certain assumptions, classical behavior terms appear. We use these terms in simulations of simple systems, like the double well potential, to check its validity and describe the effect that incoherent scattering processes have in the tunneling of particles.

Q 21.5 Tu 16:00 Lichthof

Collisional properties of ultracold ^{40}Ca atoms — •Oliver Appel, Sebastian Kraft, Felix Vogt, Fritz Riehle, and Uwe Sterr — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

We recently succeeded in achieving a ^{40}Ca Bose-Einstein condensate [1]. The understanding of collisional properties like the ground state scattering length and the 3-body loss coefficient were crucial steps on our way to the BEC. On the other hand the dense ensemble near the critical temperature provides us with new opportunities to study collisions both between ground state and excited atoms. Here we present various methods of determining the ground state scattering length and the 3-body loss coefficient as well as the current status of our photoassociation measurements on the $^1S_0$–$^3P_1$ asymptote.

[1] S. Kraft, F. Vogt, O. Appel, F. Riehle, and U. Sterr, Phys. Rev. Lett. **103**, 130401 (2009).

Q 21.6 Tu 16:00 Lichthof

Towards the realization of an erbium BEC — •Henning Brammer, Riad Bourouis, and Martin Weitz — Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, 53115 Bonn, Germany

The erbium atom in its $4f^{12}6s^2\ ^3H_6$ ground state has a large orbital angular momentum of L = 5. Quantum gases realized so far have an S-ground state configuration, so that in far detuned laser fields with detuning above the upper state fine structure splitting the trapping potential is determined by the scalar electronic polarizability. In contrast, for an erbium quantum gas with its $L > 0$ ground state the trapping potential also for far detuned dissipation-less trapping laser fields becomes dependent on the internal atomic state (spin).

Moreover, Raman transitions between different ground state spin projections become possible with e.g. Nd:YAG laser fields, which can allow for a Fourier-synthesis of in principle arbitrarily shaped lattice potentials using the technique of multiphoton lattices. This has prospects for novel quantum phase transitions in e.g. strongly correlated frustrated lattice configurations.

We present experimental work aimed at the laser cooling and dipole trapping of atomic erbium, which should then allow for evaporative cooling towards quantum degeneracy. The setup including both our vacuum and optical system will be shown. For frequency stabilization of the cooling laser, we use a home-built erbium hollow chathode lamp. The laser frequency has been stabilized to the erbium cooling transition near 400.9 nm by Doppler-free FM-spectroscopy. These results and the current status of the cooling experiment will be reported.

Q 21.7 Tu 16:00 Lichthof

Dynamics of 1D fermionic systems using Matrix Product States — •Michael Lubasch, Mari Carmen Bañuls, and Juan Ignacio Cirac — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, D-85748 Garching, Germany

The focus of our work lies on the Fermi-Hubbard model which is an effective model for strongly interacting fermions on a lattice allowing to study the interplay between kinetic energy, local interaction and Pauli principle. More precisely, we investigate the 1D Fermi-Hubbard model in a harmonic confinement. This is experimentally realized by ultracold fermions in an optical lattice which is confined by a superimposed harmonic trap. All theoretical parameters of the model can be tuned precisely in the experiment.

Concerning our numerical approach, the confined 1D Fermi-Hubbard Hamiltonian can be mapped to a local 1D spin Hamiltonian. These kinds of local spin Hamiltonians are perfectly suited for investigation within the framework of Matrix Product States (MPS). MPS provide an alternative formulation of the Density Matrix Renormalization Group, laying particular emphasis on the amount of entanglement present in the state (Verstraete et al., PRL 93, 227205 (2004)).

Within this framework, we simulate thermal states and the time evolution of easily preparable initial states as they may appear in current experiments with ultracold fermions.

Q 21.8 Tu 16:00 Lichthof

Towards a two-species quantum degenerate gas of ^{6}Li and ^{133}Cs — •Rico Pires, Marc Repp, Kristina Meyer, Johannes Deiglmayr, and Matthias Weidemüller — Physikalisches Institut, Ruprecht-Karls Universität Heidelberg, Heidelberg, Germany

We present the design of the new experimental apparatus currently being built. The setup will allow the formation of clouds of ultracold Li and Cs atoms via standard laser cooling techniques. Successive loading into optical dipole traps and subsequent evaporative cooling enables us to achieve quantum degeneracy. From this starting point, two different routes can be taken. The ramping of Feshbach fields followed by stimulated Raman adiabatic passage (STIRAP) can be used to create deeply bound LiCs molecules. As these exhibit the largest dipole moment among all alkali atom combinations, they present a promising candidate for the observation of dipolar effects such as new quantum phases. On the other side, the ability to tune the interaction strength via the magnetic field, allows one to study few body effects in this ensemble.

Q 21.9 Tu 16:00 Lichthof

Towards disorder experiments in 2D optical lattices — •Mathis Baumert[1], Nadine Meyer[1,2], Mike Holynski[1], Amy Rudge[1], Jochen Kronjäger[1], and Kai Bongs[1] — [1]School of Physics and Astronomy, University of Birmingham, UK — [2]Institute for Laser Physics, University of Hamburg, Germany

We are presenting progress towards a new setup for a ^{87}Rb - ^{40}Ka quantum gas mixture experiment aiming for in situ single site resolution in order to investigate disorder effects in the phase diagram. The disorder will be implemented either by the fermionic species or by a spatial light modulator (SLM).

In addition the interactions can be tunable via well known Feshbach resonances to look into Bose glass phases and Anderson localisation in 2D.

In this poster we display glueing techniques for glass-metal window seals and a low power consuming magnetic coil design. We also present simulations for optical lattices in 2D and possible realisations of arbitrary optical potentials via SLM techniques.

We acknowledge support by EPSRC under grants EP/E036473/1 and EP/H009914/1.

Q 21.10 Tu 16:00 Lichthof

Parametric amplification of vacuum fluctuations in spinor Bose-Einstein condensates — Carsten Klempt[1], Oliver Topic[1], Garu Gebreyesus[2], Manuel Scherer[1], •Bernd Lücke[1], Frank Deuretzbacher[2], Phillip Hyllus[3], Wolfgang Ertmer[1], Luis Santos[2], and Jan Arlt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Institut für theoretische Physik, Leibniz Universität Hannover — [3]INFM BEC, Trento

The nature of the vacuum state and its fluctuations constitutes one of the most fascinating aspects of modern physics. Particularly in optics parametric amplification of such fluctuations is an important tool for generating non-classical states of light. These concepts can be transfered to matter-wave optics using spinor Bose-Einstein condensates.

To demonstrate this we use a sample initially prepared in the $m_F = 0$ state, where spin-changing collisions triggered by quantum fluctuations may lead to the creation of correlated pairs in $m_F = \pm 1$. We show that the pair creation efficiency is strongly influenced by the interplay between the quadratic Zeeman effect and the confinement in the external trapping potential. This confinement has previously been neglected in homogeneous approximations and leads to a multi-resonant dependence on the magnetic field.

On these resonances we conclusively demonstrate that the system can act as a parametric amplifier for vacuum fluctuations, providing a new microscope to investigate the vacuum state and a promising method for entanglement and squeezing production in matter waves.

Q 21.11 Tu 16:00 Lichthof

Far-from-equilibrium dynamics in a Kondo lattice of ultracold fermionic alkaline-earth atoms — •Matthias Kronenwett[1], Thomas Gasenzer[1], Michael Foss-Feig[2], and Ana Maria Rey[2] — [1]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg — [2]JILA, University of Colorado, Boulder CO-80309, USA

We study the dynamics of ultracold Fermi gases far from thermal equilibrium. We employ a functional-integral approach based on the Schwinger-Keldysh closed time path integral 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 N, where N is the number of atomic hyperfine states. 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. This formalism is especially suited to describe far-from-equilibrium dynamics in a Kondo lattice of ultracold fermionic alkaline-earth atoms where N can be as large as 10.

Q 21.12 Tu 16:00 Lichthof

Massless Dirac-Weyl Fermions in a $\mathcal{T}_3$ Optical Lattice — •Dario Bercioux[1,2], Daniel F. Urban[2,3], Hermann Grabert[1,2], and Wolfgang Haeusler[2,4] — [1]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität, D-79104 Freiburg, Germany — [2]Physikalisches Institut, Albert-Ludwigs-Universität, D-79104 Freiburg, Germany — [3]Departamento de Física de la Materia Condensada C-XII, Facultad de Ciencias, Universidad Autónoma de Madrid, E-28049, Madrid, Spain — [4]Institut für Physik, Universität Augsburg, D-86135 Augsburg, Germany

We propose an experimental setup for the observation of quasi-relativistic massless Fermions. It is based on a $\mathcal{T}_3$ optical lattice, realized by three pairs of counter-propagating lasers, filled with fermionic cold atoms. We show that in the long wavelength approximation the $\mathcal{T}_3$ Hamiltonian generalizes the Dirac-Weyl Hamiltonian for the honeycomb lattice, however, with a larger value of the pseudo-spin $S = 1$. In addition to the Dirac cones, the spectrum includes a dispersionless branch of localized states producing a finite jump in the atomic density. Furthermore, implications for the Landau levels are discussed. Bercioux *et al.*, Phys. Rev. A **80**, 063603 (2009).

Q 21.13 Tu 16:00 Lichthof

A new type of hexagonal optical lattice for ultracold quantum gases — •Julian Struck, Parvis Soltan-Panahi, Wiebke Plenkers, Andreas Bick, Georg Meineke, Christoph Becker, Patrick Windpassinger, and Klaus Sengstock — Universität Hamburg, Institut für Laser-Physik, Luruper Chaussee 149, 22761 Hamburg

Ultracold atoms in optical lattices offer unique access to controllable quantum many-body systems, reaching from the weakly-interacting to the strongly-correlated regime. Here we report on the realization of a new type of optical lattice with a hexagonal symmetry.

The lattice laser configuration allows for the generation of spin-dependent as well as spin-independent optical potentials by changing the polarizations of the beams. Our experimental setup gives us the full control over the internal degrees of freedom in the hyperfine ground-state manifold of ^{87}Rb. This enables us to prepare and to investigate multi-component systems in this type of lattice. We will report on important experimental aspects like the phase stabilization of the lattice beams.

The first results obtained in the spin-dependent lattice show rich prospects with respect to transport, interaction and entropy phenomena when mixtures of different spin-states are loaded in this lattice. The spin-independent lattice can be used to simulate the effects of geometrical frustration on spins in the quantum magnetism regime.

Q 21.14 Tu 16:00 Lichthof

Momentum-resolved Bragg spectroscopy in optical lattices — •Jasper S. Krauser, Sören Götze, Philipp T. Ernst, Jannes Heinze, Malte Weinberg, Christoph Becker, and Klaus Sengstock — Universität Hamburg, Institut für Laser-Physik, Luruper Chaussee 149, 22761 Hamburg, Germany

Quantum gases in optical lattices are particularly well suited to provide an experimental interface between quantum optics and solid-state physics. However, their detection and analysis, especially the characterization of their excitation spectrum, still remain challenging.

Here we report on a comprehensive study of superfluids in optical lattices by Bragg spectroscopy. We show systematic measurements of the band structure with momentum resolution over the whole first Brillouin zone and for different lattice depths. The results clearly show the influence of interaction on the excitations such as the sensitivity to density and particle numbers. In addition, we discuss several technical issues like the experimental setup and methods.

Our measurements demonstrate the applicability of Bragg spectroscopy in optical lattices and pave the way for detailed studies of strongly correlated phases and quantum gas mixtures.

Q 21.15 Tu 16:00 Lichthof

Bosonic Optical Lattice with a Staggered Magnetic Field — Georg Wirth, •Matthias Ölschläger, and Andreas Hemmerich — Institut für Laser-Physik, Universität Hamburg

Using a bichromatic light-shift potential a two-dimensional square optical lattice with a time-modulation term can be realized that introduces rotation with alternating directions in each plaquette. This scenario can be described by a Hubbard model with an additional staggered magnetic field. For bosons, besides the uniform superfluid and Mott insulating phases, known from the conventional Bose-Hubbard model, the zero-temperature phase diagram exhibits a novel kind of finite-momentum superfluid phase, characterized by quantized staggered rotational flux in each plaquette.

In addition to a brief physical motivation we present the experimental progress.

Q 21.16 Tu 16:00 Lichthof

Fermionic quantum gases with tunable interactions in optical lattices — •Michael Schreiber[1], Ulrich Schneider[1], Jens Philipp Ronzheimer[1], Lucia Hackermüller[2], Thorsten Best[3], Sebastian Will[1], Simon Braun[1], Tim Rom[1], Kin Chung Fong[4], and Immanuel Bloch[1] — [1]Ludwig-Maximilians-Universität München — [2]University of Nottingham, UK — [3]Albert-Ludwig Universität Freiburg — [4]Caltech, Pasadena, USA

Fermionic atoms in optical lattices form a very rich many-body system that can serve as a quantum simulator for condensed matter physics. The atoms implement the Fermi Hubbard Hamiltonian with high experimental control over the relevant parameters.

In our system we sympathetically cool ^{87}Rb and ^{40}K in an optically plugged quadrupole trap and an optical dipole trap. After evaporation, a balanced spin mixture of ^{40}K atoms, whose interactions can be changed using a Feshbach resonance, is loaded into a blue-detuned optical lattice.

In the case of repulsive interactions we observe a transition from compressible, metallic states over Mott-insulating to band insulating states for increasing harmonic confinements. On the attractive side we investigate an anomalous expansion, which is related to the pseudogap phase, when the interaction becomes strongly attractive. In addition we study the free expansion of a band insulator in a homogeneous lattice and identify different regimes ranging from ballistic expansion to diffusion dynamics. The latter can effectively suppress the expansion of the high density core of the cloud.

Q 21.17 Tu 16:00 Lichthof

Experiments on entanglement of ultracold atoms on an atom chip — •Jad Camille Halimeh[1,2], Max Fabian Riedel[1,2], Pascal Böhi[1,2], Theodor Wolfgang Hänsch[1,2], and Philipp Treutlein[1,2] — [1]Ludwig-Maximilians-Universität, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

Atom chips provide a robust, compact, and scalable experimental setup that is ideal for the development, implementation, and testing of quantum-enhanced technologies such as quantum information processing, quantum simulation, and quantum metrology. On our atom chip, state-selective microwave near-field potentials allow for the coherent manipulation of both internal and motional states of ultracold atoms. Elastic collisional interactions are used to create multi-particle entanglement within a single Bose-Einstein condensate (BEC). Proposals to further use these microwave near-field potentials to realize a quantum phase gate with single atoms on an atom chip have been presented. We are currently investigating methods to experimentally entangle two small BECs. This will allow us to study quantum collisional phase shifts and investigate the possibility of using small BECs for quantum information processing.

Q 21.18 Tu 16:00 Lichthof

Non-abelian atom optics with cold atoms — •Torben Alexander Schulze[1], Ernst-Maria Rasel[1], and das QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Quantenoptik, LU Hannover — [2]ZARM, Uni Bremen — [3]Institut für Physik, HU Berlin — [4]Institut für Laserphysik, Uni Hamburg — [5]Institut für Quantenphysik, Uni Ulm — [6]MPQ, München — [7]Institut für angewandte Physik, TU Darmstadt — [8]Midlands Ultracold Atom Research Centre, University of Birmingham, UK — [9]FBH, Berlin

The flexibility and the versatility of ultra-cold gases allowed for exploring a multitude of aspects in solid state physics, which are very difficult to observe in condensed matter systems where the control of the order parameter or the interaction impose many challenges. However, the broad spectrum of possible applications is limited by the charge neutrality of the atoms. This motivates the quest for Artificial Electromagnetism, where atoms mimic charged particles in electromagnetic fields. In our project, we investigate realistic schemes for non-abelian potentials with ultra-cold quantum gases based on spatially dependent atom-light-interaction. In such systems, fascinating effects could be observed, i.e. Double and Negative Reflection, the non-Abelian Aharonov-Bohm effect or quasi-relativistic behavior of cold atoms.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50WM0835-0839.

Q 21.19 Tu 16:00 Lichthof

Optical interface created by laser-cooled atoms trapped in the evanescent field surrounding an optical nanofiber — •Rudolf Mitsch, Melanie Müller, Daniel Reitz, Eugen Vetsch, Samuel T. Dawkins, and Arno Rauschenbeutel — QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz

We optically trap neutral cesium atoms close to the surface of an optical nanofiber with a diameter of 500 nm. The atoms are cooled with a standard magneto-optical-trap and loaded into a 1d optical lattice formed 200 nm above the fiber surface by a two-color evanescent field surrounding the fiber. The red- and blue-detuned trap lasers are far detuned and have a total power of about 40 mW, resulting in a trap depth of a few hundred μK. In order to detect the atoms in the trap, we measure the transmission of a weak resonant probe beam, launched through the fiber. At resonance, each atom absorbs about one percent of the probe via evanescent field coupling, yielding a high optical density of up to 18 for about 2000 trapped atoms. In the dispersive regime, we measure the interaction-induced phase shift experienced by the probe via the effect on its polarization state. Finally, using an optical conveyor belt technique, we demonstrate transport of the atoms along the fiber. Our work opens the route towards the realization of hybrid quantum systems that combine atoms with, e.g., solid state quantum devices and towards non-linear optics applications based on electromagnetically induced transparency.

Financial support by the ESF (EURYI Award) and the Volkswagen Foundation (Lichtenberg Professorship) is gratefully acknowledged.

Q 21.20 Tu 16:00 Lichthof

State-insensitive micro dipole trap for cesium atoms — •Piyaphat Phoonthong, Peter Douglas, Arne Wickenbrock, and Ferruccio Renzoni — Department of Physics and Astronomy, Univerity College London, WC1 5BT London, UK

We describe the experimental realization of a state-insensitive dipole trap for cesium atoms. By tightly focussing a running beam at the cesium "magic wavelength" of 935.6 nm, we demonstrate trapping of cesium atoms with lifetimes up to 2.5 s. The lifetime is strongly dependent on the actual atomic ground state, as verified with the use of a depumper to control ground state preparation. We measured a beam waist of $w_0 = (6.69 \pm 0.05)\mu$m. For the typical laser power used in the experiment, this results into a trap with depth of 2mK and measured oscillation frequencies equal to $\omega_r/(2\pi) = (18.5 \pm 0.1)$ kHz, $\omega_z/(2\pi) = (550 \pm 10)$ Hz.

Q 21.21 Tu 16:00 Lichthof

Cooling of an optically trapped ion — •Stephan Duewel[1,2], Christian Schneider[1], Martin Enderlein[1], Thomas Huber[1], and Tobias Schaetz[1] — [1]Max-Planck-Institut für Quantenoptik, Garching, Deutschland — [2]Ludwig-Maximilians-Universität München, München, Deutschland

Recently, an optical dipole trap for atomic ions has been realized by our group. However, the reported lifetime of a few milliseconds is limited because of heating. Here we want to discuss cooling schemes for ions in optical dipole traps and report on first experimental data. Due to large Stark shifts and the requirements on the polarization of the dipole trap lasers, cooling mechanisms have to be modified in a way as to suit this new regime of optical trapping. Arising possibilities for new experiments at the border between atom and ion trapping are presented.

Q 21.22 Tu 16:00 Lichthof

A new Experiment for the investigation of ultra-cold Potas-

sium Rubidium Mixtures — Georg Kleine Büning, •Johannes Will, Jan Peise, Wolfgang Ertmer, and Jan Arlt — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

We present an experimental apparatus, which will allow us to investigate mixtures of ^{87}Rb with the bosonic isotopes of potassium (^{39}K, ^{41}K) and also enable the use of Feshbach-resonances. In the experiment the desired isotopes are collected in a magneto-optical trap from the background vapour. A magnetic quadrupole trap is used to transport the pre-cooled atoms mechanically into a glass cell with better vacuum. There the atoms are transferred into a novel hybrid optical and magnetic trap. Subsequently sympathetic cooling will be used to bring the desired isotopes of rubidium and potassium to quantum degeneracy. Finally a magnetic field can be tuned to the Feshbach resonances to manipulate the interaction strength.

Particular attention will be given to the design of the novel hybrid trap, which recently allowed for the realisation of a BEC of about 1x10^6 ^{87}Rb atoms, and the microwave force evaporation method.

Q 21.23 Tu 16:00 Lichthof

Ultracold fermionic potassium atoms in a CO_2 -laser optical dipole trap — •Christian Bolkart, Alexander Gatto, Ondrej Sobora und Martin Weitz — Institut für Angewandte Physik, Rheinische Friedrich-Wilhelms-Universität Bonn, Wegelerstrasse 8, 53111 Bonn

We will report progress in an experiment directed towards realisation of a fermionic potassium Fermi gas with all-optical techniques. The quantum gas will be used for studies of a supersolid phase transition with fermionic atoms in an optical lattice. In our experiment a cold atomic 40K beam emitted from a two-dimensional MOT is used to load a dark magneto optic trap. The density of the trapped atoms is increased by switching to a compressed MOT where we ramp our magnetic field to higher values and reduce the intensity of our repumping laser. We subsequently transfer 10^6 fermionic potassium atoms in the quasistatic dipole trapping potential realized with a tightly focused CO_2-laser beam with wavelength near 10.6 μm. After 500 ms of plain evaporation the dipole traped atomic cloud is further cooled by forced evaporation, i.e. the potential depth is reduced by lowering the optical power of the CO_2-laser. At the final potential depth approximately 40000 atoms remain at a temperature of 200 nK. With the given geometrical trap frequency of the dipole trap and the atom number after evaporation, we estimate $T/T_F = 0.8$.

In the future, we plan to further improve the forced evaporation in order to reach the quantum degenerate regime, i.e. $T/T_F < 0.5$. The present status of the the experiment will be summarised.

Q 21.24 Tu 16:00 Lichthof

Uniting BECs in a ring cavity — •Christine Gnahm, Simone Bux, Gordon Krenz, Claus Zimmermann, and Philippe A.W. Courteille — Physikalisches Institut, Universität Tübingen

For the realization of the atom laser, consisting of bright coherent matter waves, it is of interest to be able to replenish the source of Bose-Einstein condensate from which the laser beam emerges. This could be done by feeding it from a second independently produced condensate. One obstacle in uniting two independently produced Bose-Einstein condensates is the random relative phase of their macroscopic wave functions. Jaksch et al. [1] propose a scheme in which the phase difference can be damped by a ring cavity acting as an effective zero temperature reservoir. Our aim is to measure this damping in a Ramsey-type experiment. Two condensates in two hyperfine ground states of ^{87}Rb are produced. They are coherently coupled by a two photon transition, realized by a microwave-radiofrequency combination. Additionally, they are coupled via a spontaneously decaying intermediate level. One transition of this irreversible Raman process is driven by a light field, the other stimulated by a ring cavity. We will present first experimental results on the way to ultracold fusion of Bose-Einstein condensates.

[1] D. Jaksch, S. A. Gardiner, K. Schluze, J. I. Cirac, and P. Zoller, Phys. Rev. Lett. **86**, 4733 (2001)

Q 21.25 Tu 16:00 Lichthof

High resolution imaging of an ultracold quantum gas — •Peter Würtz[1], Tatjana Gericke[1], Andreas Vogler[1,2], Fabian Etzold[1], Tobias Weber[1,2], Frank Markert[1], and Herwig Ott[1,2] — [1]Institut für Physik, Johannes Gutenberg-Universität, Mainz — [2]Fachbereich Physik, Technische Universität Kaiserslautern

We describe a detection and manipulation technique based on scanning electron microscopy which allows for the detection of single atoms in a quantum gas with a spatial resolution of better than 150 nm. A focussed electron beam with a FWHM of 100 nm is moved over the atom cloud and ionizes atoms by electron impact ionization. The produced atoms are subsequently extracted and detected.

We produce a ^{87}Rb condensate in a single beam optical dipole trap formed by a focussed CO_2 laser beam. We implemented a two-dimensional with 600 nm lattice spacing to study quantum gases in periodic potentials. Our imaging technique enables us not only to resolve single lattice sites but also to remove atoms from selected sites without affecting neighboring sites. The method offers a versatile experimental platform for the *in situ* study of ultracold quantum gases in various trapping geometries, as well as the study of dissipative manipulations on Bose-Einstein condensates.

Q 21.26 Tu 16:00 Lichthof

Ionization dynamics and antiblockade of an ultracold Rydberggas — •Nele Müller[1], Thomas Amthor[1], Christoph S. Hofmann[1], Georg Günter[1], Hanna Schempp[1], Christian Giese[2], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg — [2]Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

Using time-resolved spectroscopic measurements of the Penning ionization signal we are able to identify slight variations in the Rydberg pair distribution of randomly arranged ultracold atoms. For attractive interaction potentials, atoms excited to Rydberg states on the red-detuned wing of the resonance are observed to ionize first. In this case pairs of atoms with small separation are excited and these experience strong attractive forces[1]. This approach can also be applied to repulsively interacting Rydberg states, where atoms excited on the blue-detuned wing of the resonance ionize faster[2]. We further extend this method by using Autler-Townes-splittings to achieve specific detunings to match the coupling energy of one optical transition to the interaction energy of the long-range Rydberg interactions. Hence, the otherwise blocked excitation of close pairs becomes feasible (antiblockade)[3]. Our experimental results agree well with a pair interaction model[4].

[1] T. Amthor et al., Phys. Rev. Lett 98, 023004 (2007)
[2] T. Amthor et al., Phys. Rev. A 76, 054702 (2007)
[3] C. Ates et al., Phys. Rev. Lett. 98, 023002 (2007)
[4] T. Amthor et al., arXiv:0909.0837v1

Q 21.27 Tu 16:00 Lichthof

Linsensysteme zur Fokussierung und Nachbeschleunigung einzelner Ionen — •G. Jacob[1], W. Schnitzler[1], R. Fickler[2], F. Schmidt-Kaler[1] und K. Singer[1] — [1]Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, D-89069 Ulm, Deutschland — [2]Universität Wien, Institut für Quantenoptik, Quantennanophysik & Quanteninformation, Boltzmanngasse 5, A-1090 Wien, Österreich

Mittels einer elektrostatischen Einzellinse [1] haben wir einen Ionenstrahl aus einzelnen $^{40}Ca^+$ Ionen von anfänglich $83(^{+8}_{-3})\,\mu$m auf einen 1σ-Radius von $(4.62\pm1.25)\,\mu$m fokussiert [2] und somit auf 1/18 seiner ursprünglichen Größe reduziert. Erzeugt wurde dieser durch eine deterministische, auf einer linearen Paul-Falle basierenden Einzelionenquelle [3]. Des Weiteren wurden numerische Simulationen [4] durchgeführt, um eine geschaltete Einzellinse zu entwickeln, welche die extrahierten Ionen sowohl zu fokussieren, als auch deren kinetische Energie - etwa für eine Implantation in ein Substrat - durch Nachbeschleunigen zu steigern vermag. Die Ergebnisse lassen dabei einen 1σ-Radius in der Größenordnung weniger Nanometer bei einer gleichzeitigen Erhöhung der kinetischen Energie auf 2-6 keV erwarten.

[1] R. Fickler *et al.*, J. Mod. Optics **56**, 2061 (2009)
[2] W. Schnitzler *et al.*, quant-ph/0912.1258, submitted to NJP
[3] W. Schnitzler *et al.*, Phys. Rev. Lett. **102**, 070501 (2009)
[4] K. Singer *et al.*, quant-ph/0912.0196, submitted to RMP

Q 21.28 Tu 16:00 Lichthof

Kryogene Mikro-Ionenfalle mit integrierter Fasercavity — •Frank Ziesel, Max Hettrich, Michaela Petrich, Daniel Seyfried, Gerhard Huber, Ulrich Poschinger, Andreas Walther und Ferdinand Schmidt-Kaler — Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, 89069 Ulm

Mikrostrukturierte Paulfallen ermöglichen die Manipulation der internen und externen Freiheitsgrade einzelner oder mehrerer Ionen, was sie zu einem wichtigen Werkzeug in der Quanteninformationsverarbeitung macht. Unser Aufbau umfasst eine Ionenfalle [1] mit minimalem Ion-Elektroden Abstand von 125 μm sowie einen Kryostaten, der die Kühlung der gesamten Falle auf Temperaturen von 77 K bzw. 4 K ermöglicht. Hierdurch lässt sich die Heizrate um mehrere Größenordnungen reduzieren [2], was die Fidelity von Gatteroperationen verbessert. Die verringerte Heizrate ermöglicht längere Transportzeiten, sowie den Betrieb eines integrierten Faserresonators mit einem Ion-Spiegel Abstand von 50 μm. Mit der gemessenen Finesse von über 30 000 und dem kleinen Modenvolumen lassen sich Experimente im Bereich starker Kopplung [3] zwischen einzelnen Ionen und dem Resonatorfeld durchführen.

[1] S. Schulz et al., New J. Phys. **10**, 045007 (2008)
[2] J. Labaziewicz *et al.*, Phys. Rev. Lett. **100**, 013001 (2008)
[3] Y. Colombe *et al.*, Nature **450**, 272-277 (2007)

Q 21.29 Tu 16:00 Lichthof

Real-Time Feedback on Single Atoms in a High-Finesse Optical Resonator of Variable Length — •Christian Sames, Markus Koch, Alexander Kubanek, Alexei Ourjoumtsev, Matthias Apel, Pepijn Pinkse, Karim Murr, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany

Strongly coupling atoms to the light field of a high-finesse optical resonator is a key ingredient to study light-matter interaction at the single quantum level. A problem still awaiting a satisfactory solution is to keep the atom inside the resonator sufficiently long. The trapping time can be dramatically enhanced by applying real-time feedback onto the atomic motion [1]. We present improved experimental results obtained with a new setup consisting of an optical resonator with much higher information rate than in previous experiments. Moreover, the mirror spacing can be varied macroscopically, enabling us to alter physical parameters as the coupling-constant g or the cooperativity parameter C online.

[1] A. Kubanek et al., Nature 463, 898 (17th December 2009)

Q 21.30 Tu 16:00 Lichthof

Compact electronics for laser system in microgravity — •Thijs Wendrich for the Lasus Team — Institut für Quantenoptik, Leibniz Universität Hannover

Atom interferometers are a symbiosis of matter and photonic waves. A lot of effort needs to be invested in the lasers and the electronic components to achieve the required performance for the manipulation of atoms with light. In the existing framework of the Quantus collaboration, the Lasus project aims to develop robust and miniaturized diode laser systems with spectroscopy and the associated control electronics for use in a compact apparatus for experiments with ultra cold degenerate quantum gases, operating in microgravity environments such as the drop tower in Bremen. In addition, it will prepare us for future space missions. In particular the external cavity diode laser including optical isolator, the spectroscopy and all of the electronics (laser current driver, temperature controller, PID controller, etc.), have to fit in a volume of about 1 liter. However, due to the stringent limits on the volume as well as the mass, all components need to be custom built to achieve the desired compactness with a high degree of automation while still delivering the very high performance needed for high precision experiments. In this poster the current progress on the electronics part of the project, which is being developed in Hannover, will be presented. The Lasus project is a collaboration of FBH Berlin, HU Berlin, U Hamburg and LU Hannover supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number 50WM0939.

Q 21.31 Tu 16:00 Lichthof

Laser stabilisation for the production of rovibronic ground-state molecules — •Raffael Rameshan[1], Almar Lercher[1], Markus Debatin[1], Bastian Schuster[1], David Baier[1], Francesca Ferlaino[1], Tetsu Takekoshi[1], Grimm Rudolf[1,2], and Hanns-Christoph Nägerl[1] — [1]Institut für Experimentalphysik, Universität Innsbruck — [2]IQOQI Innsbruck

Samples of polar ground-state molecules in the quantum-gas regime offer intriguing prospects for the investigation of novel physical phenomena. We aim to produce a gas of RbCs ground-state molecules near quantum degeneracy by first associating atoms to weakly bound molecules on a Feshbach resonance. Subsequently, the molecules are coherently transferred to the rovibrational ground state of the ground electronic potential by two-photon Stimulated Raman Adiabatic Passage (STIRAP). The STIRAP lasers have to be phase-coherent on the timescale of the transfer process. Ultra-narrow-linewidth lasers enable long STIRAP transfer times and consequently optimized adiabaticity. In addition, long STIRAP times avoid Fourier broadening of the STIRAP resonance and hence allow frequency-selective addressing of individual hyperfine levels of the ground-state molecules. We plan to construct a Raman laser system with sub-Hertz relative linewidth by locking two grating-stabilised diode lasers to ultra-high finesse optical resonators(1). To suppress fast phase fluctuations, the lasers will feature a long external resonator design (2).

(1) M. Notcutt et al.; Optics Letters 30, 1815-1817 (2005) (2) J. Alnis et al.; Eur. Phys. J. Special Topics 163, 89-94 (2008)

Q 21.32 Tu 16:00 Lichthof

Matter wave interferometry for determination of molecular transition dipole moments — •Sha Liu, Horst Knöckel, and Eberhard Tiemann — Institut für Quantenoptik, Leibniz Universität Hannover

A molecular matter wave interferometer has been employed to measure the molecular transition dipole moment of the $B^1\Pi_u$ - $X^1\Sigma_g^+$ transition of K_2. A K_2 beam is created in a supersonic expansion of potassium vapor out of a nozzle. A pair of laser beams works as beam splitters to coherently split the matter wave, employing the $b^3\Pi_{0_u^+}$ - $X^1\Sigma_g^+$ transition. The high collimation of the molecular beam yields a large coherence length in transverse direction, such that under the given experimental conditions the two outgoing matter waves overlap laterally, establishing a Ramsey type matter wave interferometer. The phase difference between the matter waves is sensitive to phase drifts of the optical phases of the beam splitters, therefore the optical phases of the beam splitters are locked with respect to each other for high long term stability. A near resonant laser field is introduced between the laser beams for the beam splitter. This field couples near resonantly the ground state level of the beam splitter transition with an excited level of the $B^1\Pi_u$ state. Thus the passing molecule feels a potential hill or valley depending on the detuning. The phase shift of the matter wave interference by the AC-Stark effect is used to determine the transition dipole moment of the B-X transition of K_2. Details of the experiment and results and experience regarding the prospect of a matter wave interferometer in such applications will be presented.

Q 21.33 Tu 16:00 Lichthof

Atom Interferometry in a mobile setup to measure local gravity — •Matthias Hauth, Alexander Senger, Malte Schmidt, Sebastian Grede, Christian Freier, and Achim Peters — Humboldt Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Hausvogteiplatz 5-7, 10117 Berlin

GAIN (Gravimetric Atom Interferometer) is a mobile gravimeter, based on interfering ensembles of laser cooled ^{87}Rb atoms in an atomic fountain configuration. With a targeted accuracy of a few parts in 10^{10} for the measurement of local gravity, g, this instrument will offer about an order of magnitude improvement in performance over the best currently available absolute gravimeters. Together with the capability to perform measurements directly at sites of geophysical interest, this opens up the possibility for a number of interesting applications.

We give an introduction into the working principle of our mobile atom interferometer and into the realisation of its subsystems optimized for mobility. Furthermore, first measurements of local gravity as well as some main characteristics of the instrument are presented.

Q 21.34 Tu 16:00 Lichthof

Atom interferometry in microgravity — •Markus Krutzik[1], Achim Peters[1], and das QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Physik, HU Berlin — [2]Institut für Quantenoptik, LU Hannover — [3]ZARM, Uni Bremen — [4]Institut für Quantenoptik, Uni Ulm — [5]Institut für Laserphysik, Uni Hamburg — [6]IAP, TU Darmstadt — [7]MPQ, Garching — [8]FBH, Berlin — [9]Midlands Ultracold Atom Research Centre, University of Birmingham, UK

Microgravity promises to substantially extend the science of degenerate quantum gases towards nowadays inaccessible regimes of low temperatures, macroscopic dimensions of coherent matter waves and longer unperturbed evolution. To utilize this excellent environment for interferometry schemes and applications like inertial quantum sensors with high precision is one of the main goals of the QUANTUS project.

As a source for coherent matter waves we use a Bose-Einstein condensate of Rubidium 87, whose ultra-long free evolution of 1 second in microgravity was already demonstrated at the drop tower in Bremen (ZARM). In order to realize a Mach-Zehnder interferometer we choose Bragg diffraction as a coherent beam splitting process. With this setup we are able to measure spatial and temporal coherences in the extended parameter regime available during free fall.

In addition we are working on a dual-species interferometer with Bose-Fermi gases. With this new apparatus we focus on precision measurements of the universality of the free fall. A major experimental challenge is to design catapult capable Raman laser systems, which have to withstand 30g accelerations during the catapult launch.

Q 21.35 Tu 16:00 Lichthof

A mobile Strontium optical frequency standard — •Ole Kock, Steven Johnson, Jochen Kronjaeger, and Kai Bongs — School of Physics and Astronomy, University of Birmingham, United Kingdom

Today first optical clocks have demonstrated performance beyond the current Cs atomic frequency standard. They are entering a sensitivity regime, where interdisciplinary applications such as relativistic geodesy , i.e. the determination of the earth geoid potential via relativistic frequency shifts, become feasible. On this poster we present the progress of a mobile optical frequency standard with Strontium necessary for such an application. We acknowledge support by EPSRC under grant EP/E036473/1.

Q 21.36 Tu 16:00 Lichthof

Towards an optical lattice clock with ^{87}Sr — •Stephan Falke, Christian Lisdat, Joseph Sundar Raaj Vellore Winfred, Thomas Middelmann, Fritz Riehle, and Uwe Sterr — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Optical clocks can achieve a higher stability and lower systematic uncertainty than the best current microwave clocks. Both, ion clocks and optical lattice clocks are currently under investigation as candidates for a redefinition of the SI second. A very promising candidate for an optical lattice clock is strontium, in particular the fermionic isotope ^{87}Sr where the doubly forbidden $^1S_0 - {}^3P_0$ transition is weakly allowed (natural linewidth 1.2 mHz) and collisional shifts are suppressed because two identical fermions cannot undergo s-wave scattering.

We trap ^{87}Sr atoms in a horizontal 1-D 'magic wavelength' optical lattice, in which the atoms are confined in the Lamb-Dicke regime and hence motional effects are suppressed. Due to the hyperfine structure, the laser cooling and trapping of ^{87}Sr is more complicated compared to the most abundant isotope ^{88}Sr, which has been investigated in our laboratory previously. We will present how we cool, trap, prepare, and interrogate ^{87}Sr as well as considerations and measurements towards reducing the uncertainty budget of a ^{87}Sr optical lattice clock.

The work is supported by the Centre for Quantum Engineering and Space-Time Research (QUEST), ESA, DLR, and the ERA-NET Plus Programme.

Q 21.37 Tu 16:00 Lichthof

Atomic structure of the Th II — •Jerzy Dembczyński, Magdalena Elantkowska, Jarosław Ruczkowski, Danuta Stefańska, and Gustaw Szawioła — Chair of Quantum Engineering and Metrology, Faculty of Technical Physics, Poznan University of Technology, Nieszawska 13B, 60-965 Poznan, Poland

Recently, the ^{229}Th isomer attracts attention, as a possible optical frequency standard. The detailed knowledge concerning the fine and hyperfine structures of the thorium isomer should help in searching for the transition suitable for detecting of the clock isomer resonance.

It stimulates our extensive work on the fine structure of ^{232}Th and the hyperfine structure of ^{229}Th. In our multi-configuration, semiempirical calculations, based on the experimental data, we determine the even and odd parity level scheme of Th ion, taking into account higher excited electron configurations. The predicted values of the hyperfine splittings of ^{229}Th will be also presented.

This work was supported by Polish Ministry of Science and Higher Education under the project N519 033 32/4065

Q 21.38 Tu 16:00 Lichthof

High performance iodine frequency reference for tests of the LISA laser system — •Klaus Döringshoff, Katharina Möhle, Moritz Nagel, Evgeny V. Kovalchuk, and Achim Peters — Humboldt Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Hausvogteiplatz 5-7, 10117 Berlin

In our group different concepts for tunable optical frequency references for the spaceborne gravitational wave detector LISA are developed and tested. Here we present our fixed and absolut frequency reference for the validation of tunability and stability of these new frequency references.

For absolut frequency stabilization the frequency doubled output of a 1064 nm Nd:YAG laser is stabilized to the a_{10} component of the R(56)32-0 transition of $^{127}I_2$. Using a threefold-pass scheme through a 80 cm iodine cell and the modulation transfer spectroscopy technique a frequency stability of $\sim 1\times10^{-14}$ at 1s integration time and frequency noise $\sim 4\,\mathrm{Hz}/\sqrt{\mathrm{Hz}}$ at Fourier frequencies of 1-100 Hz is achieved. We give a detailed analysis of significant parameters and systematic effects and present our efforts aiming at a frequency stability in the 10^{-16} range at averaging times of 1000 s. An outlook will be given for a frequency stabilization at 508 nm, where transitions with linwidths below 10 kHz have been observed. These are promising for high performance frequency references superior to those at 532 nm.

In addition the frequency stability of a high performance ULE cavity with a turning point of it's thermal expansion curve above room temperature will be presented.

Q 21.39 Tu 16:00 Lichthof

Thermal noise of optical reference cavities — •Thomas Legero, Thomas Kessler, and Uwe Sterr — Physikalisch-Technische Bundesanstalt (PTB) and Centre for Quantum Engineering and Space-Time Research (QUEST), Bundesallee 100, 38116 Braunschweig, Germany

The frequency stability of state-of-the-art cavity-stabilized laser systems is limited by the thermal noise (Brownian motion) of the cavity. Simple estimates of the thermal noise level for spacer, mirror substrates and mirror coatings have been given by Numata *et al.* [1]. To reduce the noise, cavity designs with fused silica mirrors and additional ULE rings for compensating thermal expansion effects [2] have been proposed. To model the more complex cavities we calculate the thermal noise from the fluctuation dissipation theorem using the finite element method [1,3]. The simulations show that a considerable part of the dissipated energy in the spacer derives from a deformation in radial direction leading to an increased noise level compared to the simple estimates of [1]. We discuss consequences for future desgins of low thermal noise cavities.

[1] K. Numata *et al.* Camp, Phys. Rev. Lett. **93**, 250602 (2004).
[2] T. Legero and U. Sterr, German Patent DE 102008049367 B3
[3] Y. Levin, Phys. Rev. D. **57**, 659-663 (1998)

Q 21.40 Tu 16:00 Lichthof

High precision cold atom gyroscope — •Timo Denker, Sven Abend, Peter Berg, Michael Gilowski, Christian Schubert, Gunnar Tackmann, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover

Over the years, matter wave interferometry has become a powerful tool for high precision inertial measurements. The research goal of the CASI project (Cold Atom Sagnac Interferometer) is to realize a gyroscope with a sensitivity of a few 10^{-9} rad/s/Hz$^{1/2}$ for 10^8 atoms per shot, using laser cooled Rubidium. The atomic ensemble is launched in a pulsed mode onto a flat parabola with a forward drift velocity of $2,79\,\mathrm{m/s}$ leading to an interrogation time of over 50 ms. Via coherent beamsplitting using Raman transitions, the atomic trajectories forming the interferometer paths can enclose an area of several mm^2. Vibrations, acoustics, as well as intensity fluctuations, the electronic feedback, and wave front distortions, contribute to the phase noise budget of the interferometer. In addition, the detection system also affects the integrity of the signal. Since the various interferometer noise sources limit the achievable sensitivity, their impact on the performance of the interferometer has to be considered. In this poster, the improvements of the individual parts of the interferometer and the resulting enhancement of the sensitivity will be presented. This work is supported by the DFG, QUEST, and IQS.

Q 21.41 Tu 16:00 Lichthof

Quantum Gate Operations on Logical Qubits in a Decoherence-Free Subspace using Geometric Optimal Control Theory — •Anton Haase[1], Lorenza Viola[2], and Christiane P. Koch[1] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Germany — [2]Department of Physics and Astronomy, Dartmouth College, Hanover, New Hampshire, USA

We study single qubit operations on logical qubits in a decoherence-free subspace of an open quantum system. The decoherence dynamics are described in the framework of the Lindblad master equation. Our model system allows for the encoding of one logical qubit in two physical qubits, where environment induced dephasing takes place.

The main difficulty is that effecting operations on the logical qubit introduces couplings with decohering states through the action of the available control fields on the physical qubits. We address this problem with optimal control theory based on Pontryagin's maximum principle to find the global optimum for carrying out logical single qubit operations.

Q 21.42 Tu 16:00 Lichthof

Stabilizing two-qubit interactions by dynamical decoupling — •Holger Frydrych[1], Pavel Bazant[2], Gernot Alber[1], and Igor Jex[2] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Darmstadt — [2]Department of Physics, FJFI CVUT, Prague

Certain tasks of quantum information processing, such as swap operations or more general perfect state transfer, may require particular two-qubit interactions between the qubits involved. In such cases any additional perturbations, even if they affect single qubits only, are harmful and have to be avoided. In this contribution a dynamical decoupling method is presented with which arbitrary one-qubit perturbations of a qubit network can be suppressed without affecting any two-qubit couplings up to third order average Hamiltonian theory. This method applies to arbitrary numbers of qubits and it relies on the existence of appropriate orthogonal arrays with three levels and of strength two. Possibilities of fault-tolerant implementations are discussed.

Q 21.43 Tu 16:00 Lichthof

Error Suppression in a Quantum Register with Non-ideal Controls — •Pavel Bažant[1], Oliver Kern[2], Gernot Alber[2], and Igor Jex[1] — [1]Department of Physics, FNSPE at Czech Techical University, Prague, Czech Republic — [2]Institut für Angewandte Physik, TU Darmstadt, Germany

Unwanted interactions among qubits in a quantum register can be effectively suppressed by means of external control operations. However, if the control is non-ideal, it acts as an additional error source. We show that if this additional error remains constant among different applications of the same control operation, it can be suppressed together with the interqubit interactions.

Q 21.44 Tu 16:00 Lichthof

Optimierung eines Rydberg-Phasengatters — •Matthias Müller[1], Tommaso Calarco[1], Christiane P. Koch[2] und Daniel Reich[2] — [1]Institut für Quanteninformationsverarbeitung, Universität Ulm — [2]Institut für Theoretische Physik, Freie Universität Berlin

Mithilfe der Optimal Control Theory soll ein Laserpuls berechnet werden, der ein Phasengatter zwischen zwei Rydbergatomen realisiert. Die beiden Rydberg-Atome sind in optischen Fallen eingefangen und der Laser stimuliert Übergänge zwischen Hyperfeinstrukturniveaus. Ziel der Arbeit ist es, mit dem Krotov-Algorithmus, einem Algorithmus zur numerischen Minimierung von Funktionalen, die Pulsintensität als Funktion der Zeit so zu optimieren, dass nach einer festen Zeit ein Phasengatter auf einem logischen Unterraum des gesamten Zustandsraumes erreicht wird.

In einem zweiten Schritt wird der Krotov-Algorithmus abgewandelt, sodass das Optimierungsziel nicht mehr das Quantengatter selbst, sondern nur sein verschränkender Anteil ist. Das Quantengatter kann dann durch zusätzliche (zeitkostengünstige) Einzelqubittransformationen hergestellt werden.

Auf dem Poster präsentiere ich den aktuellen Stand meiner Diplomarbeit zu diesem Thema.

Q 21.45 Tu 16:00 Lichthof

How to quantify simultaneity in quantum measurements? — •Michael Busshardt and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm

The prototype for a simultaneous measurement of two conjugate variables was introduced by Arthurs and Kelly in 1965. Nowadays, it serves as a blueprint for a variety of similar setups. Starting from this seminal approach we investigate a refined scheme to measure position and momentum of a free particle. The setup relies on coupling the particle at hand to two ancilla systems, which serve as measurement pointers. By considering explicitly time-dependent interactions we can quantify the simultaneity of the measurement. The question arises, how much information can be obtained in such a measurement setup.

Q 21.46 Tu 16:00 Lichthof

Light-induced charging effects on dielectric surfaces in the vincinity of trapped ions — •Maximilian Harlander[1], Wolfgang Hänsel[2], Michael Brownnutt[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck — [2]Institut für Quantenoptik und Quanteninformation der Akademie der österreichischen Wissenschaften

Microfabricated ion traps are discussed as one of the most promising candidates for a quantum mechanical computer. Reducing the electrode-ion distance offers a rich selection of trapping potentials and arrays of traps can, in principle, be operated in parallel. However, the proximity of the electrodes and other surfaces poses strong constraints on the materials used. In particular, near-by glass surfaces that may be used for high-finesse cavities around the ions or for light collection represent a challenge, since the dielectric surfaces may charge up and perturb the trapping potential. Furthermore, thin oxide layers formed on the electrodes of the ion trap may accumulate charges and contribute to this perturbation.

By bringing a glass substrate close to a surface ion trap, the charging has been studied in a controlled manner. Two distinct mechanisms of charging have been observed, both being light-induced with different wavelength dependence. The results allow an estimate of the rate of charge production and will prove useful for future designs of integrated microscopic ion traps.

Q 21.47 Tu 16:00 Lichthof

Secret key rates in quantum key distribution using Rényi entropies — •Silvestre Abruzzo, Hermann Kampermann, Markus Mertz, Sylvia Bratzik, and Dagmar Bruss — Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, D-40225 Düsseldorf, Germany

The secret key rate r of a quantum key distribution protocol depends on the involved number of signals and the accepted "failure probability". We reconsider a method to calculate r focusing on the analysis of the privacy amplification given by [1]. This approach involves an optimization problem with an objective function depending on the Rényi entropy of the density operator describing the classical outcomes and the eavesdropper system. This problem is analyzed for a generic class of QKD protocols and the current research status is presented.

[1]R.Renner and R. König, in *Second Theory of Cryptography Conference, TCC 2005*, Vol. 3378 of LNCS, edited by J.Kilian (Springer, New York, 2005), pp. 407-425

Q 21.48 Tu 16:00 Lichthof

Construction of complete sets of cyclic mutually unbiased bases — Oliver Kern[1], Kedar Ranade[1,2], •Ulrich Seyfarth[1], and Gernot Alber[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, 64289 Darmstadt, Germany — [2]Institut für Quantenphysik, Universität Ulm, Albert-Einstein-Allee 11, 89069 Ulm, Germany

Complete sets of mutually unbiased bases (MUBs) have interesting applications in quantum information science. The quantum cryptographic six-state protocol, for example, relies on a special kind of complete set of MUBs. Contrary to general complete sets of MUBs [1,2] it has the additional property of being cyclic, i.e. all bases involved are generated from one particular basis by multiple applications of a single unitary transformation. In this contribution details of a recently developed method [3] are presented which allows to construct complete sets of cyclic mutually unbiased bases in even prime power dimensions. The relevance of these complete sets of cyclic MUBs for security bounds of quantum cryptographic protocols are discussed. This work was supported by CASED.

[1] A. Klappenecker and M.Rötteler, LNCS 2948, 262 (2004)
[2] R. Gow, arXiv:math/0703333v2
[3] O.Kern, K. Ranade and U.Seyfarth, in preparation

Q 21.49 Tu 16:00 Lichthof

Quantum Teleportation Between Stationary Macroscopic Objects — •Bao Xiao-Hui[1,2], Xu Xiao-Fan[1], Li Che-Ming[1,3], Yuan Zhen-Sheng[1,2], and Pan Jian-Wei[1,2] — [1]Physikalisches Institut der Universitaet Heidelberg, Philosophenweg 12, Heidelberg 69120, Germany — [2]Hefei National Laboratory for Physical Sciences at Microscale and Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China — [3]Department of Physics and National Center for Theoretical Sciences, National Cheng Kung University, Tainan 701, Taiwan

Quantum teleportation is a process to transfer a quantum state of an object without transferring the state carrier itself. So far, most of the teleportation experiments realized are within the photonic regime. For the teleportation of stationary states, the largest system reported is a single ion. We are now performing an experiment to teleport the state of an macroscopic atomic cloud which consists about 10^6 single atoms. In our experiment two atomic ensembles are utilized. In the first ensemble A we prepare the collective atomic state to be teleported using the quantum feedback technique. The second ensemble B is utilized to generate entanglement between it collective state with a scattered single-photon. Teleportation is realized by converting the atomic state of A to a single-photon and making a Bell state measurement with the scattered single-photon from ensemble B.

Q 21.50 Tu 16:00 Lichthof

Pulsed coherent Rydberg excitation in thermal microcells — •Bernhard Huber, Thomas Baluktsian, Harald Kübler, Andreas Kölle, Christian Urban, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Germany

In order to create quantum devices based on the Rydberg blockade mechanism, it is necessary to have a confinement of the excitation volume to less than the blockade radius in a frozen gas of atoms; i.e. the excitation times need to be shorter than the timescales of the respective dephasing mechanisms. While ultracold gases seem to be the obvious choice, our approach utilizes thermal atomic vapor in small glass cells which offer multiple advantages like good optical access and scalability. Such a system can be realized by confining the atoms to geometries in the μm regime. Lifetime-limiting effects due to the method of confinement like resonant interactions of the Rydberg atoms with polaritonic excitations in the glass have been studied [1]. Utilizing a bandwidth-limited pulsed laser system for the excitation we can create high Rabi-frequencies and thus short enough excitation times. First measurements of two-photon-excitations permitted probing of the Rydberg excitation dynamics on a ns-timescale.

[1] H. Kübler et al., accepted by Nature Photonics, arXiv:0908.0275

Q 21.51 Tu 16:00 Lichthof

Using ultra-high Q bottle microresonators for cold atom cavity quantum electrodynamic experiments — •Danny O'Shea, Christian Junge, Christian Hauswald, Sebastian Nickel, Alexander Rettenmaier, and Arno Rauschenbeutel — QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz

We describe the active frequency stabilization of a fully tunable whispering-gallery-mode microresonator with an ultra-high quality factor exceeding 3×10^8 using the Pound-Drever Hall technique. The critically coupled bottle microresonator is stabilized to 8–10% of its linewidth, or 200 kHz rms, in an ambient air environment. This represents an important advancement for our planned cavity quantum electrodynamic experiment with a bottle microresonator coupled to laser-cooled rubidium atoms. We have constructed an apparatus to deliver the atoms to the location of the bottle microresonator using an atomic fountain. The current status of our experiment is presented and we show first results towards the active stabilization of the bottle resonator to an atomic resonance in ultra-high vacuum.

Financial support by the DFG (Research Unit 557), the ESF (EURYI Award), and the Volkswagen Foundation (Lichtenberg Professorship) is gratefully acknowledged.

Q 21.52 Tu 16:00 Lichthof

Spin dynamics of one and two atoms strongly coupled to an optical resonator — •René Reimann[1], Wolfgang Alt[1], Martin Eckstein[1], Tobias Kampschulte[1], Mkrtych Khudaverdyan[1], Lingbo Kong[1], Sebastian Reick[1], Alexander Thobe[1,2], Artur Widera[1], and Dieter Meschede[1] — [1]Institut für Angewandte Physik, Universität Bonn — [2]Institut für Laser-Physik, Universität Hamburg

In our experiment we transport a predetermined small number of cold caesium atoms into a high-finesse optical resonator using an optical dipole trap [1]. By monitoring the transmission of a probe laser beam resonant with the cavity we measure the atomic spin state: A single atom in the strongly coupled state shifts the cavity out of resonance with the laser and strongly reduces its transmission, while an atom in the uncoupled state does not change the transmission. Continuous observation reveals quantum jumps between the two hyperfine ground states [2]. The spin dynamics of one and two atoms is inferred from these random telegraph signals using Bayesian analysis and optimal binning time, yielding maximum information about the system.

[1] M. Khudaverdyan *et al.*, New J. Phys. **10**, 073023 (2008)
[2] M. Khudaverdyan *et al.*, Phys. Rev. Lett. **103**, 123006 (2009)

Q 21.53 Tu 16:00 Lichthof

Atom-Photon-Interfaces - Single-Photon Generation and Shaping — •Peter Nisbet[1], Jerome Dilley[1], Gunnar Langfahl-Klabes[1], Genko Vasilev[2], Daniel Ljunggren[3], and Axel Kuhn[1] — [1]Clarendon Laboratory, Oxford, UK — [2]Dept. of Phys., Sofia University, Bulgaria — [3]Dept. of Appl. Physics, KTH Stockholm, Sweden

Single atoms coupled to high-finesse cavities provide a unique way to deterministically generate a stream of single photons of MHz bandwidth [1]. Atom-cavity schemes are also in principle reversible, this would allow quantum state mapping between static (atom-cavity) and flying (photon) qubits which could be scaled up into a quantum network.

We report on the latest status of a strong coupling atom-cavity system based on ^{87}Rb. Atoms are loaded into the cavity ($\mathcal{F} = 125000$, $L = 90\mu m$) using an atomic fountain which gives rise to millisecond interaction times.

We also show a tweak to deliver single photons of arbitrary temporal shape. For any possible shape we derive an analytic expression for the driving laser pulse [2].

[1] Hijlkema, M. *et al.* Nature Physics **3**, 253 (2007)
[2] Vasilev, G. *et al.* arXiv:0907.0761v1

Q 21.54 Tu 16:00 Lichthof

A cavity QED system for atom-photon interfacing and multi-atom investigations — •Kyle Arnold, Markus Baden, and Murray Barrett — Centre for Quantum Technologies, National University of Singapore, Singapore

We report our progress towards an atom-photon network using cavity QED. Our system utilizes a far detuned optical lattice to transfer atoms into a high finesse cavity and permits us to load single atoms in a deterministic way. In addition, a secondary dipole force trap facilitates loading atoms at very high density giving approximately 104 atoms per lattice site transferred to the cavity mode. An intra-cavity trapping laser and an additional optical lattice permit a 3-D lattice to be established in the cavity. Trapping frequencies in this geometry easily allow atoms to be cooled to the ground state. We will present our ongoing investigations with this system.

Q 21.55 Tu 16:00 Lichthof

Methods in Implementing 2 Dimensional Arrays of Ion Traps — •Muir Kumph[1], Michael Niedermayr[1], Regina Lechner[1], Michael Brownnutt[1], and Rainer Blatt[2] — [1]Institut für Experimentalphysik, Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Innsbruck, Austria

Microfabricated ion traps are one of the most promising candidates for a scalable quantum mechanical computer. In such a system, individual ions can be held with long coherence times, while allowing the ions to interact in a controlled way via laser mediated gates (eg.Molmer-Sorensen). 2D arrays of ion traps open up new possibilities of gate operation and algorithm implementation. Investigating a mesoscopic scale, low-count array, surface ion trap, we look at the feasibility of addressing the ions by magnetic fields, micro-lens arrays and tightly-focussed free-space light. Adjacent linear Paul traps as well as 2 dimensional arrays of ring traps are discussed in relation to the above addressing techniques. Methods for driving the array of micro ion traps in a cryostat via novel radio frequency resonators are also to be highlighted.

Q 21.56 Tu 16:00 Lichthof

Analytic approximations of the Jaynes-Cummings-Hubbard model with application to ion chains — •Alexander Mering[1], Michael Fleischhauer[1], Peter A. Ivanov[2], and Kilian Singer[2] — [1]Fachbereich Physik and research center OPTIMAS, Technische Universität Kaiserslautern — [2]Institut für Quanteninformationsverarbeitung, Universität Ulm

We discuss analytic approximations to the ground-state phase diagram of the homogeneous Jaynes-Cummings-Hubbard (JCH) Hamiltonian with general short-range hopping. Specifically, we consider the cases of a linear array of coupled cavities and a linear ion chain describing radial phonon excitations of the ions coupled to an external laser field tuned to the red motional sideband with Coulomb-mediated hopping. We derive approximate analytic expressions for the boundaries between Mott-insulating and superfluid phases and give explicit expressions for the critical value of the hopping amplitude within the different approximation schemes together with a comparison to mean-field results. Additionally, in the case of an array of cavities which is represented by the standard JCH model, we compare both approximations to numerical data from density-matrix renormalization-group (DMRG) calculations.

Q 21.57 Tu 16:00 Lichthof

Characterisation of non-classical radiation generated in semiconductor systems using multi-pixel photon detectors — •Robert Löffler, Gerolf Burau, and Heinrich Stolz — Universität Rostock, Institut für Physik, Universitätsplatz 3, 18055 Rostock

The characterisation of multi-photon quantum states requires the use of photon number resolving detectors. Such devices are urgently needed for applications in quantum computation and information. But beside that, they are also suitable for a more fundamental view on nature like identifying whether a quantum state is classical or non-classical (coherent or squeezed) due to their photon statistics. Here we propose an adequate setup consisting of a multi-pixel photon counting diode and a low noise amplification circuit integrated in a modified low temperature cryostat (down to 10K). We present recent measurements on photon statistics of semiconductor lasers and LEDs and compare them with reconstructions of the photon distributions in the presence of dark counts, cross talk and loss with high precision. Our system is appropriate for measuring and reconstructing unknown quantum states e.g. excitons in quantum dots as well.

Q 21.58 Tu 16:00 Lichthof

Femtosecond pulsed ultraviolet enhancement cavity as high power spontaneous parametric down conversion source — •Roland Krischek[1,2], Witlef Wieczorek[1,2], Akira Ozawa[1], Nikolai Kiesel[1,2], Patrick Michelberger[1,2], Thomas Udem[1], and Harald Weinfurter[1,2] — [1]Max-Planck-Institut für Quantenoptik, D-85748 Garching — [2]Department für Physik, LMU München, D-80799 München

Current multi-photon entanglement experiments are mostly based on the process of spontaneous parametric down conversion (SPDC). Typically, the SPDC process is pumped by femtosecond ultraviolet (UV) pulses obtained from a frequency-doubled titanium-sapphire (Ti:Sa) laser at a repetition rate of about 80MHz. However, today's pump sources suffer from weak pump powers (<2W) resulting in low multi-photon count rates. Here, we present a new setup to boost the multi-photon generation rate of SPDC experiments. For this purpose we introduce a femtosecond enhancement cavity in the UV to pump a nonlinear crystal inside. The cavity enhances resonantly the frequency-doubled Ti:Sa pulses. We reach a maximal UV power of 7W at the repetition rate of the Ti:Sa laser (80MHz). We characterize the spectra of the intra-cavity laser pulses and estimate the pulse duration inside the cavity by interferometric autocorrelation. In addition, we show the multi-photon count rates as a function of the pump power, reaching an improvement of the six-photon count rates by two orders of magnitude. Our results pave the way to various applications not only in photonic quantum logic, but also in nonlinear optics research.

Q 21.59 Tu 16:00 Lichthof

Biphoton source at 710nm using a periodically poled MgO doped stoichiometric lithium tantalate crystal — •Sebastian Wander, Dirk Puhlmann, and Martin Ostermeyer — Institute for Physics and Astronomy, University of Potsdam, Karl-Liebknecht-Str 24/25, 14476 Potsdam, Germany

Correlations between photons are interesting for a number of applications and concepts in metrology, in particular for resolution improvements in different methods of quantum imaging. As used in most experiments of quantum imaging the most efficient single photon detectors, silicon avalanche photo detectors, have a sensitivity maximum around 700nm. To generate correlated photons in this wavelength region efficiently, special nonlinear optical materials are needed for this purpose. Periodically poled MgO doped Lithium Tantalate (PP-MgO:SLT) is an attractive nonlinear material because of its high nonlinear coefficients , its high resistance to optical damage and its wide optical transparency down to the UV spectral range [1]. In this paper we present a source for biphotons based on PP-MgO:SLT. The nonlinear crystal is pumped by the third harmonic of a Nd:YAG laser emitting 11ps long pulses. The generated biphotons have a central wavelength of 710nm. To characterize the correlations of the biphotons different methods are applied. Diffraction at a blazed grating [2] offers information about the spatial degree of correlation of the photons.

[1] A. Bruner et al, Optics Letters 28, 194 (2003)
[2] M. Ostermeyer, D. Puhlmann, D. Korn, JOSA-B 26, 2347 (2009)

Q 21.60 Tu 16:00 Lichthof

Studies on the gap of a solid immersion lens-diamond interface using raytracing — •Stefan Bischof — 3. Physikalisches Institut, Universität Stuttgart

An NV center is a vacancy in diamond with a neighboring nitrogen atom. Its flourescence gives allows to determine its quantum state. At low temperatures this read out process could be used for quantum computation. Its application as a photon source for quantum computation. An increase of collection of photons allows the realisation of single shot read out.

The loss of photons on a diamond-air interface can be reduced by using a half-ball shaped solid immersion lens (SIL). Light irradiated from the center of a ball suffers no internal reflexion on the ball surface. A raytracing simulation shows interesting properties of a SIL. The projection of the light beams on the object plane shows a gaussian profile.

The parameter x_0 for the misalignment from the optical axis broke the symmetry of the problem. Varying the parameters shows: the center of the gaussian profile still remains in the optical axis. Taking multi-beam-interference into account the gaussian profile is modulated depending on the gap height. The control of this modulation allows to have even higher count rates than without a gap.

Q 21.61 Tu 16:00 Lichthof

Towards emitter-cavity-coupling of new single color centers in diamond — Roland Albrecht, •Christian Hepp, Elke Neu, Janine Riedrich-Möller, David Steinmetz, and Christoph Becher — Technische Physik, Universität des Saarlandes, D-66123 Saarbrücken

An approach to increase the viability of single color centers in diamond is to couple their optical emission to microcavities. 2D photonic crystal microcavities (PhC) are being considered as well suited candidates for this task providing theoretical Q-factors of 10^5 at modal volumes of less than $1(\lambda/n)^3$ as well as an integral scalability. We show preliminary results on PhC realization in thin (300 nm) nanocrystalline diamond films produced by focused ion beam milling that suggest a Q-factor of ≈ 100 which is limited by the material absorption as we conclude from our theoretical models.

On the other hand the state-of-the-art single photon emitter in diamond - the NV-center - turns out to be only poorly suited for a coupling of its zero phonon line to a cavity mode because it radiates predominantly into broad vibronic sidebands. On the road to find defects with smaller linewidth we report on Si- and Ni-based color centers in bulk diamond. The Ni-center (810 nm) exhibits a high signal-to-noise-ratio (69 kcounts/s) and a small linewidth of 2 nm at room temperature; moreover it proofs clear single photon emission featuring a second-order-correlation function of $g^2(0) = 0.1$. Silicon vacancy (SiV) centers were created by spatially resolved ion implantation showing the high potential of this technique for SiV-centers.

Q 21.62 Tu 16:00 Lichthof

Model free, direct measurement of Casimir-Polder-Potentials in the transition regime — •Christian Stehle, Helmar Bender, Philippe W. Courteille, Carsten Marzok, Claus Zimmermann, and Sebastian Slama — Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen

The attractive force between atoms and surfaces is often referred to as Casimir-Polder force (CP). The form of the potential generating this force depends on the distance of the atoms from the surface. In the short range limit, for distances much closer than the wavelength of the atomic transition, the interaction can be regarded as an electrostatic interaction with a z^{-3} power law. In the long range limit retardation effects have to be taken into account, which leads to a z^{-4} power law. On the poster we present measurements of the CP force in the transition regime between these two limits. The measurements were performed by using a new method, which is based on the reflection of ultra cold atoms from an evanescent wave barrier. Note that this is the first method for the direct measurement of CP forces in the transition regime without the need for any assumption on the potential shape.

Q 21.63 Tu 16:00 Lichthof

Reproducible chaos-induced mesoscopic superpositions of Bose-Einstein condensates — •Bettina Gertjerenken, Stephan Arlinghaus, Niklas Teichmann, and Christoph Weiss — Institut für Physik, Carl von Ossietzky Universität Oldenburg, 26111 Oldenburg

In a parameter regime for which the mean-field (Gross-Pitaevskii) dynamics become chaotic, mesoscopic quantum superpositions in phase space can occur in a double-well potential which is shaken periodically. For experimentally realistic initial states like the ground state of some 100 atoms, the emergence of mesoscopic quantum superpositions in phase space is investigated numerically. It is shown to be reproducible even if the initial conditions slightly change. While the final state is not a perfect superposition of two distinct phase-states, the superposition is reached an order of magnitude faster than in the case of the collapse and revival phenomenon. Furthermore, a generator of entanglement generation is identified.

Q 21.64 Tu 16:00 Lichthof

Retardation effects on entanglement between atoms in a cavity — •Qurrat-ul- Ain[1], Zbigniew Ficek[2], and Jörg Evers[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]The National Centre for Mathematics and Physics, King Abdulaziz City for Science and Technology, Riyadh, Saudi Arabia

In the standard setup of atoms coupled to a cavity, a finite time is required by light to travel between the atoms and the cavity boundaries. In suitable parameter regimes, these retardation effects can affect the time evolution of the combined system of atoms and cavity field to a large degree [1].

Here, we study the effects of retardation on the entanglement dynamics of a system of two two-level atoms placed inside a one-dimensional ring cavity. For this, we calculate the time evolution of the concurrence [2], which quantifies the entanglement between the two atoms. We indentify suitable parameter ranges for the study of retardation effects, analyze sudden death of entanglement [3] in the presence of retardation, and interpret the obtained results in terms of the traveling time of light between the atoms and the cavity mirrors.

[1] E. V. Goldstein and P. Meystre, Phys. Rev. A **56**, 5135 (1997).
[2] W. K. Wootters, Phys. Rev. Lett. **80**, 2245 (1998).
[3] T. Yu and J. H. Eberly, Phys. Rev. Lett. **93**, 140404 (2004).

Q 21.65 Tu 16:00 Lichthof

Study of entanglement dynamics through a partial P-representation — •Ansgar Pernice and Walter T. Strunz — TU Dresden

We investigate entanglement dynamics of a qubit coupled to harmonic oscillators. Initially, we assume "system" and "environment" to be independent and represented by mixed states. We find it convenient to express the total state in terms of a partial P-representation, whose definiteness we relate to entanglement. Our results help to elucidate the role of entanglement in open system dynamics.

Q 21.66 Tu 16:00 Lichthof

Towards Coherent Control of Photons using Electromagnetically Induced Transparency — •Andreas Neuzner, Eden Figueroa und Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

Over the last decade the effect of electromagnetically induced transparency (EIT) and the related effect of storage of light have received extensive attention as a potential candidate for the realization of quantum memories. Towards this goal several milestones have been reached, the most important being the storage of single photons using EIT [1]. Nevertheless, these experiments so far do not offer access to the temporal envelope of the single photon read back from the storage medium.

We envision a device that can store single photons and allows for full control over the temporal shape of the retreived photon. We have set up an EIT-experiment based on a ^{87}Rb vapour cell and store weak classical pulses. Currently a protocol to optimize the storage efficiency is being implemented [2] and we explore possibilities to employ this setup as a storage device for single photons generated from a cavity QED based source [3].

[1] M.D. Eisaman, A. André, F. Massou, M. Fleischhauer, A.S. Zibrov, and M.D. Lukin, Nature **438**, 837 (2005).
[2] I. Novikova, A.V. Gorshkov, D.F. Phillips, A.S. Sørensen, M.D. Lukin, and R.L. Walsworth , PRL **98**, 243602 (2007).
[3] M. Hijlkema, B. Weber, H.P. Specht, S.C. Webster, A. Kuhn, and G. Rempe, Nature Physics **3**, 253 (2007).

Q 21.67 Tu 16:00 Lichthof

Raman-Nath-Description of the Free-Electron Laser — •Matthias Knobl and Wolfgang P. Schleich — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

The free-electron laser (FEL) is an alternative laser device with a widely tunable wavelength of the emitted radiation. Most FEL's operate in the regime of classical physics where quantum physical descriptions are not needed. Since recent projects are trying to go beyond the classical limit, we discuss the quantum mechanical regime of the FEL, using an approach based on a set of Lie-algebraic operators. This leads to the spherical Raman-Nath equation of the FEL.

Q 21.68 Tu 16:00 Lichthof

Photon diode: performing nonunitary operations on quantum light — •Gor Nikoghosyan and Michael Fleischhauer — Department of Physics and research center OPTIMAS, University of Kaiserslautern, Germany

We discuss the interaction of two quantized modes of light with a spectrally broadened atomic ensemble. We show that the system is analogous to a two level system interacting with a bosonic reservoir, where the photonic modes correspond to the atomic states and the atomic ensemble corresponds to the modes of the reservoir. In contrast to the photonic reservoirs, the atomic ensembles can be easily controlled which can be used to simulate the dynamics of an open two level system in a reservoir with tunable spectrum. Due to the coupling with the atoms the analog of spontaneous decay for photons is obtained. This process leads to an irreversible transfer of photons from one mode to the other. The effect can be used for large variety of applications; e.g. the creation of new quantum states, the transfer of photons of optical frequency to microwave domain and vice versa, or the construction of a diode for photons, i.e. a device where single photon pulses injected in any of the two input ports will be directed to the same output port.

Q 21.69 Tu 16:00 Lichthof

Multifractality in quantum maps — •John Martin[1], Ignacio Garcia-Mata[2], Olivier Giraud[3,4], and Bertrand Georgeot[3,4] — [1]Institut de Physique Nucléaire, Atomique et de Spectroscopie, Université de Liège, Bât. B15, B - 4000 Liège, Belgium — [2]Departamento de Física, Lab. TANDAR, Comisión Nacional de Energía Atómica, Av. del Libertador 8250, C1429BNP Buenos Aires, Argentina — [3]Université de Toulouse, UPS, Laboratoire de Physique Théorique (IRSAMC), F-31062 Toulouse, France — [4]CNRS, LPT (IRSAMC), F-31062 Toulouse, France

We present our results on the multifractal properties of wave functions for (a) a one-parameter family of quantum maps displaying the whole range of spectral statistics intermediate between integrable and chaotic statistics, (b) wave functions at the Anderson transition in the kicked rotator with three incommensurate frequencies (experiments on this system have been performed by Garreau et al.). We perform extensive numerical computations and provide analytical arguments showing that the generalized fractal dimensions are directly related to the parameter of the underlying classical map, and thus to other properties such as spectral statistics.

Q 21.70 Tu 16:00 Lichthof

Fluorescence Resonance Energy Transfer Microscopy — •Julia Tisler, Gopalakrishnan Balasubramanian, Rolf Reuter, Anke Lämmle, Fedor Jelezko, and Jörg Wrachtrup — 3. Physikalisches Institut, Stuttgart, Germany

We present fluorescence resonance energy transfer (FRET) between a single nitrogen-vacancy (NV) center in diamond and organic dye molecule.

A nanodiamond with a single NV colour center was placed to the tip of a atomic force microscope. Using this single NV center as a probe the sample was investigated. By scanning such tip over a sample containing dye molecules we were able to perform FRET microscopy. This new technique uses Förster energy transfer as optical contrast mechanism. Resolution of such scanning probe microscope is shown to be orders of magnitude better than that imposed by Abbe limit.

Q 21.71 Tu 16:00 Lichthof

Vertikal emittierende Laserdioden als Seed-Quelle eines gepulsten Titan:Saphir-Lasers — •Simon Metzendorf, Daniel Depenheuer, Thorsten Führer und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, Laser und Quantenoptik, Schlossgartenstr. 7, 64289 Darmstadt

Vertikal emittierende Laserdioden (VCSEL, engl. Vertical-Cavity Surface-Emitting Laser) zeichnen sich u.a. durch ihr rotationssymmetrisches Strahlprofil, niedrige Betriebsströme sowie ihren longitudinalen Einmodenbetrieb und die damit verbundene gute Durchstimmbarkeit der Wellenlänge aus. Mittels eines mikroelektromechanischen Systems (MEMS) lässt sich der kontinuierlich abstimmbare Bereich eines VCSELs auf über 50 nm vergrößern [1].

Die Verwendung einer solchen Laserdiode als Injection-Seeder für einen gepulsten Titan:Saphir-Laser führt zu einem Lasersystem hoher Ausgangsleistung, welches ebenso kontinuierlich durchstimmbar ist und ns-Pulse nahe des Fourierlimits liefert. Das System ist im Hinblick auf seine Arbeitswellenlänge besonders flexibel, da mit Hilfe nichtlinearer optischer Prozesse der Spektralbereich von 190 nm bis 6000 nm abdeckt werden kann [2]. Der aktuelle Fortschritt des Projekts wird vorgestellt.

[1] B. Kögel et al., *IEEE Sens. J.*, **11**, 1483-1489 (2007)
[2] D. Depenheuer et al., *Appl. Phys. B*, **97**, 583-589 (2009)

Q 21.72 Tu 16:00 Lichthof

Resonatorinterne Frequenzverdopplung von grün emittierenden Praseodym-Lasern — •Teoman Gün, Ernst Heumann und Günter Huber — Universität Hamburg, Institut für Laser-Physik

In diesem Beitrag wird die Erzeugung von tief-ultravioletter (DUV) Strahlung bei einer Wellenlänge von 261,3 nm mittels resonatorinterner Frequenzverdopplung eines Praseodym-Lasers demonstriert. Dabei werden Praseodym-dotierte $LiYF_4$ (YLF)- und $LiLuF_4$ (LLF)-Kristalle über eine GaN-Laserdiode (LD) mit einer Ausgangsleistung von 1 W und der Emissionswellenlänge von 444 nm, oder einem optisch gepumpten Halbleiterlaser (OPS) mit einer Ausgangsleistung von 5,5 W und der Emissionswellenlänge von 479,5 nm gepumpt. Auf der Grundwelle des LD-gepumpten Pr(0,65at.%):YLF-Lasers konnten bei einer absorbierten Leistung von 594 mW und 1,9% Auskopplung maximal 42,5 mW Laserleistung bei der Wellenlänge von 522,7 nm erzielt werden. Die Frequenzkonversion erfolgt über einen 6,5 mm langen für 523 nm antireflexions-beschichteten Beta-Barium-Borat-Kristall unter kritischer Phasenanpassung vom Typ I. Dabei wurde eine maximale DUV-Leistung von 22,5 mW generiert, welches einer Konversionseffizienz von 53% bezogen auf die maximale Ausgangsleistung für die Grundwelle und einer optisch-optischen Gesamteffizienz von 3,8% entspricht. Experimente mit einem OPS-gepumpten Pr(0,45at.%):LLF-Kristall ergaben DUV-Ausgangsleistungen von maximal 416 mW und somit eine optisch-optische Gesamteffizienz von 7,6%.

Q 21.73 Tu 16:00 Lichthof

Faserverstärker basierter Ar^+-Laserersatz — •Benjamin Rein, Tobias Beck und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, Laser und Quantenoptik, Schloßgartenstraße 7

Ein Faserverstärker mit einer weit abstimmbaren Seedquelle und anschließender Frequenzverdopplung wird vorgestellt. Die Seedquelle besteht aus einem External Cavity Diode Laser mit einer leistungsstarken Laserdiode bei 1028 nm. Der Verstärker basiert auf einer Yb-dotierten, polarisationserhaltenden Faser und die Ausgangsstrahlung hat die spektralen Eigenschaften des Seedlasers. Mit einer anschließenden Intracavity-Frequenzverdopplung ist es möglich, einen durchstimmbaren schmalbandigen Ersatz für einen Ar-Ionenlaser bei einer Wellenlänge von 514 nm zur Verfügung zu stellen. Diese weite modensprungfreie Abstimmbarkeit wird durch ein neues, auf Polarisationsspektroskopie basierendes, Locking-Verfahren realisiert.

Q 21.74 Tu 16:00 Lichthof

$Nd:YVO_4$ Hochleistungsverstärkersystem mit langen Pikosekunden Impulsen und effizienter Erzeugung der zweiten Harmonischen — •Markus Lührmann, Christian Theobald, Richard Wallenstein und Johannes A. L'huillier — Photonik-Zentrum Kaiserslautern e.V., Deutschland

Optisch parametrische Verstärkung gechirpter fs-Impulse (OPCPA) ist gut etabliert. Eine effiziente Verstärkung benötigt Pumpimpulse hoher Energie mit Impulsdauern von mehreren hundert ps und guter Strahlqualität. Bis jetzt wurden OPCPAs mit Wiederholraten von bis zu einem kHz bei Pumpimpulsenergien von wenigen mJ betrieben. Die so verstärkten fs-Impulse großer Spitzenintensität sind gut geeignet um hohe Harmonische oder Röntgenstrahlung zu erzeugen. Diese Strahlung wiederum ist interessant für verschiedene Anwendungen wie Photoelektronen Spektroskopie oder die Verbrennungsdiagnose. Die Anwendungen würden allerdings stark von Wiederholraten höher als 10 kHz profitieren.

Wir haben daher eine Pumpquelle für einen OPCPA mit 20 kHz Wiederholrate entwickelt. Ein bereits vorgestellter Diodengepumpter regenerativer Verstärker auf Basis von $Nd:YVO_4$ wurde um eine lineare Nachverstärkung erweitert. Es werden nahezu Fourier limitierte Impulse mit mehr als 2,5 mJ Impulsenergie bei einer Wiederholrate von 20 kHz und frei einstellbaren Impulsdauern von 180 ps bis etwa 1 ns erzeugt. Durch eine externe hocheffiziente Frequenzverdoppelung auf 532 nm können so Impulsenergien von über 2 mJ generiert werden. Die erzeugte Strahlung ist annähernd beugungsbegrenzt.

Q 21.75 Tu 16:00 Lichthof

Concept of a second order Littrow external cavity diode laser — •Björn Hemb, Michael Britzger, Daniel Friedrich, Maximilian Wimmer, André Thüring, Karsten Danzmann, and Roman Schnabel — Institut für Gravitationsphysik, Leibniz Universität Hannover und Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) Callinstrasse 38 D-30167 Hannover

Optical feedback for laser diodes is typically realised with gratings in first order Littrow or Littman configurations. The latter generates a better frequency selection, but includes a loss channel for the light power. An alternative concept is based on a so-called 3-port-grating that provides three diffraction orders. The external cavity is mounted in second order Littrow configuration. Hence the external cavity is assembled perpendicular to the grating surface. The first diffraction order serves for coupling into the external cavity.

We present a detailed analysis of the applicability of dieletric 3-port reflection gratings for external cavity optical feedback of laser diodes. The design is intended to engender optical feedback without any loss channel and with minor complexity.

Q 21.76 Tu 16:00 Lichthof

Towards a multi-Watt femtosecond optical parametric oscillator tunable between 1.5μm and 1.9μm wavelength — •Robin Hegenbarth[1], Jan-Philipp Negel[1], Felix Hoos[1], Bernd Metzger[1], Andy Steinmann[1], János Hebling[2], and Harald Giessen[1] — [1]4th Physics Institute, University of Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany — [2]Department of Experimental Physics, University of Pécs, Ifjúság út 6, H-7624 Pécs, Hungary

We develop a cost-effective, synchronously pumped singly resonant optical parametric oscillator (OPO) tunable between 1.5 μm and 1.9 μm signal wavelength. We expect up to 40 percent conversion efficiency and <200 fs FWHM pulse duration. The OPO signal is generated in an MgO-doped periodically poled lithium niobate (MgO:PPLN) crystal. The pump source is a fiber laser with 1030 nm wavelength, 3 W average output power, <500 fs FWHM pulse duration, and 37 MHz repetition rate. We also use a 5 W average output power Yb:KGW laser as pump source, which scales up the OPO's signal power even more. This OPO will be used as a pump source of a Mid-IR optical parametric oscillator with several hundred mW average output power tunable between 5 μm and 12 μm wavelength with $AgGaSe_2$ as a nonlinear crystal. Another application is the generation of terahertz radiation via optical rectification in GaAs.

Q 21.77 Tu 16:00 Lichthof

Ultra-sensitive fluorescence spectroscopy of isolated surface-adsorbed molecules using an optical nanofiber — •Ariane Stiebeiner, David Papencordt, Nils Konken, Ruth Garcia-Fernandez, and Arno Rauschenbeutel — QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz

The strong radial confinement and the pronounced evanescent field of the guided light in optical nanofibers allow the controlled interaction with particles which are deposited near or on the fiber surface. Using the guided mode of the nanofiber waist of a tapered optical fiber for excitation and fluorescence collection, we present spectroscopic measurements on surface-adsorbed organic dye molecules. In order to efficiently couple light into and out of the nanofiber over a broad spectral range, we have optimized the taper geometry based on numerical simulations and experimental studies. As a result, surface coverages as small as 0.1 % of a compact monolayer still give rise to fluorescence spectra with a good signal to noise ratio. The effect of self-absorption in our system can be quantitatively modelled and is negligible for low surface coverages. We are currently setting up a cryogenic apparatus for low temperature measurements. The new setup, together with the high sensitivity of our method, should allow us to perform nanofiber-based spectroscopy on the single molecule level.

We gratefully acknowledge financial support by the EC (STREP

"CHIMONO"), the ESF (EURYI), and the Volkswagen Foundation (Lichtenberg Professorship).

Q 21.78 Tu 16:00 Lichthof

Laser spectroscopy of trapped Th^+ ions: towards nuclear laser spectroscopy of Th-229 — •Kai Zimmermann, Oscar Andrey Herrera Sancho, Maxim Okhapkin, Christian Tamm, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, Braunschweig

We have built a linear Paul trap for laser spectroscopy of Th^+ ions. The trap is loaded with up to 10^5 ions by ablation from a thorium metal target using a nitrogen laser. The ion cloud is cooled to room temperature by collisions with $\approx 10^{-3}$ mbar of helium buffer gas. An extended cavity diode laser is used to excite the strongest Th^+ resonance line at 401.9 nm. Low-lying metastable levels are quenched by collisions with the buffer gas. This allows cyclic laser excitation and the observation of a fluorescence signal of more than 1 photon/s/ion.

This is a first step in a project towards laser excitation and detection of the nuclear excited state of Th-229 at 7.6 eV. We plan to perform multi-photon excitation of the electron shell and resonant transfer of the excitation to the nucleus, making use of the dense electronic level structure of Th^+.

Q 21.79 Tu 16:00 Lichthof

Photodiodenarray für die Leistungsstabilisierung von Lasern — •Patrick Kwee, Benno Willke und Karsten Danzmann — Albert-Einstein-Institut Hannover

Hoch empfindliche Photodetektoren werden in fast allen optischen Experimenten benötigt, um optische Signale in elektronische zu wandeln. Leistungsstabilisierungen von Lasern für optische Präzisionsexperimente, wie z.B. interferometrische Gravitationswellendetektoren, haben dabei eine der höchsten Anforderungen an diese Photodetektoren. Neben technischen Rauschquellen limitiert Schrotrauschen die Empfindlichkeit eines Photodetektors fundamental. Um das relative Schrotrauschen zu reduzieren, muss die Laserleistung und damit der detektierte Photostrom erhöht werden, wobei bereits das Leistungslimit herkömmlicher Photodioden erreicht ist. Durch die Aufteilung der Laserleistung auf ein Array aus 8 Photodioden, konnte ein hoher Gesamtstrom von 400 mA detektiert werden und damit eine bislang unerreichte Empfindlichkeit erzielt werden. Das hoch empfindliche Photodiodenarray und Ergebnisse einer durch Schrotrauschen limitierten Leistungsstabilisierung im Bereich von $2 \times 10^{-9}\,\mathrm{Hz}^{-1/2}$ bei 10 Hz eines Nd:YAG Lasers bei 1064 nm werden vorgestellt.

Q 21.80 Tu 16:00 Lichthof

Performance of all-optical phase-preserving amplitude regeneration techniques — •Daniel Endres[1], Klaus Sponsel[2], Christian Stefan[2], Georgy Onishchukov[2], Bernhard Schmauss[1], and and Gerd Leuchs[2] — [1]University of Erlangen, Erlangen, Germany — [2]Max-Planck Institute for the Science of Light, Erlangen, Germany

With the advance to higher bitrates and advanced modulation formats in fiber optical communication, the demand for new all-optical signal regeneration techniques arises. Two widely considered types of such regenerators are the nonlinear amplifying loop mirror [1] (NALM) based on a nonlinear fiber Sagnac interferometer and a fiber optical parametric amplifier [2] (FOPA) driven as an optical limiter.

In this work we compare these two techniques in their capability to reduce amplitude noise of phase-modulated signals with emphasis on differential phase-shift keying and their possible application in transmission systems. Both regenerators deteriorate the signal by excess noise generation of various origins. While the NALM performance is mainly limited due to Rayleigh backscattering, the major noise source of a FOPA is the pump noise. The work involves both simulation and experimental results.

[1] K. Cvecek, K. Sponsel, G. Onishchukov, B. Schmauss and G. Leuchs: 2R-Regeneration of an RZ-DPSK signal using a nonlinear amplifying loop mirror, IEEE Phot.Tech.Lett. **17**,3 p.146 (2005)
[2] K. Inoue: Optical level equalization based on gain saturation in fibre optical parametric amplifier, Electronics Letters **36**,12 p.1016 (2000)

Q 21.81 Tu 16:00 Lichthof

Laser-based acceleration of non-relativistic electrons in a photonic structure — •John Breuer and Peter Hommelhoff — Max-Planck-Institut für Quantenoptik, Garching bei München, Germany

We present simulation results of the acceleration of non-relativistic electrons passing by a fused-silica transmission grating that is illuminated with Titanium:sapphire femtosecond laser pulses. The concept of periodic field reversal is used to directly accelerate electrons with the electromagnetic field of the laser. We have optimized the grating parameters towards maximum momentum transfer and expect accelerating gradients of up to 100 MeV/m for 27-keV electrons traveling by the grating at a distance of 30 nm. We will describe the current status of a recently started proof-of-principle experiment and discuss applications of this new form of laser-based electronic motion control.

Q 21.82 Tu 16:00 Lichthof

A high-harmonic microfocus beamline for photoemission spectroscopy — •Roland Kalms, Armin Azima, Filip Budzyn, Patrick Rüdiger, Thomas Klee, Michael Schulz, Lasse Schroedter, Marek Wieland, and Markus Drescher — Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We present the design and characterisation of a high-harmonic beamline with an experimental endstation suited for photoemission spectroscopy on (magnetised) surfaces. The pulses of a femtosecond laser system (800 nm, 3 mJ, 30 fs, 1 kHz) are focussed into a gas-filled tube to create high-harmonic emission. The output in the VUV-range (around 90 eV with Neon as target medium) which can be spectrally characterised with a self-made grating spectrometer has been optimised with respect to the intensity and the beam profile. After the selection of the desired harmonic order via a multilayer mirror the radiation is focussed with an ellipsoidal mirror onto the sample surface. The experimental endstation of the beamline allows the in-situ preparation of thin films and is equipped with a time-of-flight spectrometer and a scanning stage for spatially resolved photoemission studies. One can also apply a pulsed magnetic field to remanently magnetise the samples for XMLDAD measurements.

Q 21.83 Tu 16:00 Lichthof

Accurate generation of polarization-shaped fs laser pulses with application to photoelectron imaging spectroscopy — •Jens Köhler, Marc Krug, Cristian Sarpe-Tudoran, Tim Bayer, 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

Femtosecond polarization pulse shaping is a tool to generate laser pulses with a time-dependent polarization profile on an ultrashort timescale. The realization of such pulses is often affected by undesired polarization-dependent amplitude modulations and phase shifts introduced by the pulse shaper itself as well as other optical elements in the beam. In order to ensure *accurate* generation of polarization-shaped pulses, these effects have to be taken into account and the optical setup has to be corrected accordingly. Different schemes for detection and compensation of these effects are presented and compared. Recently, realization of accurately generated polarization-shaped laser pulses in the interaction region of a vacuum chamber has been demonstrated by photoelectron imaging spectroscopy [1]. Currently, we extend the application of our polarization shaping capabilities to the generation of complex-shaped free-electron wave packets characterized by three-dimensional tomographic reconstruction methods [2]. First results are presented.

[1] M. Wollenhaupt et al., Applied Physics B, 95(2), 245-259, (2009)
[2] M. Wollenhaupt et al., Applied Physics B, 95(4), 647-651, (2009)

Q 21.84 Tu 16:00 Lichthof

Single-sweep production of complex 3D-waveguide devices in fused-silica produced by adaptive femtosecond laser writing — •Matthias Pospiech[1], Benjamin Väckenstedt[1], Moritz Emons[1], Guido Palmer[1], and Uwe Morgner[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland — [2]Laser Zentrum Hannover e.V.

We report on a novel method to create multiple waveguides simultaneously in different depths in fused silica. A combination of adaptive beam shaping with femtosecond laser writing is used to simultaneously write two waveguides with changing separation and depth. The method is based on a programmable phase modulator with dynamically varying phase-pattern during the writing process. It can be employed to demonstrate various photonic devices such as couplers, splitters and interferometers. We give an introduction into the method and demonstrate the latest results.

Q 21.85 Tu 16:00 Lichthof

Status of the ELBE-DRACO X-ray source — •Axel Jochmann, Alexander Debus, Christoph Erler, Ulf Lehnert, Stephan Kraft, Michael Bussmann, Thomas Cowan, Roland Sauerbrey, and Ulrich Schramm — Forschungszentrum Dresden-Rossendorf, Bautzner Landstr. 400, 01328 Dresden, Germany

We report on the latest status of the Thomson-Backscattering experiment at the FZ Dresden-Rossendorf. The unique opportunity to interact a 150 TW high intensity laser pulse with an electron linac of small emittance and high brilliance enables us to create a bright X-ray light source for a variety of medical and chemical studies. The high average current of the ELBE linear accelerator opens up the possibility to scale the experiment to high average power if matched with a laser of high repetition rate. To transport laser and electron beam to the also newly installed experimental chamber we built two beamlines into the shielded target area. Therefore we are using an active stabilization system which was installed and commissioned.

Q 21.86 Tu 16:00 Lichthof

Processes of different nature in femtosecond-laser-induced electron emission from ultrasharp metal tips — •Michael Krüger, Markus Schenk, Johannes Hoffrogge, Hanno Kaupp, and Peter Hommelhoff — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

We investigate electron emission from sharp tungsten tips induced by few-cycle femtosecond laser pulses. This unique combination of tip and laser pulse should provide high temporal and spatial coherence of the photo-emitted electrons. We report on emission processes triggered by 6fs Ti:sa laser pulses. A retarding field electron spectrometer enables identification of these processes. Typically we observe 10^{-4} to 10^{+3} electrons per pulse depending on the experimental parameters. At low laser intensities ($< 10^{12}$ W/cm^2), multiphoton absorption and subsequent over-barrier emission occur (3-photon process). We can tune the effective workfunction by applying a static electric field to the tip, and thus are able to decrease the number of photons necessary to overcome the potential barrier (2-photon process). At high DC electric fields, additionally tunneling of photo-excited electrons out of the tip is observed (photo-field emission, 1-photon process). At high laser intensities on the order of 10^{12} W/cm^2, electrons with energies corresponding to absorption of up to 7 photons are found (above-threshold photoemission). The nonlinearity of the processes can be determined by interferometric autocorrelation traces using the tip as nonlinear element. We model the observed energy distributions and have evidence that emission takes place via surface states for a certain parameter range.

Q 21.87 Tu 16:00 Lichthof

Glass-fiber-based Fabry-Perot resonators — •Christian Wuttke[1], Boris N. Chichkov[3], Andreas Jöckel[1], Michael Kappl[2], Jürgen Koch[3], Kotaro Obata[3], and Arno Rauschenbeutel[1] — [1]QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz — [2]Max-Planck-Institut für Polymerforschung, 55128 Mainz — [3]Laser Zentrum Hannover e.V., 30419 Hannover

We present experimental results on the fabrication and characterisation of glass-fiber-based Fabry-Perot resonators. In one approach Bragg-reflectors are created on optical nanofibers which can be used to build a fiber-coupled monolithic microresonator. Optical nanofibers are realised from standard optical fibers in a heat and pull process to produce a waist with a diameter of 500 nm. The structure is realised by coating the waist with periodically varying polymer films using two photon polymerization (2PP) or carving structures out of the nanofiber waist by focused ion beam milling (FIB) or laser ablation. The optical properties are spectrally characterised by transmission and reflection measurements and compared to theoretical predictions using a finite difference time domain model. Another approach uses dielectric mirrors that are applied to the endfacets of standard optical fibers with an integrated taper. These resonators can be used to precisely measure the loss of the taper. Long term measurements are made under different environmental conditions.

Financial support by the ESF (EURYI Award) and the Volkswagen Foundation (Lichtenberg Professorship) is gratefully acknowledged.

Q 21.88 Tu 16:00 Lichthof

Fabrication of Bragg Gratings for Silicon-on-Insulator Waveguides — •Harald Richter[1], David Stolarek[1], Lars Zimmermann[1,2], Joachim Bauer[1], Steffen Marschmeyer[1], Ivano Giuntoni[2], Andrzej Gajda[2], and Bernd Tillack[1,2] — [1]IHP Frankfurt, Im Technologiepark 25, 15236 Frankfurt (Oder) — [2]Technische Universität Berlin, HFT 4, Einsteinufer 25, 10587 Berlin

Bragg gratings established in the last years as an important waveguide component for achieving wavelength selective filter functions. Fiber based Bragg grating structures can be considered state of the art for applications in the optical communications and for sensing. The implementation of such components on silicon waveguides is highly desirable, to permit the realization of integrated resonators and optical filters for wavelength selection or for dispersion compensation. We present a wafer level technology based on deep ultra-violet (DUV) lithography to fabricate Bragg gratings on Silicon-on-insulator (SOI) rib waveguides. The principle of the used double patterning technique is presented, as well the influence of the process variations on the device performances. Usable structures were realized, exhibiting a small overlay error and non-rectangular grating profile. The optical characterization showed that the presented technique is capable to provide gratings with performance comparable to state of the art gratings patterned with electron-beam lithography.

Q 21.89 Tu 16:00 Lichthof

Propagation of ultrafast pulses in transparent media — Hatem Dachraoui, •Christian Oberer, Martin Michelswirth, and Ulrich Heinzmann — Molecular and Surface Physics, Faculty of Physics, Bielefeld University

Time- and space-resolved optical transmittance has been used to study the propagation of a femtosecond laser pulse in transparent media (fused silica, LiF) at various input laser energies (5 - 50 TW/cm^2). The results identify different regimes of propagation, revealing the interplay between self-focusing, multiphoton absorption, and plasma defocussing.

Q 21.90 Tu 16:00 Lichthof

Slow Light Enhanced Four Wave Mixing Processes — •Sebastian Jakobs, Bernd Schmid, Alexander Petrov, and Manfred Eich — Institute for Optical end Electronic Materials, Hamburg University of Technology

In this presentation slow light enhanced four wave mixing processes in a silicon based photonic crystal wave guide (PCW) are discussed. Slow light in the frequency range of interest is achieved through variation of hole radii and through variation of the position of holes in the second and third row. The focus will be on slow light enhancement of degenerate four wave mixing (DFWM) and third harmonic generation (THG) in the case of a pure silicon PCW as well as in the case of a PCW infiltrated with functionalised nonlinear organic polymers.

DFWM is proposed as an amplification method and the conversion efficiency is increased by means of the group index dependence of the nonlinear gain g. At the same time phase matching is achieved by adjusting the dispersion relation appropriately.

A concept for slow light enhanced THG is presented and analysed, in which the fundamental and the third harmonic waves are guided in the structure and phase matched.

Q 21.91 Tu 16:00 Lichthof

Purcell effect and light collection from a single emitter inside a diamond nano rod — •Helmut Rathgen[1], Birgit Hausmann[2], Marko Loncar[2], Fedor Jelezko[1], Jörg Wrachtrup[1], Phil Hemmer[1], and Tom Babinec[2] — [1]3. Physikalisches Institut, Uni Stuttgart — [2]Laboratory for Nanoscale Optics

We study the emission of light from single NV centers inside diamond nano rods. The rod acts on the emitter in two ways: 1. as an air clad optical fiber with a very high refractive index (n=2.4), resulting in an exceptionally high N.A., thus enabling efficient collection of emitted light 2. The strong optical confinement in radial direction results in an increase of the spontaneous emission rate and Purcell Effect. The device holds promis for a high brightness single photon source operating under ambient conditions, and is suitable for room temperature photonic and quantum information processing applications.

Q 21.92 Tu 16:00 Lichthof

Injection locking of a phonon laser — •Sebastian Knünz[1], Maximilian Herrmann[1], Valentin Batteiger[1], Guido Saathoff[1], Theodor W. Hänsch[1], Kerry Vahala[2], and Thomas Udem[1] — [1]MPQ, Garching, Germany — [2]Caltech, Pasadena, USA

A single trapped ion, addressed by a red-detuned cooling laser and simultaneously illuminated by a blue-detuned pump laser can exhibit oscillatory motion with a well defined threshold. We have shown that this is the result of stimulated emission of center-of-mass phonons, providing saturable amplification of the motion. This constitutes the mechanical analogue of a laser [1]. Additionally we report on a first application of our phonon laser which further substantiates the analogy to an optical laser: we lock the phonon laser to an external rf signal, an effect widely known as injection locking. Using phase sensitive stroboscopic imaging and a spatially selective Fourier transform technique to generate motional spectra we find excellent agreement with injection locking theory in and outside the locking range. Since the forces which evoke this effect are in the order of 10^{-21} N this system appears to be promising for ultra-sensitive force detection. [1] K. Vahala et al., Nature Physics 5, 682 (2009).

Q 22: Quantum Effects: Entanglement and Decoherence II

Time: Wednesday 10:30–12:15 Location: A 310

Q 22.1 We 10:30 A 310

Dynamic entanglement in oscillating molecules and potential biological implications — •Gian Giacomo Guerreschi[1,2], Jianming Cai[1,2], Sandu Popescu[3,4], and Hans J. Briegel[1,2] — [1]Institut für Theoretische Physik, Universität Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation der ÖAW, Innsbruck, Austria — [3]H.H. Wills Physics Laboratory, University of Bristol, U.K. — [4]Hewlett-Packard Laboratories, Stoke Gifford, U.K.

The fragility of entanglement under noise and decoherence is often used as an argument to dismiss the possibility of entanglement in biological systems. Here, we however demonstrate that entanglement can persistently recur in an oscillating two-spin molecule coupled to a hot and noisy environment, in which no static entanglement can survive. The system, driven through the oscillatory motions, represents a non-equilibrium quantum system. As a building block, the present simple mechanism supports the perspective that entanglement can exist also in systems which are exposed to a hot environment and to high levels of decoherence, which we expect e.g. for biological systems. Experimental simulation of our model with trapped ions is within reach of the current state-of-the-art quantum technologies.

Q 22.2 We 10:45 A 310

Bell*s inequalities can be violated due to a trivial experimental loophole. Nonlocality is still unproven — •Karl Otto Greulich — Fritz Lipmann Institut Jena

Usually, optical experiments on the violation of Bell*s inequalities are theoretically explained with an atom as light source which emits two entangled photons. The experimental verification is, however, completely different. In essentially all real experiments, a down-converting birefringent crystal, pumped by a laser, is used. Thereby it is assumed that one can work, by sharp attenuation and spatial selection, in the *single photon* limit. This approach is risky, since there is growing evidence that it is extremely difficult, if not impossible, to safely achieve such a single photon limit from a multi atom light source. If in this respect a minimal error occurs, Bell*s inequalities can be violated in a very trivial way. Since this loophole so far never has been considered, a safe proof of nonlocality is still elusive.

Q 22.3 We 11:00 A 310

Environment-induced bound entanglement — •Julio T. Barreiro[1], Philipp Schindler[1], Otfried Gühne[2,3], Thomas Monz[1], Michael Chwalla[1], Volckmar Nebendahl[2], Markus Hennrich[1], and Rainer Blatt[1,3] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria — [2]Institut für Theoretische Physik, Universität Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria — [3]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, 6020 Innsbruck, Austria

Entanglement, the most powerful physical resource for quantum information, has been conjectured to decay, under the influence of decoherence, into a seemingly unprofitable form, known as bound entanglement. Bound entangled states have several applications, but most importantly, they underpin our understanding of multiparticle entanglement and its dynamics under decohering environments.

Here, we discuss our experiments with trapped calcium ions showing the existence of bound entanglement in nature. By embedding an entangled and distillable quantum state of four qubits in a dephasing environment (via spontaneous decay), we explore the rich dynamics of multiparticle entanglement. Upon the action of the environment, we observe the transition from multiparticle entanglement, via bound entanglement, to a fully separable state. The environment possibly even leads to a novel kind of bound entangled state, separable in all bipartitions, but not fully separable. To our knowledge, our work is the first to experimentally explore such multiparticle entanglement dynamics.

Q 22.4 We 11:15 A 310

Scattering laser light on cold atoms: multiple scattering signals from single-atom responses — •Tobias Geiger[1], Thomas Wellens[1], Vyacheslav Shatokhin[1,2], and Andreas Buchleitner[1] — [1]Institute of Physics, University of Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany — [2]Stepanov Institute of Physics, National Academy of Sciences, Nezavisimosti Ave 68, 220072 Minsk, Belarus

We present a new approach to calculate the spectrum of a strong laser field multiply and inelastically scattered between cold atoms. A detailed diagrammatic ansatz is used to reduce the known master equation results derived in the complete composite Hilbert space of a few atoms to optical Bloch equations for *single atoms*, which can be linked to each other in a self consistent way. Equivalence between the exact solution and our new approach is derived in the case of large distances between the atoms. Putting our new approach to work, the treatment of mutiple scattering of intense laser light by a dilute cloud of many atoms comes into reach.

Q 22.5 We 11:30 A 310

Quantum non-linear optics with ultra-cold atoms in an optical lattice — •Hessam Habibian[1,2], Stefano Zippilli[2], Stefan Rist[1,2], and Giovanna Morigi[2] — [1]Grup d'Óptica, Departament de Física, Universitat Autònoma de Barcelona, E-08193 Barcelona, Spain — [2]Theoretische Physik, Universität des Saarlandes, D-66041 Saarbrücken, Germany

In this work, it is shown that an array of atoms inside an optical cavity can act as a controllable quantum non-linear optical medium. Here, the quantum properties of the generated light can be tuned by changing the interparticle distance with respect to cavity mode wavelength.

We characterize the quantum nature of the emitted light by the lattice as a function of the interparticle distance and the coupling amplitude between the lattice and the electromagnetic field and we discuss in which regime for the parameters the system can act as a single photon source.

Q 22.6 We 11:45 A 310

Detection of avoided crossings by fidelity — •Patrick Plötz[1,2], Michael Lubasch[1,2,3], and Sandro Wimberger[1,2] — [1]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 19, 69120 Heidelberg — [2]Heidelberg Graduate School of Fundamental Physics, Albert-Ueberle-Str. 3-5, 69120 Heidelberg — [3]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

The overlap of eigenstates of two slightly different Hamiltonians—the fidelity—is proposed as an easy-to-use detector of avoided crossings in the energy spectrum [1]. It has been used to detect quantum phase transitions in the ground state of many-body quantum systems, and we lift its application to the complete energy spectrum. The value of this new Hilbert space measure for characterising complex quantum spectra is underlined by spectral analysis of many-body Bose–Hubbard systems.

[1] P. Plötz, M. Lubasch, and S. Wimberger, *Detection of avoided crossings by fidelity*, arXiv:0909.4333v1 [quant-ph].

Q 22.7 We 12:00 A 310

Complete suppression of atomic spontaneous emission and exited level shift with a half cavity — •Hétet Gabriel, Slodicka Lukas, Hennrich Markus, and Blatt Rainer — Institut für Experimentalphysik Innsbruck University, Austria

In this presentation we investigate the emission properties of a single atom in front of a spherical mirror covering half of the emission solid angle. We show that in this configuration it is possible to completely suppress the spontaneous emission of the atom and the level shift of its excited electronic state.

First, we explain the underlying physical process on a simplied one dimensional model. We then present a three dimensional theory that demonstrates that the density of modes around a linearly polarized atomic dipole can reach zero within a small volume around the atom.

We discuss the implications of such a finding for quantum information processing and QED effects in free space, and present the ongoing experimental efforts towards observing large effects using single trapped ions in front of high numerical aperture optical elements.

Q 23: Quantum Effects: Light Scattering and Propagation II / QED I

Time: Wednesday 10:30–12:30 Location: A 320

Group Report Q 23.1 We 10:30 A 320

Thermal Casimir–Polder forces — •Stefan Yoshi Buhmann[1], Simen Ådnøy Ellingsen[2], and Stefan Scheel[1] — [1]Quantum Optics and Laser Science, Blackett Laboratory, Imperial College London, Prince Consort Road, London SW7 2AZ, United Kingdom — [2]Department of Energy and Process Engineering, Norwegian University of Science and Technology, N-7491 Trondheim, Norway

We discuss the influence of thermal photons on the Casimir–Polder force between atoms and bodies within the framework of macroscopic quantum electrodynamics. The internal evolution of an atom is found to be governed by environment-dependent heating and cooling rates [1]; examples are given for the ground-state heating rates of polar molecules near a room-temperature surface. On this basis, the time-dependent Casimir–Polder force between an atom and a body at finite temperature is studied [2]. It is shown that a thermal non-equilibrium may lead to resonant forces even on ground-state atoms [3]. We discuss the prospect of enhancing these forces via cavities to facilitate atom manipulation [4]. After the atom has reached thermal equilibrium with its environment, the atom is subject to the nonresonant Lifshitz force only.

[1] S. Y. Buhmann *et al.* Phys. Rev. A **78**, 052901 (2008).
[2] S. Y. Buhmann, S. Scheel, Phys. Rev. Lett. **100**, 253201 (2008).
[3] S. Å. Ellingsen *et al.*, Phys. Rev. A **79**, 052903 (2009).
[4] S. Å. Ellingsen *et al.*, Phys. Rev. A **80**, 022901 (2009).

Q 23.2 We 11:00 A 320

Casimir force on amplifying bodies — •Agnes Sambale[1], Dirk-Gunnar Welsch[1], and Stefan Yoshi Buhmann[2] — [1]Theoretisch-Physikalisches Institut, F.-Schiller-Universität Jena, Germany — [2]Blacket Laboratory, Imperial College London, United Kingdom

Although most studies on the Casimir forces have so far assumed absorbing bodies, it has recently been realized that besides importance in fundamental research, dispersion forces on amplifying (meta)materials can lead to far-reaching applications. For instance, amplifying media may enhance the influence of left-handed material properties or even lead to repulsive forces.

Within the framework of macroscopic quantum electrodynamics in arbitrary linear media and Lorentz force approach, we present a formula for the Casimir force acting on an amplifying, locally responding, and isotropic polarisable body (Phys. Rev. A 80, 051801(R), 2009). We show that the force can be decomposed into a resonant part arising from emission processes and an off-resonant part looking formally the same as for a purely absorbing medium. We demonstrate that the Casimir force on a weakly polarisable (partially) amplifying body in a purely absorbing environment can be expressed as a sum over the Casimir–Polder forces on the excited atoms the body consists of. This result reveals the common (microscopic) origin of dispersion forces even for excited systems.

Q 23.3 We 11:15 A 320

Direct Measurement of intermediate-range Casimir-Polder potentials — •Helmar Bender, Phillippe Courteille, Carsten Marzok, Christian Stehle, Claus Zimmermann, and Sebastian Slama — Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen

The zero-point vacuum fluctuations of the electromagnetic field are a result of fundamental importance in quantum electrodynamics (QED). One of its few measurable effects is the force between a groundstate atom and a solid surface. Measurements of the corresponding Casimir-Polder (CP) potential exist for both, the short distance regime and the long distance regime where retardation has to be taken into account.

We present the first direct measurement of the CP-potential in the intermediate regime at distances of about 150-250 nm where retardation slowly comes into play. The measurement is based on the reflection of ultracold Rb-atoms from evanescent wave barriers. With this method we are able to deduce the CP-potential as a function of the distance without making any prior assumptions on its shape.

The results are compared to the analytical expressions existent for the long- and the short range regime as well as to a full QED-calculation. The full QED-calculation agrees best with our data.

Q 23.4 We 11:30 A 320

Counting Statistics in Multi-stable Systems — •Gernot Schaller, Gerold Kiesslich, and Tobias Brandes — Institut für Theoretische Physik, Hardenbergstraße 36, Technische Universität Berlin, D-10623 Berlin, Germany

Using a generic model for stochastic transport through a single quantum dot that is modified by the Coulomb interaction of environmental (weakly coupled) quantum dots, we derive general properties of the full counting statistics for multi-stable Markovian transport systems. We study the temporal crossover from multi-modal to broad uni-modal distributions depending on the initial mixture, the long-term asymptotics and the divergence of the cumulants in the limit of a large number of transport branches. These findings demonstrate that the counting statistics of a single resonant level may be used to probe background charge configurations.

[1.] G. Schaller, G. Kießlich, and T. Brandes, `arXiv:0912.2887`.

[2.] G. Schaller, G. Kießlich, and T. Brandes, Phys. Rev. B **80**, 245107 (2009).

Q 23.5 We 11:45 A 320

Hemispherical resonators with embedded nanocrystal-quantum-dot-emitters — •Johannes Haase[1], Paul Mundra[2], Günter Risse[4], Susumu Shinohara[3], Martina Hentschel[3], Hartmut Fröb[1], Alexander Eychmüller[2], and Karl Leo[1] — [1]Institut für Angewandte Photophysik, TU-Dresden — [2]Physikalische Chemie / Elektrochemie, TU-Dresden — [3]Max-Planck-Institut für Physik komplexer Systeme, Dresden — [4]Gesellschaft zur Förderung von Medizin-, Bio- und Umwelttechnologien e.V., Dresden

Spherical resonators have the outstanding ability to confine light in three dimensions with comparatively highly quality factors Q as a result of the high efficient total internal reflection. By embedding emitters into those cavities, it is possible to couple their emission to the whispering gallery modes (WGM) of the sphere. The incoupling of excitation light and especially the selective excitation of different regions in the sphere, however, is often a problem. We therefore investigate a new method to produce hemispherical resonators on a distributed Bragg reflector (DBR). Consequently, we have a three dimensional confinement at the emission wavelength and a planar side (the DBR), which is transparent at the excitation wavelength. Thus it is possible to selectively excite emitters in different areas of the hemisphere. We show the preparation of these structures with embedded nanocrystal-quantum-dots (NQD) as emitters. Additionally, we report on the results of micro-photoluminescence measurements of these structures, showing a highly efficient incoupling of NQD emission into WGMs. The modes can be described using a two-dimensional model.

Q 23.6 We 12:00 A 320

Polarization noise in hollow-core photonic crystal fibers — •Wenjia Zhong[1,2], Bettina Heim[1,2], Dominique Elser[1,2], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max-Planck-Institut für die Physik des Lichts, Erlangen — [2]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, Erlangen

Thermally induced Brillouin scattering in glass fibers can lead to phase and polarization noise. Although this kind of noise is weak, it can degrade the purity of quantum states. In hollow-core photonic crystal fibers (HCPCFs), light is guided due to a photonic-bandgap structure consisting of a periodic array of air holes in silica glass. Since the light travels in the central air core, Brillouin scattering is supposed to be reduced as compared to a solid-core fiber. Still a precise characterization is necessary in order to estimate the influence of this noise in quantum experiments.We perform quantum-noise-limited measurements of polarization noise in a HCPCF considering several transverse modes of light.

Q 23.7 We 12:15 A 320

Motional effects on the efficiency of excitation transfer — •Markus Tiersch[1,2], Ali Asadian[1,2], Gian Giacomo Guerreschi[1,2], Jianming Cai[1,2], Sandu Popescu[3,4], 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, Technikerstr. 25, A-6020 Innsbruck, Austria — [3]H.H. Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol BS8 1TL, U.K. — [4]Hewlett-Packard Laboratories, Stoke Gifford, Bristol BS12 6QZ, U.K.

The transfer of energy plays a vital role in many natural and technological processes. In this work, we study the effects of classical motion on the electronic excitation transfer through a chain of interacting molecules. Our investigation demonstrates that for various types of oscillations, in a suitable range of frequencies, the efficiency of the energy transfer is significantly enhanced. This enhancement is a signature of the collaborative interplay between the coherent evolution of the excitation and the classical motion of the molecules. This effect has no analogue in the classical, incoherent energy transfer. In addition, we discuss control techniques to optimize the excitation transfer along the chain.

Q 24: Quantum Gases: Mixtures and Spinor Gases

Time: Wednesday 10:30–12:30 Location: E 001

Q 24.1 We 10:30 E 001

Bose-Fermi Mixtures in Optical Lattices at Finite Temperature Beyond the One-Band Approximation — •Matthias Ohliger[1], Marcus Cramer[2], and Jens Eisert[1] — [1]Institute for Physics and Astronomy, University of Potsdam, Potsdam, Germany — [2]Institute for Mathematical Sciences, Imperial College, London, United Kingdom

In this talk we address the question how an admixture of spin-polarized Fermions alter the properties and especially the position of the superfluid transition of Bosons in an optical lattice. Different mechanism have been discussed in the literature focusing eiter on zero-temperature effects like self-trapping or thermal effects.

We have performed both analytic and numerical calculations to simultaneously account for finite temperature and interactions beyond the one-band Bose-Fermi-Hubbard model. We show results corresponding to realistic experimental parameters and discuss the regimes where the different effects are most important and also the interplay between them.

Q 24.2 We 10:45 E 001

Parametric amplification of quantum spin fluctuations in a spinor Bose-Einstein condensate — •Gebremedhn Gebreyesus[1], Philipp Hyllus[2], Frank Deuretzbacher[1], and Luis Santos[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167, Germany — [2]BEC-INFM, Dipartimento di Fisica, Università di Trento, Via Sommarive 14, I-38050 Povo, Italy

In this presentation we analyze the spinor dynamics in spinor condensates (with particular emphasis on the Rb87 F=2 case). Starting from an initial condensate in the Zeeman state m=0, the initial stages of the dynamics are characterized by a correlated pair-creation into m=+1 and -1 which closely resembles parametric amplification in quantum optics. This coherent dynamics is induced by spin-changing collisions, but, as we shall show in detail, the actual amplification gain largely depends on the interplay between these collisions, quadratic Zeeman effect, and external confinement. In particular, the magnetic-field dependence of the amplification (which presents a striking multiresonant character) is shown to map the instability of the corresponding spin excitations. We analyze also in detail the triggering mechanism showing that under proper conditions the systems is basically insensitive against spurious seeding, being purely driven by quantum spin fluctuations. In the last part of this presentation we shall discuss recent results on the number statistics of the parametrically amplified clouds in m=+1 and -1.

Q 24.3 We 11:00 E 001

Excitation modes of a parametric amplifier for matter waves — Carsten Klempt[1], Oliver Topic[1], Garu Gebreyesus[2], •Manuel Scherer[1], Bernd Lücke[1], Frank Deuretzbacher[2], Phillip Hyllus[2], Wolfgang Ertmer[1], Luis Santos[2], and Jan Arlt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Institut für theoretische Physik, Leibniz Universität Hannover

Matter wave optics with ultracold atoms has reached the point where non-classical states can be prepared and their fascinating properties can be explored. In optics, parametric down conversion is routinely used to generate light with squeezed observables as well as highly entangled photon pairs. The applications of these non-classical states range from fundamental tests of quantum mechanics to improved interferometers and quantum computation. Therefore, it is of great interest to realize such non-classical states with matter waves. Bose-Einstein condensates with non-zero spin can provide a mechanism analogous to parametric down conversion, thus enabling the generation of non-classical matter waves. We have observed magnetic field dependent spin resonances where the spin dynamics is dramatically enhanced. On these resonances, a parametric amplification process produces entangled atom pairs in excited spatial modes which are similar to the modes of a classical membrane with fixed boundary conditions. Intriguingly, these spatial modes can carry orbital angular momentum. A first analysis shows that the system may serve as a source of atomic Bell pairs with entangled angular momentum states, possibly allowing for Bell type measurements with neutral atoms.

Q 24.4 We 11:15 E 001

Phase diagram of Bose-Fermi mixtures in the light fermion limit — •Alexander Mering and Michael Fleischhauer — Fachbereich Physik and research center OPTIMAS, Technische Universität Kaiserslautern

We present analytic results for the phase diagram of Bose-Fermi mixtures in the limit of ultralight fermions. Starting from a discussion of the dependence of the Mott insulating phases on the density of fermions we show how the bosonic phase diagram can be understood in terms of a purely bosonic system with underlying complex potential induced by the fermions. Treating the special case of half fermionic filling we show the emergence of a charge density wave phase with a strong interplay between bosons and fermions. In terms of an effective theory we derive the full phase diagram in this case, giving analytic results for all incompressible phases including the CDW phase. Furthermore the existence of regions of coexistence between Mott insulators and CDW is predicted. All analytic results are supported by numerical results obtained by DMRG, showing a good agreement to the analytic predictions.

Q 24.5 We 11:30 E 001

Dynamical Correlations in Spinor-Bose Gases — Jürgen Bosse[1], •Benno Liebchen[1], and Axel Pelster[2,3] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Institut für Physik und Astronomie, Karl-Liebknecht-Str. 24 14476 Potsdam, Germany — [3]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

The dynamical structure factor $S(\mathbf{q},\omega)$ and the response spectrum $G''(\mathbf{q},\omega)$ of both particle and magnetization density have been calculated for trapped ideal $F=1$ spinor-Bose gases at *finite* temperatures. Such systems with fixed magnetization are known to show two BEC phase transitions [1]. The resulting nonlinear relation between the magnetic field and the magnetization is presented for various temperatures. In the special case of a homogeneous system, earlier results for the *linear* magnetic susceptibility are reproduced [2,3].

[1] T. Isoshima, T. Ohmi, and K. Machida, J. Phys. Soc. J. **69**, 3864 (2000)
[2] J. Bosse, K.N. Pathak, and G.S. Singh, arXiv:0912.2833, Physica A **389**, 408 (2010)
[3] J. Bosse, K.N. Pathak, and G.S. Singh, arXiv:0912.2841

Q 24.6 We 11:45 E 001

Dipolar effects on the parametric amplification of spinor Bose-Einstein condensates — •Frank Deuretzbacher, Gebremedhn Gebreyesus, and Luis Santos — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167, Germany

In this presentation we analyze the spinor dynamics in spinor Bose-Einstein condensates (with particular emphasis on the Rb87 F=1 case). Starting from an initial condensate in the Zeeman state m=0, the initial stages of the dynamics are characterized by a correlated pair-creation into m=+1 and -1 which closely resembles parametric amplification in quantum optics. This coherent dynamics is induced by spin-changing collisions, which having a very low energy scale associated, are very sensitive to other small energy scales. In particular, as we shall discuss in detail in this presentation, the spinor dynamics is shown to be largely modified by the weak magnetic dipole-dipole interactions. We analyze in detail the dipolar effects (in particular the modification of the parametric amplification dependening on the magnetic-field orientation) and how these effects are extremely sensitive with respect to even rather weak magnetic field gradients in the experiments. In the last part of this presentation, we shall discuss the formation of spatial patterns in the parametrically amplified clouds in m=+1 and -1.

Q 24.7 We 12:00 E 001

Towards the creation of a quantum gas of polar ground state molecules — •Markus Debatin[1], Almar Lercher[1], Bastian Schuster[1], Raffael Rameshan[1], David Baier[1], Francesca Ferlaino[1], Tetsu Takekoshi[1], Rudolf Grimm[1,2], and Hanns-Christoph Naegerl[1] — [1]Institut für Experimentalphysik Universität Innsbruck — [2]Institut für Quantenoptik und Quanteninformation IQOQI Innsbruck

The creation of quantum gases of deeply-bound ground state molecules, c.f. Danzl et al.[1] and Ni et al. [2], has recently attracted a lot of attention. In our Rb-Cs mixture experiment the focus is on the creation of a bosonic quantum gas of polar ground state RbCs molecules using a stimulated adiabatic Raman transfer (STIRAP) scheme similar to that used in Ref. [1]. Our current goal is the creation of a dual-species BEC as a precursor to molecule production and STIRAP. We are able to create large all-optical BECs for Rb and Cs separately, but comparatively high 3-body interspecies loss rates present a challenge. In the talk, data on 3-body effects is presented and approaches to stabilize the mixture are discussed. After creating a high phase-space density mixture we will create Feshbach molecules and perform high-resolution molecular spectroscopy with the aim to develop a scheme for RbCs ground-state transfer.

[1] J.G. Danzl et al., Science 321, 1062 (2008),
[2] K.-K. Ni et al., Science 322, 231 (2008).

Q 24.8 We 12:15 E 001

Quantum phase diffusion in interacting Bose-Fermi mixtures — •Simon Braun[1], Sebastian Will[1], Thorsten Best[2], Philipp Ronzheimer[1], Michael Schreiber[1], Ulrich Schneider[1], Tim Rom[1], Lucia Hackermüller[1], Kin-Chung Fong[1], Dirk-Sören Lühmann[3], and Immanuel Bloch[1] — [1]Ludwig-Maximilians-Universität München — [2]ALU Freiburg — [3]Universität Hamburg

The system of ultracold bosonic atoms in a 3D optical lattice is commonly described by the Bose-Hubbard model (BHM). While this model only takes into account the lowest Bloch band, theoretical studies indicate that interactions may bring multi-band effects into play.

We have been able to observe and quantify multi-band physics beyond the single-band BHM by studying quantum phase diffusion of a ^{87}Rb BEC in a 3D optical lattice. We observed more than 40 collapses and revivals of the matterwave field, the period of which is determined by the onsite interaction energy. This technique allowed for a precise measurement of interaction energies, being in excellent agreement with theoretical results of a multi-orbital calculation.

In the presence of fermionic ^{40}K atoms, the quantum phase diffusion dynamics show a strong dependence on the interspecies interaction between K and Rb, which can be conveniently tuned via a Feshbach resonance. By driving Raman transitions between Zeeman sublevels we can additionally switch the interspecies interaction almost instantaneously. Our measurements show how interspecies interactions both affect the number statistics in the system and lead to renormalized Hubbard parameters, again revealing multi-band physics in optical lattices.

Q 25: Quantum Information: Quantum Communication I

Time: Wednesday 10:30–12:30 Location: E 214

Q 25.1 We 10:30 E 214

Atmospheric quantum communication with continuous polarization variables — •Bettina Heim[1,2], Dominique Elser[1,2], Claudia Dürr[1,2,3], Tim Bartley[1,2,4], Christoffer Wittmann[1,2], Denis Sych[1,2], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max-Planck-Institut für die Physik des Lichts, Erlangen — [2]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg — [3]Hochschule für Angewandte Wissenschaften - FH München — [4]Clarendon Laboratory, University of Oxford

We present experimental work on the demonstration of free space quantum communication using continuous polarization variables. In a prepare-and-measure setup, binary-encoded coherent polarization states are transmitted through an atmospheric quantum channel of 100m. The signal states are measured using homodyne detection with the help of a local oscillator (LO) occupying the same spatial mode as the signal. Thus, the interference of signal and LO is excellent. Additionally, the LO acts as spatial and spectral filter, which allows for unrestrained daylight operation. Currently, we are working on expanding the link distance to 1.6km in an urban environment. Influences of the turbulent atmosphere resulting in spatial beam jitter could cause attenuation as well as intensity noise at the detector [1]. We investigate these potentially harmful effects and present methods to compensate for them.

[1] B. Heim et al., Applied Physics B, published online
http://dx.doi.org/10.1007/s00340-009-3838-8

Q 25.2 We 10:45 E 214

Coherent optical memory with GHz bandwidth — •Klaus Reim[1], Joshua Nunn[1], Virginia Lorenz[2], Ben Sussman[3], Ka Lee[1], Nathan Langford[1], Dieter Jaksch[1], and Ian Walmsley[1] — [1]Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU, UK — [2]Department of Physics, University of Delaware, Newark, DE 19716, USA — [3]National Research Council of Canada, Ottawa, Ontario K1A 0R6, Canada

Quantum memories, capable of controllably storing and releasing a light pulse, are a crucial component for quantum computers and quantum communications. So far, quantum memories — either ensemble based or single absorbers — have operated with bandwidths of kHz or MHz. Robust, higher bandwidth (faster) quantum memories operating with very short laser pulses are a prerequisite for reliable and broadband quantum technology devices that allow for high-speed quantum processing and high data transfer rates in completely secure quantum networks. Here we report the coherent storage and retrieval of sub-nanosecond low intensity light pulses with spectral bandwidths exceeding 1 GHz in cesium vapor. The memory interaction takes place via a far off-resonant two-photon transition in which the memory bandwidth is dynamically generated by the strong control field. This makes the memory robust to environmental noise and allows an increase of speed by a factor of almost 1000 compared to existing quantum memories. The memory works with a total efficiency of 15 % and its coherence is demonstrated by directly interfering the stored and retrieved pulses.

Q 25.3 We 11:00 E 214

Entanglement properties of optical coherent states under amplitude damping — •Ricardo Wickert[1,2], Nadja Kolb Bernardes[1,2], and Peter van Loock[1,2] — [1]Optical Quantum Information Theory Group, Max Planck Institute for the Science of Light — [2]Institute of Theoretical Physics I, Universität Erlangen-Nürnberg

Quantum Error Correction (QEC) codes aim to protect the information in fragile quantum states by encoding them into a larger Hilbert space; Entanglement Purification (EP) protocols aim to distill higher entanglement from a number of identically prepared copies of lower entanglement. It is known that QEC codes can be recast as EP schemes and vice-versa [1]. Through concurrence, we characterize the distillation capabilities of a known error correcting code for the amplitude damping channel [2]. An upper bound is established considering the non-orthogonality of the coherent-state basis [3].

[1] C. Bennett et al., Phys. Rev. A 54, 3824 (1996)
[2] S. Glancy et al., Phys. Rev. A 70, 22317 (2004)
[3] R. Wickert at al., in preparation (2009)

Q 25.4 We 11:15 E 214

Hybrid quantum repeater with imperfect memories — •Nadja Kolb Bernardes[1,2] and Peter van Loock[1,2] — [1]Optical Quantum Information Theory Group, Max Planck Institute for the Science of Light — [2]Institute of Theoretical Physics I, Universität Erlangen-Nürnberg

We discuss the efficiency of quantum error correction (QEC) codes for quantum repeaters based on atomic qubit-entanglement distribution through optical coherent-state communication (hybrid quantum repeater [1]). In particular, we consider nonlocal distributions of two-qubit entangled memory pairs based on unambiguous discrimination measurements of coherent states [2]. The conditionally prepared, entangled states will be subject to local memory dephasing, which is to be suppressed by means of QEC codes. For this realistic case of imperfect memories, we explore the regimes in which the encoding pays off and where it does not. Our model gives the minimum requirements on the local memories, unencoded or encoded,in order to outperform direct transmissions or quantum relay approaches.

[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).
[2]P. van Loock,N. Lütkenhaus, W. J. Munro, Kae Nemoto,Phys. Rev. A 78, 062319 (2008).

Q 25.5 We 11:30 E 214

Displacement Controlled Photon Number Resolving Detector for Optical Coherent States. — •Christoffer Wittmann[1,2], Ulrik L. Andersen[1,2,3], Masahiro Takeoka[4], Denis Sych[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Institute for Optics, Information and Photonics, University of Erlangen-Nuremberg, Erlangen, Germany — [3]Department of Physics, Technical University of Denmark, Lyngby, Denmark — [4]National Institute of Information and Communications Technology (NICT), Tokyo, 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 are not able to achieve error free sensitivity in principle. We propose and experimentally realize a novel detection strategy for the discrimination of two optical coherent states [1]. The scheme is then extended for probabilistic discrimination by accepting also inconclusive measurement outcomes. We show that our discrimination strategy based on an optimized displacement and a photon number resolving measurement, allows for smaller error rates than the homodyne strategy [2] and demonstrate this experimentally [3]. [1] C. Wittmann et al., Phys. Rev. Lett. 101, 210501 (2008) ; [2] C. Wittmann et al., Jour. Mod. Opt., published online (arXiv:0905.2496v1 [quant-ph]), (2009); [3] C. Wittmann et al., arXiv:0906.2859 [quant-ph], (2009).

Q 25.6 We 11:45 E 214

Quantum Random Numbers Based on the Vacuum State — •Christian Gabriel[1,2], Christoffer Wittmann[1,2], Denis Sych[1,2], Ruifang Dong[1,2], Wolfgang Mauerer[3], Ulrik L. Andersen[1,2,4], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Guenther-Scharowsky-Str. 1, 91058 Erlangen, Germany — [2]Institute for Optics, Information and Photonics, University Erlangen-Nuremberg, Staudtstr. 7/B2, 91058 Erlangen, Germany — [3]Siemens AG, Corporate Technology, Otto-Hahn-Ring 6, 81739 Munich, Germany — [4]Department of Physics, Technical University of Denmark, 2800 Kongens Lyngby, Denmark

We present a random number generator (RNG) based on the measurement of a quadrature amplitude of a pure quantum state, namely the vacuum state. By determining the entropy of the system and applying a suitable one-way function it can be assured that the random numbers originate from quantum noise solely and classical noise sources have no influence on the generated bit sequences. As quantum mechanics postulates completely random measurement outcomes, the generated numbers are truly random. The optimized information capacity of the system is determined, leading to increased bit generation speeds. Furthermore, the random numbers are assured to be unique, i.e. they cannot be known by an adversary. This is guaranteed by the measurement of a pure state. This feature makes our RNG advantageous to many earlier generators as it offers not only a truly random but also a secure generation of bits.

Q 25.7 We 12:00 E 214

Experimental results for quantum state discimination — •Gesine Steudle, Sebastian Knauer, Ulrike Herzog, and Oliver Benson — Humboldt-Universität zu Berlin, Institut für Physik, AG Nano-Optik

The discrimination of quantum states [1,2] is a fundamental part of quantum communication and quantum crytography. Particularly, the discrimination of two non-orthogonal quantum states can performed unambiguously only at the expense of admitting inconclusive results. In this contribution we present an experimental setup for optimal unambiguous discrimination between two non-orthogonal mixed states [3,4]. We show experimental results of state discrimination on the single photon level. A first approach utilizes attenuated light from a laser light source whereas a second approach will implement a true single photon source. The latter is based on Stranski-Krastanow-grown InAs dots which are embedded in a pin-junction to establish electrical pumping [5].

[1] J. A. Bergou et al., Lect. Notes Phys. 649, 417 (2004)
[2] S. M. Barnett and S. Croke, Adv. Opt. Photon. 1, 238 (2009)
[3] U. Herzog, Phys. Rev. A 75, 052309 (2007)
[4] U. Herzog and O. Benson, J. Mod. Opt. 56, 1362 (2009)
[5] A. Lochmann et al., Electron. Lett. 42, 774 (2006)

Q 25.8 We 12:15 E 214

Concentration of Phase Information — •Christian Müller[1,2], Mario Usuga[3,1], Christoffer Wittmann[1,2], Petr Marek[4], Radim Filip[4], Ulrik L. Andersen[3,1], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Günther-Scharowsky-Str. 1, Bau 24, 91058 Erlangen, Germany — [2]Institute of Optics, Information und Photonics, University of Erlangen-Nuremberg, Staudtstr. 7/B2, 91058 Erlangen, Germany — [3]Department of Physics, Technical University of Denmark, Building 309, 2800 Kgs. Lyngby, Denmark — [4]Department of Optics, Palacký University, 17. Listopadu 50, Olomuc 77200, Czech Republic

The phase of coherent states is a degree of freedom that plays an important role in the field of quantum information and communication. The accessible phase information suffers under the influence of attenuation and it is hence desirable to be able to amplify phase information. Linear amplifiers fail to fulfill this task [1], so that more sophisticated schemes are needed . Previous proposals [2] had the drawback of relying on single photon sources and high interferometric stability, making implementation hardly feasible. We show in theory [3] and experiment, that a novel probabilistic scheme is capable of increasing the phase information. It is based purely on the addition of thermal noise and subsequent heralding, conditioned on the result of a photon number resolving detector.

[1] H.A. Haus and J.A. Mullen Phys. Rev. 128.2407 (1962)
[2] T.C. Ralph and A.B. Lund (2008) arXiv:0809.0326 [quant-ph]
[3] P. Marek and R. Filip (2009) arXiv:0907.2402[quant-ph]

Q 26: Laser Development: Solid State Lasers III

Time: Wednesday 10:30–12:30 Location: F 128

Q 26.1 We 10:30 F 128

Cavity dumped mode locked Nd:YAP laser at 1341 nm — •Sha Wang, Xin Wang, Hanjo Rhee, Stefan Meister, and Hans Eichler — Institute of Optic and Atomic Physics, Technical University Berlin, Str. des 17. Juni 135, 10623 Berlin, Germany

LD end pumped active- and passive- mode locked Nd:YAP laser at 1341 nm is studied. With V3+:YAG of 89% initial transmission as saturable absorber, 0.82 mJ output pulse train with FWHM 570 ns is obtained. A RTP crystal and a half wave plate are used as a cavity dumper. A single pulse of 0.12 mJ with pulse duration less than 1 ns is obtained. The dumped pulse is amplified by a double pass diode end pumped amplifier to 0.7 mJ.

Q 26.2 We 10:45 F 128

Reduktion des zeitlichen Jitters in einem passiv gütegeschalteten Microchiplaser mittels self-injection-seeding — Alexander Steinmetz, •Andreas Martin, Dirk Nodop, Jens Limpert und Andreas Tünnermann — Institut für Angewandte Physik, Friedrich-Schiller-Universität Jena, Thüringen

Es wird ein einfaches, effizientes System zur Reduktion des zeitlichen Jitters für die Anwendung in gütegeschalteten Microchiplaser durch self-injection-seeding mittels einer optischen Faser als Verzögerungsstrecke präsentiert. Eine Reduktion des Jitters um mehrere Größenordnungen ist erreicht worden. Der zeitliche Jitter passiv gütegeschalteter Laser begrenzt die Einsatzmöglichkeiten dieser und ähnlicher Laser. Hauptsächlich resultiert dieser aus der Resonatordynamik, Umgebungsinstabilität und dem statistischen Charakter des Startprozesses des Pulses, der spontanen Emission von Photonen im Lasermedium. Um diesen limitierenden Faktor zu umgehen, wurde eine einfache und kostengünstige Methode entwickelt, basierend auf der Rückkopplung eines erzeugten Laserpulses. Dieser wird über eine optische Faser verzögert, und dem Resonator kurz vor der Ausbildung des nächsten Pulses wieder zugeführt. Die statistische Initialisierung des Pulses im Resonator wird somit durch den deterministischen Prozess der Rückkopplung ersetzt, womit der zeitliche Jitter verringert wird. Mit möglichen Pulsdauern um 50ps, einer variablen Repetitionsrate bis einigen MHz und self-injection-seeding sind diese Microchiplaser eine sehr attraktive Quelle für viele Anwendungen, welche hohe Anforderungen an die zeitliche Stabilität stellen.

Q 26.3 We 11:00 F 128

Laser oscillator coupling scheme using gain grating holograms in Nd:YAG — •Roland Ullmann, Robert Elsner, and Martin Ostermeyer — Institute for Physics and Astronomy, University of Potsdam, Karl-Liebknecht-Str 24/25, 14476 Potsdam, Germany

Advanced Lidar measurement methods require pulsed lasers with a high frequency stability in MHz-range or even below. To achieve this, several techniques based on active electronic feedback loops like Pound-Drever-Hall [1] can be used. A passive coupling between a frequency stable master and a pulsed slave laser would be advantageous for mobile and remote applications e.g. on a satellite. Such a passive coupling can be realized via gain gratings. Frequency fluctuations of the slave's resonator are compensated by self adjustment of the gain grating position inside the active medium. The diffraction properties of these gain gratings are experimentally investigated and compared to a numerical model. Further advantageous properties of gain gratings include self-Q-switching and phase conjugation [2]. In our scheme, a non planar ring oscillator (NPRO) is used as master laser and initializes the gain grating.

References: [1] M. Ostermeyer, T. Waltinger, M. Gregor, Opt. Commun. 282(16):3302-3307 (2009)

[2] M. J. Damzen, R. P. M. Green, and K. S. Syed, Opt. Lett. 20, 1704- (1995)

Q 26.4 We 11:15 F 128

Einfrequentes Lasersystem mit 210W Ausgangsleistung für die nächste Generation von Gravitationswellendetektoren — •Lutz Winkelmann, Oliver Puncken, Maik Frede, Christian Veltkamp, Jörg Neumann, Dietmar Kracht und Peter Wessels — Laser Zentrum Hannover e.V., 30419 Hannover, Germany

Eine Methode zur Detektion von Gravitationswellen basiert auf der hochgenauen Längenmessung mittels Michelson Interferometern mit großen Armlängen. Die Messempfindlichkeit und damit Reichweite dieser Detektoren ist limitiert durch das Schrotrauschen. Dieses kann durch eine Ausgangsleistungssteigerung der genutzten Laserstrahlquelle verringert werden. Zu diesem Zweck wurde ein hochstabiles Festkörperlasersystem mit einer Ausgangsleistung von 210 W entwickelt. Dieses gliedert sich in einen Master Oszillator (NPRO, 2 W) mit einem Power Amplifier (4 x Nd:YVO_4, Einzeldurchgang, 35 W) und einen Nd:YAG Hochleistungsoszillator. Für den Einfrequenzbetrieb werden beide Stufen nach dem Pound-Drever-Hall Verfahren injektionsgekoppelt. Eine hohe Ausgangsleistung bei gleichzeitig guter Strahlqualität wird durch die Verwendung von vier longitudinal gepumpten und depolarisationskompensierten Nd:YAG Kristallen gewährleistet. Die Kristalle sind asymmetrischen in einem Ringresonator angeordnet und bilden die Hochleistungsstufe des Systems. Der mit einem optischen Resonator hoher Güte gefilterte Ausgangsstrahl hat eine Leistung von 170 W im TEM_{00} Mode. Durch mechanische Verbesserungen und Einsatz eines langsamen Längenaktuators konnte die Injektionskopplung trotz Temperatur- und Luftdruckänderungen stabilisiert werden.

Q 26.5 We 11:30 F 128

A new laser source for trapping Lithium — •Ulrich Eismann[1], Frédéric Chevy[1], Fabrice Gerbier[1], Gérard Trénec[2], Jacques Vigué[2], and Christophe Salomon[1] — [1]Laboratoire Kastler Brossel, CNRS UMR 8552, UPMC, Ecole Normale Supérieure, 24 rue Lhomond, 75231 Paris, France — [2]Laboratoire Collisions Agrégats Réactivité, CNRS UMR 5589 - Université Paul Sabatier Toulouse 3, Route de Narbonne, 31062 Toulouse Cedex, France

We present a powerful new laser setup for light-induced manipulation of Lithium atoms which is currently being developed within the framework of the Fermix experiment at ENS.

The design is based on a diode-pumped solid state Nd:YVO_4 ring laser, operating on the $^4F_{3/2} \rightarrow {}^4I_{13/2}$ transition near 1342 nm. The infrared light is subsequently frequency doubled to the Lithium-6 D2 resonance at 670.977 nm in an enhancement cavity using periodically poled Potassium Titanyl Phosphate (ppKTP). Hereby, a special locking technique is applied.

The results obtained so far indicate a higher performance in terms of power, spatial mode quality and simplicity compared to the existing laser sources in the same wavelength range.

Q 26.6 We 11:45 F 128

Kompaktes ns-Lasersystem für die Anwendung im Weltraum — •Tino Lang[1], Rafael Huss[3], Mathias Ernst[1], Christian Kolleck[1,2], Jörg Neumann[1,2] und Dietmar Kracht[1,2] — [1]Laser Zentrum Hannover e.V., Hollerithallee 8, D-30419 Hannover, Germany — [2]Centre for Quantum-Engineering and Space-Time Research - Quest, Welfengarten 1, D-30167 Hannover, Germany — [3]Micreon GmbH, Garbsener Landstr. 10, D-30419 Hannover, Germany

Der Einsatz von Lasersystemen im Weltraum oder unter extremen Umweltbedingungen stellt außerordentliche Anforderungen an deren mechanische und thermische Stabilität. Im Gegensatz dazu steht gerade in der Weltraumanwendung die Notwendigkeit eines möglichst leichten und kompakten, sowie optisch unempfindlichen Designs. Wir stellen ein auf Nd:YLF basierendes, longitudinal gepumptes Lasersystem mit einer Pulsenergie von 1,5 mJ vor, welches speziell für den Betrieb unter extremen Temperaturen und hohen Beschleunigungskräften entwickelt wurde. Der passiv gütegeschaltete Oszillator im nur 23 g schweren und 100 mm langen, luftdichten Laserkopf ist dabei über eine optische Faser mit den ebenfalls fasergekoppelten Einzel-Emitter-Pumpdioden verbunden. Eine mögliche Anwendung des Lasersystems besteht in der Laser-induced Breakdown Spectroscopy (LIBS).

Q 26.7 We 12:00 F 128

Injection seeded frequency stabilized Nd:GSAG ring laser for water vapor detection — •Xin Wang, Adalbert Ding, and Hans Eichler — Institut für Optik und Atomare Physik, Technische Universität Berlin, Straße des 17 Juni 135, Berlin 10623, Germany

Long range water vapor DIAL systems require efficient and rugged laser sources. The quasi-three-level transition from R1 to Z5 in Nd:GSAG with 943nm wavelength is a promising candidate. An actively Q-switched Nd:GSAG ring laser was established. It was injection seeded by a tunable distributed feedback laser diode. Laser frequency

was stabilized by ramp-hold-fire method. Single frequency laser pulses with 13mJ pulse energy at 10Hz repetition rate were obtained. By tuning the wavelength of the seed laser a 0.80nm tuning range of the pulsed Nd:GSAG laser was obtained. It covers the four wavelengths required by water vapor DIAL. Measured by Fabry-Perot interferometer the spectral line width was approximately 50MHz.

Q 26.8 We 12:15 F 128

Crystal Field Tuning von Erbium-dotierten Mischgranaten für die Realisierung Laser-basierter Detektionssysteme von atmosphärischen Spurengasen — •Theo Bank, Christian Brandt, Klaus Petermann und Günter Huber — Institut für Laser-Physik, Universität Hamburg

Augensichere Festkörperlaser basierend auf Erbium-dotierten Mischgranaten eignen sich auf Grund ihres Emissionsspektrums um 1,6 μm zur Messung atmosphärischer Spurengase wie z.B. Kohlendioxid. Durch Abmischung des Wirtskristalls, das so genannte Crystal Field Tuning, konnten die Emissionsmaxima des Laserions um bis zu 10 nm verschoben werden. Ursache hierfür ist die Änderung der Energieaufspaltung durch die Variation der Platzgröße des Laserions. Mit dieser Technik war es möglich die schmalen Absorptionsbanden des zu messenden Spurengases exakt mit einem Laserübergang anzufahren.

Q 27: Ultrashort Laser Pulses: Applications I

Time: Wednesday 10:30–12:30 Location: F 342

Q 27.1 We 10:30 F 342

Ultra-short pulse laser proton acceleration — •Karl Zeil, Stephan Kraft, Michael Bussmann, Thomas Cowan, Thomas Kluge, Josefine Metzkes, Tom Richter, and Ulrich Schramm — Forschungszentrum Dresden-Rossendorf, Bautzner Landstrasse 400, 01328 Dresden

We present a systematic investigation of ultra-short pulse laser acceleration of protons yielding unprecedented maximum proton energies of 17 MeV using the Ti:Sapphire lased high power laser of 100 TW Draco at the Research Centre Dresden-Rossendorf. For plain few micron thick foil targets a linear scaling of the maximum proton energy with laser power is observed and attributed to the short acceleration period close to the target rear surface. Although excellent laser pulse contrast was available slight deformations of the target rear were found to lead to a predictable shift of the direction of the energetic proton emission away from target normal towards the laser direction. The change of the emission characteristics are compared to analytical modelling and 2D PIC simulations.

Q 27.2 We 10:45 F 342

High Intensity Laser-Driven Ion Acceleration — •Andreas Henig[1,2], Daniel Kiefer[1,2], Daniel Jung[1,2], Jörg Schreiber[1,2], Rainer Hörlein[1,2], Sven Steinke[3], Matthias Schnürer[3], Thomas Sokollik[3], Peter Nickles[3], Xueqing Yan[1], Toshi Tajima[2], Jürgen Meyer-ter-Vehn[1], Manuel Hegelich[2,4], Wolfgang Sandner[3], and Dietrich Habs[1,2] — [1]Max-Planck-Institut für Quantenoptik, D-85748 Garching — [2]Department für Physik, Ludwig-Maximilians-Universität München, D-85748 Garching — [3]Max-Born-Institut, D-12489 Berlin — [4]Los Alamos National Laboratory, New Mexico 87545, USA

Ion acceleration by intense laser-plasma interactions is a very active field of research whose development can be traced in a large number of publications over the last few years. Past studies were mostly performed irradiating thin foils where protons are predominantly accelerated to energies up to 60 MeV in an exponentially decaying spectrum by a mechanism named target normal sheath acceleration (TNSA). We present our latest experimental advances on acceleration schemes away from TNSA, such as shock acceleration [Henig *et al.*, PRL **102**, 095002 (2009)], ion beam generation from relativistically transparent targets [Henig *et al.*, PRL **103**, 045002 (2009)] and radiation-pressure acceleration [Henig *et al.*, PRL **103**, 245003 (2009)]. These results are a major step towards highly energetic, mono-chromatic ion beams generated at high conversion efficiencies as demanded by many potential applications. Those include fast ignition inertial confinement fusion (ICF) as well as oncology and radiation therapy of tumors.

Q 27.3 We 11:00 F 342

Low-Divergent, Energetic Electron Beams from Ultra-Thin Foils — •Thomas Kluge[1], Michael Bussmann[1], Sandrine Gaillard[1], Kirk Flippo[2], Cort Gautier[2], Thomas Lockard[4], M Lowenstern[5], Yasuhiko Sentoku[4], Karl Zeil[1], Stephan Kraft[1], Ulrich Schramm[1], Thomas Cowan[1], Roland Sauerbrey[1], J.E. Mucino[5], and Brady Gall[3] — [1]Forschungszentrum Dresden-Rossendorf e.V., Dresden, Germany — [2]Loas Alamos National Laboratory, Los Alamos, USA — [3]University of Missouri, Columbia, USA — [4]University of Nevada, Reno, USA — [5]University of Michigan, Ann Arbor, USA

We present recent experiments performed at the LANL Trident laser facility. A well collimated, energetic (up to ~90 MeV) electron beam has been observed in the laser direction following the short pulse (600 fs) high-intensity laser interaction with ASE-preheated ultra-thin solid foils. These results are in contrast to the typical low-energy divergent electrons accompanying ions in the target normal direction usually seen in solid targets. 2D particle-in-cell simulations suggest the excitation of a wakefield that can accelerate electrons to tens of MeV.

Q 27.4 We 11:15 F 342

Electron bunch length measurements from laser-accelerated electrons using single-shot THz time-domain interferometry — •Alexander Debus[1], Michael Bussmann[1], Ulrich Schramm[1], Roland Sauerbrey[1], and Stefan Karsch[2] — [1]Forschungszentrum Dresden-Rossendorf, Institute for Radiation Physics, 01328 Dresden, Germany — [2]Max-Planck-Institute für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany

Laser-plasma wakefield based electron accelerators are expected to deliver ultrashort electron bunches with unprecedented peak currents. However, their actual pulse duration has never been directly measured in a single-shot experiment. We present measurements of the ultrashort duration of such electron bunches by means of THz time-domain interferometry. With data obtained using a 0.5J, 45fs, 800nm laser and a ZnTe-based electro-optical setup we demonstrate the duration of laser-accelerated, quasi-monoenergetic electron bunches at a best fit of 32fs (FWHM) with a 90% upper confidence level of 38fs.

Q 27.5 We 11:30 F 342

Simultaneous diagnostics of laser-accelerated protons and electrons — •Josefine Metzkes, Karl Zeil, Stephan Kraft, Tom Richter, Thomas Cowan, Roland Sauerbrey, and Ulrich Schramm — Forschungszentrum Dresden-Rossendorf, 01314 Dresden, Germany

Pulses of energetic protons with energies of several MeV can be produced by focusing an ultra-short intense laser pulse onto a solid target. The protons stem from the target rear side where they gain energy in an electric field that builds up due to charge separation effects triggered by electrons that are accelerated during the interaction of the laser with the target.

In order to investigate the acceleration of protons at solid targets which is expected to be strongly correlated to the properties of the electrons that set up the electric field at the target rear side we have set up a diagnostic which allows for the simultaneous online analysis of the accelerated protons as well as electrons. Here we are going to present first experimental results that have been measured at a table-top Ti:Sapphire laser with a pulse length of 30 fs and a peak intensity exceeding 10^{21} W/cm^2. From these data fundamental parameters can be derived that allow for a testing of theoretical scaling laws for the proton acceleration mechanism.

Q 27.6 We 11:45 F 342

Strong-field photoelectron emission from metal nanotips — Reiner Bormann, Max Gulde, Sergey Yalunin, Alexander Weismann, and •Claus Ropers — University of Göttingen, Courant Research Center Nano-Spectroscopy and X-Ray Imaging, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

The generation of ultrashort, localized electron pulses is of fundamental interest for future applications in time-resolved electron imaging and diffraction. Femtosecond electron sources of great spatial coherence make use of a combination of local field enhancement at metal nanotips and nonlinear photoelectric effects. Previous studies have resulted in a controversial debate about the underlying physical processes.

Here, we present our most recent theoretical and experimental results regarding ultrafast photoelectron emission from nanometric gold tips. For the first time, we conclusively show the transition between the multiphoton and the optical field emission (i.e. tunneling) regimes. Direct evidence for this transition is found from both the power dependence of the total current and the spatial characteristics of the resulting electron beam. The results are supported by theoretical modeling.

Q 27.7 We 12:00 F 342

Proton, Electron and K-Alpha Emission from Micro-Scale Copper Cone Targets — •Thomas Kluge[1], Sandrine Gaillard[1], Kirk Flippo[2], Michael Bussmann[1], Yasuhiko Sentoku[5], Eduardo Mucino[6], Mariano Lowenstern[6], Cort Gautier[2], John Kline[2], Dustin Offermann[2], Jonathan Workman[2], Fred Archuleta[2], Raymond Gonzales[2], Thomas Hurry[2], Randall Johnson[2], Samuel Letzring[2], David Montgomery[2], Sha-Marie Reid[2], Tsutomu Shimada[2], Brady Gall[3], Thomas Lockard[5], Emmanuel d'Humieres[4], Tomas Cowan[1], and Jenny Rassuchine[1] — [1]Forschungszentrum Dresden-Rossendorf e.V., Dresden, Sachsen — [2]Los Alamos National Laboratory, Los Alamos, USA — [3]University of Missouri, Columbia, USA — [4]CELIA, Université Bordeaux, France — [5]University of Nevada, Reno, USA — [6]AOSS, Ann Arbor, USA

We have conducted two sets of laser-ion acceleration experiments at the LANL 200 TW Trident short-pulse laser comparing regular size flat foils, reduced mass targets and new Cu micro-cone targets to elucidate the production of hot electrons and ions in these targets. Results from the latest experiment show proton energies in excess of ~65 MeV for the cones, compared to ~55 MeV for reduced mass targets and ~45 MeV for regular flat foils for high contrast. Data from a Cu Kα 2D imaging crystal, an X-ray single hit CCD, proton beam images on RCF film stacks, and an electron/proton spectrometer are presented.

Q 27.8 We 12:15 F 342

Design considerations for high-yield x-ray sources using travelling-wave Thomson scattering — •Alexander Debus, Matthias Siebold, Axel Jochmann, Michael Bussmann, Ulrich Schramm, and Roland Sauerbrey — Forschungzentrum Dresden-Rossendorf, Institute for Radiation Physics, 01328 Dresden, Germany

Our design of a high-yield Thomson source makes use of the compact electron bunches, as achievable from laser wakefield accelerators or advanced, low-emittance linear accelerators. We show that the restrictions on the x-ray photon yield by the Rayleigh limit can be avoided with an ultrashort laser pulse in an oblique angle scattering geometry using tilted pulse fronts, where electrons and laser remain overlapped while both beams travel over distances much longer than the Rayleigh length. For large scattering angles up to 75° the use of varied line-spacing (VLS) gratings is proposed for spatio-temporal beam shaping to achieve optimal overlap. Compared to head-on (180°) Thomson scattering the photon numbers for ultrashort and bright x-ray pulses could with this approach be improved by several orders of magnitude. For small interaction angles ($\leq 10°$) interaction distances can be scaled up into the meter range, which could make the SASE-FEL regime accessible using optical undulators driven by existing laser technology.

Q 28: Ultra Cold Atoms, Ions and BEC II (with A)

Time: Wednesday 10:30–12:30 Location: F 303

Q 28.1 We 10:30 F 303

Creating versatile atom traps by combining laser light and magnetic fields — •Stephan Middelkamp[1], Michael Mayle[1], Igor Lesanovsky[2], and Peter Schmelcher[1] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Hamburg, Germany — [2]School of Physics and Astronomy, Faculty of Science, University of Nottingham, Nottingham, UK

We utilize the combination of two standard trapping techniques, a magnetic trap and an optical trap in a Raman setup, to propose a new versatile and tunable trap for cold atoms. The thus created potential has got several advantages compared to conventional trapping potentials: One can easily convert the type of the trap, e.g. from a single well to a double well trap. One can trap atoms in different internal states in different trap types enabling the realization of new experiments with multi-component Bose-Einstein condensates. One can achieve variations of the trapping potential on small length scales ($\sim \mu$m) without the need for microstructures. We present the potential surfaces for different setups, show their tunability, give a semi-analytical expression for the potential, and propose experiments which can be realized within such a trap.

Q 28.2 We 10:45 F 303

Few-boson tunneling in a double well with spatially modulated interaction. — •Budhaditya Chatterjee[1], Ioannis Brouzos[2], Sascha Zöllner[3], and Peter Schmelcher[2] — [1]Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg, Germany — [2]Zentrum für Optische Quantentechnologien , Universität Hamburg, Luruper Chaussee 149, Gebäude 69, 22761 Hamburg, Germany — [3]Niels Bohr International Academy, Niels Bohr Institute, Blegdamsvej 17, 2100 Copenhagen, Denmark

We study few-boson tunneling in a one-dimensional double well with a spatially modulated interaction. The dynamics changes from Rabi oscillations in the non-interacting case to a highly suppressed tunneling for intermediate coupling strengths followed by a revival near the fermionization limit. The dynamics is explained on the basis of the few-body spectrum and stationary eigenstates. For higher number of particles, $N \geq 3$ it is shown that the inhomogeneity of interaction can be tuned to generate tunneling resonances. Finally a tilted double-well and its interplay with the interaction asymmetry is discussed.

Q 28.3 We 11:00 F 303

Superconducting Atom Chips — Tobias Mueller[1,2], Rachele Fermani[1,2], Bo Zhang[1], Kin Sung Chan[1], Michael J. Lim[1,3], and •Rainer Dumke[1] — [1]School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore — [2]Centre for Quantum Technologies, National University of Singapor, Singapore — [3]Rowan University, New Jersy, USA

We store and control ultra-cold atoms in a new type of trap using magnetic fields of vortices in a high temperature superconducting microstructure. This is the first time ultra-cold atoms have been trapped in the field of magnetic flux quanta. We generate the attractive trapping potential for the atoms by combining the magnetic field of a superconductor in the remanent state with external homogeneous magnetic fields. We show the control of crucial atom trap characteristics such as an efficient intrinsic loading mechanism, spatial positioning of the trapped atoms and the vortex density in the superconductor. The measured trap characteristics are in good agreement with our numerical simulations.

Q 28.4 We 11:15 F 303

Rotating three-dimensional solitons in Bose Einstein condensates with attractive nonlocal interaction — Fabian Maucher[1], Stefan Skupin[1,2], and •Wieslaw Krolikowski[3] — [1]Max Planck Institute for the Physics of Complex Systems — [2]Friedrich-Schiller-University, Institute of Condensed Matter Theory and Solid State Optics, 07743 Jena, Germany — [3]Laser Physics Centre, Research School of Physics and Engineering, Australian National University, Canberra, ACT 0200, Australia

We study the dynamics of rotating high order solitons (azimuthons) in Bose Einstein condensates with attractive nonlinear, nonlocal and isotropic interaction. In particular, we consider a "Gaussian" and a "1/r"-response, i.e., prototypes for short and long-range interaction. Azimuthons are a straightforward generalization of usual (nonrotating) solitons and feature an additional parameter, the angular frequency. The most simple three-dimensional azimuthons are tori with angular phase ramp and azimuthal amplitude modulations. Approximate variational methods allow a rather good approximation of the angular velocity of the azimuthons (compared to full 3d numerical simulation). It is possible to control this angular frequency by varying the repulsive contact interaction using Feshbach resonance techniques. The observed structures are very robust, even in cases where the initial conditions are rather far from the exact solutions. We conjecture that self-trapped azimuthons are generic for condensates with attractive nonlocal interaction.

Q 28.5 We 11:30 F 303

Two-way conversations between cold atoms and semiconductors — •Thomas Judd[1,2], Robin Scott[2], German Sinuco[2], Tom Montgomery[2], Andrew Martin[3], Peter Krüger[2], and Mark Fromhold[2] — [1]University of Tübingen, Germany — [2]University of Nottingham, UK — [3]University of Melbourne, Australia

There has been significant work in the past few years on hybrid devices which combine cold atoms with solid state structures. The hope is to create devices which combine the key advantages of both systems - the purity of a quantum coherent atom cloud, and the versatility of microchips - to study fundamental physics and further quantum technologies. To date there has been much success in manipulating cold atoms with microchips and semiconductors to create a measurable signal in the atom cloud. However, it has not been possible to perform the reverse procedure of using cold atoms to create a measurable signal in a solid state device. If this two-way coupling can be achieved, a range of possibilities open up such as long-term quantum memory chips. Here we use simulations to show that Fresnel zone plates could assist these efforts by strongly and coherently focusing ultracold atoms onto a semiconductor chip with a two-dimensional electron gas (2DEG). The atoms are shown to deplete the 2DEG, thereby strongly increasing its resistivity to measurable levels. The technique provides a solution to the long standing problem of short-range atom focusing while at the same time opening the door to a new form of non-destructive lithography which can create electronic components on a 50nm scale.

Q 28.6 We 11:45 F 303

An AC electric trap suitable for ground-state CO molecules — •Amudha Kumari Duraisamy, Adela Marian, Wieland Schöllkopf, and Gerard Meijer — Fritz-Haber-Institut, Faradayweg 4-6, Berlin, Germany

When trapping polarizable neutral particles using AC electric fields, the parameter which determines the strength of the interaction is α/m, where α is the (total) quadratic Stark coefficient and m is the mass of the particle. As this ratio is nearly identical for ^{87}Rb and ^{12}CO in their ground states, they would behave very similarly when confined in an AC electric trap. We have already demonstrated and studied trapping of ground-state Rb in a macroscopic AC electric trap with a depth of a few microkelvins [1, 2] . We now propose to use the Rb atoms as a case study for the behaviour of AC-trapped ground-state CO molecules.

To this end, we have implemented a new AC trap where all the dimensions were scaled down by a factor of two to increase the available trap depth. Stable electric trapping is observed in a wider range of switching frequencies around 300 Hz, in agreement with trajectory calculations. We have trapped about 1.3×10^5 atoms with densities of 8×10^9 cm^{-3} for an electric field of 60 kV/cm at the center of the trap.

Refrences

1. S. Schlunk et al., PRL **98**, 223002(2007),
2. S. Schlunk et al., PRA **77**, 043408(2008)

Q 28.7 We 12:00 F 303

Gap and screening in Raman scattering of a Bose condensed gas — •Patrick Navez[1] and Kai Bongs[2] — [1]Universitaet Duisburg-Essen, Lotharstrasse 1, 47057 Duisburg, Germany — [2]University of Birmingham, Edgbaston, Birmingham, B15 2TT, England

We propose different spectroscopic methods to explore the nature of the thermal excitations of a trapped Bose condensed gas: 1) a four photon process to probe the uniform region in the trap center: 2) a stimulated Raman process in order to analyze the influence of a momentum transfer in the resulting scattered atom momentum distribution. We apply these methods to address specifically the energy spectrum and the scattering amplitude of these excitations in a transition between two hyperfine levels of the gas atoms. In particular, we exemplify the potential offered by these proposed techniques by contrasting the spectrum, expected from the non conserving Bogoliubov approximation valid for weak depletion, to the spectrum of the finite temperature extensions like the conserving generalized random phase approximation (GRPA). Both predict the existence of the Bogoliubov collective excitations but the GRPA approximation distinguishes them from the single atom excitations with a gapped and parabolic dispersion relation and accounts for the dynamical screening of any external perturbation applied to the gas. Two feasible experiments are discussed, one concerns the observation of the gap associated to this second branch of excitations and the other deals with this screening effect. Ref: P. Navez and K. Bongs, Eur. Phys. Lett. (in press).

Q 28.8 We 12:15 F 303

Cold atoms near superconductors — •Helge Hattermann, Florian Jessen, Brian Kasch, Daniel Cano, Max Kahmann, Dieter Koelle, Reinhold Kleiner, and József Fortágh — Physikalisches Institut, Eberhard-Karls-Universität Tübingen, CQ Center for Collective Quantum Phenomena and their Applications, Auf der Morgenstelle 14, D-72076 Tübingen, Germany

We report on the measurement of atomic spin coherence near the surface of a superconducting niobium wire. As compared to normal conducting metal surfaces, the atomic spin coherence is maintained for time periods beyond the Johnson noise limit. The result provides experimental evidence that magnetic near field noise is strongly suppressed close to the superconductor. For very small distances to the wire surface, the magnetic field exclusion due to the Meissner effect reduces the trap depth and leads to atom losses. Based on our results, we discuss possibilities to circumvent these detrimental losses and to coherently couple ultracold atoms to solid state devices, opening the way towards the construction of hybrid quantum systems.

Q 29: Precision Measurements and Metrology III

Time: Wednesday 14:00–16:15 Location: A 310

Q 29.1 We 14:00 A 310

Stabilising the distance of 10 m separated optical tables to 100 pm/sqrt(Hz) — •Katrin Dahl for the 10 m Prototype team — Max-Planck-Institut für Gravitationphysik (Albert-Einstein-Institut) und Institut für Gravitationsphysik, Leibniz Universität Hannover, Callinstr. 38, D-30167 Hannover

The AEI 10 m Prototype Interferometer will develop and test new techniques for the third generation of ground based interferometric gravitational-wave detectors. Furthermore, it provides an ultra-low displacement-noise environment which will be used for other experiments, e.g. related to GRACE follow-on or macroscopic quantum mechanics. To create such a quiet environment, seismically isolated optical tables separated by just above 10 m will be suspended in a large scale ultra-high vacuum system. The relative motion between these tables will be measured by a dedicated set of heterodyne Mach-Zehnder interferometers. With this setup the distance between the tables can then be stabilised via feedback to voice-coil actuators. In this talk we will present first measurements performed between two seismically non-isolated tables separated by about 10 m.

Q 29.2 We 14:15 A 310

Design and control aspects of the AEI 10 m Prototype Interferometer — •Christian Gräf for the AEI 10m Prototype Team — Max-Planck-Institut für Gravitationphysik (Albert-Einstein-Institut), Institut für Gravitationsphysik, Leibniz Universität Hannover

The AEI 10 m Prototype Interferometer aims at beating the Standard Quantum Limit (SQL) at frequencies of about 100 Hz. To reach this ambitious goal all free design parameters of the underlying optical layout need to be thoroughly optimized with regard to bringing down classical noise, eventually allowing for operating the inteferometer with an exclusively quantum noise-limited sensitivity at frequencies in the measuring band. Retaining the feasibility of stably controlling the instrument in all relevant degrees of freedom, using digital feedback control, is a vital boundary condition for the experiment design. Due to the high complexity of the optical system, simulations play a key role in this process. This talk summarizes the status of design and control aspects of the prototype interferometer.

Q 29.3 We 14:30 A 310

Digital control and data system for the AEI 10m prototype interferometer — •Michael Born for the 10m Prototype team — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Institut für Gravitationsphysik, Leibniz Universität Hannover, Callinstr. 38, D-30167 Hannover

A 10m prototype interferometer is currently under construction in Hannover, Germany. One primary goal is to reach and surpass the standard quantum limit of interferometry for 100g test masses [1]. The control and data taking for this complex experimental facility will be carried out with a dedicated digital system. All relevant servo loops will be implemented digitally using a realtime control and data system (CDS) that will also be used for next generation gravitational wave detectors. Control algorithms can be implemented via Matlab/Simulink models or C-code from which a realtime capable module is subsequently generated. In the initial configuration about 500 EPICS channels will be recorded or controlled. Among these are channels for the control of the frequency reference cavity, the main interferometer, and the isolated optical tables inside the UHV envelope. Control signals for these tables will be derived from a supension platform interferometer which adapts LISA Pathfinder phasemeter technology. The data from the phasemeter are read from an enhanced parallel port (EPP) via a newly designed microcontroller-based ethernet interface. The digital control and data system as well as the novel interface to the phasemeter will be introduced in detail.

[1] http://10m-prototype.aei.uni-hannover.de

Q 29.4 We 14:45 A 310

Seismic Attenuation for the 10m Prototype — •Alexander Wanner for the AEI 10m Prototype Interferometer team — Max-Planck-Institut für Gravitationphysik (Albert-Einstein-Institut), Institut für Gravitationsphysik, Leibniz Universität Hannover, Callinstr. 38, D-30167 Hannover

A 10m Prototype Interferometer facility is currently being set up at the AEI in Hannover. The prototype interferometer will be used to test and develop some of the techniques for potential future upgrades of the gravitational-wave detector GEO600. Furthermore, experiments to explore quantum mechanical effects in macroscopic objects will be run in this facility. By now the ultra-high vacuum system is installed and fully operational. The next step is the installation of seismically isolated optical tables.

The basic stage of isolation will be a set of passive attenuation tables, based on the Advanced LIGO HAM-SAS design. Geometric antispring filters will provide vertical isolation (70dB above several Hertz). Attenuation in the horizontal direction (60dB above several Hertz) will be provided by inverted pendulum legs. Several sensors will provide signals for a real-time control system to allow further attenuation via feed-back actuators at the tables. This talk gives an overview of the design of the seismic attenuation system and of the most relevant subsystems of these tables for the 10m Prototype Interferometer.

Q 29.5 We 15:00 A 310

The AEI 10m Prototype Interferometer — •Stefan Gossler for the 10m Prototype team — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) und Leibniz Universität Hannover

A 10m Prototype Interferometer is currently being set up at the AEI in Hannover, Germany. Among the main objectives are the demonstration of novel techniques for future generations of GW detectors, as well as building an instrument operating at and beyond the standard quantum limit of interferometry for 100g test masses.

For the pre-isolation of the experimental setup we will install three seismically isolated optical tables inside a large (ca. $100m^3$) ultra-high vacuum envelope. The differential motion of these tables will be stabilised via a set of Mach-Zehnder interferometers. All relevant optical components will be mounted on top of these isolated tables by means of multiple-cascaded pendulum suspensions. A suspended triangular ring cavity of finesse ca. 7300 will, in conjunction with a molecular iodine reference, serve as a frequency reference for the stabilisation of the 35W Nd:YAG laser. The main instrument is a 10m Michelson interferometer with Fabry-Perot cavities in the arms. The end mirrors will be made of Khalili-style Fabry-Perot cavities to minimise the effective coating thermal noise. The design of the interferometer is done such that the sum of all classical noises lies well below the sum of quantum noise in a frequency band around 100Hz. The layout, status, and progress of the AEI 10m prototype will be given in this talk.

Q 29.6 We 15:15 A 310

Frequency stabilization system for a sub-SQL experiment with the AEI 10 m Prototype — •Fumiko Kawazoe for the 10m Prototype — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), 30167 Hannover, Germany

The AEI 10 m Prototype Interferometer is will provide a test-bed for very sensitive interferometric experiments, such as the sub-SQL interferometer. It will test new techniques to reach and even surpass the Standard Quantum Limit. In order for the sub-SQL interferometer to achieve the required sensitivity all limiting noise sources need to be suppressed sufficiently. Laser frequency noise will be the main focus of this presentation. The AEI Prototype Interferometer will use a laser frequency stabilization system composed of a 12 m high-finesse triangular frequency reference cavity. The mirrors of the cavity are individually suspended from triple pendulum systems. The laser frequency noise will be suppressed to a level of 10^{-16} to $< 10^{-18}\,\mathrm{m}/\sqrt{\mathrm{Hz}}$, from ~ 20 Hz to 1 kHz in terms of a reference-cavity length-noise.

Q 29.7 We 15:30 A 310

Towards the SQL: How to avoid thermal noise using detuned cavities — •Tobias Westphal for the AEI 10m Prototype — Albert Einstein Institut & MPI für Gravitationsphysik, Callinstrasse 38, 30167 Hannover

High sensitivity interferometric experiments are strongly pushing towards the fundamental limits of classical interferometry and beyond. However, thermal noise associated with the dielectric coating stacks of the interferometer mirrors imposes a potential show stopper on the way to such a sensitivity.

One possibile avenue towards a reduced coating thermal noise is to replace highly reflective mirrors by detuned cavities. These so called Khalili cavities will be used for the AEI 10m Prototype Interferometer sub-SQL experiment.

In this talk the theoretical framework will be presented along with the plans for the experimental realisation including the optical design and the according control schemes.

Q 29.8 We 15:45 A 310

Simultaneous stabilization and correlated noise in a single-mode pumped non-planar ring oscillator — •Robin H. Bähre, Tobias Meier, Benno Willke, and Karsten Danzmann — Albert-Einstein-Institute, Max-Planck-Institute for Gravitational Physics, and Institut für Gravitationsphysik, Leibniz Universität Hannover, Callinstr. 38, D-30167 Hannover

Simultaneous stabilization is an approach to non-planar ring oscillator (NPRO) laser stabilization that achieves significant suppression of laser power noise by elimination of correlated frequency noise.

A key component to the success of this experiment is a stable pump source of the NPRO. We have set up a Ti:sapphire solid-state laser as a pump source at 808 nm to provide the required pump beam quality, frequency stability and output power to achieve the quantum noise limit of the NPRO laser power.

We report simultaneous stabilization of the laser power of such a Ti:sapphire single-mode pumped Nd:YAG NPRO with a continuous-wave output power of 75 mW at 1064 nm. We present the results of a table-top experiment in air and an improved setup on a platform that is suspended as a pendulum in a seismically and acoustically isolating tank.

Q 29.9 We 16:00 A 310

Wideband frequency stabilization of a 200-W injection-locked laser — •Hyunjoo Kim[1], Rick Savage[2], Benno Willke[1], and Karsten Danzmann[1] — [1]Albert-Einstein-Institut, Hannover, Germany — [2]LIGO Hanford Observatory, USA

We present a wideband frequency stabilization servo system for a 200-W injection-locked Nd:YAG laser that uses the Pound-Drever-Hall locking technique with a high-finesse optical cavity to control the frequency of the master laser. The Advanced LIGO laser consists of a non-planar ring oscillator followed by a four-rod, single-pass, 35-W amplifier and a 200-W injection-locked oscillator. A pre-modecleaner filters the laser light, after which sample beam is directed to frequency stabilization control loop. Additional downstream frequency sensor enables further stabilization via nested control loop. The injection-locked oscillator cavity and the pre-modecleaner introduce transfer functions that make realizing the required 500 kHz unity gain frequency more challenging. We describe a scheme for compensation of the induced phase delays by a phase-lead network in the servo electronics and the results of preliminary measurements with the wideband frequency stabilization servo.

Q 30: Quantum Effects: QED II / Interference and Correlations III

Time: Wednesday 14:00–16:00 Location: A 320

Q 30.1 We 14:00 A 320

On the Quantum Theory of the FEL — •Paul Preiss[1], Roland Sauerbrey[2], and Wolfgang P. Schleich[1] — [1]Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany — [2]Forschungszentrum Dresden-Rossendorf, D-01328 Dresden, Germany

The free-electron laser (FEL) is an alternative laser device with a widely tunable wavelength of the emitted radiation. Usually, FEL's operate in the so-called classical regime where quantum effects can be neglected. Recent developments in accelerator and laser physics permit the realization of a FEL in the quantum regime. We discuss the effects emerging in a quantum FEL by considering the time evolution of the density operator of the system.

Q 30.2 We 14:15 A 320

On-demand positioning of a preselected quantum emitter on a fiber-coupled toroidal microresonator — Markus Gregor, •Rico Henze, Tim Schröder, and Oliver Benson — AG Nanooptik, Institut für Physik, Humboldt-Universität zu Berlin, Hausvogteiplatz 5-7, 10117 Berlin

Toroidal microresonators are a valuable system to study cavity quantum electrodynamic (cQED) effects due to their high Q factors and small mode volume. It is particularly interesting to couple single quantum emitters to these cavities in order to investigate their potential for applications in quantum information processing. We present here a novel technique which uses tapered optical fibers to manipulate and transfer a preselected diamond nanocrystal onto such microcavities. Optical coupling of few nitrogen vacancy (NV) color centers contained inside the nanocrystal to the resonator modes is demonstrated by detecting the fluorescence via a tapered optical fiber coupler. A clear antibunching in the photon correlation measurement is observed indicating emission from only six NV centers residing inside the nanocrystal. The latter is confirmed by a photoluminescence spectrum at liquid helium temperature resolving individual zero phonon lines.

Q 30.3 We 14:30 A 320

Non-perturbative 2-photon Compton scattering from a circularly polarized laser — •Daniel Seipt and Burkhard Kämpfer — Forschungszentrum Dresden-Rossendorf, PF 510119, 01314 Dresden, Germany

An electron, moving in a strong laser field, emits photons. The Furry picture with Volkov states and propagators allows for a non-perturbative treatment of multi-photon laser-electron interactions. While the 1-photon emission has a classical analog [1], the 2-photon emission (double Compton effect) is a pure quantum effect, where the two photons have a certain degree of polarization entanglement. At low laser intensity one recovers [2], while at high laser intensity ($a_0 \gtrsim 1$) strong-field effects become important. These will be quantified in the talk, thus extending [3].

[1] T. Heinzl, D. Seipt, B. Kämpfer, `arXiv: 0911.1622v2`, (2009) [2] F. Mandl, T. H. R. Skyrme, Proc. Roy. Soc. A **215** 497, (1952). [3] E. Lötstedt, U. Jentschura, Phys. Rev. Lett. 103, 110404 (2009).

Q 30.4 We 14:45 A 320

A matterless double-slit — •Ben King, Antonino Di Piazza, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Quantum electrodynamics predicts that photons can interact with one another non-linearly in vacuum. When the intensity of the corresponding electromagnetic fields is sufficiently large, the macroscopic effect of this miniscule cross-section becomes measurable [1]. We demonstrate how a scenario, in which photons from a probe laser are scattered by two, strongly-focused, ultra-intense laser beams, can be regarded as a novel double-slit experiment, devoid of material constituents. It is shown that with the next generation of strong lasers, one can in principle measure the corresponding diffraction pattern [2].

[1] V. B. Berestetskii, L. P. Pitaevskii, E.M. Lifshitz, Quantum Electrodynamics, (Butterworth-Heinemann, 1996)

[2] B. King, A. Di Piazza, C. H. Keitel, Nature Photonics (in press).

Q 30.5 We 15:00 A 320

Towards the experimental realisation of an ideal quantum measurement — •Jürgen Volz, Roger Gehr, Guilhem Dubois, Jérôme Estève, and Jakob Reichel — Laboratoire Kastler-Brossel de l'ENS, 24 rue Lhomond, Paris, France

Error free qubit readout is one of the key ingredient to quantum information processing. In the case of atomic qubits, such as ions or neutral atoms, the most effcient methods rely on measuring the response of the qubit to an optical excitation. Using resonant light, as in the shelving technique, or far off resonance illumination, all these techniques are intrinsically destructive in the sense that at least one spontaneous emission is required to infer the qubit state. In this Letter, we demonstrate a cavity assisted qubit detection scheme that enables us to detect the qubit state with almost no photon scattering. We use the fact the atom-cavity system lies in the strong coupling regime, where depending on the internal atomic state we either observe a large or almost zero cavity transmission. Therefore, the role of spontaneous emission is replaced by cavity transmission carrying the necessary information for the state readout. Our results show that with this method we induce three times less scattering than possible a perfect free-space detector for the same detection error.

Q 30.6 We 15:15 A 320

Measurement of Arbitrary-Order Coherences in a Single Light Beam with two Polarizations — •Uwe Schilling[1], Joachim von Zanthier[1], and Girish S. Agarwal[2] — [1]Institut für Optik, Information und Photonik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany — [2]Department of Physics, Oklahoma State University, Stillwater, Oklahoma 74078-3072, USA

We present a scheme which allows to measure N-th order coherences of two orthogonally polarized light fields in a single spatial mode at very limited experimental costs. We show that to implement such a measurement, it is sufficient to determine N-th order *intensity moments* after the light beam has passed through two quarter-wave plates, one half-wave plate, and a polarizing beam splitter for specific settings of the wave plates. This method can be applied for arbitrarily large N and we give a set of explicit values for the settings of the wave plates, constituting an optimal measurement of the N-th order coherences for any N. While the most interesting application may be a full state tomography of Fock states, one can utilize our method for arbitrary (classical and nonclassical) states; in fact the general concepts are not even limited to polarization optics.

Q 30.7 We 15:30 A 320

A new paradigm for non-locality by many single photon emitters - violations of locality for visibility less than 50% — •Ralph Wiegner[1], Christoph Thiel[1], Joachim von Zanthier[1], and Girish S. Agarwal[2] — [1]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, 91058 Erlangen, Germany — [2]Department of Physics, Oklahoma State University, Stillwater, Oklahoma 74078-3072, USA

We investigate the spatial intensity-intensity correlations in the fluorescence light of multiple single-photon emitters and demonstrate that these correlations may violate locality. As it turns out, for $N > 2$ emitters, the widely-used CHSH inequalities are not suitable to prove the non-local character of the correlations. We therefore derive a new inequality, based on a Bell-Wigner-type inequality, of the form

$$0 \leq x_1 x_4 - x_1 x_2 - x_1 x_3 + x_2 x_3$$

which holds for $0 \leq x_1, x_2, x_3 \leq x_4 \leq 1$. Using this inequality, we demonstrate the non-local character of the correlations even for a visibility of the signal below 50%. Our results apply to a wide variety of single photon emitters like trapped ions, quantum dots, molecules and nitrogen vacancies in diamonds.

Q 30.8 We 15:45 A 320

Quantum displacement detection with a beam of paired photons — Martin Ostermeyer and •Carsten Henkel — Universität Potsdam, Germany

Light beams with strong correlations in the transverse plane, be they classical or quantum, can improve the resolution of optical images and even lead to novel concepts ("ghost imaging"). We discuss here the application of correlated photon pairs for the precision detection of the transverse displacement of a beam. The photon pairs can be produced with spontaneous parametric down-conversion and have EPR-like correlations in their positions and momenta. A non-classical regime is available where correlation lengths are below the diffraction limit [1]. We discuss the quantum noise limits for the beam displacement with a split detector scheme [2], both with and without the requirement of coincident photon detection.

[1] M. Ostermeyer, D. Korn, D. Puhlmann, C. Henkel, J. Eisert, J. mod. Opt. 56 (2009) 1829
[2] C. Fabre, J. B. Fouet, A. Maître, Opt. Lett. 25 (2000) 76; M. T. L. Hsu, V. Delaubert. P. K. Lam, W. P. Bowen, J. Opt. B 6 (2004) 495

Q 31: Quantum Gases: Interaction Effects II

Time: Wednesday 14:00–16:00 Location: E 001

Q 31.1 We 14:00 E 001

Bose-Einstein condensates with induced $1/r$ interactions and embedded vorticity — •Poulcheria Christou, Patrick Köberle, Axel Keller, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Cold quantum gases with electromagnetically induced attractive $1/r$ interaction have been proposed by O'Dell et. al. as systems in which, in addition to the short-range contact interaction a long-range interaction between the atoms is present. We study rotating Bose-Einstein condensates with $1/r$ interaction in the frame of the Gross-Pitaevskii theory by variational calculations, and by imaginary time evolution on a two-dimensional grid. We analyse the stability of the localised vortices by solving the Bogoliubov-de Gennes equations of the system numerically.

Q 31.2 We 14:15 E 001

Coherent oscillations in a many-body Wannier-Stark system — •Patrick Plötz and Sandro Wimberger — Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 19, 69120 Heidelberg

We study the effect of a many-body interaction on inter-band oscillations in a two-band Bose-Hubbard model with external Stark force. We identify a regime of strong inter-band coupling and observe an interaction-induced collapse and revival of the resonant inter-band oscillations. Effective models for oscillations in and out of resonance are presented and analytical predictions for the collapse and revival time of the oscillations are given.

Q 31.3 We 14:30 E 001

Macroscopic quantum tunnelling and bounce solutions of Bose-Einstein condensates with attractive interactions — •Rolf Häfner, Holger Cartarius, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Solutions of the Gross-Pitaevskii equation for Bose-Einstein condensates with $1/r$ interaction reveal the existence of a metastable ground state, which can decay in the collapse of the wave function. The decay rate can be calculated from the bounce trajectory in imaginary time. Using a variational approach with a Gaussian wave function, it is possible to introduce canonical variables and to find the bounce trajectory by solving Hamilton's equations of motion in an inverted potential.

Generalizing the variational approach by the use of a wave function built from a superposition of Gaussians leads to non-canonical equations of motion for the Gaussian parameters which allow us to investigate the imaginary-time dynamics of the condensate. We show how bounce solutions in these coordinates can be found which are the prerequisite for the calculation of the decay rate of the metastable ground state.

Q 31.4 We 14:45 E 001

Variational studies of Bose-Einstein condensates with embedded vorticity — •Matthias Zimmer, Poulcheria Christou, Stefan Rau, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

The Gross-Pitaevskii equation of condensates with embedded vortices and $1/r$ interaction is solved using a variational principle and modified Gaussian wave packets to consider the vorticity in the Bose-Einstein condensate. The result provides insight in the stability of stationary solutions with respect to the vorticity and the attractive interaction strength. Unlike the direct numerical solutions, where the Gross-Pitaevskii equation is solved at every point in the mesh, it is possible to derive not only the stable branches of the stationary solution but also the unstable which are born in a tangent bifurcation.

Q 31.5 We 15:00 E 001

Generating 'Schrödinger-cat' states via scattering of quantum matter wave solitons — •Christoph Weiss — Institute of Physics, Carl von Ossietzky University, D-26111 Oldenburg, Germany

The generation of spatial quantum superpostions via scattering solitons off a laserfocus can be understood with a mathematically justified [1] (for numeric investigations on the N-particle level see Ref. [2]).

The motion of two attractively interacting atoms in an optical lattice is investigated in the presence of a scattering potential. The initial wavefunction can be prepared by using tightly bound exact two-particle eigenfunction for vanishing scattering potential. This allows to numerically simulate the dynamics in the generation of two-particle Schrodinger cat states using a scheme recently proposed for scattering of quantum matter wave solitons.

[1] C. Weiss and Y. Castin, Phys. Rev. Lett. 102, 010403 (2009).
[2] A. I. Streltsov, O. E. Alon, and L. S. Cederbaum, Phys. Rev. A 80, 043616 (2009).
[3] C. Weiss, arXiv:0910.1162v1 [cond-mat.quant-gas] (2009).

Q 31.6 We 15:15 E 001

Pitchfork bifurcations in blood-cell shaped dipolar Bose-Einstein condensates — •Stefan Rau, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

We demonstrate that the method of coupled Gaussian wave packets is a full-fledged alternative to direct numerical solutions of the Gross-Pitaevskii equation of condensates with electromagnetically induced attractive $1/r$ interaction, or with dipole-dipole interaction. Moreover, Gaussian wave packets are superior in that they are capable of producing both stable and unstable stationary solutions, and thus of giving access to yet unexplored regions of the space of solutions of the Gross-Pitaevskii equation. We apply the method to clarify the theoretical nature of the collapse mechanism of blood-cell shaped dipolar condensates: On the route to collapse the condensate passes through a pitchfork bifurcation, where the ground state itself turns unstable, before it finally vanishes in a tangent bifurcation.

Q 31.7 We 15:30 E 001

Ultracold dipoles on a ring — •Sascha Zöllner[1], Georg M. Bruun[2], and Stephanie M. Reimann[2] — [1]Niels Bohr International Academy, Niels Bohr Institute, Blegdamsvej 17, 2100 Copenhagen, Denmark — [2]Mathematical Physics, LTH, Lund University, 2100 Lund, Sweden

Dipolar bosons and fermions in a quasi-one-dimensional (1D) ring potential have the interesting feature of combining the physics of 1D gases with anisotropic effects. Depending on the orientation of their dipole moments and the dipolar interaction strength, there may be a competition between repulsive and attractive regions on the ring. We identify three basic phases based on simulations in a few-body system:

(i) a repulsive regime resembling an inhomogeneous 1D Bose (Fermi) gas,

(ii) a Wigner-crystal-like state with a non-equidistant spatial distribution, and

(iii) bound states of identical bosons (fermions) localized in the strongly attractive regions on the ring.

We discuss how these states arise in a crossover from weak to strong dipolar interactions, with an emphasis on the particle-number dependence.

Q 31.8 We 15:45 E 001

Phonon instability and structured ground-states in multilayer stacks of dipolar Bose-Einstein condensates — •Patrick

Köberle and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Dipolar interactions between atoms in ultra-cold quantum gases are long-ranged and anisotropic. The latter feature is responsible for a wealth of effects studied in single condensates both theoretically and experimentally. The long-range nature, however, makes it possible to couple individual condensates trapped in deep optical lattices. We study the ground-state of a stack of condensates aligned in the direction of the polarization axis [1] and find a strong dependence of the phonon instability on the number of condensates, which is a direct consequence of the long-range nature of the dipole-dipole interaction. Moreover, in the very vicinity of the phonon instability, we find several types of structures in the density distribution of the atoms.

[1] P. Köberle and G. Wunner, Phys. Rev. A **80**, 063601 (2009)

Q 32: Quantum Information: Atoms and Ions II

Time: Wednesday 14:00–16:00 Location: E 214

Q 32.1 We 14:00 E 214

Universal enhancement of the optical readout fidelity of single electron spins — •Matthias Steiner, Neumann Philipp, Beck Johannes, Jelezko Fedor, and Wrachtrup Jörg — 3. Physikalisches Institut, Universität Stuttgart, Germany

Single spins in diamond associated with a Nitrogen-Vacancy (NV) center are one of the major candidates for room temperature quantum devices. They might be applied as quantum processors or single spin based magnetometers with unprecedented spatial and magnetic field resolution. Many of the possible applications rely on nearby nuclear spins that can be coherently controlled and coupled to the electron spin. Here we demonstrate how a switchable flip-flop process among the electron spin and several nuclear spins can be used to (1.) initialize the nuclear spin register, (2.) to read out the nuclear spin states directly and (3.) greatly improve the signal-to-noise ratio for the readout of quantum information.

Q 32.2 We 14:15 E 214

Coupling of individual electron spins in a room temperature solid — •Philipp Neumann, Roman Kolesov, Boris Naydenov, Johannes Beck, Florian Rempp, Matthias Steiner, Fedor Jelezko, and Jörg Wrachtrup — 3. Physikalisches Institut, Universität Stuttgart, Germany

Building quantum information devices goes far beyond the coherent control of single quantum systems. The challenge for every physical realization of such devices lies at the coherent coupling of their individual constituents that enables generation of nonlocal quantum states. This has been demonstrated for a variety of systems one of them being the Nitrogen-Vacancy (NV) defect center in diamond.[1,2] This artificial atom represents an electron spin qubit at room temperature. Together with surrounding nuclear spins in the diamond lattice quantum registers of up to 4 spin qubits have been realized.[3] Another way of scaling up this spin system is the direct magnetic dipolar coupling of closely spaced NV centers. Here we show recent results of such coupling of two NV centers. Conditional two-qubit gates are realized and the interaction is used to determine the relative position of the two centers in the diamond lattice with an uncertainty of one unit cell.

[1] M.V.G. Dutt *et al., Science* **316,** 1312 (2007)
[2] P. Neumann *et al., Science* **320,** 1326 (2008)
[3] N. Mizuochi *et al., PRL* **80,** 041201(R) (2009)

Q 32.3 We 14:30 E 214

Nanoscale electric field sensing via the Stark effect of a single NV^- center in diamond — •Helmut Rathgen[1], Florian Dolde[1], Tobias Nöbauer[2], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Uni Stuttgart — [2]Atom Chip Group, TU Wien

We measure the Stark effect of a single Nitrogen vacancy center in diamond, and demonstrate its capability as a nanoscale electric field sensor. High sensitivity towards slowly oscillating electric fields is reached through coherent refocussing of the electron spin, following Hahn-echo and Carr-Purcell-Meiboom-Gill (CPMG) scheme. Experimental data of the Stark effect is confronted with current model Hamiltonians of the NV^- center. A highly local (nm scale) electric field measurement is enabled by using NV-doped diamond nano crystals, paving the way to in situ biological field sensing applications.

Q 32.4 We 14:45 E 214

Quantum non-demolition measurement of a single nuclear spin — •Johannes Beck[1], Philipp Neumann[1], Matthias Steiner[1], Florian Rempp[1], Helmut Rathgen[1], Philip Hemmer[2], Nawid Zarrabi[1], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart, Germany — [2]Department of Electrical and Computer Engineering, Texas A&M University, USA

Rapidly growing quantum technologies exploit the fundamental aspects of measurement in quantum mechanics. Here we experimentally demonstrate non-demolition projective measurement of a single nuclear spin associated with a nitrogen-vacancy (NV) center in diamond under ambient conditions. This enables the detection of quantum jumps and the quantum Zeno effect and will push spin-based measurement precision beyond the standard quantum limit.

Q 32.5 We 15:00 E 214

Fast and Robust Laser Cooling of Trapped Systems — •Javier Cerrillo Moreno — Inst. for Mathematical Sciences, Imperial College, London, UK — Quantum Optics and Laser Science group, Imperial College, London, UK — Inst. für Theoretische Physik, Universität Ulm, Germany

We present a robust and fast laser cooling scheme suitable for trapped ions, atoms or cantilevers. Based on quantum interference, generated by a special laser configuration, it is able to rapidly cool the system such that the final phonon occupation vanishes to zeroth order in the Lamb-Dicke parameter in contrast to existing cooling schemes. Furthermore, it is robust under conditions of fluctuating laser intensity and frequency, thus making it a viable candidate for experimental applications.

Q 32.6 We 15:15 E 214

Interfacing Ions and Photons at the Single Quantum Level — •Matthias Keller, Anders Mortensen, Alexander Wilson, Daniel Crick, Fedja Orucevic, Hiroki Takahashi, Nicolas Seymour-Smith, Elisabeth Brama, Andrew Riley-Watson, and Wolfgang Lange — University of Sussex, Brighton, BN1 9QH, United Kingdom

The complementary benefits of trapped ions and photons as carriers of quantum information make it appealing to combine them in a joint system. Cavity-QED provides a setting in which the quantum states of ions and photons can be interfaced efficiently. The most suitable scheme to use depends on the strength of the coherent ion-field coupling and the cavity damping rate. For moderate coupling, quantum entanglement may be generated probabilistically. Multiple ions are projected to an entangled state upon detecting photons emitted from the cavity. For stronger coupling, deterministic transfer of quantum states between ions and photons is possible, linking ionic qubit states with the two orthogonal polarization modes of the cavity. Entanglement of ions in a cavity may even be generated through the exchange of virtual photons. This requires the coupling to exceed considerably the cavity damping rate. We will report on progress in the realization of these schemes at the University of Sussex.

Q 32.7 We 15:30 E 214

Quantum Optics Experiments in a Segmented Microchip Ion Trap — •Ulrich Poschinger, Gerhard Huber, Andreas Walther, Max Hettrich, Markus Deiss, Frank Ziesel, Kilian Singer, and Ferdinand Schmidt-Kaler — Institut für Quanteninfarmationsverarbeitung, Universität Ulm, Albert-Einstein-Allee 11, 89069 Ulm

We present recent results from our experiment aiming at scalable quantum simulation and information. We first show how a qubit is implemented by using the Zeeman split groundstate levels of a $^{40}Ca^+$ ion. Emphasis is put on how the challenging conditions in our microtrap [1] compared to standard traps affect readout, ground state cooling and coherent manipulations [2]. We then present first experiments based on these techniques, including coherent manipulations on two-ion crystals, implementation of spin-dependent and spin-independent light forces, creation and characterization of Schrödinger cat states and quantum state tomography.

[1] S. Schulz et al., New Journal of Physics 10, 045007(2008)
[2] U. G. Poschinger et al., J. Phys. B 42, 154013 (2009)

Q 32.8 We 15:45 E 214

Effects of Ion-Trap RF-Potential on Atom-Ion Scattering Processes — •Björn Arnold[1], Tommaso Calarco[1], and Zbigniew Idziaszek[2] — [1]Institute for Quantum Information Processing, University of Ulm, D-89069 Ulm, Germany — [2]Institute for Theoretical Physics, University of Warsaw, 00-681 Warsaw, Poland

We investigate collisions of a single ion trapped in RF potential with a single atom trapped in a static trap. Within the one- and three-dimensional models we examine the effects of the time-dependent ion trap on the collision dynamics and on the average particle energies. We first perform our calculations employing an idealized model of atom-ion interaction provided through a delta potential, later we turn to a more realistic description involving long-range $1/r^4$ atom-ion interaction supplemented by the quantum-defect boundary conditions at short range. We introduce different description methods for the wavefunction and its time evolution by applying simple expansions in different ortho-normal bases and Floquet expansion.

Q 33: Laser Development: Semiconductor Lasers / Nonlinear Effects II

Time: Wednesday 14:00–16:00 Location: F 128

Q 33.1 We 14:00 F 128

Gekoppelte Ringresonatoren mit Tapered Amplifier und miniaturisiertem SHG Resonator zur effizienten Frequenzverdopplung auf 488 nm — •Danilo Skoczowsky, Andreas Jechow, Axel Heuer und Ralf Menzel — Universität Potsdam, Institut für Physik und Astronomie, Lehrstuhl für Photonik, Karl-Liebknecht-Straße 24–25, 14476 Potsdam

Die effiziente Erzeugung von sichtbarer Laserstrahlung ist für viele Anwendungen von hohem Interesse. Neben der direkten Erzeugung beispielsweise mit Laserdioden ist die Frequenzverdopplung von infraroter Laserstrahlung nach wie vor eine gängige Technik. Wird die Intensität der Grundwelle mit Hilfe eines Resonators überhöht, so kann der Verdopplungsprozess deutlich effizienter ablaufen. Diese Technik erfordert jedoch eine Stabilisierung der Frequenz des Pumplasers and die Resonanzfrequenz des hochvergüteten Resonators oder umgekehrt.

Vorgestellt wird ein neues, passives Kopplungskonzept basierend auf einem „Tapered Amplifier“ in einer ringförmigen Resonatoranordnung, an den ein zweiter, miniaturisierter Ringresonator gekoppelt ist. Dieser ist hochvergütet ausgeführt und enthält einen periodisch gepolten, nichtlinearen Kristall zur Frequenzverdopplung. Beide Resonatoren sind rein optisch gekoppelt ohne aktive Regelung. Es konnten bisher über 300 mW blaues Licht bei 488 nm generiert werden. Das blaue Licht ist nahezu beugungsbegrenzt und hat eine Bandbreite von 50 MHz. Die Emission ist zeitlich stabil mit Fluktuationen $< 1\,\%$.

Q 33.2 We 14:15 F 128

Untersuchung der Specklereduktion bei inkohärent gekoppelten Diodenlasern im externen Resonator — •Antonio Saghati, Danilo Skoczowsky, Axel Heuer und Ralf Menzel — Universtität Potsdam, Institut für Physik und Astronomie, Photonik, Karl-Liebknechtstraße 24-25 14476 Potsdam

Speckle sind störend für diverse Anwendungen wie zum Beispiel die Displaytechnologie und Linienprojektion. Eine Möglichkeit Speckle zu reduzieren ist die Verwendung von breitbandigen Strahlquellen.

Um Laserlicht mit guter Strahlqualität und einer Bandbreite von mehreren nm zu erzeugen ist die inkohärente Kopplung von Diodenlasern mittels spectral beam combining (SBC) gut geeignet. Dieses Verfahren kann als “Wavelength-Multiplexing” im Resonator verstanden werden.

Mit einem AR beschichteten Diodenlaser-Array bestehend aus 40 Emittern wurde mit SBC eine Ausgangsleistung von 500 mW, eine Strahlqualität von $M^2 < 2$ und eine Bandbreite von ≈ 4 nm realisiert.

Der Einfluß der Bandbreite auf die Speckle wurde bei verschiedenen Betriebsparametern untersucht.

Q 33.3 We 14:30 F 128

Investigations on wave chaos phenomena in VCSELs — •Andreas Molitor[1], Matthias Breuer[1], Pierluigi Debernardi[2], and Wolfgang Elsässer[1] — [1]Institute of Applied Physics, Damstadt University of Technology, Schloßgartenstr 7, 64289 Darmstadt, Germany — [2]IEIIT-CNR c/o Politecnico di Torino, Corsa Duca degli Abruzzi 24, 10129 Torino, Italy

VCSELs are modern low-cost semiconductor laser structures that have become standard lasers in optical datacom applications. The same properties, which make them so interesting for applications, imply also high invulnerability to instabilities or chaos. We experimentally investigate the onset of wave chaos in VCSELs with different shaped resonators [1]. Signatures of chaos are found by analyzing highly-resolved transverse mode spectra measured with a Czerny-Turner-spectrometer and a single photon counting system. The nearest-neighbor eigenvalue distribution is determined from the mode spacing normalized by its mean value. Furthermore, cumulated eigenvalue spacing distributions are derived in order to analyze the optical spectra. This cumulated distribution allows to differentiate between regular behavior for circular and chaotic characteristics for non-circularly shaped apertures, respectively. These first results are complemented by investigations on surface grating relief VCSELs where the emission and in particular the polarization can be controlled technologically [2].

[1] T.Gensty et al., PRL 94, 233901 1-4 (2005)
[2] J. M. Ostermann et al., Opt. Commun. 246, 511 (2005)

Q 33.4 We 14:45 F 128

Characterization of novel TBR laser diodes at 980nm — •Christof Zink, Danilo Skoczowsky, Andreas Jechow, Axel Heuer, and Ralf Menzel — Universität Potsdam, Institiut für Physik und Astronomie, Lehrstuhl Photonik, Karl-Liebknecht-Straße 24-25, 14476 Potsdam

Broad area (BA) lasers are the most efficient light sources available, but suffer from poor beam quality due to the lack of tranversal mode selection. By incorporating a transverse Bragg grating into a BA laser diode it is possible to select one transversal mode. The resulting transverse Bragg resonance (TBR) waveguide can be designed to have a single transversal mode that is distributed throughout the entire width of the laser for efficient, stable and single transversal mode operation even at high powers. In addition the modal gain at the desired lasing frequencies can be increased by designing the dispersion of the TBR modes. This concept promises higher output powers and improved efficiency compared to traditional index-guided laser diodes. Preliminary measurements of different laser samples with two or three quantum well structures and a Bragg grating with grating period of 3μm will be presented. Furthermore, the TBR lasers were operated in an external resonator which allows selecting different types of modes.

Q 33.5 We 15:00 F 128

Erzeugung von 267 fs-Impulsen durch Colliding Pulse Mode-locking in Zweisektions-Diodenlasern und externer Kompression — •Thorsten Ulm, Florian Harth und Johannes A. L'huillier — Photonik-Zentrum Kaiserslautern e.V., Kohlenhofstr. 10, 67663 Kaiserslautern

Mit einem Oszillator-Verstärker-System auf der Basis von InGaAs-Diodenlasern und einem nachfolgenden Gitterkompressor wurden 267 fs lange Impulse mit 708 mW mittlerer Leistung, 661 W Spitzenleistung, 213 pJ Impulsenergie und 3,3 GHz Wiederholrate erzeugt. Die spektrale Breite beträgt 7 nm. Die Zentralwellenlänge ist 920 nm. Lasersysteme dieser Bauart sollen in Zukunft zusammen mit Faserverstärkern für die nichtlineare Optik und die Mikromaterialbearbeitung genutzt werden.

Zur Impulserzeugung wurde die Methode des *Colliding Pulse Mode-locking* eingesetzt. Der zur passiven Modenkopplung benötigte Absorber ist in den Wellenleiter einer Zweisektions-Diode integriert. Eine Gegenspannung reduziert die Erholzeit des Absorbers und stabilisiert die Modenkopplung. Um Gain-Sättigung und Selbstphasenmodulation im nachfolgenden Trapezverstärker zu vermeiden, müssen die Impulse eine Dauer von mehreren Pikosekunden haben. Die relativen Intensitäten und der Kollisionspunkt der umlaufenden Impulse wurden im Hinblick auf einen möglichst starken und linearen Frequenzchirp systematisch optimiert. Die Kompensation des linearen Chirps im Gitterkompressor erzeugt Femtosekunden-Impulse mit einem Zeit-Bandbreite-Produkt, das nur um den Faktor 1,8 über dem theoretischen Limit liegt.

Q 33.6 We 15:15 F 128

Schmalbandiger GaSb-OPSDL bei 2 μm Wellenlänge — •Philipp Koopmann[1,2], Samir Lamrini[2], Karsten Scholle[2] und Peter Fuhrberg[2] — [1]Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]LISA laser products, Max-Planck-Str. 1, 37191 Katlenburg-Lindau

An Lasern mit Wellenlängen im Bereich um 2 μm besteht ein großes Interesse, da diese in einer Vielzahl von Anwendungen eingesetzt werden. So finden sie z. B. in der Medizin, in der Gas-Detektion und in LIDAR-Systemen Verwendung. Mit optisch gepumpten Halbleiter-Scheibenlasern (OPSDL) lassen sich kompakte Aufbauten und hohe Strahlqualitäten realisieren. OPSDLs auf (AlGaIn)(GaSb)-Basis ermöglichen Laseraktivität im Bereich von 1,9 μm bis 2,7 μm. Mit diesem System konnten von uns Ausgangsleistungen von bis zu 2,6 W erreicht werden, wobei der OPS bei einer Wellenlänge von 976 nm gepumpt wurde. Mittels eines doppelbrechenden Filters konnte die Wellenlänge des Lasers über 60 nm durchgestimmt werden. Wurde anstelle eines Auskoppelspiegels ein Volumen Bragg Gitter (VBG) verwendet, konnte die Wellenlänge des Lasers fixiert und die Linienbreite auf unter 2,4 MHz reduziert werden. Die maximale Ausgangsleistung bei Verwendung des VBG war auf 750 mW begrenzt. Die verwendeten Gitter ermöglichten Lasertätigkeit bei 1960 nm, 2013 nm und 2021,3 nm.

Q 33.7 We 15:30 F 128

Modellierung und Anwendung eines Verfahrens zur Verbesserung der Eigenschaften von Laserdioden mit externem Resonator (ECDL) — •Thorsten Führer, Benjamin Rein und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, AG Laser und Quantenoptik, Schlossgartenstr. 7, D-64289 Darmstadt

Für viele Bereiche, beispielsweise in der Sensorik oder der Präzisionsspektroskopie, sind ECDLs unverzichtbar. Je nach Anwendung ist dabei ein großer modensprungfreier Durchstimmbereich oder ein stabiler ECDL-Betrieb bei einer konstanten Wellenlänge nötig. In beiden Fällen ist es essentiell, den Diodenstrom und die Länge des externen Resonators aufeinander abzustimmen, um die Resonanz des Gesamtsystems zu erhalten. Durch Übertragen der Resonanzinformation auf den Polarisationszustand des Laserlichts kann der Stokes-Parameter S_1 als Fehlersignal für einen geschlossenen Regelkreis verwendet werden. Dadurch konnte ein modensprungfreier Durchstimmbereich von 130 GHz mit einer nicht AR-beschichteten Laserdiode erreicht werden. Ferner konnte durch eine heterodyne Messung gezeigt werden, dass im gelockten Fall auch bei einer Drift der Resonatorlänge eine niedrige Linienbreite aufrechterhalten wird. Ungelockt kann es zu multi-mode Betrieb sowie einer Linienverbreiterung kommen. Zur Modellierung des Fehlersignals wird der ECDL als 3-Spiegel-Interferometer aufgefasst und der Polarisationszustand mit Hilfe des Jones-Formalismus beschrieben. Aufgrund des großen Parameterraums wurde das Modell mit Hilfe eines evolutionären Algorithmus an die Messdaten angepasst. Es zeigt sich eine exzellente Übereinstimmung von Modell und Messung.

Q 33.8 We 15:45 F 128

Stabiler Diodenlaser-gepumpter, Idler resonanter CW OPO auf Basis von MgO:PPLN — •Andreas Lenhard[1], Sebastian Zaske[1], Johannes L'huillier[2] und Christoph Becher[1] — [1]Universität des Saarlandes, Technische Physik, Campus E2.6, 66123 Saarbrücken — [2]Technische Universität Kaiserslautern, Fachbereich Physik, Erwin-Schrödinger-Str 46, 67663 Kaiserslautern

Diodenlasersysteme basierend auf InGaAs-Trapezverstärkern erreichen im Bereich 920 nm hohe Ausgangsleistungen bei gleichzeitig nahezu beugungsbegrenzter Strahlqualität. Dies erlaubt ihren effizienten Einsatz in der nichtlinearen Optik.

Wir stellen einen cw optisch parametrischen Oszillator vor, der von einem Diodenlaser master-oscillator-power-amplifier (MOPA) System bei 923 nm gepumpt wird. Der OPO Resonator ist resonant für die Pump- und Idlerwellenlänge und wird durch ein Pound-Drever-Hall Verfahren auf die Wellenlänge der Pumpquelle stabilisiert. Zur Erzeugung des Fehlersignals wird direkt der Diodenlaserstrom moduliert, was zusätzliche Modulatoren im Strahlengang überflüssig macht. Das MOPA-System als Referenz für die Stabilisierung erlaubt die amplituden- und frequenzstabile Erzeugung der Signalstrahlung und modensprung-freien Betrieb des OPO für mehr als eine Stunde. Bei 2.5 W Pumpleistung wird eine Ausgangsleistung von bis zu 220 mW erreicht. Als nichtlineares Medium dient ein 38 mm langer, periodisch gepolter MgO:$LiNbO_3$ Kristall bei Periodenlängen von 26.6 μm und 26.4 μm. Durch Ändern von Kristalltemperatur oder Pumpwellenlänge wird Signalstrahlung in einem Bereich von $1.4 - 1.6$ μm erzeugt.

Q 34: Ultrashort Laser Pulses: Applications II

Time: Wednesday 14:00–16:00 Location: F 342

Q 34.1 We 14:00 F 342

Ultimate fast optical switching of a photonic microcavity — •Georgios Ctistis[1,3], Alex Hartsuiker[1], Julien Claudon[2], Jean-Michel Gérard[2], and Willem L. Vos[1,3] — [1]Center for Nanophotonics, FOM Institute for Atomic and Molecular Physics (AMOLF), Amsterdam, Netherlands — [2]CEA-CNRS Nanophysics and Semiconductors joint laboratory, Grenoble, France — [3]Complex Photonic Systems (COPS), MESA+ Institute for Nanotechnology, University of Twente, Netherlands

Exciting prospects arise when photonic nanostructures are switched on ultrafast timescales. Of particular interest is the ultrafast switching of the resonance of a cavity wherein photons are stored for a long time in a tiny volume. Such switching permits the quantum electrodynamical manipulation of the stored photons, or the optical properties of a source embedded in the cavity. Here we have switched the resonance in the telecom range of an ultrafast ($\tau_{cav} = 0.9$ ps) cavity by the instantaneous electronic Kerr effect. Essential steps in our experiments are fabricating a dedicated cavity with a resonance in the telecom range and employing low-energy pump photons. This switching mechanism potentially allows beyond-THz modulation rates that could be of use for extremely fast datamodulation.

Q 34.2 We 14:15 F 342

Faserlasergepumpter Femtosekunden LBO optisch parametrischer Oszillator — •Jörn Epping, Carsten Cleff, Petra Gross und Carsten Fallnich — Institut für Angewandte Physik, Westfälische Wilhelms-Universität, Corrensstr. 2, 48149 Münster

Es wird ein synchron gepumpter einfachresonanter Femtosekunden LBO-OPO vorgestellt. Als Pumpquelle dient ein diodengepumpter Ytterbium-Faser-Oszillator, bei dem nach einem zweistufigen Yb-Verstärker die Impulse komprimiert und in einem LBO-Kristall frequenzverdoppelt werden. Die erzeugten Pumpimpulse haben eine Dauer von 300 fs bei einer Wellenlänge von 525 nm und eine mittlere Leistung von 6 W bei einer Repetitionsrate von 61 MHz. Begrenzt durch die verwendeten Spiegel kann die Signalwellenlänge des OPOs von $780 - 950$ nm und die Idlerwellenlänge von $1200 - 1600$ nm durch die Veränderung der Kristalltemperatur variiert werden. Die Bandbreite der erzeugten Signalimpulse ist gegenüber den Pumpimpulsen vergrößert und ermöglicht eine Kompression unterhalb der Pumpimpulsdauer. Die weite Durchstimmbarkeit des OPOs und die intrinsische Synchronität zwischen Signal- und Idlerimpulsen sowie zu den Impulsen des Yb-Faserlasers ermöglichen den Einsatz für Mikroskopie mit kohärenter anti-Stokes Raman Streuung (CARS), welche sowohl eine hohe räumliche Auflösung, als auch eine chemische Selektivität ermöglicht.

Q 34.3 We 14:30 F 342

Ultrashort-pulsed, ultra-broadband nondiffracting tubular beam generated with a phase only spatial light modulator — •Martin Bock and Ruediger Grunwald — Max Born Institute, Max-Born-Straße 2a, 12489 Berlin, Germany

Tubular beams propagating diffractionless were generated with a high-resolution liquid crystal on silicon spatial light modulator (LCoS-SLM). Contrary to higher-order Laguerre-Gauss or Bessel-Gauss modes [1,2], such beams exhibit no significant extrinsic orbital angular momentum. The new approach is based on generating adapted angular distributions by shaping the beam with a bi-prism bent to an annulus (torus-axicon) which was programmed into the SLM. The active area was completely involved by including a convex conical center thus leading to high energy efficiency. A diverging wave from the center is superimposed with a converging wave from the outer parts. In the experiments we used a Ti:sapphire oscillator emitting 10 fs pulses to illuminate the SLM. The ring-shaped wavepacket resulting from the interference of the parts constituting the wave was found to propagate in the fashion of a nondiffracting beam. With 20 fs, the pulse duration was only slightly changed. We suppose that this was mainly caused by the cover glass of the SLM.

[1] D. McGloin, et al., Opt. Comm. 225, 215-222 (2003).
[2] I. G. Mariyenko, Opt. Express 13, 7599-7608 (2005).

Q 34.4 We 14:45 F 342

Photonic fiber for flexible sub-20 fs pulse delivery — •Jens Bethge[1], Tuan Le[2], Julia Skibina[3], Andreas Stingl[2], and Günter Steinmeyer[1] — [1]Max Born Institute, Berlin, Germany — [2]Femtolasers Produktions GmbH, Vienna, Austria — [3]Saratov State University, Saratov, Russia

A flexible femtosecond pulse delivery is desirable for many applications, e.g,. microscopy, endoscopy, and photodynamic therapy. We report on the experimental demonstration of sub-20 fs pulse delivery with a spectrally flat phase through 80 cm of chirped photonic crystal fiber (CPCF)[1]. The delivery is utilizing chirped mirrors for dispersion precompensation of the coupling optics as well as the remaining waveguide dispersion of the CPCF. Even tough the use of precompensation has been recently shown for large mode area fibers with a solid core [2], our improved concept of a hollow-core fiber sets a new world record on short pulse delivery and is scalable towards higher energies. Since the dispersion contribution of the fiber is flat and virtually vanishing for all wavelengths involved, we are able to precompensate the dispersion of the optics and of the fiber with only 8 bounces off chirped mirrors. This is an easy-to-implement technique for delivering bandwidth-limited pulses of sub-20 fs duration over meter distances, promising interesting future applications.

[1] J. S. Skibina, et al., Nature Photonics 2, 679 - 683 (2008).
[2] T. Le, et al., Opt. Express 17, 1240-1247 (2009).

Q 34.5 We 15:00 F 342

Multimodales Koppeln in ultrakurzpuls geschriebenen Faser-Bragg-Gittern — •Ria Becker[1], Jens Thomas[1], Stefan Nolte[1] und Andreas Tünnermann[1,2] — [1]Friedrich-Schiller-Universität Jena, Institut für Angewandte Physik, Max-Wien-Platz 1, 07743 Jena — [2]Fraunhofer-Institut für Angewandte Optik und Feinmechanik IOF, Albert-Einstein-Str. 7, 07745 Jena

Faser-Bragg-Gitter (FBG) haben sich als faserintegrierte Reflektoren in einmodigen Fasern zu Schlüsselelementen für optische Kommunikationssysteme und Sensoren etabliert. Bei mehrmodigen Fasern jedoch erzeugen FBG's multimodale Reflektionen, für die es keine effizienten Filtermöglichkeiten gibt. Herkömmlichen Einschreibeverfahren beruhen auf photosensitiven Prozessen. Daher betrifft die Brechzahlmodifikation den ganzen Faserkern. Verwendet man jedoch femtosekunden Laserpulse für die Erzeugung der FBG's, kann man partiell im Kern die Brechzahl modifizieren. Die Erzeugung des Brechzahlhubs beruht auf nichtlinearer Absorption, so dass das die Modifikation nur im Fokus des Laserstrahls auftritt. Mit Hilfe der gekoppelten Modentheorie kann gezeigt werden, dass durch Variation der Position der Brechzahlmodifikation im Kern die Kopplung in Moden höherer Ordnung gesteuert werden kann. Bei Hochleistungsfaserlasern werden Fasern mit großen Kerndurchmessern benötigt, die oft leicht mehrmodig sind. Die dadurch entstehenden multimodalen Reflektionen verursachen Instabilitäten. Durch partielle Modifikation des Faserkerns konnten diese unterdrückt, und ein stabiler Laserbetrieb gewährleistet werden.

Q 34.6 We 15:15 F 342

Non-adiabatically changing the frequency of light in a transient microcavity — •Georgios Ctistis[1], Philip J. Harding[1,2], Huib Bakker[2], Alex Hartsuiker[2], Julien Claudon[3], Allard Mosk[1], Jean-Michel Gérard[3], and Willem L. Vos[1,2] — [1]Complex Photonic Systems (COPS), MESA+ Institute for Nanotechnology, University of Twente, The Netherlands — [2]Center for Nanophotonics, FOM Institute for Atomic and Molecular Physics (AMOLF), Amsterdam, The Netherlands — [3]CEA-CNRS Nanophysics and Semiconductors joint laboratory, Grenoble, France

We study frequency-resolved femtosecond pump-probe reflectivity of a planar GaAs/AlAs microcavity. About 8 ps after a pump pulse, we observe an excess signal due to a non-adiabatic frequency change of the stored light by more than 4 linewidths away from the cavity resonance. Strikingly, the frequency change of light occurs at a time when the pump pulse is long gone. The frequency change is caused by the accumulated phase change of the light stored in the transient cavity. In agreement with an analytical model, the excess reflectivity is high when the cavity resonance frequency strongly shifts compared to the cavity linewidth within one cavity storage time.

Q 34.7 We 15:30 F 342

Fiber Based Ultrashort Pulse System with Kilowatt Level Average Power — Tino Eidam[1], •Stefan Hanf[1], Thomas Andersen[2], Enrico Seise[1], Chrisitan Wirth[3], Thomas Schreiber[3], Thomas Gabler[4], Jens Limpert[1], and Andreas Tünnermann[1,3] — [1]Friedrich-Schiller-University Jena, Institute of Applied Physics, Albert-Einstein-Str. 15, 07745 Jena, Germany — [2]NKT Photonics, Blokken 84, DK-3460 Birkeroed, Denmark — [3]Fraunhofer Institute for Applied Optics and Precision Engineering, Albert-Einstein-Str. 7, 07745 Jena, Germany — [4]JT Optical Engine, Prüssingstr. 41, 07745 Jena, Germany

Ultrashort pulse laser systems combining simultaneously high peak and average power are desirable in many applications. Especially the high pulse repetition rate results in a reduced measurement time in fundamental science and in an increased processing speed for industrial applications. Extreme parameters, i.e. mJ-level pulses at average powers beyond one kilowatt and diffraction limited beam quality, is still a huge challenge for every existing laser architecture. The application of the chirped pulse amplification (CPA) technology in combination with photonic crystal fibers (PCFs) led to ultrashort pulses with mJ-level pulse energies. Herein we present a three-stage fiber CPA system generating 830 W of compressed average power at 78 MHz pulse repetition frequency and 640 fs pulse duration. Beside these record parameters we discuss possibilities to overcome limitations of current large mode area fiber amplifiers imposed by transversal spatial hole burning enabling fiber CPA systems with kW average power and GW peak power.

Q 34.8 We 15:45 F 342

Ultrafast solid-state lasers for frequency comb stabilization — •T. Südmeyer[1], M. C. Stumpf[1], S. Pekarek[1], A. E. H. Oehler[1], C. Fiebig[2], K. Paschke[2], G. Erbert[2], J. M. Dudley[3], and U. Keller[1] — [1]Department of Physics, ETH Zurich, Switzerland — [2]Ferdinand-Braun-Institut für Höchstfrequenztechnik, Berlin, Germany — [3]Institut FEMTO-ST, CNRS-Université de Franche-Comté, Besançon, France

Very recently, we demonstrated the first self-referencable ultrafast solid-state laser oscillator operating in the 1500 nm spectral region. Here we present for the first time the full CEO frequency stabilization and repetition rate stabilization of this laser. Our system is based on a 170-fs Er:Yb:glass laser generating 110 mW output power at less than 1.5 W electrical power consumption. It generates a coherent octave spanning frequency comb in a polarization maintaining highly nonlinear fiber (PM-HNLF) without any amplification. Our free-running CEO-beat is 49 dB above the noise floor and its linewidth of 3.6 kHz is more than an order of magnitude lower than typically obtained by free-running ultrafast fiber laser systems. The CEO frequency was stabilized by feedback on the diode current from a phase-locked loop (PLL). A stable CEO-beat was observed even with pulse durations above 260 fs.

Furthermore, we present the first femtosecond SESAM-modelocked Yb:KGW laser operating at 1 GHz repetition rate. We generated 120 mW output power in 317-fs pulses at 1030 nm for 1.7-W pump power from a high-brightness single-frequency DBR tapered diode laser.

Q 35: Precision Measurements and Metrology IV

Time: Wednesday 16:30–19:00 Location: A 310

Q 35.1 We 16:30 A 310

FPGA basiertes, ultrapräzises RF Phasenmeter, als Konzeptstudie für den Gravitationswellendetektor LISA — •Markus Wussler[1,2], Franziska Kittelmann[1,3], Claus Braxmaier[1,2], Peter Gath[1], Martin Gohlke[1,4], Ulrich Johann[1], Thilo Schuldt[2,4], Hans-Reiner Schulte[1], Steffen Waimer[1,5] und Dennis Weise[1] — [1]EADS Astrium GmbH — [2]HTWG Konstanz — [3]Fachhochschule Gelsenkirchen — [4]Humboldt Universität zu Berlin — [5]Hochschule Esslingen

Zur Durchführung der Weltraummission LISA (Laser Interferometer Space Antenna), einer Mission von ESA und NASA, mit dem Ziel Gravitationswellen nachzuweisen und zu messen, benötigt man ein ultrapräzises Phasenmeßsystem. Dieses vergleicht die Frequenz und die Phasenlage eines Mess-Lasers relativ zu einem Referenz-Laser. Durch Überlagerung der beiden Laser entsteht ein Schwebungssignal, welches digitalisiert wird. Phase und Frequenz des Signals werden mittels DPLL (Digital Phase Locked Loop), realisiert auf einem FPGA (Field Programmable Gate Array) Board, ermittelt und weiter verarbeitet. Der Eingangsfrequenzbereich reicht von 2 bis 19 MHz. Ziel der Messung ist es ein Rauschlevel von kleiner als 6 microrad/sqrt(Hz) innerhalb der LISA Messbandbreite (0,1mHz bis 1Hz) zu erreichen. Im Vortrag wird der Prototyp vorgestellt, bereits vorhandene Messungen gezeigt, sowie auf vorhandene Limitierungen eingegangen. Es zeigt sich, dass das Phasemeter die Performanceanforderung bereits in weiten Frequenzbereichen erfüllt.

Q 35.2 We 16:45 A 310

Bridging the gap between LISA phasemeter raw data and astrophysical data analysis — •Yan Wang, Gerhard Heinzel, and Karsten Danzmann — AEI Hannover (Max-Planck-Institut für Gravitationsphysik), Leibniz Universität Hannover

LISA (Laser Interferometer Space Antenna) is intend to measure gravitational waves by using laser interferometry over astronomical distances. The input astrophysical LISA data are the TDI variables, which are combinations of time shifted phasemeter data and spacecraft distances that roughly synchronized to a common timescale. In practice, these raw phasemeter data are contaminated by the free-running local clocks. In this talk, I would talk about how and to what extent we could make the phasemeter raw data qualified for TDI combinations.

Q 35.3 We 17:00 A 310

Optical Bench Development for LISA — •Dennis Weise[1], David Robertson[2], Henry Ward[2], Michael Tröbs[3], Gerhard Heinzel[3], Karsten Danzmann[3], Joep Pijnenburg[4], Harm Hogenhuis[4], and Luigi d'Arcio[5] — [1]Astrium GmbH — [2]Glasgow University — [3]Albert-Einstein Institute — [4]TNO Science and Industry — [5]ESA/ESTEC

Under ESA contract, a team of Astrium GmbH as prime contractor, the University of Glasgow, the Albert-Einstein Institute, and TNO is developing an Elegant Breadboard of the Optical Bench for the future Laser Interferometer Space Antenna (LISA) Mission. For detection and characterization of gravitational waves between 3×10^{-5} and 1 Hz, LISA will be implemented in a triangular constellation of 3 identical spacecraft, linked by heterodyne laser interferometry in an active transponder scheme over a 5 million kilometer distance. For each laser link, the Optical Bench realizes both remote and local beam metrology with respect to inertial proof masses inside the spacecraft, as well as various ancillary functions such as point-ahead correction, acquisition sensing, transmit beam conditioning, laser redundancy switching, etc.

The purpose of this project is a comprehensive demonstration of the Optical Bench functions, including in particular Nanoradian and Picometer optical metrology in the required degrees of freedom. We will give an overview of the development approach, the planned optical layout and design of the Optical Bench, the special equipment required for integration and verification, and introduce the pre-experiments used for prior validation of the technical concepts.

Q 35.4 We 17:15 A 310

Piezo-Tunable High Finesse Cavity for LISA — •Katharina Möhle, Klaus Döringshoff, Moritz Nagel, Evgeny V. Kovalchuk, and Achim Peters — Humboldt Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Hausvogteiplatz 5-7, 10117 Berlin

The interferometric read out of the space-borne gravitational wave detector LISA requires a high frequency stability of the employed Nd:YAG lasers. This should be achieved in three steps, including prestabilization to a Fabry-Perot cavity. The prestabilization has to feature a tunability of ± 30 MHz, in order to accommodate slow Doppler-shifts caused by yearly variation of the triangular satellite configuration.

Given the constraint of not using an optical modulator for offset locking, the first approach for a tunable prestabilization is to make the cavity itself tunable by adding a piezoelectric actuator. The frequency stability obtained with a commercial multilayer PZT piezo actuator is about $10\ \mathrm{Hz}/\sqrt{\mathrm{Hz}}$ above 0.1 Hz fulfilling the LISA requirements.

We will discuss how the actuator affects the mechanical stability of the cavity taking into account typical piezo material effects like hysteresis, creep and aging, but also other effects like thermal expansion and voltage noise. To demonstrate the feasibility of the integration within the LISA arm locking concept we included the piezo-cavity in an outer feedback loop. Thus the stability of an ultra stable reference cavity could be transferred to the piezo-cavity by stabilizing the cavity length (bandwidth 3 kHz).

Q 35.5 We 17:30 A 310

LISA Phasemeter Development: ADC-jitter correction — •Iouri Bykov, Joachim Kullman, Benjamin Sheard, Juan Jose Esteban, Antonio Francisco Garsia Marin, Gerhard Heinzel, and Karsten Danzmann — Max-Planck Institut für Gravitationsphysik, Callinstr. 38, 30167 Hannover

The gravitational wave detector LISA (Laser Interferometer Space Antenna) aims to detect and observe in details gravitational waves from astronomical sources. One of the most important components of LISA is the Phase-Measurement System (PMS). We present the latest results of PMS development with emphasis on jitter-correction of Analog-to-Digital Converters (ADCs) used in phase measurements. The use of the presented jitter-correction techniques allows to meet LISA-requirements (noise performance) for PMS.

Q 35.6 We 17:45 A 310

Clock noise removal in the LISA mission — •Markus Otto, Gerhard Heinzel, and Karsten Danzmann — AEI Hannover (Max-Planck-Institut für Gravitationsphysik), Leibniz Universität Hannover

The detection of gravitational waves with the Laser Interferometer Space Antenna (LISA) in the 0.1 mHz - 1 Hz band is mainly disturbed by the laser phase noise. By Time Delay Interferometry (TDI), it is possible to remove this disturbance while the gravitational wave signal remains unchanged. For this, prompt and time-delayed signals are combined in a suitable way.

However, to synthesize those data stream combinations, the analog interferometer signal has to be transformed to a digital signal by an Analog Digital Converter (ADC). The ADC is driven by an extremely accurate clock (ultra stable oscillator, USO). This clock has inherent noise and thus introduces clock noise into the data streams. In our talk we will give a short overview of the clock noise problem and then discuss some possible solutions to cancel out the clock noise.

Q 35.7 We 18:00 A 310

Der Advanced LIGO bow-tie Pre-Modecleaner — •Jan Hendrik Pöld, Benno Willke und Karsten Danzmann — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) und Institut für Gravitationsphysik, Leibniz Universität Hannover, Germany

Ein Pre-Modecleaner (PMC) ist ein optischer Resonator, der benutzt wird, um die Strahlqualität eines Lasers zu verbessern. Dabei spielen drei Filtereffekte dieses Resonators eine besondere Rolle. Da der PMC mit Hilfe des Pound-Drever-Hall Verfahrens resonant in der Grundmode gehalten wird, agiert er als Filter für Moden höherer Ordnung, die im einfallenden Laserstrahl enthalten sind. Des Weiteren werden Strahllagefluktuationen durch den PMC gefiltert und Schwankungen der Laserleistung bei Radiofrequenzen unterdrückt.

Im Gravitationswellendetektor Advanced LIGO wird für die Stabilisierung des Lasers ein PMC benötigt. In diesem Fall muss beim

Design zusätzlich die hohe Laserleistung berücksichtigt werden, durch die optische Komponenten beschädigt werden können, da das zirkulierende Feld im Resonator um ein vielfaches höher als die eingekoppelte Laserleistung ist.

In diesem Vortrag werden die Filtereffekte eines PMCs beschrieben und auf die Herausforderungen beim Design des Advanced LIGO PMCs eingegangen. Abschließend werden die Ergebnisse der Charakterisierung des stabilisierten Advanced LIGO Lasersystems vorgestellt.

Q 35.8 We 18:15 A 310

Leistungsstabilisierung des Advanced LIGO Lasers — •Christina Krämer, Patrick Kwee, Benno Willke und Karsten Danzmann — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institiut) und Institut für Gravitationsphysik der Leibniz Universität Hannover, Germany

Die Empfindlichkeit von interferometrischen Gravitationswellendetektoren skaliert sowohl mit der eingestrahlten Laserleistung als auch mit der Leistungsstabilität. Daher werden für die nächsten Generationen von Gravitationswellendetektoren Hochleistungslaser benötigt, die nur ein sehr geringes Leistungsrauschen aufweisen.

Bei dem Advanced LIGO Laser wird die erforderliche Leistungsstabilität mit Hilfe eines aktiven Regelkreises erreicht, der es ermöglicht das relative Leistungsrauschen bei 10 Hz auf $2*10^{-9}\,\mathrm{Hz}^{-1/2}$ am Interferometer zu verringern. Die aktive Regelung besteht aus einer inneren und einer äußeren Regelschleife. Beide unterscheiden sich durch die Art und die Position des jeweiligen Detektors. Der innere Regelkreis stabilisiert die Leistung auf $10^{-8}\,\mathrm{Hz}^{-1/2}$ vor. Der äußere Regelkreis wird die erforderliche Stabilität von $2*10^{-9}\,\mathrm{Hz}^{-1/2}$ im Gravitationswellendetektor ermöglichen.

Die Leistungsstabilisierung des Advanced LIGO Lasers mit Hilfe der inneren Regelschleife wird vorgestellt sowie das Konzept für den äußeren Regelkreis.

Q 35.9 We 18:30 A 310

Quasi-monolithic Interferometer for the Examination of the fundamental Non-reciprocity of a single-mode polarization maintaining Fiber for space Applications — •Roland Fleddermann, Christian Diekmann, Frank Steier, Michael Tröbs, Gerhard Heinzel und Karsten Danzmann — Albert-Einstein-Institut Hannover, Max-Planck-Institut für Gravitationsphysik und Universität Hannover, Callinstr. 38, 30167 Hannover

The Laser Interferometer Space Antenna (LISA) mission by ESA and NASA for the detection of gravitational waves in the frequency range from 0.1 mHz to 1 Hz requires optical fibers for the exchange of light between optical benches on satellites.

Reciprocal noise can be subtracted in this application, but non-reciprocal noise would limit the measurement sensitivity. Therefore, a quasi-monolithic, interferometric measurement setup was developed that is capable of measuring non-reciprocal phase variations with a sensitivity of $\approx 6\,\mu\mathrm{rad}/\sqrt{\mathrm{Hz}}$ (corresponding to $1\,\mathrm{pm}/\sqrt{\mathrm{Hz}}$ at 1064 nm). The measurement principle of this setup resembles the actual application on board LISA. Using this setup a measurement noise between $4\,\mu\mathrm{rad}/\sqrt{\mathrm{Hz}}$ and 400 $\mu\mathrm{rad}/\sqrt{\mathrm{Hz}}$ ($\approx 0.6-60\,\mathrm{pm}/\sqrt{\mathrm{Hz}}$ at 1064 nm) was observed for frequencies ranging from 1 mHz to 1 Hz.

We give an overview over first results of the non-reciprocal fiber noise obtained using this setup and on investigations on the influence of external noise sources.

Q 35.10 We 18:45 A 310

Testing the optical bench of the Laser Interferometer Space Antenna — •Michael Tröbs[1], Christoph Baune[1], Johanna Bogenstahl[2], Luigi d'Arcio[3], Marina Dehne[1], Christian Diekmann[1], Ewan Fitzsimons[2], Roland Fleddermann[1], Gerhard Heinzel[1], Christian Killow[2], Michael Perreur-Lloyd[2], David Robertson[2], Dirk Schütte[1], Thomas Schwarze[1], Malte Vogt[1], Gudrun Wanner[1], Henry Ward[2], Dennis Weise[4], and Karsten Danzmann[1] — [1]AEI Hannover — [2]Glasgow University — [3]European Space Agency — [4]Astrium GmbH

The space-based gravitational-wave detector Laser Interferometer Space Antenna (LISA) shall detect gravitational-waves by measuring distance changes between its three satellites with interferometers.

Currently, the first prototype of the so-called optical bench, that contains the interferometric setups for the lengths measurements of LISA, is being built for the European Space Agengy (ESA). This optical bench will be tested at the Albert-Einstein-Institute and its functionality and sensitivity will be characterised. For this purpose, special tools and pre-experiments are necessary, that will be discussed in this talk.

Q 36: Ultracold Atoms: Single Atoms (with A)

Time: Wednesday 16:30–17:45 Location: A 320

Group Report Q 36.1 We 16:30 A 320

Real-time feedback control of a single atom trajectory — •Alexander Kubanek, Markus Koch, Christian Sames, Alexei Ourjoumtsev, Pepijn Pinkse, Karim Murr, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Garching, Germany

Feedback is a general, well developed technique, which provides an important tool to control classical systems in a wide variety of fields. Novel features arise when transferring the idea of feedback into the quantum domain, e.g. to engineer non-trivial quantum states. An interesting question is whether one can influence quantum trajectories by measurement and feedback without violating Heisenberg uncertainty relations. A prerequisite for this is to measure and react in real time with a minimum measurement rate and, hence, disturbance.

By combining the arsenal of cavity QED techniques with blue-light trapping we have now achieved a longstanding goal, namely the real-time feedback control on the motion of a single atom. The feedback acts on a time scale that is 70 times faster than the typical time for the evolution of the centre of mass of the atom. Individual probe photons carrying information about the atomic position activate a dipole laser that steers the atom towards or away from the cavity centre. Depending on the specific implementation, the trapping time is increased by a factor of more than four and the localisation of the atom improved owing to feedback cooling. Such a feedback technique teaches us that one can control an apriori unpredictable atomic trajectory, and marks a step towards the exploration of quantum trajectories.

A. Kubanek, et al., Nature, in press (2009)

Q 36.2 We 17:00 A 320

Fokussierung eines Einzelionenstrahls — •W. Schnitzler[1], G. Jacob[1], R. Fickler[2], F. Schmidt-Kaler[1] und K. Singer[1] — [1]Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, D-89069 Ulm, Deutschland — [2]Universität Wien, Institut für Quantenoptik, Quantennanophysik & Quanteninformation, Boltzmanngasse 5, A-1090 Wien, Österreich

Basierend auf einer segmentierten linearen Paul-Falle [1] wurde ein Verfahren entwickelt, welches es ermöglicht, deterministisch eine vorgegebene Anzahl von Ionen zu laden. Diese Ionen werden anschließend deterministisch aus der Falle extrahiert und in einem Abstand von 257 mm in einen Spot mit einem 1σ-Radius von $(4.62\pm1.25)\,\mu$m fokussiert [2]. Verglichen mit dem anfänglichen Strahlradius von $83(^{+8}_{-3})\,\mu$m wird der Einzelionenstrahl somit auf 1/18 seiner ursprünglichen Größe verkleinert. Aufgrund der geringen Strahldivergenz und der schmalen Geschwindigkeitsverteilung unserer Einzelionenquelle ist die chromatische und sphärische Aberration an der Einzellinse stark reduziert, was einen vielversprechenden Ausgangspunkt für die Fokussierung einzelner, in ein Substrat zu implantierender Ionen darstellt [3-5]. Ein neuartiges Linsendesign soll die Auflösung noch weiter verbessern und eine Nachbeschleunigung der Ionen auf mehrere keV ermöglichen.

[1] W. Schnitzler *et al.*, Phys. Rev. Lett. **102**, 070501 (2009)
[2] W. Schnitzler *et al.*, quant-ph/0912.1258, submitted to NJP
[3] B. Kane, Nature **393**, 133 (1998)
[4] F. Jelezko *et al.*, Phys. Rev. Lett. **93**, 130501 (2004)
[5] T. Shinada *et al.*, Nature **437**, 1128 (2005)

Q 36.3 We 17:15 A 320

Highly efficient, sub microsecond photoionisation detection of single ^{87}Rb atoms — •Florian Henkel[1], Michael Krug[1], Julian Hofmann[1], Wenjamin Rosenfeld[1], Markus Weber[1], and Harald Weinfurter[1,2] — [1]Department für Physik der LMU, Schellingstrasse 4/III, 80799 München — [2]Max-Planck-Institut für

Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching

We experimentally demonstrate a technique suitable for detecting single optically trapped atoms in less than $1\,\mu$s with high efficiency. The scheme is based on hyperfine-state-selective photoionisation of single atoms and subsequent detection of the correlated photoion-electron pairs via two channel electron multipliers. By coincidently counting these single pairs [1], both detectors are calibrated to absolute values, with single detector efficiencies exceeding $\eta_{ele} = (0.875 \pm 0.002)$ and $\eta_{ion} = (0.926 \pm 0.010)$. Moreover, defining both as a joint CEM detector, a single neutral atom detection efficiency of $\eta = (0.991 \pm 0.002)$ within $t = 389.3 \pm 3.6$ ns following an ionisation event is achieved.

The detection scheme has a potential range of fundamental applications such as real-time probing of ultracold ensembles with sub-poissonian accuracy, as destructive, single-shot readout unit for atomic qubits or as detector for a loophole-free test of Bell's inequality with a pair of trapped atoms at remote locations [1].

[1] J. Dunworth *et al.*, Rev. Sci. Instrum. **11**, 167 (1940), P. Kwiat *et al.*, Appl. Opt. **33**, 1844 (1994).

[2] T. Campey *et al.*, Phys. Rev. A **74**, 043612-9 (2006), W. Rosenfeld *et al.*, Adv. Sci. Lett. **2**, 469 (2009).

Q 36.4 We 17:30 A 320

Feedback-optimierte Operationen mit linearen Ionenkristallen — •Stefan Ulm[1], Johannes F. Eble[1], Peter Zahariev[2], Ferdinand Schmidt-Kaler[1] und Kilian Singer[1] — [1]Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, D-89069 Ulm, Germany — [2]Bulgarian Academy of Science, Institute of Solid State Physics, Tzarigradsko Chaussee Blvd. 72, 1784 Sofia, Bulgaria

Wir berichten von Transportoperationen mit linearen $^{40}Ca^{+}$-Kristallen unter Anwendung zeitabhängiger, elektrischer Potentiale [1]. Um die Ionen zu kontrollieren, verwenden wir in unserer Methode die aktuelle Positionsinformation, die wir aus der Fluoreszenz der Ionen erhalten und nicht vorher aus einem Fallenmodel berechnete Spannungsrampen [2]. Wir zeigen, mit Hilfe dieser Rückkopplungstechnik den Transport einer vorher festgelegten Anzahl von Ionen sowie die Trennung und Vereinigung von Ionenkristallen. Die Rückkopplungssteuerung ist ein robustes Schema und gleicht experimentelle Fehler wie Bauungenauigkeiten und statische Aufladungen der Falle aus. Außerdem erlaubt unsere Methode, dass der Rechner eine selbst erlernte Spannungsrampe für den geforderten Prozess erzeugt und damit eine vorgegebene Anzahl von Ionen mit einer Erfolgswahrscheinlichkeit von über 99.8 % zwischen zwei Punkten hin und her transportiert. Dieses Verfahren kann dazu verwendet werden, den Betrieb eines zukünftigen, ionenbasierten Quantencomputers zu vereinfachen.

[1] J. F. Eble *et al.*, quant-ph/0912.2527

[2] M. A. Rowe *et al.*, Quant. Inf. and Comp. 2, 257 (2002)

Q 37: Matterwave Optics I

Time: Wednesday 17:45–19:00 Location: A 320

Q 37.1 We 17:45 A 320

BEC simulations for controlled release from shallow traps — •Holger Ahlers[1], Ernst Maria Rasel[1], and das QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Quantenoptik, LU Hannover — [2]ZARM, Uni Bremen — [3]Institut für Physik, HU Berlin — [4]Institut für Laserphysik, Uni Hamburg — [5]Institut für Quantenphysik, Uni Ulm — [6]MPQ, München — [7]Institut für angewandte Physik, TU Darmstadt — [8]Midlands Ultracold Atom Research Centre, University of Birmingham, UK — [9]FBH, Berlin

Our BEC experiment at the ZARM Droptower aims to realise high precision interferometric measurements with matter waves. In order to exploit the advantage of long expansion times in a microgravity environment, a high degree of control and a detailed understanding of the dynamics during preparation are needed. For this purpose a detailed model of the atom-chip-based experiment has been developed and helps in designing optimized experimental sequences. These simulations allow for investigating the high potential of quantum gases in microgravity for new and challenging experiments.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50WM0835-0839.

Q 37.2 We 18:00 A 320

Applications of Bose-Einstein-Condensates in microgravity — •Hauke Müntinga[1] und das QUANTUS Team[1,2,3,4,5,6] — [1]ZARM, Universität Bremen — [2]Institut für Quantenoptik, LU Hannover — [3]Institut für Physik, HU Berlin — [4]Institut für Laserphysik, Universität Hamburg — [5]Institut für Quantenphysik, Universität Ulm — [6]MPQ, München

We report on the current status of the QUANTUS free fall BEC experiment at the ZARM drop tower in Bremen.

After the first realization of a BEC in microgravity in 2007, we were able to observe condensates after 1 s of free evolution. The extremely shallow traps possible in microgravity and resulting ultralow temperatures of a few nK allow for further studies ranging from coherence properties of condensates to inertial sensors based on matter waves.

In our talk we will focus on the implementation of a matter wave interferometer into our apparatus, which aims to extend measurement times to unprecedented durations and sensitivities, and therefore leads the way to future experiments on other microgravity platforms like sounding rockets and the ISS. These goals are worked on in close cooperation with QUEST and the PRIMUS project.

The QUANTUS project is a collaboration of U Hamburg, U Ulm, HU Berlin, MPQ Munich, ZARM at U Bremen and LU Hannover. It is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50WM0836.

Q 37.3 We 18:15 A 320

Bose-Einstein Condensation Experiments in Microgravity — •Stephan Tobias Seidel[1], Ernst Maria Rasel[1], and das QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Quantenoptik, LU Hannover — [2]ZARM, Uni Bremen — [3]Institut für Physik, HU Berlin — [4]Institut für Laserphysik, Uni Hamburg — [5]Institut fÌr Quantenphysik, Uni Ulm — [6]MPQ, München — [7]Institut für angewandte Physik, TU Darmstadt — [8]Midlands Ultracold Atom Research Centre, University of Birmingham, UK — [9]FBH , Berlin

The successful demonstration of Bose-Einstein-Condensation in microgravity in 2007 opens the way to realize an atom interferometer operated in the unique environment of weightlessness. Within the QUANTUS project (Quantum systems under microgravity) an atom interferometer based on Rubidium 87 will be implemented in the drop tower at ZARM, Bremen. The apparatus produces a BEC of 10^4 atoms at a temperature of a few nK. In this regime it is possible to operate an interferometer with a coherent evolution on a timescale up to 1 second. The Mach-Zehnder atom interferometer is based on Bragg-scattering as a coherent beam splitter mechanism.

Furthermore, the produced BEC has a chemical potential of almost 10^{-31} J and a healing length on the order of $7\,\mu$m. These properties make it an ideal source for the study of quantum transport phenomena in disordered potentials.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant numbers DLR 50 WM 0835 - 0839.

Q 37.4 We 18:30 A 320

Advanced laser systems for drop tower experiments within QUANTUS II and beyond — •Max Schiemangk[1], Achim Peters[1], and das QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Physik, HU Berlin — [2]Institut für Quantenoptik, LU Hannover — [3]Institut für Laserphysik, Uni Hamburg — [4]ZARM, Uni Bremen — [5]Institut für Quantenphysik, Uni Ulm — [6]MPQ, München — [7]Institut für angewandte Physik, TU Darmstadt — [8]Midlands Ultracold Atom Research Centre, University of Birmingham, UK — [9]FBH, Berlin

In preparation for future quantum gas experiments in space, preliminary experiments are currently performed at the ZARM drop tower in Bremen and a sounding rocket mission is planned for the near future. In this context compact and robust laser systems have been developed.

An overview of the planned laser system capable of performing atom interferometry experiments will be given. The talk will present, e.g., the concepts of a hybrid integrated master oscillator power amplifier

(MOPA) and a mesoscopic spectroscopy stabilized reference laser. The MOPA consists of a laser chip, an amplifier, and microoptical components all integrated on a 10×50 mm^2 microbench. The reference laser combines this microbench technology with a macroscopic vapor cell.

The QUANTUS project is a collaboration of LU Hannover, ZARM at U Bremen, U Ulm, U Hamburg, and HU Berlin. It is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50WM0835-0839.

Q 37.5 We 18:45 A 320

A Compact Atom Chip Based Experiment with Bose-Fermi Mixtures in Microgravity — •Waldemar Herr[1], Ernst Maria Rasel[1], and das QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Quantenoptik, LU Hannover — [2]ZARM, Uni Bremen — [3]Institut für Physik, HU Berlin — [4]Institut für Laserphysik, Uni Hamburg — [5]Institut für Quantenphysik, Uni Ulm — [6]MPQ, München — [7]Institut für angewandte Physik, TU Darmstadt — [8]Midlands Ultracold Atom Research Centre, University of Birmingham, UK — [9]FBH, Berlin

The Principle of Equivalence lies at the heart of the theory of General Relativity. Taking the advantage of long free evolution times, mass independent confining potentials and perturbation free environment, QUANTUS2 aims to push the existing frontiers further to perform high precision experiments in the quantum domain. In this context, we realize a new setup fulfilling the criteria of being extremely compact, in order to operate in the catapult mode of the droptower in Bremen doubling the time of microgravity up to 9 seconds. The experiment is planned to use ^{87}Rb and ^{40}K as degenerate Bose-Fermi mixtures in order to carry out experiments on tests of the Weak Equivalence Principle in quantum domain. Up to date progress and future prospects of this ambitious and technically challenging project will be presented in this talk.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50WM0835-0839.

Q 38: Quantum Gases: Bosons III / Lattices I

Time: Wednesday 16:30–19:00 Location: E 001

Q 38.1 We 16:30 E 001

Dipolar Bose-Einstein condensates: stability properties and physics in deep optical lattices. — •Kazimierz Łakomy[1], Rejish Nath[1,2], and Luis Santos[1] — [1]Institut für Theoretische Physik , Leibniz Universität, Hannover, Appelstrasse 2, D-30167, Hannover, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, D-01187 Dresden, Germany

Due to their partially attractive character, dipole-dipole interactions may drive instability in dipolar gases. In this presentation we analyze in detail the instability of pancake-like condensates both against phonon- and the roton-instability as a function of the dipole strength and the strength of short-range interactions. After briefly reviewing the different types of instabilities in dipolar condensates, we show that the boundary between stability and roton instability presents a reentrant shape, which allows for scenarios where the system is only stable for a window of dipole strengths, i.e. the system is photon- or roton-unstable for small and large dipole-strengths. We determine as well the universal critical short-range interaction below which the gas is always unstable. In the last part of the talk we shall discuss recent results on the properties of solitons in dipolar condensates in deep optical lattices.

Q 38.2 We 16:45 E 001

Interaction of a BEC with a surface: towards a many-body cavity QED — •Jürgen Schiefele and Carsten Henkel — Universität Potsdam, Institut für Physik und Astronomie

We consider the collective Casimir-Polder interaction between a trapped gas of condensed Bosons and a plane surface through the coupling of the condensate atoms with the electromagnetic field. Technically, we aim at a systematic perturbation theory describing the electromagnetic self-energy of a trapped Bose gas near a surface. In the leading order, the interaction energy is—as expected—proportional to the number of atoms in the condensate mode, but atom-atom interactions lead to corrections compared to the single-atom theory. The interaction energy in the next order is proportional to the number of pairs in the condensate mode.

Q 38.3 We 17:00 E 001

Quantum phases of polar bosons in ladder-like lattices — •Xiaolong Deng and Luis Santos — ITP, Leibniz Universität Hannover, Hannover, Germany

In this work we numerically investigate by DMRG polar bosons, e.g. polar bosonic molecules, loaded in a two-leg ladder. We are particularly interested in the role played by the inter-site dipole-dipole interaction in the ground-state phases of the system. We evaluate ground-state correlation functions, characterize various quantum phases for different interaction regimes, and identify the phase diagram for different fillings. We also predict some novel quantum phases which appear when incorporating the true long-range and anisotropic character of the dipole-dipole interaction.

Q 38.4 We 17:15 E 001

Measuring atomic correlations via photon counting — •Stefan Rist[1,2] and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66041 Saarbrücken, Germany — [2]Departament de Fisica, Universitat Autonoma de Barcelona, E-08193 Bellaterra, Spain

A scheme is presented, which allows one for measuring the quantum state of an ultracold atomic gas by means of the first-order coherence of light, which interacts dispersively with the gas. The scheme is based on an interferometric-like setup, and allows one for determining, amongst others, the single-particle correlation function, as well as correlations between atomic field and density. The results are evaluated for ultracold atoms in one- and two-dimensional optical lattices, across the superfluid / Mott-insulator transition.

Q 38.5 We 17:30 E 001

Single site addressability in optical lattices — •Christof Weitenberg[1], Manuel Endres[1], Jacob Sherson[1], Marc Cheneau[1], Rosa Glöckner[1], Ralf Labouvie[1], Immanuel Bloch[1,2], and Stefan Kuhr[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching — [2]Ludwig-Maximilians-Universität, Fakultät für Physik, Schellingstr. 4, 80799 München

Single site resolution in short-wavelength optical lattices, which have a significant tunnel coupling, is a challenging task. We prepare a BEC of rubidium atoms in a 3D lattice of 532 nm spacing. Using the 5S1/2 to 6P3/2 transition at 420nm, our imaging system (NA=0.7) will yield a resolution of 380nm and there-fore allow single site resolved detection and manipulation.

So far we have taken in trap fluorescence images with a resolution of 700 nm using the 5S1/2 to 5P3/2 transition at 780nm and demonstrated the micro-manipulation of a few atoms with a tightly focused dipole trap. To extract one or a few slices and remove the atoms that are out of the depth of focus we use microwave transitions in a magnetic field gradient.

The single site resolution will open up a new class of experiments in quantum simulation of strongly correlated systems - like the in-situ observation of the Mott insulator or the investigation of non-equilibrium phenomena - and in quantum information processing - like local spin manipulation or quantum gates with Rydberg atoms.

Q 38.6 We 17:45 E 001

Quantum Gas Microscope - A Next Generation Quantum Simulator — •Markus Greiner[1], Waseem Bakr[1], Jonathon Gillen[1], Amy Peng[1], and Simon Foelling[2] — [1]Harvard-MIT Center for Ultracold Atoms and Department of Physics, Harvard University, Cambridge, MA, USA — [2]Ludwig-Maximilians-Universität, Munich, Germany

Ultracold atoms give the unique opportunity to experimentally realize and study increasingly complex many-body quantum systems. One approach is to employ large samples of ultracold atoms and, for example, carry out quantum simulations of condensed-matter models. The opposite approach is to assemble quantum information systems with full control over all degrees of freedom, atom by atom, ion by ion. I will present work in which we have created a quantum gas microscope that bridges between these two worlds. Thousands of individual atoms are detected with near-unity fidelity on individual sites of a Hubbard regime optical lattice. In addition, the single site addressability can be used for creating arbitrary potential landscapes and for local atom manipulation. This novel approach opens many new possibilities for quantum simulations and quantum information applications.

Q 38.7 We 18:00 E 001

Confinement-induced resonances in 1D quantum systems — •Elmar Haller, Manfred J. Mark, Johann G. Danzl, Russell Hart, Lukas Reichsöllner, Andreas Klinger, Oliver Krieglsteiner, and Hanns-Christoph Nägerl — Institut für Experimentalphysik und Zentrum für Quantenphysik, Universität Innsbruck, Technikerstraße 25, A-6020 Innsbruck, Austria

Strong external potentials can be employed to confine atoms to one-dimensional (1D) and two-dimensional (2D) spatial geometry. For a 1D system with strong repulsive interaction, a dramatic change of the atomic scattering properties is predicted as the s-wave scattering length approaches the transversal confinement length [1]. We report on the observation of such a confinement-induced resonance (CIR) in a degenerate gas of Cs atoms in a 2D optical lattice. The versatility of a confinement-controlled interaction strength is demonstrated by creating a double resonance with a transversally asymmetric wave guide. We observe a splitting of the CIR and the occurrence of additional scattering resonances. One possible application of a CIR is the creation of a "super Tonks Girardeau gas", which is an excited, strongly-correlated gas phase with strong attractive interaction [2,3].

[1] M. Olshanii, Phys. Rev. Lett. **81**, 938-941 (1998).
[2] E. Haller, et. al., Science **325**, 1224 (2009).
[3] E. Astrakharchik, et. al., Phys. Rev. Lett. **95**, 190407 (2005).

Q 38.8 We 18:15 E 001

Paired and Usual Superfluidity in Spin-1 Optical Lattices — •Leonardo Mazza[1], Matteo Rizzi[1], Maciej Lewenstein[2], and J.Ignacio Cirac[1] — [1]Max-Planck Institut für Quantenoptik, Garching, Deutschland — [2]ICREA and ICFO, Barcelona, Spain

We discuss the possibility of simulating three-body repulsive contact interactions using experimentally feasible ultracold atoms setups. In particular, we consider a spin-1 (F=1) atomic Mott insulator (MI) with one atom per site, whose three local degrees of freedom are mapped into local bosonic occupation numbers less than two. This simulates a system with infinite three-body repulsion and null two-body interaction. Suitable laser assisted couplings via an auxiliary F=2 ancilla tailor the ratio between single-particle and pair-correlated hopping.

This suggests to explore an enriched phase diagram where also a pair-superfluid (PSF) is present. First of all, we investigate the transition between the usual superfluid phase (SF) and the paired one as a function of particle density and ratio of the two hopping parameters. Numerics is performed in 1D with DMRG and algebraic decay of correlations is exploited to discriminate the phases.

Finally, we move on to the theoretical Hubbard model with the insertion of the pair-correlated hopping term. Besides the usual MI for dominating two-body repulsion, and SF phase for prevailing single-particle hopping parameter, a collapsed phase emerges when the paired hopping is leading. This strongly restricts the PSF region of the phase diagram, and motivates resorting to the previous experimental proposal in order to observe such an exotic phase.

Q 38.9 We 18:30 E 001

Two-mode Bose gas: Beyond classical squeezing — •Cédric Bodet and Thomas Gasenzer — Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg

The dynamical evolution of squeezing correlations in an ultracold Bose-Einstein distributed across two modes is investigated theoretically in the framework of the Bose-Hubbard model. We study the development of non-classical correlations and relative number squeezing in regimes where the system is strongly interacting. Comparing the full quantum evolution with classical statistical simulations allows to identify quantum aspects of the squeezing formation. In the quantum regime, the measurement of squeezing allows to distinguish even and odd total particle numbers.

Q 38.10 We 18:45 E 001

Enhancement and suppression of the Landau-Zener tunneling in the presence of time-dependent disorder — •Ghazal Tayebirad[1,2] and Sandro Wimberger[1,2] — [1]Institüt für Theoretische Physik, Universität Heidelberg, Philosophenweg 19, D-69120 — [2]Heidelberg Graduate School of Fundamental Physics, Albert-Ueberle-Str. 3-5, D-69120

We investigate the coherent control of the transport and of the decay of Bose-Einstein condensates from the ground band in a lattice structure with time-dependent disorder. To this respect, we study the time evolution of ultra-cold atoms loaded into a quasi-1D geometry supporting a stochastic potential and subjected to an additional static force. Our disordered lattice can be created by superimposing two standing waves with incommensurable wavelengths which have a time-dependent random phase shift with respect to each other. We demonstrate that stochastic noise [1] in the system can be used to engineer the transport of ultra-cold atoms without changing system intrinsic parameters. Our results show how an appropriately chosen random phase either enhances, suppresses, or hardly affects the Landau-Zener tunneling out of the ground band of the lattice.

[1] R. Mannella, A gentle introduction to the integration of stochastic differential equations, Lecture Notes in Physics, 557 (Springer, Heidelberg, 2000)

Q 39: Quantum Information: Atoms and Ions III

Time: Wednesday 16:30–19:00 Location: E 214

Group Report Q 39.1 We 16:30 E 214

Optical trapping of an ion — •Christian Schneider, Martin Enderlein, Thomas Huber, Stephan Duewel, Robert Matjeschk, Hector Schmitz, and Tobias Schaetz — Max-Planck-Institut für Quantenoptik

After more than 50 years of successfully trapping ions in Paul traps and more than 20 years of confining atoms in optical dipole traps followed by optical lattices, we were able to do the first step to merge these fields by trapping an ion optically. We initialize the system via trapping and laser cooling the ion in our linear Paul trap setup, switch on the optical dipole trap and switch completely off the Paul trap. After a waiting time the Paul trap is switched on and the optical dipole trap switched off again. We check for the presence of the ion via fluorescence. With experimentally measured survival durations (lifetimes) of single ions of the order of milliseconds, the lifetime is limited by optical heating processes of the dipole trap.

In the near future, we aim to realize cooling to increase the life time and to investigate the limitations on the coherence times. Loading two ions and/or one ion and atoms into the identical one-dimensional optical lattice could be explored soon. This approach demonstrates not only the feasibility of optically trapping ions, but also hybrid systems of Paul and optical traps, providing long range interaction, individual addressability and a potentially intriguing interplay between neutral and charged particles.

Q 39.2 We 17:00 E 214

Quantum gate between logical qubits in decoherence-free subspace implemented with trapped ions — •Peter Ivanov, Ulrich Poschinger, Kilian Singer, and Ferdinand Schmidt-Kaler — Institut für Quanteninformationsverarbeitung, Universität Ulm, Albert-Einstein-Allee 11, 89081 Ulm, Germany

We propose an efficient technique for the implementation of a geometric phase gate in a decoherence-free subspace with trapped ions. In this scheme, the quantum information is encoded in the Zeeman sublevels of the ground state and two physical qubits are used to make up one logical qubit with ultra long coherence time. The physical realization of a geometric phase gate between two logic qubits is performed with four ions in a linear crystal simultaneously interacting with single laser beam. We investigate in detail the robustness of the scheme with respect to the right choice of the trap frequency and provide a detailed analysis of error sources, taking into account the experimental conditions. Furthermore, possible applications for the generation of cluster states for larger numbers of ions within the decoherence-free subspace are presented.

Q 39.3 We 17:15 E 214

Realization of a quantum walk with one and two trapped ions — •Florian Zähringer[1,2], Gerhard Kirchmair[1,2], Rene Gerritsma[1,2], Enrique Solano[3], Rainer Blatt[1,2], and Christian Roos[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, A-6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, ÖAW, Otto-Hittmair-Platz 1, A-6020 Innsbruck, Austria — [3]Ikerbasque, Basque Foundation for Science, Alameda Urquijo 36, 48011 Bilbao, Spain

We experimentally demonstrate a quantum walk on a line in phase space using one and two trapped ions [1]. A walk with up to 23 steps is realized by subjecting an ion to state-dependent displacement operations interleaved with quantum coin tossing operations. To analyze the ion's motional state after each step we apply a technique that directly maps the probability density distribution onto the ion's internal state. The measured probability distributions and the position's second moment clearly show the non-classical character of the quantum walk. To further highlight the difference between the classical (random) and the quantum walk, we demonstrate the reversibility of the latter. Finally, we extend the quantum walk by using two ions, giving the walker the additional possibility to stay instead of taking a step.

[1] F. Zähringer et al., arXiv: 0911.1876 (2009)

Q 39.4 We 17:30 E 214

Combining dressed states and ion traps for coherent qubits — •Nuala Timoney, Ingo Baumgart, and Christof Wunderlich — Fachbereich Physik, Universität Siegen, 57068 Siegen

Coherence time is an important property of a quantum computer. A weakness of an ion trap quantum computer, is its potential dependence on magnetic field sensitive levels. Ambient magnetic field noise is the cause of the shorter coherence times of magnetic field sensitive levels (5 ms) compared to their field insensitive counterparts (500 ms) as observed in $^{171}Yb^{+}$. A scheme is suggested which is based on using dressed states as qubits, adiabatically turning on the fields before and turning the fields off at the end of the operations.

A three level system of hyperfine states is dressed by microwave photons and prepared in its dark state using STIRAP, Rabi oscillations are observed between the dark and the ground state and a Ramsey time measurement reveals a preliminary coherence time of 6.06 ms. In comparison a simpler two level dressed state scheme, which is based on a magnetic field insensitive transition with a dependence of the transition energy on the Rabi frequency of the dressing field, revealed a preliminary coherence time of 17 ms.

The coherence time measured is presently restricted by technical problems which will be improved in future experiments.

Q 39.5 We 17:45 E 214

Ion-Photon and Photon-Ion Interfaces for Quantum Networks — Felix Rohde[1], Nicolas Piro[1], Carsten Schuck[1], Marc Almendros[1], Jan Huwer[1], Joyee Ghosh[1], Markus Hennrich[1], Albrecht Haase[1], Francois Dubin[1], and •Jürgen Eschner[1,2] — [1]ICFO - Institut de Ciencies Fotoniques, Mediterranean Technology Park, 08860 Castelldefels (Barcelona), Spain — [2]FR Experimentalphysik, Universität des Saarlandes, Campus E2.6, 66123 Saarbrücken

We report experimental progresses towards the realization of tools for quantum networking with single ions, such as two-photon interference from two remote, bandwidth tunable single photon sources and the generation of polarization correlated photon pairs from a single ion. A possible strategy to create remote entanglement in a quantum network is to generate entangled photon pairs by means of parametric down-conversion and make them interact with distant atoms, thereby transferring entanglement from photonic to atomic qubits. We present the realization of a first step towards such entanglement transfer, the absorption of a single down-conversion photon by a single $^{40}Ca^{+}$ ion, heralded by the partner photon.

Q 39.6 We 18:00 E 214

Trapping of Ytterbium Ions with a Stylus Trap — •Andrea Golla[1,2], Robert Maiwald[1,2], Simon Heugel[1,2], Alessandro Villar[2], Markus Sondermann[1,2], and Gerd Leuchs[1,2] — [1]Institut für Optik, Information und Photonik (IOIP), Universität Erlangen-Nürnberg, Staudtstr. 7/B2, 91058 Erlangen — [2]Max-Planck-Institut für die Physik des Lichts (MPL), Günther-Scharowsky-Str. 1/Bau 24, 91058 Erlangen

Recently, a needle like Paul trap with high optical and physical accessibility has been developed and tested using magnesium ions [1]. We want to employ such a stylus trap for localizing a single ion in the focal point of a deep parabolic mirror. In the planned experiment, singly and doubly ionized ytterbium will be coupled to the light field from the nearly full solid angle. Yb^{2+} will be produced by photoionization of trapped and laser cooled Yb^{+}. Here, we report on the successful trapping of single Yb^{+} ions with the stylus trap and discuss the experimental progress.

[1] R. Maiwald *et al.*, Nature Physics **5**, 551-554 (2009)

Q 39.7 We 18:15 E 214

Quantum Gates utilizing the Phonon Modes of an Ion Coulomb Crystal in a Magnetic Field — •Jens Domagoj Baltrusch[1,2], Antonio Negretti[3], Jacob M. Taylor[4], and Tommaso Calarco[3] — [1]Theoretische Physik, Universität des Saarlandes, Germany — [2]Grup d'Òptica, Universitat Autònoma de Barcelona, Bellaterra, Spain — [3]Institut für Quanteninformationsverarbeitung, Universität Ulm, Germany — [4]Joint Quantum Institute, University of Maryland and NIST, College Park, MD, USA

Ion Coulomb crystals rotating in the magnetic field of a Penning trap have been proposed for a scalable implementation of quantum gates [Porras & Cirac PRL96 250501 (2006); Taylor & Calarco PRA78 062331 (2008)]. So far these approaches are quite difficult to implement since they are limited to a crystal rotation frequency of half the cyclotron frequency, which could be as large as hundreds of MHz. However, at lower rotation rates the magnetic field of the trap induces a coupling between the positions and the momenta of the ions. This coupling complicates the calculation of the phonon modes, which are an essential component in the implementation of two-qubit gate operations. We examine a method based on Williamson's theorem [Williamson Amer.J.of Math.58 141 (1963)] to calculate the phonon modes in the case of position-momentum coupling, show numerical results of the determination of the equilibrium positions and the normal modes for different rotation rates of the ion crystal, and discuss the simulation of the necessary gate operations.

Q 39.8 We 18:30 E 214

State-independent experimental test of quantum contextuality with trapped ions — •Gerhard Kirchmair[1,2], Florian Zähringer[1,2], Rene Gerritsma[1,2], Matthias Kleinmann[2], Otfried Gühne[2,3], Adan Cabello[4], Rainer Blatt[1,2], and Christian F. Roos[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, A-6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation,ÖAW, Otto-Hittmair-Platz 1, A-6020 Innsbruck, Austria — [3]Institut für theoretische Physik, Universität Innsbruck, Technikerstr. 25, A-6020 Innsbruck, Austria — [4]Departamento de Física Aplicada II, Universidad de Sevilla, E-41012 Sevilla, Spain

In this talk, I will present the realization of a recent proposal for a state-independent test of quantum contextuality. I will start with a brief overview of a gate mechanism that allows for entangling ions without ground state cooling and experimental results obtained with two ions. Then, I will present recent experiments in which we apply the gate for a quantum non-demolition measurement of two-ion spin correlations. This technique makes it possible to sequentially measure several compatible observables on a single quantum system and to correlate the measurement results. In this way, we have been able to realize a state-independent test of quantum contextuality. The experimental results [1] demonstrate that the observed correlations cannot be explained by non-contextual hidden variable theories.

[1]Kirchmair G. et.al. *Nature* **460**, 494 (2009)

Q 39.9 We 18:45 E 214

Quantum simulation of the Dirac equation — Rene Gerritsma[1], Gerhard Kirchmair[1], Florian Zähringer[1], Enrique Solano[2], Rainer Blatt[1], and •Christian Roos[1] — [1]Institut für Quantenoptik und Quanteninformation, Otto-Hittmair-Platz 1, 6020 Innsbruck, Österreich — [2]Departamento de Quimica Fisica, Universidad del Pais Vasco - Euskal Herriko Unibertsitatea, 48080 Bilbao, Spain

The Dirac equation is a cornerstone in the history of physics, merging successfully quantum mechanics with special relativity, providing a natural description of the electron spin and predicting the existence of anti-matter. However, the Dirac equation also predicts some peculiar effects such as Klein's paradox and Zitterbewegung, an unexpected quivering motion of a free relativistic quantum particle first examined by Schrödinger. In this talk, we report on a proof-of-principle quantum simulation of the one-dimensional Dirac equation using a single trapped ion, which is set to behave as a free relativistic quantum particle [1]. We measure as a function of time the particle position and study Zitterbewegung for different initial superpositions of positive and negative energy spinor states, as well as the cross-over from relativistic to nonrelativistic dynamics.

[1] R. Gerritsma et al, arXiv:0909.0674, accepted for publication in Nature.

Q 40: Quantum Information: Quantum Computing

Time: Wednesday 16:30–18:45 Location: F 128

Q 40.1 We 16:30 F 128

Quantum error correction with trapped ions — •Philipp Schindler[1], Thomas Monz[1], Julio Thomas Barreiro[1], Michael Chwalla[1], Volckmar Nebendahl[1], Markus Hennrich[1], and Rainer Blatt[1,2] — [1]Inst. f. Exphysik, Universität, Innsbruck — [2]Ins. f. Quantenoptik u. Quanteninformation, Innsbruck

We report on the experimental realization of a three-qubit quantum error-correcting code with trapped calcium ions. The implemented algorithm detects and corrects for a single-qubit phase error. The correction step is performed without any classical measurement and can therefore more easily be reapplied. The pulse sequence for this algorithm was compiled with the aid of an optimization technique resulting in a very compact sequence with a computational time similar to that of single Cirac-Zoller CNOT gate. We fully analyze the single qubit process with quantum process tomography and achieve a process fidelity of F=84(2)%.

Q 40.2 We 16:45 F 128

Processing of quantum information by linear optical systems — •Lev Plimak, Daniela Denot, and Wolfgang Schleich — Institut für Quantenphysik, Universität Ulm

We consider a series of Gedankenexperiments showing that results of any photodetection measurement performed on two optical beams originating from a beam-splitter may be imitated by a photodetection measurement performed directly on the original beam. This conclusion is further extended to an arbitrary lossless optical transformer with the number of output ports exceeding the number of input ones.

Q 40.3 We 17:00 F 128

Multiqubit Decoherence in Ion-trap Quantum Computation — •Thomas Monz[1], Philipp Schindler[1], Julio Barreiro[1], Michael Chwalla[1], Bill Coish[2,3], Markus Hennrich[1], and Rainer Blatt[1,4] — [1]Inst. f. Experimentalphysik, Innsbruck, AT — [2]Inst. f. Quantum Computing, Waterloo, CA — [3]Kavli Inst. f. Theoretical Physics, Santa Barbara, US — [4]Inst. f. Quantenoptik u. Quanteninformation, Innsbruck, AT

In a linear string of calcium ions we have realised high-fidelity Schrödinger-Cat states with more than six qubits. Fidelities exceed 95% for up to 4 ions and 88% for six ions. These high fidelities allow to investigate decoherence of highly entangled quantum states in the presence of collective dephasing, the predominant decoherence source in ion-trap quantum computation. Modelling the noise to be stationary and Gaussian, we derive and experimentally confirm a model that predicts an exponential decay of the fidelity that scales with the power of N^2 with N being the number of qubits. Such a scaling behaviour has severe effects on the applicability of quantum computation in ion-trap based quantum computation and related fields such as quantum metrology.

Q 40.4 We 17:15 F 128

Efficient manipulation of quantum systems via optimal control techniques — •Robert Fisher[1], Thomas Schulte-Herbrüggen[1], Christof Wunderlich[2], Fedor Jelezko[3], Jörg Wrachtrup[3], and Steffen Glaser[1] — [1]Department Chemie, Technische Universität München, Germany — [2]Fachbereich Physik, Universität Siegen, Germany — [3]3 Physikalisches Institut, Universität Stuttgart, Germany

We apply optimal control to the design of experiments in quantum information processing. By explicitly accounting for the experimental constraints of addressability and robustness, optimal control techniques allow for the implementation of a broader, more complex class of operations, making new experiments possible. As examples, we consider the implementation of Deutsch and Grover algorithms on two coupled ^{13}C spins at an NV center in diamond, and the preparation of multi-qubit cluster states in a system of trapped ions with a non-ideal coupling topology.

Q 40.5 We 17:30 F 128

Decomposition of nonlinear gates in finite Fock space — Seckin Sefi and •Peter van Loock — Max Planck Institute for the Science of Light

In the article of Lloyd and Braunstein (PRL, 82, 1784), a set of elementary hamiltonians is given as well as a method to simulate any continuous variable hamiltonian of bosonic modes to arbitrary precision by concatenating discrete elements. The method they presented is not constructive and for the most of the hamiltonians does not allow an exact and finite decomposition to the elementary hamiltonian set. Here, complementary to work of Lloyd and Braunstein, we discuss the potential of finite and exact decompositions of gates on occupation number Fock states in finite dimensional encoding. We show that for a finite decomposition of any logical gate on single d level qudit Fock space, a number of $d(d-1)/2+d-1$ fixed hamiltonians with an order of nonlinearity up to $3d-3$ will be sufficient.

Q 40.6 We 17:45 F 128

The fractal structure of Clifford cellular automata — •Vincent Nesme, Johannes Gütschow, and Reinhard Werner — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover

It is a well-known fact that the spacetime diagrams of some cellular automata have a fractal struc- ture: for instance Pascal*s triangle modulo 2 generates a Sierpinski triangle. Explaining the fractal structure of the spacetime diagrams of cellular automata is a much explored topic, but virtually all of the results revolve around a special class of automata, whose main features include being irreversible, being defined on an alphabet having a ring structure and respecting this structure, and fulfilling a property known as being (weakly) p-Fermat. The class of automata that we study in this article fulfills none of these properties. The cell structure is weaker, as it does not come with a multiplication, may very well be reversible *and* interesting, and they are typically far from being p-Fermat, even weakly. However, they do produce fractal spacetime diagrams, and we will explain why and how. These automata emerge naturally from the field of quantum cellular automata, as they include the classical equivalent of the Clifford quantum cellular automata, which have been studied by the quan- tum community for several reasons. They provide a universal model of quantum computation, and they can be used to generate highly entangled states, to use as a primary resourse for measurement- bases models of quatum computing.

Q 40.7 We 18:00 F 128

Symmetry in Quantum System Theory: Rules for Quantum Architecture Design — •Thomas Schulte-Herbrüggen and Uwe Sander — Technical University of Munich (TUM), Dept. Chem., Lichtenbergstrasse 4, 85747 Garching

We investigate universality in the sense of controllability and observability, of multi-qubit systems in architectures of various symmetries of coupling type and topology. By determining the respective dynamic system Lie algebras, explicit reachability sets under symmetry constraints are provided. Thus for a given (possibly symmetric) experimental coupling architecture several decision problems can be solved in a unified way: (i) can a target Hamiltonian be simulated? (ii) can a target gate be synthesised? (iii) to which extent is the system observable by a given set of detection operators? and, as a special case of the latter, (iv) can an underlying system Hamiltonian be identified with a given set of detection operators?

Finally, in turn, the absence of symmetry provides a convenient necessary condition for full controllability. Though often easier to assess than the well-established Lie-algebra rank condition, this is not sufficient unless the candidate dynamic simple Lie algebra can be pre-identified uniquely. Thus for architectures with various Ising and Heisenberg coupling types we give design rules sufficient to ensure full controllability. In view of follow-up studies, we relate the unification of necessary and sufficient conditions for universality to filtering simple Lie subalgebras of su(N) comprising classical and exceptional types.

Q 40.8 We 18:15 F 128

Scalable quantum computation via local control of only two qubits — Daniel Burgarth[1,2], Koji Maruyama[2], •Michael Murphy[3], Simone Montangero[3], Tommaso Calarco[3,4], Franco Nori[2,5], and Martin B. Plenio[1,6] — [1]IMS and QOLS, Imperial College, London SW7 2PG, UK — [2]Advanced Science Institute, The Institute of Physical and Chemical Research (RIKEN), Wako-shi, Saitama 351-0198, Japan — [3]Institut für Quanteninformationsverarbeitung, Universität Ulm, D-89069 Ulm, Germany — [4]ECT*, 38050 Villazzano (TN), Italy — [5]Physics Department, University of Michigan, Ann Arbor, Michigan, 48109, USA — [6]Institut für Theoretische Physik, Universität Ulm, D-89069 Ulm, Germany

We apply quantum control techniques to control a large spin chain by only acting on two qubits at one of its ends, thereby implementing universal quantum computation by a combination of quantum gates on the latter and swap operations across the chain. It is shown that the control sequences can be computed and implemented efficiently. We discuss the application of these ideas to physical systems such as superconducting qubits in which full control of long chains is challenging.

Q 40.9 We 18:30 F 128

Go vs. no-go – potential and limitations of continuous-variable quantum computing by measurements — •Matthias Ohliger, Konrad Kieling, and Jens Eisert — University of Potsdam, 14476 Potsdam, Germany

In this talk, we will explore the feasibility of quantum computation using continuous-variable systems by means of local measurements only. In the first part of the talk, we will identify crucial limitations that arise when starting from Gaussian cluster states. This will be done by resorting to a Gaussian projected entangled pair picture as well as to notions of continuous-variable quantum repeater networks. In the second part, we will look at instances in which these limitations can be overcome, and how suitable encodings of qubits in oscillators and feasible non-Gaussian resource states give rise to universal schemes for quantum computing.

Q 41: Ultrashort Laser Pulses: Applications III

Time: Wednesday 16:30–19:00 Location: F 342

Q 41.1 We 16:30 F 342

Adaptive Optics for the Correction of Eye Aberrations — •Anja Hansen[1], Mohammed K. Khattab[1], Raoul-Amadeus Lorbeer[1], Holger Lubatschowski[1], and Ronald R. Krueger[2] — [1]Laser Zentrum Hannover, Hollerithallee 8, 30419 Hannover, Germany — [2]Cole Eye Institut, Cleveland Clinic Foundation, 9500 Euclid Avenue, Cleveland, USA

In ophthalmology, femtosecond laser tissue transections (photodisruption) which do not provoke any damage to the retina are currently limited to the cornea or lens. In order to not harm the retina during laser application, the laser focus needs to be either a safe distance apart from the retina or the threshold energy for the tissue interaction needs to be low enough to not destruct any peripheral tissue. For surgery in the direct vicinity of the retina the threshold energy has to be reduced to a safe level. However, the aberrations of the anterior elements of the eye cause a distortion of the wavefront and therefore a raised threshold energy when focussing into the posterior segment. We present an optical system that allows for correcting aberrations in eyes using adaptive optics consisting of a deformable mirror and a Hartmann-Shack-Sensor with a novel light source. If combined with femtosecond laser pulses this system offers the possibility for minimally invasive laser surgery in the posterior eye segment with minimized threshold energy. This offers a minimally invasive alternative to the current invasive standard vitrectomy which is very traumatic and causes complications like cataract formation which could be avoided with laser surgery.

Q 41.2 We 16:45 F 342

Determining total hemoglobin mass by means of ^{13}CO breath analysis — •Marcus Sowa and Peter Hering — Institut für Lasermedizin, Universitätsklinikum Düsseldorf, Universitätsstr. 1, 40225 Düsseldorf

The aim of our investigations is the development of a non-invasive method for the determination of the total hemoglobin mass in the human body by means of Cavity Leak-Out Spectroscopy (CALOS).
The mentioned CALOS system utilizes a CO gas laser in the mid infrared region around 5 μm. This system allows isotopologue selective online measurements of ^{13}CO with a sensitivity of 7 ppb·Hz$^{-1/2}$.
^{13}CO is a non radioactive isotopologue occurring in a ratio of about 1.1 % of the natural CO composition. CO is commonly known as a highly toxic gas but it is also endogenously produced during heme degradation. About 80 % of this CO is exhaled yielding to CO concentrations between 1 ppm to 4 ppm in healthy humans.
Transportation of CO through the body is established by hemoglobin which has a high affinity towards CO. Because of this fact inhaled CO is taken up by the blood until equilibrium between the alveolar air and the blood is reached. By determining the exhaled CO concentrations before and after the inhalation of a certain amount of CO a measure for the t-Hb mass can be calculated.
The enormous advantage of the isotopologue measurement is the very small amount of ^{13}CO which can be used for harmless CO inhalation. All data necessary for calculating the t-Hb mass are obtained from breath measurements making this method non invasive.

Q 41.3 We 17:00 F 342

Simultane Messung der Wellenfront und der Formänderung der menschlichen Augenlinse während der Akkommodation — •Heike Hoffmann[1], Claudia Grosser[2], Uwe Oberheide[3], Georg Gerten[3], Stefan Altmeyer[2] und Holger Lubatschowski[1] — [1]Laser Zentrum Hannover eV, Hannover, Deutschland — [2]Institut für Angewandte Optik, Köln, Deutschland — [3]Laserforum eV, Köln, Deutschland

Ziel ist die Zusammenführung von Wellenfrontaberrometrie und Vorderkammer OCT. Hierbei soll, während des Akkommodationsprozesses des menschlichen Auges, die Bildgebung der OCT mit der Wellenfront korreliert werden. Eine OCT-Einheit (SL-OCT, Heidelberg Engineering) wurde mit einem Aberrometer gekoppelt (iTrace, Tracey Technologies). Beide Messstrahlen wurden kolinear angepasst, um zeitgleich die Wellenfront mit der Rückstreuung der OCT aufzunehmen und miteinander zu vergleichen. Um die Akkommodation genauer zu untersuchen, wurden Akkommodationsreize gegeben. Für die Vergleichbarkeit wurden Augentropfen (Neosynephrine 5%)zum weitstellen verwendet, die die Akkommodation nicht beeinflussen. Die Zusammenführung ermöglicht sowohl die Messung der Vorder- und Rückfläche der Augenlinse mit ihrer morphologischen Änderung, als auch die Wellenfront zum gleichen Zeitpunkt. Um die unterschiedlichen Akkommodationszustände zu erhalten, wurde ein Fern- und Nahtarget verwendet. Die Ergebnisse dieser erstmals zusammengeführten Systeme zeigen ein großes Potenzial zur Analyse der Wellenfront und der zeitgleichen morphologischen Änderung der Augenlinse während der Akkommodation.

Q 41.4 We 17:15 F 342

Mikrospiegelaktorelement zur ortsselektiven Spektroskopie und Mikroskopie biologischer Proben — •Bernd Meyerer, Markus Schellenberg und Walter Neu — Fachhochschule Emden/Leer, Institut für Lasertechnik (ILO), 26723 Emden

Konventionelle Durchlichtmikroskopie ist ein Standardverfahren zur Untersuchung und Charakterisierung biologischer Proben. Die Integration eines Mikrospiegelaktors (DMD-array) ermöglicht gleichzeitig zwei Detektionswege sowohl zur Standard-Transmissionsmikroskopie als auch zur simultanen Spektralanalyse. Das Bild der auf dem Objektträger befindlichen Probe wird über den Mikrospiegelaktor auf eine Digitalkamera abgebildet. Frei selektierbare Bereiche der Probe können auf dem Bildschirm ausgewählt werden. Die Mikrospiegelposition wird damit über einen zweiten parallelen VGA-Ausgang der Grafikkarte angesteuert, um das transmittierte Licht dieses Bereichs simultan auf den Eintrittsspalt des Spektrometers (Ocean Optics HR2000+) abzubilden. Untersucht wurden Algen und Pflanzendünnschnitte, mit den natürlichen Farbstoffen Carotin und Chlorophyll sowie künstlich eingefärbte Sporen und histologische Gewebefeinschnitte. Räumlich selektierbare Flächen im Bereich von 10 Mikrometer Durchmesser lassen sich spektroskopisch eindeutig identifizieren und unterscheiden. In Abhängigkeit von der verwendeten Beleuchtungsquelle, des Mikrospiegelaktors, der optischen Qualität des Mikroskops sowie der Sensitivität des Spektrometers ist eine Reduktion der minimal auswählbaren Probefläche möglich. Automatisiert können Probenidentifikation oder Zählverfahren realisiert werden.

Q 41.5 We 17:30 F 342

Gewebedifferenzierung bei der Ablation von Hartgewebe mit gepulsten CO_2-Lasern — •Dennis Quest, Philipp Naumann, Yong-min Jo und Peter Hering — Institut für Lasermedizin, Heinrich-Heine-Universität Düsseldorf

Die berührungslose Bearbeitung von Hartgewebe hat viele Vorteile gegenüber den konventionellen mechanischen Instrumenten. Mit einem kurz gepulsten CO_2- Lasersystem in Kombination mit einer speziellen Multi-Pass-Scan-Technik und einem Wasserspray ist eine freie Wahl der Schnittgeometrie möglich. Geringe thermische Belastung für das umliegende Gewebe ist das Ergebnis. Während der Bearbeitung des Knochens ist die Überwachung des Abtragungsfortschrittes notwendig. Wichtig ist die Grenze zwischen dem zu bearbeitendem Hart- und Weichgewebe zu finden. Während der Ablation entsteht neben einem akustischen Signal ein Leuchten im sichtbaren Bereich. Dieses Leuchten kann zur Differenzierung zwischen Hart- und Weichgewebe genutzt werden. Insbesondere bei Bohrungen, in die Implantate eingesetzt werden sollen, soll der Abtragungsprozess nach Durchbohren des Knochens gestoppt werden. Die Realisierung dieses Verfahrens soll mit seinen Ergebnissen vorgestellt werden.

Q 41.6 We 17:45 F 342

STED nanoscopy of living hippocampal neurons in organotypic brain slices — •Nicolai T. Urban[1], Katrin Willig[1], U. Valentin Nägerl[2], and Stefan W. Hell[1] — [1]Department of NanoBiophotonics, Max Planck Institute for Biophysical Chemistry, Goettingen, Germany — [2]INSERM U862/Université Victor Segalen Bordeaux 2, Bordeaux, France

Stimulated Emission Depletion (STED) nanoscopy is a light microscopic technique that enables fluorescence imaging with nanoscale resolution. In this approach the diffraction barrier is overcome by overlapping the excitation with a doughnut-shaped, red-shifted STED beam, thereby removing the fluorescence ability of the fluorophore in the outer region of the excitation spot, leaving only a nanosized region in which the fluorophore is able to signal.

However, when attempting to image neurons deep inside the sample, spherical aberrations stemming from the refractive index mismatch between the brain tissue and the widely used oil immersion severely limit the penetration depth. The use of glycerol (n=1.45) as an immersion liquid instead lessens the refractive index mismatch noticeably. The remaining aberrations can be compensated down to a certain depth by a correction collar on the objective.

Using this approach we recorded YFP-labeled actin filaments in dendritic spines, which are protrusions on the dendrites, of living hippocampal neurons in organotypic brain slices. Spine rearrangement was imaged over long time periods in depths down to 50 μm with nanoscale resolution of $<$ 80 nm.

Q 41.7 We 18:00 F 342

Ein Brillouin-LIDAR zur Messung von Temperaturprofilen des Ozeans: Generelle Eignung eines ESFADOF-Detektors — •Andreas Rudolf, Alexandru Popescu und Thomas Walther — Institut für Angewandte Physik, AG Laser und Quantenoptik, Technische Universität Darmstadt, Schlossgartenstr. 7, D-64289 Darmstadt

Im Rahmen des globalen Klimawandels wird der Bedeutung der Weltmeere große Bedeutung zugesprochen. Deren lokaler Wärmegehalt ist eine wichtige Kenngröße für die Ozeanographie und kann durch Messung des Temperaturprofils bestimmt werden. Um weite Meeresgebiete schnell, kostengünstig und berühungslos zu erfassen, bietet sich die lasergestützte Messung an Bord eines Helikopters an. Hierzu wird ein flugtaugliches Brillouin-LIDAR entwickelt, welches die temperaturabhängige Brillouin-Streuung als Indikator ausnutzt. Als Strahlquelle dient ein gepulster Faserverstärker mit einer nachgeschalteten Frequenzverdopplungseinheit. Es werden fourier-limitierte Pulse mit einer Länge von 10 ns bereitgestellt. Die spektral hochauflösende Detektion wird durch einen ESFADOF-Kantenfilter (**E**xcited **S**tate **F**araday **A**nomalous **D**ispersion **O**ptical **F**ilter) realisiert, welcher die Brillouin-Frequenzverschiebung von 7-8 GHz in ein Transmissionssignal überführt. In diesem Beitrag wird aufgezeigt, dass Transmissionskanten von bis zu 25% innerhalb weniger GHz erreicht werden können. Zudem wurde die gezielte Erzeugung der gewünschten Transmissionskanten demonstriert. Die Ergebnisse zeigen daher die prinzipielle Eignung eines ESFADOFs für das Brillouin-LIDAR. Darüber hinaus werden die Grenzen für einen stabilen Betrieb des Detektors diskutiert.

Q 41.8 We 18:15 F 342

Ground Sted Depletion (GSD) Nanoscopy of NV Color Centers in Diamond with Single Digit Resolution — •Dominik Wildanger, Eva Rittweger, and Stefan W. Hell — Department of NanoBiophotonics, Max Planck Institute for Biophysical Chemistry, Göttingen, Germany

We present a new implementation of fluorescence microscopy based on the depletion of the fluorophores ground state providing a resolution far beyond the diffraction limit. Therefore we utilize an intense excitation beam which features an intensity minimum at its center (e.g. a doughnut shaped beam). Given high enough laser power the ground state of fluorophores in close vicinity to the minimum is depleted while a fluophore at the very center remains in the ground state. Scanning through the sample leads to a negative high resolution image. In order to obtain a positive image the picture has to be deconvolved with the excitation PSF. As an alternative to the negative images we show a pump probe configuration in which we probe the color centers that remain in the ground state with a second, chopped excitation beam. Subtraction of both signals with a lock-in amplifier renders directly a positive image. A lateral resolution of approx. 8 nm was obtained. Our study underscores the key role of exploiting (molecular) states for overcoming the diffraction barrier in far-field optical microscopy

Q 41.9 We 18:30 F 342

Optische Aerosolfalle mit Injektion durch eine Glaskapillare — •Marcel Horstmann, Karl Probst und Carsten Fallnich — Institut für Angewandte Physik, Westfälische Wilhelms-Universität Münster, Corrensstraße 2-4, 48149 Münster

Wir stellen ein faserbasiertes Fallensystem zum Transfer von Aerosolteilchen in eine optische Pinzette vor. Die Aerosolteilchen werden dabei mittels Strahlungsdruck durch eine Glaskapillare in die Probenkammer transferiert und dort durch entgegengesetzt propagierendes Licht aus einer Glasfaser stabilisiert.

Die so erfolgte Entkopplung von Nebel- und Probenkammer ermöglicht den Einsatz der optischen Pinzette mit definierten Eigenschaften zur Manipulation einzelner Aerosolteilchen. Aufgrund der geringeren Dämpfung der Teilchen in Luft im Vergleich zu Flüssigkeiten bieten sich uns interessante Möglichkeiten zur Untersuchung der Dynamik von Mehrteilchen-Systemen in optischen Fallen.

Q 41.10 We 18:45 F 342

Colocalization analyses by two-color STED microscopy — •Johanna Bückers, Daniel Neumann, Stefan Jakobs, Lars Kastrup, and Stefan W. Hell — Max Planck Institute for Biophysical Chemistry, Dept. of NanoBiophotonics, Am Fassberg 11, 37077 Göttingen, Germany

Far-field fluorescence microscopy is among the most common methods in the biosciences today. One of its few drawbacks − the relatively poor spatial resolution − has been overcome since the invention of stimulated emission depletion (STED) microscopy and other nanoscopy concepts which allow imaging on the nanoscale.

Early STED microscopes were based on rather complex setups and high-maintenance laser systems, but the advent of supercontinuum laser sources enable the implementation of compact and tunable STED microscopes. Even further, due to the broad spectrum of available wavelengths two-color imaging can be realized comfortably, such that the interplay of e. g. different proteins in biological samples can be studied. For such colocalization analyses special care has to be taken regarding the cross-talk between differently labeled structures, and one has to ensure that there is no shift of the two images during the recording. Therefore, we developed an approach to quasi-simultaneous two-color STED microscopy, which allows cross-talk correction by means of linear unmixing, based on a pulse-interleaved acquisition scheme. This approach is applied for several biological tasks, e. g. to reveal the different degrees of colocalization of proteins in the mitochondrial membrane.

Q 42: Precision Measurements and Metrology V

Time: Thursday 10:30–12:30 Location: A 310

Q 42.1 Th 10:30 A 310

NV color centers for magnetic field sensing at the nanoscale — •Friedemann Reinhard[1], Eike Oliver Schäfer-Nolte[1,2], Markus Ternes[2], Bernhard Grotz[1], Helmut Rathgen[1], Gopalakrishnan Balausbramanian[1], Julia Tisler[1], Klaus Kern[2], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]Universität Stuttgart, 3. Physikalisches Institut — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart

One of the most promising applications of the NV color center in diamond is to use it as a magnetic field sensor with sub-nanometer spatial resolution. This prospect arises from the fact that its spin sublevels are sensitive to magnetic fields, only ca. 1kHz wide and are accessible to pulsed optical-microwave precision spectroscopy. I present our work towards such a scanning probe diamond nano-magnetometer, focussing on two aspects: Firstly, the development of tailored atomic force microscopes with an efficient optical and microwave access. Secondly, the study of the surface properties of diamond, most notably of magnetic and electric noise, which presumably limits the coherence time of NV centers near the diamond surface and in nanodiamonds.

Q 42.2 Th 10:45 A 310

High-resolution laser spectroscopy of the $^2S_{1/2} - {}^2F_{7/2}$ octupole transition in $^{171}Yb^+$ — •Nils Huntemann, Ivan Sherstov, Maxim Okhapkin, Burghard Lipphardt, Christian Tamm, and Ekkehard Peik — Fachbereich Zeit und Frequenz, Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

We present our results on the spectroscopy of the electric octupole transition $^2S_{1/2}(F = 0) \rightarrow {}^2F_{7/2}(F = 3)$ of a single trapped laser-cooled $^{171}Yb^+$ ion. This transition is of special interest as an optical frequency standard because the $^2F_{7/2}$ state has an extremely long natural lifetime of approximately 6 years. As a result, the stability of the frequency standard will not be limited by its natural linewidth, but by the laser system. The strong dependence of the transition frequency on the value of the fine structure constant α suggests long-term comparisons with other optical frequency standards, especially the $^2S_{1/2} - {}^2D_{3/2}$ electric quadrupole transition in $^{171}Yb^+$, in order to test the constancy of α.

We developed a diode-laser system with a relative frequency stability better than 2×10^{-15} at 1 s and a very low nonlinear frequency drift to excite this transition. We obtain excitation spectra of the octupole transition with a resonant excitation probability of about 65 % and an essentially Fourier transform-limited resolution of 13 Hz. These results compare favourably with previous work [Hosaka *et al.*, Phys. Rev. A **79** 033403 (2009)].

Q 42.3 Th 11:00 A 310

Laser noise reduction by means of the optical Kerr Effect — •André Thüring, Alexander Khalaidovski, Nico Lastzka, Daniel Wahlmann, Benno Willke, Karsten Danzmann, and Roman Schnabel — Institut für Gravitationsphysik, Leibniz Universität Hannover und Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstrasse 38, D-30167 Hannover

Conventional laser power stabilization techniques rely on the photoelectric detection of high light powers and on the filtering by means of linear optical resonators. These techniques are limited on the one hand by the intrinsic noise of the photo-detection, and on the other hand by the linewidth of the filter resonators being used. Here we present an alternative method for the noise reduction of high power lasers. It is based on the optical Kerr effect and can be used either for a pure optical passive noise reduction or as sensing device that does not require the photo-detection of high light powers. We report on the results of a first proof-of-principle experiment where a noise reduction of about 32 dB was achieved.

Q 42.4 Th 11:15 A 310

Präzise interferometrische Frequenzmessung und -stabilisierung für durchstimmbare Laser — •Thomas Kinder[1], Thomas Müller-Wirts[1], Johannes Brachmann[2] und Kai Dieckmann[2,3] — [1]TEM Messtechnik GmbH, Hannover — [2]Max-Planck-Institut für Quantenoptik, Garching — [3]Centre for Quantum Technologies - National University of Singapore

Laser mit veränderbarer optischer Frequenz finden Anwendung in vielen Bereichen., z.B. Spektroskopie, Abstandsmessung usw. Oft erfordert die Endanwendung eine hoch präzise Messung und Stabilisierung der Laserfrequenz. Wir stellen dazu ein Anordnung vor, deren Kern ein Interferometer als frequenzempfindlicher Detektor bildet. Dabei ist die Phase des erzeugten Quadratursignals ein Maß für die Laserfrequenz. In einer Rückkoppelschleife wird die Differenz der gemessenen Phase zu einem computergenerierten Sollwert auf den zu regelnden Laser zurückgegeben. Auf diese Weise kann die Frequenz auf beliebige, auch variable (!) Werte innerhalb des Durchstimmbereiches des Lasers stabilisiert werden, also auch während eines Scans. Das elektronische Auflösungsvermögen beträgt etwa 380kHz – bei einem beliebig großen Stimmbereich. Um die absolute Genauigkeit in dieselbe Großenordnung zu bringen, muss man zum einen die elektronische Phasenmessung auf 0,1mrad kalibrieren, und zum anderen muss man den Freien Spektralbereich des Interferometers mit einer relativen Unsicherheit von 10^{-9} bestimmen. Wir beschreiben die Methode am Beispiel eines Ti:Saphir-Ringlasers und zeigen Messergebnisse hinsichtlich Auflösung, Wiederholbarkeit, Langzeitstabilität und Absolutgenauigkeit.

Q 42.5 Th 11:30 A 310

Fixing a laser beam in space for hydroxide-catalysis bonding — •Martin Sommerfeld, Marina Dehne, Benjamin Sheard, Gerhard Heinzel, and Karsten Danzmann — Albert-Einstein-Institute Hannover, Max-Planck-Institute for gravitational physics and Leibniz University Hannover, Callinstr. 38, D-30167 Hannover

To build thermal and mechanical very stable interferometers for spaceborn missions, the technology of hydroxide-catalysis bonding is used. During assembly of the optical components, the position of laser beams in space must be controlled in four degrees of freedom. This is particularly important for the beam height and vertical slope which cannot be corrected by shifting components. To solve this problem a device to measure the position and the angle of the incoming beam is built and calibrated. The current status of ongoing development will be presented.

Q 42.6 Th 11:45 A 310

Systematic study of the hfs splitings for 3d elements by ABMR-LIRF method — •Przemysław Głowacki, Andrzej Krzykowski, Andrzej Jarosz, Danuta Stefańska, and Jerzy Dembczyński — Chair of Quantum Engineering and Metrology, Poznań University of Technology,
ul. Nieszawska 13B, 60-965 Poznań, Poland

The atomic beam apparatus was donated to our Chair by Prof. W. Ertmer from the Institute of Applied Physics of the University of Bonn, and further modernized and improved. With the use of ABMR-LIRF method (atomic beam magnetic resonance, detected by laser induced resonance fluorescence) and a new magnetic shield in the apparatus, it was possible to obtain the values of the hfs (hyperfine structure) intervals in investigated elements with an accuracy of about 1 kHz [1]. This allowed us to determine precisely the values of the hfs constants A and B (magnetic dipole and electric quadrupole interactions), as well as made the estimation of the values of the hfs constants C (magnetic octupole interaction) for the 3d elements possible.

This work was performed within the framework of DS63-029/10.

References

[1] A. Jarosz, D. Stefańska, M. Elantkowska, J. Ruczkowski, A. Buczek, B. Furman, P. Głowacki, A. Krzykowski, Ł. Piątkowski, E. Stachowska, J. Dembczyński, J. Phys. B: At. Mol. Opt. Phys. **40**, 2785-2797 (2007)

Q 42.7 Th 12:00 A 310

Demonstration of a squeezed zero-area Sagnac interferometer topology for future gravitational wave detectors — •Tobias Eberle, Sebastian Steinlechner, Jöran Bauchrowitz, Vitus Händchen, Karsten Danzmann, and Roman Schnabel — Institut für Gravitationsphysik, Leibniz Universität Hannover und Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) Callinstrasse 38 D-30167 Hannover

The design study for the Einstein Telescope (ET), the future European laser-interferometric gravitational wave detector, is on going. An option for the interferometer topology is a zero-area Sagnac. The

Sagnac interferometer is a speed-meter and therefore a quantum non-demolition device that in principle can beat the standard quantum limit. The sensitivity of gravitational wave detectors can be further enhanced by the injection of squeezed light. In this talk we present the experimental demonstration of a table-top zero-area Sagnac interferometer at 1064nm whose sensitivity was increased with squeezed light.

Q 42.8 Th 12:15 A 310

Application of polarising optics in space interferometry — •Marina Dehne, Benjamin Sheard, Gerhard Heinzel, Michael Tröbs, and Karsten Danzmann — Albert- Einstein-Institut Hannover, Max-Planck-Institut für Gravitationsphysik und Universität Hannover, Callinstr. 38, D-30167 Hannover

Polarising optics will play a key role in future satellite projects like the LISA mission or a GRACE follow-on mission. In these missions it is foreseen to use polarising components in the laser interferometer for beam steering. It is therefore important to investigate the influence of these components on the interferometer sensitivity and to validate the length stability. The talk will describe the design and construction of a quasi-monolithic interferometer for comparing the interferometric performance of non-polarising and polarising optics. Preliminary results will be presented.

Q 43: Ultracold Molecules (with MO)

Time: Thursday 10:30–12:00 Location: E 001

Group Report Q 43.1 Th 10:30 E 001

Ultracold chemistry and dipolar collisions in a quantum gas of polar KRb molecules — •Silke Ospelkaus[1,2], Kang-Kuen Ni[2], Marcio de Miranda[2], Brian Neyenhuis[2], Dajun Wang[2], Jun Ye[2], and Deborah Jin[2] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]JILA, NIST & University of Colorado, Boulder, USA

Polar molecular quantum gases promise to open new scientific frontiers and research directions. Due to their large electric dipole moment, polar molecules interact via long-rage and anisotropic interactions. The control of these interactions provides unique opportunities ranging from the control of ultracold chemical reactions, applications to quantum information processing, novel strongly correlated quantum many-body systems to collisional control on the quantum level with external electric and magnetic fieds. Here, we report on our recent experiments with a quantum gas of fermionic polar 40K87Rb molecules. We report the preparation of a near-quantum degenerate gas of rovibronic ground state molecules in a single hyperfine state and in particular in the absolute lowest quantum state - implementing full control over all internal molecular quantum degrees of freedom (electronic, vibrational, rotational and hyperfine). We discuss experimental evidence for chemical reactions at ultracold temperatures and show that simple quantum mechanical rules such as quantum statistics, single scattering partial waves, and quantum threshold laws provide the basis for understanding of the molecular loss rates at ultracold temperature. Finally, we report the observation of dipolar collisions in the polar molecular gas.

Q 43.2 Th 11:00 E 001

Enhancement of Photoassociation to Create Ultracold Molecules — •Ruzin Aganoglu, Mamadou Ndong, and Christiane Pia Koch — Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin

Ultracold molecules can be created coherently by shaped ultrashort laser pulses. Since the broad bandwidth of femtosecond pulses addresses both atomic and molecular transitions and atomic excitation leads to trap loss, the spectral amplitude of the pulse at the atomic resonance frequency needs to be completely suppressed. This is most easily achieved by cutting off the pulse amplitude at the atomic resonance frequency and higher spectral components [1]. However the process leaves then most of the pulse idle. Here a two-photon photoassociation scheme is suggested to drive the desired narrow transition with a broad-band laser. Local control theory is used to define conditions on the pulse such that atomic transitions stay dark while molecular transitions are excited. Moreover to increase the initial pair density at inter-nuclear distances where the photoassociation probability is high, the concept of non-resonant field control [2] is combined with shape resonances. [1] A. Merli et al., Phys. Rev. A 80, 063417 (2009) [2] M. Lemeshko and B. Friedrich, Phys. Rev. Lett. 103, 053003 (2009)

Q 43.3 Th 11:15 E 001

Effect of molecular structure on the stabilization of ultracold molecules — •Mamadou Ndong, Fabian Borschel, and Christiane P. Koch — Institut für Theoretische Physik, Freie Universität Berlin, Germany

Ultracold molecules are created from ultracold atoms using Feshbach resonances or photoassociation. As a result, the molecules are vibrationally highly excited. They can be stabilized by transferring them to their vibrational ground state via STIRAP or with optimally shaped pulses.

Using optimal control theory, we investigate the effect of the long-range behavior of the excited state potential, spin-orbit coupling and singlet-triplet mixing on the energy and the spectral range of the optimal pulse that performs the stabilization. We present a detailed study of the role of the long-range behavior of the excited state potential comparing Na_2 and KRb. Moreover, the spin-orbit coupling interaction for KRb is taken into account to study effects of resonant coupling and singlet-triplet mixing.

Q 43.4 Th 11:30 E 001

Population redistribution of vibrational ground state levels in ultracold polar molecules — •Johannes Deiglmayr[1,2], Marc Repp[1], Olivier Dulieu[3], Roland Wester[2], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg — [2]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg — [3]Laboratoire Aimé Cotton, CNRS, Orsay

Recently we achieved the formation of LiCs molecules in the lowest levels of the ground state[1]. Polar molecules like LiCs can show strong long-range and anisotropic interactions, which makes ultracold dense gases of such molecules ideal systems for quantum information or the study of new quantum phases. However a large permanent electric dipole moment also leads to a stronger coupling of the internal molecular state to the environment via black-body radiation (BBR). Here the influence of BBR-driven transitions and spontaneous decay on the distribution of populated levels is investigated numerically for the ground states of LiCs and KRb using accurate potential energy curves and transition dipole moments. We will show experimental evidence for the occurrence of such redistribution processes in a sample of ultracold LiCs molecules. The molecules are formed by photoassociation and trapped in a quasi-electrostatic trap. State-selective detection of the molecules reveals population dynamics on time-scales which are in agreement with our theoretical model.

[1] J. Deiglmayr *et al.*, Phys. Rev. Lett. 101, 133004 (2008)

Q 43.5 Th 11:45 E 001

All Optical Rovibrational Ground State Preparation of HD^+-Ions — •Tobias Schneider, Bernhard Roth, Hannes Duncker, Michael Hansen, Ingo Ernsting, and Stephan Schiller — Heinrich-Heine Universität Düsseldorf, Universitätsstrasse 1, 40225 Düsseldorf

One important prerequisite for quantum measurements on molecules is the ability to control their translational as well as internal degrees of freedom. For molecular ions stored in an ion trap the motion of the molecules can be cooled via sympathetic cooling with laser cooled atomic ions. Cooling of the internal degrees of freedom is more difficult since in non-cryogenic environments interaction with black body radiation will generally distribute the molecular population over several ro-vibrational states.

We present a two laser optical pumping scheme suitable in principle for many types of diatomic molecules that allows to transfer most molecules to the ro-vibrational ground state. As a demonstration we apply the scheme HD^+ molecular ions: Optically pumping with two cw lasers driving the $(v = 0, N = 2) \rightarrow (v = 1, N = 1)$ transition at 5484 nm and the $(v = 0, N = 1) \rightarrow (v = 2, N = 0)$ transition at 2713 nm of the electronic ground state, we increase the fractional ground state population from 10% to 78(4)% which is close to the maximum of 92% predicted by numerical simulations for a room temperature environment. A detailed analysis of the experiment and of the theoretical modelling of the pumping scheme will be given.

Q 44: Quantum Information: Concepts and Methods III

Time: Thursday 10:30–12:30 Location: E 214

Q 44.1 Th 10:30 E 214

Maximally entangled states of polynomial $SL(2,\mathbb{C})$-invariant entanglement measures — •Andreas Osterloh[1] and Jens Siewert[2] — [1]FB Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany. — [2]Departamento de Química Física, Universidad del País Vasco - Euskal Herriko Unibertsitatea, Apdo. 644, 48080 Bilbao, Spain

Recently, a method for constructing $SL(2,\mathbb{C})$-invariant multipartite entanglement measures has been described for qubits by the authors [1]. These measures are particularly interesting since they are nonvanishing only for the non-zero SLOCC entanglement class as defined by Verstraete and coworkers [2]. Here, a detailed analysis is presented for those (maximally) entangled states states detected by thus-constructed polynomial SL-invariants. The analysis leads to the notion of (irreducibly) balanced states, which also proves to be tightly connected with an SLOCC classification of entanglement.

[1] A. Osterloh and J. Siewert, Phys. Rev. A **72**, 012337 (2005); –"– , Int. J. Quant. Inf. **4** 531 (2006).

[2] F. Verstraete, J. Dehaene, and B. D. Moor, Phys. Rev. A 68, 012103 (2003).

Q 44.2 Th 10:45 E 214

State reconstruction from few measurements — •Marcus Cramer[1] and Martin Plenio[2] — [1]Institute for Mathematical Sciences, Imperial College London, UK — [2]Institut für Theoretische Physik, Universität Ulm, Germany

Reconstructing a density matrix from measurement data is highly involved both from the experimental and the post-processing point of view: The number of measurements and computational resources needed to process them are exponentially large in the system size. If one knows that the system is in thermal equilibrium, one can do much better: We introduce a scheme that relies only on a linear number of correlation measurements. The computational resources needed to reconstruct the state with high fidelity from these measurements is only polynomial in the system size. The algorithm combines singular value thresholding and matrix product state methods.

Q 44.3 Th 11:00 E 214

Entanglement in quantum spin chains with broken reflection symmetry — •Zoltan Zimboras and Zoltan Kadar — Quantum Information Theory Group, ISI, Torino

Understanding the entanglement properties of systems with many degrees of freedom, such as quantum spin chains, has been one of the main recent research topics connecting quantum information theory and condensed matter physics. Huge amount of results has been accumulated about translation-invariant systems. However, the results almost exclusively correspond to systems having reflection symmetry, despite that models violating reflection invariance play a prominent role in many-body theory (e.g., in describing interactions of Dzyaloshinskii-Moriya type or non-equilibrium steady states). In this talk we will present some new results, both analytical and numerical, about the entanglement properties of non-reflection-invariant spin chains, and discuss how these differ from the reflection-invariant case (e.g., we dicuss the small "violation" of the Calabrese-Cardy formula for the finite size scaling of the entanglement entropy).

Q 44.4 Th 11:15 E 214

Quantifying entanglement from scattering data — •Harald Wunderlich[1,2,3], Marcus Cramer[1,2,3], and Martin B. Plenio[1,2,3] — [1]Institut für Theoretische Physik, Universität Ulm, Germany — [2]Institute for Mathematical Sciences, Imperial College London, United Kingdom — [3]QOLS, Blackett Laboratory, Imperial College London, United Kingdom

We demonstrate that the quantification of entanglement from scattering data according to an entanglement measure of choice (such as the robustness of entanglement or the best separable approximation) can be performed via a direct minimization of the entanglement over all states compatible with the measurement data. This can be achieved numerically employing methods from the theory of semidefinite programming.

Taking into account the symmetries allowed by the observables, the optimization may be restricted to states obeying the same symmetries. In order to illustrate the power of our method we apply this estimation method to thermal Heisenberg states.

Since for large quantum systems numerical calculations become intractable, we show how to obtain analytical lower bounds to entanglement measures via witness operators based on uncertainty relations.

Q 44.5 Th 11:30 E 214

Decoherence of spin gases induced by many-body phase gates — •Tatjana Carle[1], Wolfgang Dür[1,2], Hans J. Briegel[1,2], and Barbara Kraus[1] — [1]Institut für Theoretische Physik, Universität Innsbruck, Technikerstraße 25, A-6020 Innsbruck — [2]Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaften, Technikerstraße 21a, A-6020 Innsbruck

We present a new approach to study the properties of many-particle systems subject to decoherence. In particular, we consider a spin gas, which is a natural extension of a classical gas where the particles move along a classical trajectory, but carry a quantum degree of freedom, which interacts during collisions. Formerly, two-body collisions between the system and bath, which were described by two-body phase gates leading to a dephasing environment, were considered. There the evolution of the system and the entanglement has been investigated. Here we consider a system of particles (qubits) which is interacting via more-body phase gates with its surrounding. We study the entanglement properties of the multipartite system depending on the number of qubits the phase gate is acting on. We calculate the reduced density matrix and decoherence maps which gives us insight into the entanglement properties and time evolution of the system. In order to do so we make use of a new class of quantum states called LME states (Locally-Maximally-Entanglable), which are generated by n-body phase gates. Since the calculations are exact we treat Markovian as well as Non-Markovian scenarios and compare them to each other.

Q 44.6 Th 11:45 E 214

Controlled Antiadiabatic Crossing of Quantum Phase Transitions — Patrick Doria, Tommaso Calarco, and •Simone Montangero — Ulm University, Ulm, Germany

A control strategy that can be applied to a vast range of non integrable one dimensional systems is introduced and applied to the 1D Mott Insulator-Superfluid quantum phase transition recently demonstrated in cold atoms in optical lattice experiments. We present an optimal pulse to speed up of about an order of magnitude the experimental setup of T.Stoeferle, et. al., Phys. Rev. Lett. 92, 130403 (2004).

Q 44.7 Th 12:00 E 214

Entanglement Transmission under Adversarially Selected Quantum Noise — Rudolf Ahlswede[2], Holger Boche[1], Igor Bjelakovic[1], and •Janis Nötzel[1] — [1]Technische Universität Berlin, Lehrstuhl für Informationstheorie und theoretische Informationstechnik — [2]Universität Bielefeld, Arbeitsgruppe Information und Komplexität

We consider the problem of entanglement transmission over arbitrarily varying quantum channels (AVQC's) and prove a quantum version of the famous Ahlswede dichotomy.

To start with, we use the existence of entanglement transmission codes for compound quantum channels to obtain common-randomness-assisted entanglement transmission codes for AVQC's.

As a second step, we show that we actually only need very small amounts of common randomness, leading to the proposed quantum version of Ahlswede's dichotomy through derandomization by classical forward-communication.

As a last point, we present a first attempt to derive a necessary and sufficient condition for the capacity of the AVQC to be equal to zero.

Q 44.8 Th 12:15 E 214

Increasing the statistical significance of entanglement detection in experiments — •Bastian Jungnitsch[1], Sönke Niekamp[1], Matthias Kleinmann[1], Otfried Gühne[1], He Lu[2], Wei-Bo Gao[2], Yu-Ao Chen[2,3], Zeng-Bing Chen[2], and Jian-Wei Pan[2,3] — [1]Institut für Quantenoptik und Quanteninformation, Innsbruck, Austria — [2]Hefei National Laboratory for Physical Sciences at Microscale and Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China — [3]Physikalisches Institut, Universität Heidelberg, Heidelberg, Germany

Entanglement is often verified by a violation of an inequality like a Bell inequality or an entanglement witness. Considerable effort has been devoted to the optimization of such inequalities in order to obtain a high violation.

We demonstrate theoretically and experimentally that such an optimization does not necessarily lead to a better entanglement test, if the statistical error is taken into account. Theoretically, we show for different error models that reducing the violation of an inequality can improve the significance. We show this to be the case for an error model in which the variance of an observable is interpreted as its error and for the standard error model in photonic experiments. Specifically, we demonstrate that the Mermin inequality yields a Bell test which is statistically more significant than the Ardehali inequality in the case of a photonic four-qubit state that is close to a GHZ state.

Experimentally, we observe this phenomenon in a four-photon experiment, testing the above inequalities for different levels of noise.

Q 45: Ultra Cold Atoms, Ions and BEC III (with A)

Time: Thursday 10:30–12:30 Location: F 303

Q 45.1 Th 10:30 F 303

All-Optical Cooling and Diagnostics for Relativistic Ion Beams — •Michael Bussmann[1], Ulrich Schramm[1], Danyal F.A. Winters[2,3], Thomas Walther[4], Gerhard Birkl[4], Christina Dimopoulou[3], Fritz Nolden[3], Markus Steck[3], Bernhard Franzke[3], Christian Novotny[3,5], Christopher Geppert[3,5], Wilfried Nörtershäuser[3,5], Christophor Kozhuharov[3], Thomas Kühl[3], and Thomas Stöhlker[2,3] — [1]Forschungszentrum Dresden-Rossendorf e.V., D-01328 Dresden — [2]Ruprecht-Karls-Universität Heidelberg, D-69120 Heidelberg — [3]GSI Helmholtzzentrum für Schwerionenforschung GmbH, D-64291 Darmstadt — [4]Technische Universität Darmstadt, D-64289 Darmstadt — [5]Johannes-Gutenberg-Universität Mainz, D-55099 Mainz

Laser cooling of ion beams at relativistic energies at the Experimental Storage Ring (ESR) at GSI has shown that in order to address the complete phase space of an initially hot ion beam, laser systems have to deliver light at a wide range of frequencies. If all ions are cooled by the laser force, the beam momentum spread can be reduced to a level that cannot be resolved by standard accelerator diagnostics. In our talk we introduce new laser systems and optical diagnostics that are currently set up for an upcoming laser cooling experiment at ESR. We discuss the impact of these new developments on the detection of beam ordering referring to laser cooling experiments previously performed at the ESR.

Q 45.2 Th 10:45 F 303

Measurements of the Interaction between Ultracold Atoms and Carbon Nanostructures — •Philipp Schneeweiss[1], Michael Gierling[1], Gabriela Visanescu[1], Johannes Märkle[1], Benjamin Jetter[1], Thomas Judd[1], Michael Häffner[1], Dieter Kern[1], Carsten Weiss[2], Reinhold Walser[3], Andreas Günther[1], and József Fortágh[1] — [1]Center for Collective Quantum Phenomena and their Applications, Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen — [2]Institut für Quantenphysik, Universität Ulm, D-89069 Ulm — [3]Institut für Angewandte Physik, TU Darmstadt, Hochschulstraße 4a, D-64289 Darmstadt

We have developed an ultracold atom experiment for studying interactions between Rubidium atoms and carbon nanotubes (CNTs). In a first series of measurements, ultracold atom clouds have been used as a scanning probe for measuring the topography of CNT structures on a chip surface. A magnetic conveyor belt allows the three-dimensional nano-positioning of atomic ensembles above the chip. The method can successfully resolve extended arrays and lines of nanotubes, as well as individual, freestanding CNTs.

In a second experiment, the loss and heating rates of atom clouds spatially overlapping with a single, freestanding CNT have been measured. Using the data, we quantify the total scattering cross-section and compare it to the geometrical cross-section between the atoms and the single CNT. We find first evidence for the influence of Casimir-Polder effects in the interaction and discuss its contributions to the scattering cross-section.

Q 45.3 Th 11:00 F 303

Controlling spin dynamics in a one-dimensional quantum gas — •Philipp Wicke, Shannon Whitlock, and Klaasjan van Druten — Van der Waals-Zeeman Institute, University of Amsterdam, The Netherlands

Reducing the dimensionality of a system has dramatic consequences and leads to remarkable new physics. In this regard, quantum gases offer unique opportunities to address important open questions in quantum many-body physics, by allowing full control over all relevant parameters. We create coherent superpositions of both spin and motional degrees of freedom and probe spin dynamics of a one-dimensional (1D) Bose gas of ^{87}Rb on an atom chip. We observe interaction driven focusing of one spin component by mean field interaction with another component, directly related to the effective 1D interaction strength. We demonstrate experimental control over the 1D interaction strengths through state-selective radio-frequency dressing. The focusing behaviour is altered by tuning the transverse trapping potential in a state-dependent way. This enables, for instance, access to the point of spin-independent interactions where exact quantum many-body solutions are available.

Q 45.4 Th 11:15 F 303

Collisions of single ions with ultracold neutral atoms — •Stefan Schmid[1,2], Arne Härter[1,2], and Johannes Hecker Denschlag[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstrasse 25, 6020 Innsbruck, Austria — [2]Institut für Quantenmaterie, Universität Ulm, Albert-Einstein-Allee 45, 89081 Ulm, Germany

We have set up an experiment in which a single trapped Ba^+ ion is immersed into a sea of ultracold neutral Rb atoms.

In the Paul trap we can store single ions as well as strings of several ions cooled to the Doppler limit. We produce our BEC in a QUIC trap and transport it over 30 cm into a linear Paul trap using a moving 1D optical lattice. Subsequently the atoms are loaded into a crossed dipole trap, which is overlapped with the position of the ion.

First experimental results on the collisions of the ion with the ultracold sample are shown.

Q 45.5 Th 11:30 F 303

Nonlinear atom interferometer beats classical precision limit — •Eike Nicklas, Christian Gross, Tilman Zibold, Jérôme Estève, and Markus K Oberthaler — Kirchhoff Institute for Physics, University of Heidelberg, Germany

The phase detection precision of classical linear atom interferometers is limited by the standard quantum limit. We report on the realization of a nonlinear atom interferometer based on two hyperfine states of Bose-Einstein condensed Rubidium. The nonlinearity is provided by elastic s-wave collisions and we implemented precision control of the scattering length by employing a narrow Feshbach resonance. In a prototypal measurement with a macroscopic number of atoms we find a precision enhancement of 15% over the standard quantum limit. Within the interferometer a large entangled state with 170 entangled atoms is detected.

Q 45.6 Th 11:45 F 303

From single to many particle Rabi oscillations — •Tilman Zibold, Eike Nicklas, Christian Gross, Helmut Strobel, Ion Stroescu, Wolfgang Müssel, and Markus K. Oberthaler — Kirchhoff Institute for Physics, University of Heidelberg, Germany

We experimentally investigate the Josephson dynamics between two weakly coupled spin states in a Bose-Einstein condensate of Rubidium. The relevant parameters of this system are the interaction energy and the tunneling rate. Our system allows for the tuning of the interaction energy by an inter species Feshbach resonance whereas the tunneling rate is controlled by the two photon coupling between the modes. The Josephson dynamics can be divided in three different regimes characterized by the emergence of different dynamics. The adjustability of the system allows us to enter all these three regimes. By measuring atom number imbalance and the corresponding phase we are able to map out phase plane trajectories of all predicted dynamics. The occurrence of self trapped states is further investigated to identify the corresponding bifurcation in the phase plane portrait. The analysis of the small amplitude oscillations with mean phase 0 and pi respectively allows us a precise determination of the interaction energy between the two modes and therefore a characterization of the elastic part of the Feshbach resonance.

Q 45.7 Th 12:00 F 303

Preparation of a degenerate mesoscopic sample of fermions — •Friedhelm Serwane[1,2], Timo Ottenstein[1,2], Thomas Lompe[1,2], Gerhardt Zürn[1,2], Martin Ries[1,2], Philipp Simon[1,2], and Selim Jochim[1,2] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisches Institut, Universität Heidelberg

Systems consisting of only few degenerate interacting fermions have prominent examples in nature: e.g. nuclei in the atomic core. Our goal is the preparation of such a system with tunable properties in the laboratory using ultracold fermionic ^{6}Li atoms. Here, the interaction strength can be tuned over many orders of magnitude by means of a Feshbach resonance.

With the ability to control the number of fermions in the trap, studies of the system's properties in dependence of the atom number n will become possible. One intriguing example is the appearance of many-body effects such as superfluidity. In the extreme limit, the sample consists of only two atoms in different spin states which potentially can be used as a high-fidelity qubit.

To control n precisely, we transfer atoms from a large optical dipole trap into a micron-sized dipole trap with well separated energy levels. By applying a magnetic field gradient, we are able to spill atoms in a controlled way ending up with a highly degenerate Fermi gas. So far we can control the atom number down to 120 atoms, limited by the imaging technique. Also we were able to count single atoms in a MOT with fluorescence imaging. In the next step we will combine these techniques to study smaller samples of highly degenerate fermions.

Q 45.8 Th 12:15 F 303

Study of matter-wave speckle patterns — •Nicolas Cherroret[1] and Sergey Skipetrov[2] — [1]Quantum optics and statistics group, Institute of Physics, Albert Ludwigs University of Freiburg, Germany — [2]Laboratoire de Physique et Modélisation des Milieux Condensés, Grenoble, France

The behavior of Bose-Einstein Condensates (BECs) in disordered potentials attracts growing interest of physicists during the last few years. More specifically, the properties of a BEC released from a trap in a random potential has been studied. From the experimental viewpoint, BEC systems are very controllable and versatile, and direct measurements of the atomic spatial density n(r) can be performed. During the last two years, considerable efforts were made to study the ensemble average of n(r) in 1D, 2D, and 3D systems, with special interest in the phenomenon of Anderson localization. In the same time, very few results concern the statistics of n. However, it is well known that a wave propagating in a disordered medium generates a complicated intensity pattern ("speckle") due to multiple scattering from inhomogeneities. Since a weakly interacting BEC can be regarded as a coherent matter wave, an analogous phenomenon should also show up in the case of BECs. We analyze these "matter-wave speckle patterns" theoretically and show that they exhibit long-range density correlations, strongly enhanced at long times, which can even take negative values for sufficiently distant points.

Reference: N. Cherroret and S.E. Skipetrov, Phys. Rev. Lett. 101, 190406 (2008)

Q 46: Laser Development: Nonlinear Effects III

Time: Thursday 10:30–11:15 Location: F 128

Q 46.1 Th 10:30 F 128

Sub-10-fs Pulse aus einem MHz-NOPA mit Pulsenergien von 0,4 µJ — •Moritz Emons[1], Andy Steinmann[1], Thomas Binhammer[2], Guido Palmer[1], Marcel Schultze[1] und Uwe Morgner[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [2]VENTEON Laser Technologies GmbH

Wir präsentieren einen nicht-kollinearen parametrischen Verstärker (NOPA), welcher Pulse mit einer Pulsdauern von weniger als 10 fs mit Pulsenergien von 420 nJ erzeugt. Dieses System wird durch Mikrojoule-Pulse aus einem Yb:KYW-Oszillator mit Cavity-Dumping und einem nachgeschalteten "rod-type"-Faserverstärker im Einfachdurchgang bei einer Repetitionsrate von 1 MHz gepumpt.

Mit den 420 fs langen Pulsen aus dem Verstärker wird direkt ein ultrabreiter Seed für den NOPA-Prozess durch Weißlichterzeugung in einem YAG-Plättchen generiert, dabei ist eine zusätzliche Komprimierung der Pulse nicht nötig. Der eigentliche parametrische Prozess findet durch Überlagerung von Seed- und Pumpstrahlung in einem BBO-Kristall statt. Zur Komprimierung der erzeugten NOPA-Pulse wurde ein doppelt gechirptes Spiegelpaar in Kombination mit BaF_2 Keilen verwendet.

Mit der resultierenden Spitzenleistung von nahezu 30 MW bei 1 MHz Repetitionsrate streben wir die Erzeugung von hohen harmonischen Strahlung in Edelgasen an.

Q 46.2 Th 10:45 F 128

Synchron gepumpter pikosekunden OPO basierend auf PPLN, durchstimmbar im mittleren Infrarot mit hoher mittlerer Ausgangsleistung — •Felix Rübel[1], Gregor Anstett[2] und Johannes L'huillier[1] — [1]Photonik-Zentrum Kaiserslautern, Kohlenhofstr. 10, 67663 Kaiserslautern — [2]Fraunhofer-FOM, Gutleutstr. 1, 76275 Ettlingen

Die Erzeugung von durchstimmbarer Laserstrahlung im mittleren infraroten Spektralbereich (MIR), speziell im Bereich zwischen 4 μm und 5 μm, stellt eine besondere Herausforderung dar. Eine Möglichkeit bieten nichtlineare Frequenzkonverter. Die typischen, für diese Anwendung verwendeten Materialien (z.B. ZGP) erfordern komplexe Pumplasersysteme mit Wellenlängen größer 2 μm, während die auch für 1μm Pumpwellenlänge geeigneten Standardmaterialien (z.B. LBO) eine effiziente Frequenzkonversion ins MIR aufgrund starker Absorptionen unterbinden. Eine Ausnahme stellt $LiNbO_3$ (LN) mit einem Transparenzbereich von 0.34 μm bis zu etwa 5.5 μm dar. Allerdings besitzt es im Bereich zwischen 4 μm und 5.5 μm aufgrund erhöhter Absorptionen lediglich eine Resttransmission von weniger als 30%. Durch die hohe Nichtlinearität sowie die Möglichkeit der Quasiphasenanpassung lassen sich unter Verwendung von Nd-dotierten Lasern trotzdem effiziente Systeme im MIR realisieren. In diesem Beitrag wird die Erzeugung von durchstimmbarer Laserstrahlung im Bereich zwischen 3 μm und 5 μm in einem synchron gepumpten OPO basierend auf PPLN vorgestellt. Bei 4.5 μm wurde mit einer Repetitionsrate von 160 MHz eine mittlere Ausgangsleistung von 1.1 W in 6 ps langen Impulsen erzeugt.

Q 46.3 Th 11:00 F 128

Schmalbandiger Nanosekunden optisch parametrischer Oszillator bei 2128 nm basierend auf einem Resonator mit volumenholographischem Bragg-Gitter — •Peter Koch[1], Felix Rübel[1], Martin Nittmann[2], Thorsten Bauer[2], Jürgen Bartschke[2] und Johannes L'huillier[1] — [1]Photonik-Zentrum Kaiserslautern e. V., Kohlenhofstr. 10, 67663 Kaiserslautern — [2]Xiton Photonics GmbH, Kohlenhofstr. 10, 67663 Kaiserslautern

Für viele Anwendungen in der Medizin, der Spektroskopie aber auch in der Fernerkundung und Raketenabwehr werden leistungsstarke Strahlquellen mit einer Wellenlänge größer 4,5 μm benötigt. Jenseits von 4 μm sind allerdings keine einfachen und effizienten Laserquellen verfügbar, so dass optisch parametrische Oszillatoren eine attraktive Lösung zur Erzeugung von kohärenter und abstimmbarer Strahlung im mittleren und fernen Infrarot darstellen. Ein mögliches Konzept ist ein Tandem-OPO, bei dem in der ersten Konversionsstufe 2 μm Strahlung erzeugt wird, welche als Pumpstrahlung für einen $ZnGeP_2$-OPO in der zweiten Konversionsstufe dient. Für eine hohe Konversionseffizienz ist eine hohe spektrale Leistungsdichte der ersten Konversionsstufe wichtig. Wir berichten über einen 1064,2 nm gepumpten schmalbandigen (< 0,7 nm) OPO, welcher exakt an der Entartung mit einer Wellenlänge von 2128,4 nm läuft. Durch Verwendung eines volumenholographischen Bragg-Gitters (VBG) wurde eine mittlere Leistung von 1,7 W mit einem differenziellen Wirkungsgrad von 31,8 % und guter Strahlqualität erreicht. Durch eine Änderung der VBG-Temperatur kann die Resonanz des OPO von 2127,7 bis 2129,2 nm durchgestimmt werden.

Q 47: Photonics I

Time: Thursday 11:15–12:30 Location: F 128

Q 47.1 Th 11:15 F 128

Electrooptical properties of clear point modified liquid-crystal-based mixtures — •Martin Blasl, Kirstin Bornhorst, and Florenta Costache — Fraunhofer Institute for Photonic Microsystems, Maria-Reiche-Str. 2, 01109 Dresden, Germany

We investigate electro-optically active materials, such as the thermotropic liquid crystals of n-CB type to be used in active waveguide devices.

The n-CB exhibit in their isotropic phase high Kerr coefficients, being therefore well-suited for such devices. In addition, as opposed to their nematic or smectic phases, in their isotropic phase n-CB give rise to low scattering of the guided light.

However, to get n-CB in their isotropic phase they must be heated above their nematic-isotropic transition temperature (clear point). This means that the waveguide device should be kept at a temperature above the clear point. Our aim is to minimize the required heat power consumption of the device by lowering the clear point.

We observed that the clear point can be manipulated by embedding n-CB in different mixtures. For instance a 6-CB-oil mixture appeared in its isotropic-phase already at room temperature. DSC measurements revealed that the clear point changes with changing the oil concentration in the mixture. For instance in 6-CB the clear point shifts towards lower temperatures with increasing concentration of oil. On the other side critical angle measurements show that the Kerr effect in the mixtures remains nearly unchanged, which is of significant importance for active liquid crystals based waveguide devices.

Q 47.2 Th 11:30 F 128

Fabry-Perot-basierte elektrooptische Schalter mit Polymer-dispersed-liquid-crystals (PDLC) — •Marcus Dziedzina, Stefan Meister, Dawid Schweda, Chris Scharfenorth und Hans Joachim Eichler — Technische Universität Berlin, Institut für Optik und Atomare Physik, Berlin, Deutschland

Elektrooptische Bauelemente zur Wellenlängenselektion haben für wissenschaftliche und technische Anwendungen im Informationszeitalter eine wichtige Bedeutung erlangt. Die aktuellen Systeme können bezüglich der Größe und des Energieverbrauchs z.B. durch eine Erhöhung des Integrationsgrades wesentlich optimiert werden. Das hier dargestellte Konzept für elektrooptische Schalter beruht auf Fabry-Perot-Strukturen, welche aus zwei dielektrischen hochreflektierenden Spiegeln aufgebaut wurde. Der Brechungsindex und die Verluste des zwischen den Spiegeln befindlichen elektrooptischen Materials (Spacerschicht) mit hohem elektrooptischem Koeffizient können durch Anlegen einer äußeren Spannung und dem daraus resultierenden elektrischem Feld variiert werden. Das Feld kann durch zwei außenliegende transparente Elektroden aus Indiumzinnoxid (ITO) vermittelt werden. Bei der Spacerschicht handelt es sich im vorliegenden Fall um ein Polymer mit Nanohohlräumen, welche mit flüssigkristallinen Molekülen gefüllt sind. Die zu erwartenden Modulationsfrequenzen dieser polymer-dispersed-liquid-crystals sind gering und dementsprechend sind die Schaltzeiten begrenzt. Aufgrund des hohen elektrooptischen Koeffizienten sind die erforderlichen Schaltspannungen aber gering. Die Schalteigenschaften wurden im dritten optischen Fenster um 1550nm untersucht.

Q 47.3 Th 11:45 F 128

Der Photonenspin - Eine Naturkonstante? Messung des Photonenspins an energiearmen Photonen von Radiowellen — •Alexander Krebs und Christoph Krebs — Dr.Dr.rer.nat. Alexander Krebs, Birkenallee 1, 74238 Krautheim

Im Teilchenbild besteht sichtbares Licht aus Photonen mit dem Spin $h/2\pi$. Dieser lässt sich nicht nur wie üblich durch spektroskopische Methoden der Atomphysik, sondern auch größenordnungsmäßig durch eine makroskopische Methode in Form einer direkten Drehimpulsmessung nachweisen. (Entsprechende Versuche z.B. durch R. A. Beth, R. Dasgupta und P.K. Gupta.)

Eine experimentelle Überprüfung des Photonenspins an elektromagnetischer Strahlung sehr großer Wellenlänge erfolgte aber bisher nicht. Dennoch geht man heute von einer über alle Wellenlängenbereiche unveränderten Größe des Photonenspins aus. Die Frage ist, ob bei wachsender Wellenlänge und einer gegen 0 gehenden Photonenmasse der Photonenspin konstant bei $h/2\pi$ bleiben kann.

Aus diesem Grunde haben wir uns das Ziel gesetzt, den Photonenspin von Radiowellen zu messen. Dabei mussten wir uns ebenfalls einer makroskopischen Drehimpulsmessmethode bedienen (Streuung von zirkular polarisierten Radiowellen an einer dünnen Aluminiumscheibe), da atomphysikalische Messmethoden bei großen Wellenlängen nicht möglich sind. Unsere experimentelle Überprüfung des Spins von Radiowellenphotonen erbrachte zu unserem Erstaunen keinen messbaren Spin, obwohl die erzielte Messgenauigkeit in einem Bereich weit unterhalb des erwarteten Wertes von $h/2\pi$ lag.

Q 47.4 Th 12:00 F 128

Geometric Spin Hall Effect of Light — •Jan Korger[1,2], Christian Gabriel[1,2], Peter Banzer[1,2], Andrea Aiello[1,2], Ulrik Andersen[1,3], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]MPI für die Physik des Lichts, Erlangen, Deutschland — [2]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, Deutschland — [3]Technical University of Denmark, Kongens Lyngby, Dänemark

We describe a novel fundamental optical phenomenon and report on experimental progress towards its verification.

The effect occurs when a collimated beam is detected in a plane tilted with respect to the direction of propagation and amounts to a shift of the barycenter of the Poynting vector distribution. This shift depends on the state of polarization and tilting angle of the detector plane. It occurs whenever the beam possesses a nonzero transverse angular momentum. Unlike the conventional Spin Hall Effect of Light (SHEL) the effect we demonstrate is only determined by the geometry of the system and occurs in vacuum.

We present experimental techniques to measure the effect using conventional detectors, which are not sensitive to the Poynting vector but to the electric field density. Preliminary data is discussed and compared to numerical and analytical computations.

Q 47.5 Th 12:15 F 128

Quasi-Lichtspeicherung mittels Zeit-Frequenz-Kohärenz — •Stefan Preussler, Kambiz Jamshidi, Andrzej Wiatrek, Ronny Henker und Thomas Schneider — Institut für Hochfrequenztechnik, Hochschule für Telekommunikation Leipzig

Eine Schlüsseltechnologie für rein optische Netzwerke der Zukunft ist die Speicherung und Synchronisierung optischer Daten. In den letzten Jahren sind dabei einige Fortschritte zu verzeichnen. Es wurde gezeigt, dass es möglich ist Licht in Atomgasen zu verlangsamen und zu speichern. Die Speicherung beruht dabei auf Resonanzen des jeweiligen Systems. Diese liegen nicht in den Wellenlängenbereichen vieler Anwendungen und sind extrem schmalbandig. Vor kurzem gelang es Licht mittels einer akustischen Anregung in einer Glasfaser zu speichern. Die Speicherzeiten sind allerdings sehr gering, da sie von der Lebensdauer der akustischen Anregung abhängen. Außerdem wird für den Schreib- und Leseprozess immens viel Energie benötigt. Wir stellen hier einen komplett neuen Ansatz zur Speicherung von Licht vor. Das Prinzip beruht auf dem Zusammenhang zwischen Frequenz- und Zeitbereich des Signals. Dabei wird das Frequenzspektrum des Eingangssignals mit einem Frequenzkamm multipliziert, so dass mehrere Kopien des Eingangssignals im Zeitbereich entstehen. Mit einem optischen Schalter können die Kopien beliebig ausgeschnitten werden. Die Speicherzeit ist einfach einstellbar und frei zwischen 0 und 100ns wählbar. Außerdem ist die Methode unabhängig von der Bitrate, der Modulationsart und der Trägerfrequenz der Signale. Mit diesem System ist es z.B. möglich 1000Bit eines 10GBps Signals zu speichern.

Q 48: Ultrashort Laser Pulses: Miscellaneous

Time: Thursday 10:30–12:30 Location: F 342

Q 48.1 Th 10:30 F 342

Eindeutige Phasenrekonstruktion von ultrakurzen Pulsen mit spektralen Lücken — •Alexander Hause[1], Birger Seifert[2], Philip Rohrmann[1] und Fedor Mitschke[1] — [1]Universität Rostock, Institut für Physik, Universitätsplatz 3, 18051 Rostock — [2]Facultad de Física, Pontificia Universidad Católica de Chile, Casilla 306, Santiago 22, Chile

Wir präsentieren eine selbst-referenzierende Technik zur Messung von Amplitude und Phase ultrakurzer Laserpulse. In diesem Verfahren treten keine Vieldeutigkeiten bezüglich der relativen Phase von separierten spektralen Anteilen auf.

Bekannte Methoden zur phasensensitiven Charakterisierung wie Frog oder Spider können die relative Phase von Frequenzkomponenten, die spektral weit voneinander getrennt sind, nicht eindeutig rekonstruieren. Wir zeigen im Experiment die erfolgreiche und eindeutige Wiederherstellung der spektralen Phase mittels der Vampire-Methode.

Dazu wurden aus dem Spektrum ultrakurzer Laserpulse weite Bereiche herausgefiltert und das verbleibende Signal charakterisiert. Im Vergleich zum ungefilterten Puls konnte die spektrale Phase in den Bereichen nichtverschwindender Intensität eindeutig und mit der richtigen relativen Phase rekonstruiert werden.

Q 48.2 Th 10:45 F 342

SPIDER-Verfahren zur Charakterisierung von Superkontinua — •Sven Dobner, Nicoletta Brauckmann, Michael Kues, Petra Gross und Carsten Fallnich — Institut für Angewandte Physik, Westfälische Wilhelms-Universität Münster

Ultrakurze Laserimpulse können mit elektronischen Methoden typischerweise nicht direkt vermessen werden. Zur Charakterisierung der Form und Phase von Femtosekunden-Laserimpulsen haben sich Autokorrelation sowie FROG (Frequency Resolved Optical Gating)- und SPIDER (Spectral Phase Interferometry for Direct Electric-Field Reconstruction)-Verfahren etabliert. Superkontinua stellen aufgrund ihrer extremen spektralen Bandbreite allerdings erhöhte Anforderungen an derartige Charakterisierungsverfahren.

Wir stellen einen modifizierten ZAP (Zero Additional Phase)-SPIDER vor, der für die Charakterisierung von Impulsen mit großer Bandbreite (>100 nm) und kleiner Leistung (<10 mW) mittels Verwendung eines Fourierspektrometers zur Aufnahme des SPIDER-Spektrums optimiert wurde. Das Fourierspektrometer zeichnet sich durch eine hohe spektrale Auflösung aus, was zur Rekonstruktion der spektralen Phase aus den Modulationen des SPIDER-Spektrums nötig ist. In unserem Beitrag wird das Konzept dieser SPIDER-Variante vorgestellt und erste Messergebnisse werden präsentiert.

Q 48.3 Th 11:00 F 342

Intra-cavity interferometric autocorrelation for ultraviolet pulses by spontaneous parametric down-conversion — •Patrick Michelberger[1,2,3], Roland Krischek[1,2], Witlef Wieczorek[1,2], Akira Ozawa[1], and Harald Weinfurter[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany — [2]Department für Physik, Ludwig-Maximilians-Universität, 80797 München, Germany — [3]Clarendon Laboratory, Oxford University, Parks Road, Oxford, OX1 3PU, UK

Autocorrelation is a common method to estimate the duration of ultra-short laser pulses. In the ultra-violet regime, employing the customary process of second harmonic generation is challenging due to absorption in nonlinear crystals at short wavelengths. Here we show how to utilise spontaneous parametric down-conversion (SPDC) to generate an autocorrelation signal for UV-pulses in the infra-red. Our method relies on the n^{th} order emission of the SPDC process, emitting $2n$ photons with a rate approximately proportional to P^n for low pumping powers P. This allows one to obtain the n^{th} order autocorrelation by simply counting the $2n$ down-converted photons. Herewith the first direct measurement of 180 fs ultra-short pulses, centred around 390 nm, inside an enhancement cavity becomes feasible.

Q 48.4 Th 11:15 F 342

Phase dependence of supercontinuum generation with optical feedback — •Nicoletta Brauckmann, Michael Kues, Petra Gross, and Carsten Fallnich — Institut für Angewandte Physik, Westfälische Wilhelms-Universität, Münster

Supercontinuum (SC) generation is a nonlinear optical phenomenon where light of narrow bandwidth becomes spectrally broadened due to several nonlinear effects. In addition to the conventional input pulse and fiber parameters we experimentally and numerically investigate the influence of an optical feedback on SC generation. Specifically, a system for SC generation by using a microstructured fiber within a synchronously pumped ring cavity is presented. The feedback leads to an interaction of the generated SC with the following femtosecond laser pulses and thus to the formation of a nonlinear oscillator. Different kinds of nonlinear dynamical behavior can be observed, namely steady state, period multiplication as well as limit cycle and chaotic behavior [1]. Here, we present that the delay of the optical feedback is a critical parameter for the specific shape of the generated SC and for the regime of nonlinear behavior as the system is sensitive to the phase of the feedback. We demonstrate that it is possible to shape supercontinua via the pulse and fiber parameters and to create specific time series like period multiplication via the effect of optical feedback, which might promote novel applications.

[1.] M. Kues, N. Brauckmann, T. Walbaum, P. Groß, and C. Fallnich, Opt. Express **17**, 15827–15841 (2009).

Q 48.5 Th 11:30 F 342

Erzeugung komplexer Wellenleiterstrukturen mithilfe adaptiver Strahlformung in Quarzglas — •Benjamin Väckenstedt[1], Matthias Pospiech[1], Moritz Emons[1], Guido Palmer[1] und Uwe Morgner[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland — [2]Laser Zentrum Hannover e.V.

Mit Hilfe adaptiver Strahlformung und fs-Laserpulsen haben wir in einem einzigen Schreibvorgang verschiedene komplexe Wellenleiterstrukturen in Quarzglas (fused-silica) realisiert. Wir benutzten einen Phasenmodulator, um während des Schreibprozesses mehrere Foki zu erzeugen und deren Abstand zueinander zu verändern. Dies ermöglicht das Schreiben von komplexen Wellenleiterstrukturen, wie Teilern, Kopplern und Interferometern. Mit dieser Technik wurden beispielsweise optische Splitter erzeugt. Strahlprofile und Leitungseigenschaften wurden untersucht und die Ergebnisse werden präsentiert.

Q 48.6 Th 11:45 F 342

Wechselwirkungsdynamik räumlich separierter Kavitationsblasen beim Laser-induzierten optischen Durchbruch mittels ultrakurzer Laserpulse — •Nadine Tinne, Tammo Ripken und Holger Lubatschowski — Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover

Die dreidimensionale Bearbeitung transparenter Materialen durch die Fokussierung ultrakurzer Laserpulse hat innerhalb der letzten Jahre zahlreiche Anwendungen in der Materialwissenschaft, aber auch in der Medizin (vor allem in der Ophthalmologie) und Biophotonik gefunden. Dabei wird das Ziel verfolgt, die Bearbeitungs- bzw. in der Medizin die Behandlungsdauern erheblich zu verkürzen. Die Entwicklung der Lasersysteme bewegt sich deshalb in die Richtung, eine steigende Repetitionsrate (bis zu MHz) zu verwenden, welche allerdings einen Pulsüberlapp und somit eine Puls-zu-Puls-Wechselwirkung zur Folge haben kann. Die Mechanismen, welche bei der Wechselwirkung der in diesem Fall zeitlich und räumlich dicht aufeinander folgenden Pulse auftreten, sind im Gegensatz zum Schneideffekt, den Einzelpulse als Folge eines optischen Durchbruchs und einer daraus resultierenden Kavitation hervorrufen, weitestgehend unbekannt. Die dabei stattfindenden Prozesse können mit Hilfe der Methode der Kurzzeitphotographie sichtbar gemacht sowie in ihrer Existenz und Stärke charakterisiert werden. Eine gegenseitige Beeinflussung räumlich separierter Kavitationsblasen wurde so im Modellmedium Wasser in Abhängigkeit von Pulsenergie, Energieverhältnis und Pulsabstand untersucht, um eine Optimierung der Parameter für eine verkürzte Behandlungsdauer zu erzielen.

Q 48.7 Th 12:00 F 342

Realisierung von Volumen-Bragg-Gittern mit Hilfe ultrakurzer Pulse — •Daniel Richter[1], Christian Voigtländer[1], Jens Thomas[1], Stefan Nolte[1] und Andreas Tünnermann[1,2] — [1]Institut für Angewandte Physik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Deutschland — [2]Fraunhofer-Institut

für Angewandte Optik und Feinmechanik, Albert-Einstein-Strasse 7, 07745 Jena, Deutschland

Unter der Verwendung von ultrakurzen Laerpulsen wurden zwei Techniken zur Erzeugung von Volumen-Bragg-Gittern in Kieselglas untersucht. Mit Hilfe der *Layer-by-Layer*-Methode konnten Gitter mit Beugungseffizienzen in die erste Ordnung , in Transmissionsanordnung, von teilweise über 70% erzeugt werden. Diese besitzen aber keine nachweisbaren Reflektivitäten infolge der Periodenschwankungen.

Das Problem der Periodenschwankungen wird bei der Phasenmaskenmethode fast vollständig umgangen. Die so geschriebenen Gitter haben Beugungseffizienzen in die erste Ordnung, in Transmissionsanordnung, von etwa 90% und Reflektivitäten, in Reflexionsanordnung, von über 80% für die ersten Ordnungen.

Die Struktur der erzeugten Phasengitter weicht, im Vergleich zu bisherigen Gittern, deutlich von einer Sinusform ab und ermöglicht so höhere Reflektionsordnungen.

Aufgrund der Eigenschaft ultrakurzer Pulse sind die beiden Verfahren im Vergleich zu den bisherigen holographischen Methoden, welche an ein spezielles Glas gebunden sind, auf viele weitere transparente Materialien erweiterbar.

Q 48.8 Th 12:15 F 342

Vorarbeiten für ein flexibles Mehrphotonen Endomikroskop — •Jannes Harder — Laser Zentrum Hannover

Multi-Photonen Mikroskopie ist durch ihre hervorragenden Eigenschaften zu einem der wichtigsten Werkzeuge in der Untersuchung von biologischen Proben geworden. Durch den Einsatz von Laserlicht im infraroten Bereich ergeben sich hohe Eindringtiefen in das Gewebe, welche die Multiphotonen -Mikroskopie für den in vivo Einsatz prädestiniert. Die größten Probleme bei der Realisierung eines flexiblen Mehrphotonen Endomikroskopes sind die Bereitstellung von ultrakurzen Laserpulsen und das gleichzeitige Aufsammeln des Fluoreszenz-Lichtes mithilfe von optischen Fasern. In dieser Arbeit sollen die physikalischen Grundlagen für ein flexibles Mehrphotonen-Endomikroskop vorgestellt werden. Sowohl die Bereitstellung des Anregungs-Lichtes als auch das Auffangen des Fluoreszenz-Lichtes werden mit Hilfe einer Photonischen Kristallfaser mit Double-Clad Anordnung realisiert. Im Mittelpunkt der Arbeit steht die Leitung des Anregungs- und des Fluoreszenz-Lichtes durch die Faser. Hierbei wird der Einfluss der Faser auf die Pulsbreite und das Spektrum analysiert. Die Kompensation der Verbreiterung der für Zwei-Photonen-Effekte erforderlichen ultrakurzen Pulse durch Dispersion wird durch einen Gitterkompressor realisiert. Zur Fokussierung des Anregungslichtes auf die Probe wird ein GRIN Linsen- Objektiv genutzt. Das Emissionslicht wird nach Durchlaufen der Faser mit Hilfe eines Bandpassfilters vom Laserlicht getrennt und mithilfe eines Photomultipliers detektiert. Abschließend sollen in der vorliegenden Arbeit die Auflösungseigenschaften des Gesamtsystems überprüft werden.

Q 49: Precision Measurements and Metrology VI

Time: Thursday 14:00–16:15 Location: A 310

Q 49.1 Th 14:00 A 310

A Silent Symphony: Das weltweite Netz der Gravitationswellendetektoren — •Hartmut Grote — MPI f. Gravitationsphysik (AEI) und Leibniz Universität Hannover

Erdgebundene laser-interferometrische Gravitationswellendetektoren können ultrakleine Längenänderungen von sub-attometern messen. Derzeit gibt es fünf Standorte solcher Detektoren auf der Erde, und zwar zwei in den USA (LIGO), jeweils einen in Italien (Virgo), in Japan (Tama), und in Deutschland (GEO600 bei Hannover). Der Vortrag gibt einen Überblick über das Messprinzip dieser Maschinen und der Aktivitäten und Pläne der einzelnen Projekte. Obwohl eine direkte Messung von Gravitationswellen noch aussteht, gibt es bereits einige astrophysikalisch relevante Resultate des Lauschens nach Gravitationswellen. Über die Suche nach den Wellen hinaus, dient der GEO600-Detektor in Sarstedt bei Hannover insbesondere der Erprobung neuartiger Techniken zur Steigerung der Empfindlichkeit. Aktuell arbeiten wir an der ersten Nutzung von gequetschtem Vakuum, um dann in der Zeit von 2012-2015 dem kosmischen Konzert mit neuer Hörkraft zu lauschen.

Q 49.2 Th 14:15 A 310

Laser interferometry for next generation geodesy missions — •Benjamin Sheard, Marina Dehne, Christoph Mahrdt, Vitali Mueller, Martin Sommerfeld, Gerhard Heinzel, and Karsten Danzmann — Albert Einstein Institute, Hannover, Germany

The application of precision laser interferometry to next generation geodesy missions, including both inter-satellite ranging and laser gravity gradiometry, will be discussed. In addition an overview of the commonalities and differences with the interferometer technology developed for the space-based gravitational wave detector Laser Interferometer Space Antenna (LISA) and LISA Pathfinder and the status of the ongoing development of interferometry for next generation geodesy missions at the AEI Hannover will be presented.

Q 49.3 Th 14:30 A 310

The LISA mission - a gravitational wave detector in space — •Gerhard Heinzel[1,2] and Karsten Danzmann[1,2] — [1]Max-Planck Institut für Gravitationsphysik (Albert-Einstein Institut) Hannover — [2]Zentrum für Gravitationsphysik der Gottfried Wilhelm Leibniz Universität Hannover

LISA is being developed as a joint NASA/ESA mission with a planned launch date around 2020. Three satellites will form a giant laser interferometer with 5 million km armlength that is able to detect gravitational waves from astrophysical sources between 0.1 mHz and 1 Hz. The expected sources include black hole mergers and other extreme events in the universe which are otherwise unobservable. This talk will give an overview of the mission and the numerous ongoing experimental developments, with emphasis on the interferometer research in Hannover.

Q 49.4 Th 14:45 A 310

Modeling interferometers for space based observations of Earth's variable gravity field — •Christoph Mahrdt, Benjamin Sheard, Marina Dehne, Gerhard Heinzel, and Karsten Danzmann — Max-Planck-Institut für Gravitationsphysik und Institut für Gravitationsphysik der Leibniz Universität Hannover (Albert-Einstein-Institut)

Space based observation of Earth's time variable gravity field (GRACE) has led to new insights into the mechanisms of mass transport within the Earth. A mission to continue the observations but also improve the sensitivity of the experiment is highly desired. Substitution of the microwave ranging system by a Laser interferometer has been proposed as a way of improving the ranging sensitivity. One significant issue is the pointing between the satellites and in particular the dynamic pointing error (jitter) which will couple into the range measurement. A software toolkit to optimise the optical bench based on tracing of general astigmatic Gaussian beams and higher order Gaussian Hermite modes is being developed. I will give a short introduction to pointing jitter and present the status of the simulations.

Q 49.5 Th 15:00 A 310

Das Einstein Teleskop: ein Gravitationswellendetektor der dritten Generation — •Harald Lück für das ET Science Team — AEI Hannover, Callinstr. 38, 30167 Hannover

Neben der Detektion von Gravitationswellen ist die Gravitationswellenastronomie das Hauptziel der Gravitationswellenforschung. Astronomie mit Gravitationswellen wird Einblicke in bisher unerforschte Gebiete der Astrophysik und der Kosmologie ermöglichen. Für routinemäßige Beobachtungen mit hohem Signal- zu Rausch-Verhältnis muss die Empfindlichkeit gegenüber heutigen Gravitationswellendetektoren um einen Faktor ~100 verbessert werden. In einer europaweiten Kollaboration wird derzeit eine von der EU geförderte Design Studie durchgeführt, die ein Konzept für ein interferometrisches Gravitationswellenobservatorium entsprechender Empfindlichkeit erarbeitet. Mögliche Techniken für ein solches Observatorium werden in diesem Vortrag vorgestellt.

Q 49.6 Th 15:15 A 310

Inter-spacecraft laser ranging and data communication for LISA — •Juan Jose Esteban Delgado, Antonio Garcia Marin, Johannes Eichholz, Iouri Bykov, Joachim Kullmann, Gerhard Heinzel, and Karsten Danzmann — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) and Leibniz Universität Hannover

The LISA phase measurement system (PMS) will provide interferometric phase readout of the primary heterodyne signal at microcycle sensitivity, ranging measurements at sub-meter accuracy and data communication at rates of several kilobits per seconds. Our investigations are focused on inter-spacecraft laser ranging and data transfer for LISA using Direct Sequence Spread Spectrum (DS/SS) modulation onto the laser links. We present the setup of an optical experimental to test the levels of performance achievable with a single laser link as well as a new hardware prototype based on FPGA (Field Programmable Gate Array) processing to perform high-accuracy phase readout of the optical signal, ranging measurements, data communication and is suitable for clock noise demodulation and digital laser-phase locking.

Q 49.7 Th 15:30 A 310

Inter-spacecraft 2 GHz clock-tone transmission with high phase fidelity at ultra low frequencies — •Simon Barke, Michael Tröbs, Gerhard Heinzel, and Karsten Danzmann — Albert Einstein Institute, Hannover, Germany

Gravitational waves, predicted by Albert Einstein in 1908 to be caused by accelerated mass, come in different signal shapes and frequencies depending on their source or origin. The Laser Interferometer Space Antenna (LISA) is a joint ESA/NASA mission to observe low frequency gravitational waves as produced by super massive black hole binaries. One important noise source in LISA will be on-board reference oscillators acting as a frequency standard for the science measurement. An inter-spacecraft clock tone transfer chain (consisting of frequency multipliers or dividers, high-frequency cables, electro-optic phase-modulators, optical fibers and fiber amplifiers) is necessary to remove this non-negligible phase noise in post processing.

I will show setups to detect excess phase noise introduced by these components and present recent experimental results of upper limits on their phase noise to a 2 GHz signal as well as some dependencies of phase shift over environmental influences.

Q 49.8 Th 15:45 A 310

Implementierung und Kontrolle eines Mode Cleaner Resonators am Ausgang des Gravitationswellendetektors GEO600 — •Mirko Prijatelj und Das GEO600-Team — Albert-Einstein-Institut, Hannover, Germany

Der deutsch-britische Gravitationswellendetektor GEO600 nahe Hannover durchläuft momentan das Upgrade-Programm GEO-HF. Im Rahmen dieses Programms wird das Auslesen der Gravitationswellensignale auf homodyn Detektion umgestellt. Bei diesem Verfahren werden höheren optischen Moden am Ausgang von GEO600 störender sein als bislang. Es ist daher nötig die höheren Moden durch einen Resonator zu filtern. Fluktuationen im Versatz zwischen der Frequenz des GEO600-Ausgangsstrahls und der Resonanzfrequenz des Resonators schlagen sich ebenso als Rauschen im Gravitationswellensignal nieder wie dynamische Ausrichtungsfehler. Im Rahmen des Vortrags wird näher auf die Kontrolle des Frequenzversatzes sowie der Ausrichtung des GEO600-Ausgangsstrahls auf den Mode Cleaner Resonator eingegangen.

Q 49.9 Th 16:00 A 310

The GEO600 Squeezed Light Laser — •Henning Vahlbruch, Alexander Khalaidovski, Nico Lastzka, Christian Graef, Karsten Danzmann, and Roman Schnabel — Institut für Gravitationsphysik, Leibniz Universität Hannover und Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstrasse 38, D-30167 Hannover

Photon shot-noise is a limiting noise source in laser interferometric gravitational wave (GW) detectors. The signal to shot-noise ratio can be improved by increasing the laser power but due to light absorption and the excitation of parasitic instabilities e.g. megawatts of circulating light might become an issue. Alternatively, the signal to shot-noise ratio can also be improved by 'squeezing' the shot-noise as proposed in 1981.

The next upgrade of the GEO600 gravitational wave detector in Germany is scheduled for 2010 and will, in particular, involve the implementation of squeezed light. The required non-classical light source is assembled on a 1.5m^2 breadboard and includes a full coherent control system and a diagnostic balanced homodyne detector. Here, we present the first experimental characterization of this setup as well as a detailed description of its optical layout. A squeezed quantum noise of up to 9dB below the shot-noise level was observed in the detection band between 10Hz and 10kHz at 1064nm. We also present an analysis of the optical loss in our experiment and provide an estimation of the possible non-classical sensitivity improvement of the future squeezed light enhanced GEO600 detector.

Q 50: Micromechanical Oscillators I

Time: Thursday 15:15–16:15 Location: A 320

Q 50.1 Th 15:15 A 320

Coupling of ultracold atoms and a mechanical oscillator via an optical lattice — •Stephan Camerer, Maria Korppi, David Hunger, Theodor W. Hänsch und Philipp Treutlein — LMU München und MPQ Garching

We report on the status of an experiment which aims at coupling a single mode of a mechanical oscillator to the motion of trapped atoms. The atoms are trapped in a red detuned 1D optical lattice provided by a laser beam, which is retroreflected at the mechanical oscillators' surface. Motion of the mechanical oscillator causes shaking of the lattice and thus couples to the atomic motion. On the other hand, the motion of the atoms leads to a redistribution of photons between the two running waves forming the lattice and is thus imprinted on the power of the laser beam that is retroreflected at the oscillator. The resulting modulation of the radiation pressure constitutes a backaction of the atoms onto the mechanical oscillator. The goal is to study the dynamics of the coupled system that may be employed to cool a single mode of the mechanical oscillator.

Q 50.2 Th 15:30 A 320

Cooling of nanomechanical resonator via coupling to flux qubits — •Keyu Xia and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

In recent years, the idea of observing quantum phenomena in macroscopic objects raised considerable effort to achieve the mechanical ground state of a micro- or nanomechanical resonator (NAMR). One obstacle is that ground state cooling in most schemes can only be achieved in the so-called resolved or strong-confinement regime [1].

Here, we discuss cooling of a NAMR to its ground state in the weak-confinement regime by coupling it to flux qubits. Our first approach [2] is based on electromagnetically induced transparency (EIT) cooling which was already successfully proposed and implemented for trapped ions [3]. EIT cooling relies on favorable modification of the cooling field absorption spectrum by quantum interference. We show that our scheme has several advantages over previously known cooling mechanisms for NAMRs. Our second approach [4] does not have a straightforward analogy in trapped atoms in ions. It is based on the coupling of two interacting flux qubits to a single NAMR. We demonstrate that collective effects lead to an efficient ground state cooling of the NAMR in the weak-confinement regime.

[1] F. Elste et al., Phys. Rev. Lett., **102**, 207209 (2009)
[2] K. Xia and J. Evers, Phys. Rev. Lett. **103**, 227203 (2009)
[3] G. Morigi et al., Phys. Rev. Lett. **85**, 4458 (2000); F. Schmidt-Kaler et al., Appl. Phys. B **73**, 807 (2001)
[4] K. Xia and J. Evers, arXiv:0912.1990[quant-ph]

Q 50.3 Th 15:45 A 320

Quantum state tomography and squeezed state preparation of a mechanical oscillator — Michael R Vanner[1], •Igor Pikovski[1], Myung S Kim[2], Nikolai Kiesel[1], Klemens Hammerer[3], Caslav Brukner[1], Gerard J Milburn[4], and Markus Aspelmeyer[1] — [1]University of Vienna, Vienna, Austria — [2]Queen's University Belfast, Belfast, United Kingdom — [3]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, Innsbruck, Austria — [4]The University of Queensland, Brisbane, Australia

We propose a short pulsing scheme which allows squeezed state generation of a mechanical oscillator via projective measurements and complete quantum state tomography. Despite initial thermal occupation, we show that squeezing of the mechanical mode can be observed and low entropy states can be prepared.

Q 50.4 Th 16:00 A 320

Minimizing phonon tunneling losses in optomechanical resonators — •Garrett D. Cole[1], Ignacio Wilson-Rae[2], Michael R. Vanner[1], Simon Gröblacher[1], Johannes Pohl[3], Martin Zorn[3], Markus Weyers[3], Achim Peters[4], and Markus Aspelmeyer[1] — [1]Faculty of Physics, University of Vienna — [2]Department of Physics, Technical University Munich — [3]Ferdinand-Braun-Institute, Berlin — [4]Institute of Physics, Humboldt University Berlin

Micromechanical resonators are a promising means to observe quantum phenomena in macroscopic bodies. Within this emerging field of quantum Optomechanics, the overarching goal is to combine the concepts of quantum optics cavity with radiation-pressure coupling in order to generate and detect quantum states of optomechanical systems. In this regime, resonators of exceptional mechanical and optical quality are required, specifically, these devices must combine both high reflectivity and low mechanical dissipation (high Q) for the vibrational mode of interest. A major challenge in this endeavor is the coupling of the resonator with the external environment. Here, we present experimental and theoretical results for high-performance megahertz resonator based on freestanding epitaxial AlxGa1-xAs Bragg reflectors in which the anchoring to the supports has been engineered to minimize phonon tunneling losses. Compared with dielectric reflectors, the use of a monocrystalline heterostructure gives rise to significant improvements in the achievable Q while simultaneously exhibiting comparably low optical absorption and transmission losses.

Q 51: Quantum Gases: Fermions

Time: Thursday 14:00–16:15 Location: E 001

Q 51.1 Th 14:00 E 001

Collective Motion of Polarized Dipolar Fermi Gases in the Hydrodynamic Regime — Aristeu Rosendo Pontes Lima[1] and •Axel Pelster[2,3] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Institut für Physik und Astronomie, Karl-Liebknecht-Str. 24 14476 Potsdam, Germany — [3]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

Recently, a seminal STIRAP experiment allowed the creation of $^{40}K^{87}Rb$ molecules in the rovibrational ground state [1]. In order to describe such a polarized dipolar Fermi gas in the hydrodynamic regime, we work out a variational time-dependent Hartree-Fock approach [2]. With this we calculate dynamical properties of such a system as, for instance, the frequencies of the low-lying excitations and the time-of-flight expansion. We find remarkable effects of a strong dipole-dipole interaction such as anisotropic breathing oscillations in momentum space and a suppression of the aspect-ratio inversion after release of the harmonic trap.

[1] K.-K. Ni *et al.*, Science **322**, 231 (2008)

[2] A. R. P. Lima and A. Pelster, arXiv:0908.4583

Q 51.2 Th 14:15 E 001

Quantum solitons of spin-3/2 fermions in 1D optical lattices — •Arturo Argüelles and Luis Santos — Institut für Theoretische Physik, Leibniz Universität Hannover, Hannover, Deutschland

In this presentation we analyze the dynamics of spin-3/2 fermions in optical lattices, and in particular how this dynamics is affected by the quadratic Zeeman effect for different interaction regimes. In particular we shall present recent results on Matrix-Product-States simulations of the dynamics of hard-core spinor fermions. After briefly commenting on the possibility to have different spin-wave velocities, we shall discuss in detail the creation under proper conditions of quantum solitons. These quantum solitons are dimers at neighboring sites, which propagate without unbinding. The binding of the pair (which resembles a Peierls-Nabarro barrier) is induced by the interplay between quadratic Zeeman effect and spin-changing collisions. After discussing the existence and lifetime of these quantum solitons, we shall comment on soliton-soliton collisions, howing that the typical time for inelastic collisions (that destroy one of the two colliding solitons) is equal or larger than the soliton life-time, showing that the system can hold a meta-stable quantum-soliton gas.

Q 51.3 Th 14:30 E 001

Local probing of a degenerate Fermi gas — •Jakob Meineke, Bruno Zimmermann, Torben Müller, David Stadler, Henning Moritz, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, Hönggerberg HPF D21, 8093 Zürich, Switzerland

Ultracold atomic gases are ideal systems to study many-body quantum physics. The development of new probes offers the possibility to extract more information from these systems. We have developed an apparatus that allows local probing of a degenerate Fermi gas with a resolution of 700 nm. We prepare an optically trapped gas of degenerate ^6Li atoms in a glass cell sandwiched between two microscope objectives. This setup allows us not only to shape potentials on the scale set by the resolution of the microscopes, but also to probe the state of the atomic ensemble *in-situ* with high resolution. In this talk we will present results obtained by studying atom number fluctuations of the degenerate atomic cloud.

Q 51.4 Th 14:45 E 001

Is it possible to access the strongly interacting regime with a $^6Li^{40}K$ Fermi-Fermi mixture? — •Andreas Trenkwalder[1], Christoph Kohstall[1,2], Frederik Spiegelhalder[1], Devang Naik[1], Gerhard Hendl[1], Florian Schreck[1], and Rudolf Grimm[1,2] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Innsbruck, Austria — [2]Institut für Experimentalphysik und Zentrum für Quantenphysik, Universität Innsbruck, Innsbruck, Austria

Interspecies Feshbach resonances in the $^6Li^{40}K$ Fermi-Fermi mixture are closed-channel dominated and quite narrow. In order to determine if it is experimentally feasible to realize the strongly interacting regime, we measure the elastic and inelastic scattering properties across one of the widest interspecies resonances. Preliminary results are promising and indicate that the strongly interacting regime can indeed be reached.

Q 51.5 Th 15:00 E 001

Nonequilibrium transport of fermions through an Anderson quantum dot — •Denes Sexty — Institut fuer Theoretische Physik, Heidelberg, Deutschland

The non-equilibrium time evolution of an Anderson quantum dot coupled between two lead-reservoirs forming a chemical-potential gradient for fermions is investigated. We use Kadanoff-Beym dynamic equations derived from the two-particle irreducible effective action. The method allows the determination of the non-equilibrium (transient) as well as stationary transport through the quantum dot, and results are compared to pure perturbative approximations for different values of the interactions between the fermions. Our aim is to study the non-equilibrium transport in the Kondo regime in the framework of an extended renormalization-group treatment.

Q 51.6 Th 15:15 E 001

Phase diagram of a spin-imbalanced Fermi mixture in 1D — •Ann Sophie C. Rittner, Yean-an Liao, Tobias Paprotta, and Randall G. Hulet — Department of Physics and Astronomy and Rice Quantum Institute, Rice University, Houston, TX 77251,

The search for the Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) phase, a polarized superfluid with a spatially varying order parameter, has generated large interest in both the condensed matter and cold atoms communities. To date, there has been only indirect experimental evidence of FFLO in the heavy fermion superconductor $CeCoIn_5$. In a 1D polarized Fermi gas, the FFLO phase is predicted to occupy a large region of the phase diagram (G. Orso, Phys. Rev. Lett. 98, 070402 (2007)). We have implemented a 2D optical lattice in order to explore the phase diagram of an imbalanced spin mixture of ^6Li. In-situ density distributions show a partially polarized region at the center of the cloud surrounded by an either fully polarized Fermi gas or an unpolarized superfluid shell depending on the polarization of the cloud. The density profiles are quantitatively well-described by a non-zero temperature Bethe ansatz calculation and can be used to extract the 1d phase diagram of the imbalanced 1d Fermi gas (Y.-a. Liao *et al.*, arXiv:0912.0092). Moreover, the quantitative agreement of experiment and theory provides evidence for the existence of the elusive FFLO phase in this system.

Q 51.7 Th 15:30 E 001

Mott insulator phases of spin-3/2 fermions in one-dimensional lattices. — •Karen Rodríguez, Arturo Argüelles, Maria Colomé-Tatché, Temo Vekua, and Luis Santos — Institut für Theoretische Physik, Leibniz Univesität Hannover, Hannover,Deutschland

We study the ground state phase diagram of repulsive spin-3/2 fermions at zero magnetization in the presence of quadratic Zeeman effect(QZE). Starting from the Hamiltonian of the four-component Hubbard model we derive the effective hard-core Hamiltonian, that can be understood as a spin-chain model. This model presents effective coupling constants which show a non-trivial dependence induced by the interplay between quadratic Zeeman effect and spin-changing collision. In the absence of a quadratic Zeeman effect the ground state of the system is either in the dimer (spin Peierls) phase or in the spin liquid one. Applying a non-zero quadratic Zeeman effect the system breaks the degeneracy between the 1/2 and the 3/2 spin components, resulting in a phase transition into an effective pseudo-spin 1/2 isotropic Heisenberg antiferromagnet for a sufficiently large QZE. We characterize by means of DMRG calculations the ground state properties, including spin-spin and dimer-dimer correlations, magnetization gap and chirality, for the different regimes and determine the boundaries between the different phases. We characterize the transition between dimer phase and effective Heisenberg antiferromagnet by means of exact diagonalization techniques.

Q 51.8 Th 15:45 E 001

Feshbach resonances in Fermi mixtures of ultracold ^{40}K — •Antje Ludewig[1], Tobias Tiecke[1], Steve Gensemer[1,2], Sebastian Kraft[1,3], and Jook Walraven[1] — [1]Van der Waals-Zeeman Institute of the University of Amsterdam, The Netherlands — [2]Ethel Walker School, Simsbury, United States — [3]PTB, Braunschweig

We report on the measurement of Feshbach resonances in ultracold Fermi-Fermi mixtures of ^{40}K in an optical dipole trap (ODT). In the same trap we have realized degenerate spin mixtures of 10^6 ^{40}K atoms at T=0.3(1)T$_F$. The cold atoms are loaded from a two dimensional magneto optical trap (MOT). After evaporation in an optically plugged magnetic trap the ^{40}K atoms are loaded into optical tweezers and transported over a distance of 21.5cm into a science cell. Using microwave radiation and resonant light we prepare non degenerate mixtures of $2 * 10^5$ ^{40}K atoms in various Zeeman states. ^{40}K has a rich hyperfine structure (F=9/2) and many Feshbach resonances involving the different states are expected. We measure these resonances using magnetic field coils designed for high homogeneity. We report on our progress exploring Feshbach resonances in ^{40}K and locating resonances favourable for the investigation of many body states.

Q 51.9 Th 16:00 E 001

Quantum fluid in bilayers of ultra-cold polar Fermi molecules — Michael Klawunn, •Alexander Pikovski, and Luis Santos — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany

Quantum degenerate cold molecules with a strong electric dipole moment may soon be within experimental reach. We study a system of ultracold polar Fermi molecules confined into two neighboring layers, e.g. in a two-well potential. The main interaction between these layers is provided by the dipole-dipole forces (all dipoles are polarized in one direction). It is found that in the quantum degenerate regime, the interaction may lead to the formation of Cooper-like pairs, where a molecule in layer 1 is paired with a molecule in layer 2. We discuss the appearance of this paired state and give an outlook to future work.

Q 52: Quantum Information: Concepts and Methods IV / Photons and Nonclassical Light I

Time: Thursday 14:00–16:15 Location: E 214

Q 52.1 Th 14:00 E 214

Quantifying entanglement with covariance matrices — •Oleg Gittsovich and Otfried Gühne — Institut für Quantenoptik und Quanteninformation, Technikerstrasse 21a, A-6020, Innsbruck, Österreich

Covariance matrices are a useful tool to investigate correlations and entanglement in quantum systems. They are widely used in continuous variable systems, but recently also for finite dimensional systems powerful entanglement criteria in terms of covariance matrices have been derived. We show how these results can be used for a quantification of entanglement in bipartite systems. To that aim we introduce an entanglement parameter that quantifies the violation of the covariance matrix criterion and can be used to give a lower bounds on the concurrence. These lower bounds are easily computable and give entanglement estimates for many weakly entangled states.

Q 52.2 Th 14:15 E 214

Optimal super dense coding for correlated noise with unitary and non-unitary encoding — •zahra shadman[1], hermann Kampermann[1], chiara macchiavello[2], and dagmar bruss[1] — [1]Heinrich-Heine-Universität, Institut für Theoretische Physik III , Düsseldorf, Deutschland — [2]University of Pavia, Italy

We study an important protocol in quantum information processing, namely super dense coding in the presence of correlated noise. For this case we discuss the optimal super dense coding capacity with unitary encoding. We calculate this capacity for specific examples. We also show that in case of general encoding, the optimal capacity can be reached by preprocessing on the sender's side and unitary encoding.

Q 52.3 Th 14:30 E 214

Discrimination of graph states in experiments — •Sönke Niekamp[1], Bastian Jungnitsch[1], Oleg Gittsovich[1], Matthias Kleinmann[1], and Otfried Gühne[1,2] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Technikerstraße 21a, 6020 Innsbruck, Österreich — [2]Institut für Theoretische Physik, Universität Innsbruck, Technikerstraße 25, 6020 Innsbruck, Österreich

Which observables should one measure in order to discriminate experimentally a state against another class of states? We will consider the case that this class is given by states that can be transformed into each other by local unitaries, or by SLOCCs (cf. [1]). We are interested in experimentally feasible measurement strategies that use a small number of measurement settings. In this talk we will argue that the relative entropy, which has previously been used to assess the statistical strength of nonlocality proofs [2], gives a measure for the certainty with which a given set of observables allows us to discriminate states. We apply this measure to graph states and the measurement of their stabilizing operators. It will be shown how the stabilizer formalism helps to compute this measure and how to find sets of observables that give maximal certainty.

[1] C. Schmid, N. Kiesel, W. Laskowski, W. Wieczorek, M. Żukowski, and H. Weinfurter, Phys. Rev. Lett. 100, 200407 (2008)

[2] W. van Dam, R. D. Gill, and P. D. Grünwald, IEEE Trans. Inf. Theory 51, 2812 (2005)

Q 52.4 Th 14:45 E 214

Geometry of Dynamical Quantum Systems — •Robert Zeier and Thomas Schulte-Herbrüggen — Technische Universität München, Department Chemie, Lichtenbergstr. 4, 85747 Garching

We relate the geometry of dynamical quantum systems to the broader context of classifying Lie algebras. We give an explicit description of all possible geometries and their inclusion relations relying on results of Dynkin [1] and complementing the work of McKay and Patera [2]. Building on previous work [3,4], we use the description of all possible geometries to present readily applicable conditions for the controllability of quantum systems. We compare our approach with the standard method of deciding controllability by computing the Lie closure [5]. We emphasize the importance of our methods for the universality of quantum computers and consider partial universality with respect to subsystems. We discuss computer implementations and present concrete examples.

[1] Borel/Siebenthal, Comment. Math. Helv. 23, 200 (1949); Dynkin, Trudy Mosov. Mat. Obsh. 1, 39 (1952), Amer. Math. Soc. Transl. (2) 6, 245 (1957); Dynkin, Mat. Sbornik (N.S.) 30(72), 349 (1952), Amer. Math. Soc. Transl. (2) 6, 111 (1957)
[2] McKay/Patera, Tables of Dimensions, Indices, and Branching Rules for Representations of Simple Lie Algebras (1981)
[3] Sander/Schulte-Herbrüggen, http://arxiv.org/abs/0904.4654
[4] Polack/Suchowski/Tannor, Phys. Rev. A 79, 053403 (2009)
[5] Jurdjevic/Sussmann, J. Diff. Eq. 12, 313 (1972)

Q 52.5 Th 15:00 E 214

Experimental entanglement of a six-photon symmetric Dicke state — •Witlef Wieczorek[1,2], Roland Krischek[1,2], Nikolai Kiesel[1,2], Patrick Michelberger[1,2], Geza Toth[3,4], and Harald Weinfurter[1,2] — [1]Max-Planck-Institut für Quantenoptik, D-85748 Garching — [2]Department für Physik, LMU München, D-80799 München — [3]IKERBASQUE and Department of Theoretical Physics, The University of the Basque Country, E-48080 Bilbao — [4]Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, H-1525 Budapest

We report on the experimental implementation of a symmetric Dicke state with six photonic qubits [1]. The necessary photons are generated by the use of a novel SPDC photon source based on a femtosecond UV enhancement cavity. To observe the Dicke state, photons from this SPDC source, arranged for collinear type II emission, are symmetrically distributed by polarization-independent beam splitters into six spatial modes. We discuss characteristic properties of Dicke states with respect to their relevance for applications in quantum information protocols and for quantum metrology. For our experimental analysis we introduce efficient tools, which require significantly fewer measurement settings than a full reconstruction of the density matrix, in order to determine the fidelity and to prove genuine multi-partite entanglement [2].

[1] W. Wieczorek *et al.*, Phys. Rev. Lett. 103, 020504 (2009); R. Prevedel *et al.*, *ibid.*, 020503.
[2] G. Tóth *et al.*, New J. Phys. 11, 083002 (2009).

Q 52.6 Th 15:15 E 214

Multi-mode quantum mechanical propagation equations for waveguided PDC — Wolfgang Mauerer, •Andreas Christ, and Christine Silberhorn — MPI for the Science of Light, IQO-Group, Erlangen, Germany

In recent years parametric down-conversion (PDC) processes have been established as a reliable source of quantum states for both fundamental quantum optics experiments and quantum information applications.

Most concepts are well understood theoretically, but they usually are based on a single-mode description or rely on first-order perturbation theory. Current PDC experiments however employ ultrafast pump lasers with high peak powers, hence contributions from many spectral modes and higher-order effects are unavoidable and need to be accounted for by theory.

In this talk we present recent progress towards full quantum-mechanical propagation equations for waveguided PDC explicitly including spatio-spectral effects utilizing the Heisenberg picture and Bogoliubov transformations. We use these as a basis for further structural analysis with special emphasis on the multi-mode spectral structure, photon-number distributions and intensity dependent effects. Furthermore we present differences between the different theoretical approaches and highlight the impacts of higher-order effects.

Q 52.7 Th 15:30 E 214

Efficient all-optical switching using slow light within a hollow fiber — •Sebastian Hofferberth[1], Thibault Peyronal[2], Michal Bajcsy[2], Alexander Zibrov[2], Vladan Vuletic[1], and Mikhail Lukin[1] — [1]Harvard-MIT Center for Ultracold Atoms, Department of Physics, Harvard University, Cambridge, MA 02138 — [2]Harvard-MIT Center for Ultracold Atoms, Department of Physics, MIT, Cambridge, MA 02139

In analogy with an electronic transistor, an all-optical switch is a device in which one light beam can fully control another. Realization of efficient all-optical switches is a long-standing goal in optical science and engineering. If integrated with modern fiber-optical technologies, such devices may have important applications for optical communication and computation. Optical switches operating at a fundamental limit of one photon per switching event would further enable the realization of key protocols from quantum information science.

Here, we present an all-optical switch that makes use of cold atoms trapped inside the hollow core of a photonic crystal fiber and quantum optical techniques for generating large nonlinear interaction between light beams. We show that this switch is activated at tiny energies corresponding to few hundred photons per pulse. We also present recent experiments using stationary light techniques to further the nonlinear optical efficiency.

Q 52.8 Th 15:45 E 214

Long-range interaction of single atoms through nanowires with nontrivial topology of couplings — •David Dzsotjan[1,2] and Michael Fleischhauer[1] — [1]Technical University of Kaiserslautern, Germany — [2]Research Institute for Particle and Nuclear Physics, Budapest, Hungary

We investigate the long-range coupling of individual atoms placed close to metallic nanowires. Putting the emitter close to the surface of the wire, a strong Purcell effect can be observed: with very high probability, the emitter will decay into guided modes of the wire, the so-called surface plasmons [1], with a rate exceeding that of free space by a large factor. The strength of the coupling originates from the fact that surface plasmon modes have an extremely small mode volume, being confined at around the surface of the nanowire. There is an optimal, sub-wavelength emitter-wire distance where the coupling to the plasmon is maximal due to the losses originating from circulating currents. When two emitters are placed along the wire (both strongly coupled to a single surface plasmon mode), we observe a strong, wire-mediated long-range interaction between the emitters. As a result of this, super- and subradiance can occur over distances large compared to the resonant wavelength. Here, the states with enhanced or suppressed decay rate are the well-known symmetric or anti-symmetric Dicke states. Taking more atoms and coupling them to a wire network with a nontrivial coupling topology leads to interesting entangled states being the subradiant states of the system.

[1] D.E. Chang et al, Phys. Rev. Lett. 97, 053002 (2006); Phys. Rev. B 76, 035420 (2007)

Q 52.9 Th 16:00 E 214

Directly detecting negative Wigner functions — Andrea Mari[1], •Konrad Kieling[1], and Jens Eisert[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, 14476 Potsdam-Golm — [2]Institute for Advanced Study Berlin, 14193 Berlin

One of the most accepted signatures of non-classicality of a quantum state is the Wigner function – the phase space distribution becoming a probability distribution in the classical limit – being negative. To witness such a negative Wigner function is a valid test of having prepared a quantum state – in a mode of the light field, or even in an optomechanical system.

Yet, to reconstruct an entire Wigner function is a very difficult task, and requires a large series of highly accurate measurements. This is due to the fact that the usual way of achieving full tomographic knowledge and then reconstructing the state is highly ill-conditioned and hence prone to errors. It seems important and desirable, therefore, to find ways to directly measure signatures of Wigner function negativity, in a robust fashion, that make use of as little data as possible, which yet still give quantitative bounds.

We will introduce such certifiable bounds by bringing together phase space methods such as Bochner's theorem and optimization tools such as semi-definite programming. Also, the multi-mode version of this scheme can be used to witness entanglement. By showing applications to sample data we demonstrate the reliable functioning of the method and that it is ready to use as a tool for quantum state characterisation.

Q 53: Photonics II

Time: Thursday 14:00–16:15 Location: F 128

Q 53.1 Th 14:00 F 128

Unterdrückung verstärkter Rayleigh-Rückstreuung eines nichtlinearen verstärkenden optischen Schleifenspiegels — •Tobias Röthlingshöfer[1,2,3], Klaus Sponsel[1,2], Georgy Onishchukov[2,3], Bernhard Schmauss[3,4] und Gerd Leuchs[1,2,3] — [1]Institut für Optik, Information und Photonik, Universität Erlangen — [2]Max-Planck-Institut für die Physik des Lichts — [3]Erlangen Graduate School in Advanced Optical Technologies (SAOT) — [4]Optische Hochfrequenztechnik, Universität Erlangen

In der optischen Datenübertragung werden zunehmend phasenkodierte Modulationsformate eingesetzt. Durch nichtlineare Effekte in Übertragungsfasern, wie etwa die Selbstphasenmodulation, wird jedoch vorhandenes Amplitudenrauschen in nichtlineares Phasenrauschen umgewandelt und beeinträchtigt so besonders phasenkodierte Signale.

Mit Hilfe eines modifizierten Faser-Sagnac Interferometer, dem nichtlinearen verstärkenden Schleifenspiegels, ist die Amplituden-Regeneration auch bei phasenkodierten optischen Datenformaten, wie z.B. differentielle Phasenumtastung, möglich. Hierdurch wird die Erzeugung von nichtlinearem Phasenrauschen auf der weiteren Übertragung unterdrückt. Vor allem durch verstärke Rayleigh-Rückstreuung sind verstärkende Schleifenspiegel jedoch in ihrer Regenerationsfähigkeit limitiert.

Mittels numerischer Simulationen wurde gezeigt dass es durch eine Vorverbreiterung der Pulse möglich ist den Verstärkungsfaktor bei gleicher Regenerationsfähigkeit zu reduzieren und damit Störungen durch Rayleigh-Rückstreuung zu unterdrücken.

Q 53.2 Th 14:15 F 128

Von passiven zu schaltbaren Fabry - Perot - Filtern auf Faserendflächen — •Dawid Schweda[1], Stefan Meister[1], Marcus Dziedzina[1], Chris Scharfenorth[1], Daniela Dufft[2], Bernd Grimm[2], Sigurd K. Schrader[2] und Hans Joachim Eichler[1] — [1]Technische Unuversität Berlin, Institut für Optik und Atomare Physik, Berlin, Germany — [2]Technische Fachhochschule Wildau, Institut für Plasma- und Lasertechnik, Wildau, Germany

Integrierte fasergekoppelte Systeme gewinnen vor allem in Bereichen der Telekommunikation und Datenverarbeitung zunehmend an Bedeutung. Den aktuellen Anforderungen könnten sie durch die möglichen hohen Modulationsraten und die besonders verlustarme Signalübertragung bei geringem Energieaufwand genügen. Mit der Integration von wellenlängenselektiven Elementen direkt auf Faserendflächen, wie den hier vorgestellten durchstimmbaren Fabry-Perot-Filtern auf SM-Fasern mit 125μm Mantel- und 9μm Kerndurchmesser, soll eine mögliche technische Lösung untersucht werden. Als hybrides Schichtsystem aus dielektrischen Spiegeln (SiO_2, Ta_2O_5), transparent leitfähigen Elektroden (ITO) sowie einem elektro-optisch aktivem Polymer (Polycarbonat + Chromophor) lassen sich derartige Modulatoren realisieren. Die hierzu verwendeten Beschichtungsverfahren sind sowohl PVD-Verfahren, wie Elektronenstrahlverdampfen und Magnetron-Sputtern, als auch Sol-Gel-Verfahren, wie Dip-Coating. Untersucht werden die erzeugten Schichten hinsichtlich ihrer Ebenheit, Haftung, Dicke sowie ihrer optischen bzw. elektrischen Eigenschaften. Charakteristische Spektren bereits aufgebauter passiver Filter werden präsentiert.

Q 53.3 Th 14:30 F 128

Reduzierte Solitonen-Wechselwirkung unter Einfluss des Raman-Effekts — •Alexander Hause und Fedor Mitschke — Universität Rostock, Institut für Physik, Universitätsplatz 3, 18051 Rostock

Die Existenz von Solitonenpaaren in Glasfaserstrecken unter dem Einfluss der Raman-induzierten Selbstfrequenzverschiebung wurde kürzlich experimentell und numerisch nachgewiesen [1].

Wir präsentieren eine theoretische Beschreibung der Wechselwirkung der benachbarten Solitonen. Es wird gezeigt, dass Effekte fundamentaler Solitonen wie Anziehung oder Abstoßung unter Einfluss des Raman-Effektes reduziert werden und eine Ausbreitung mit fast gleichbleibendem Abstand möglich ist. Grund dafür ist ein periodischer Wechsel der relativen Phase beider Pulse, welcher durch die individuelle Selbstfrequenzverschiebung hervorgerufen wird [2].

Die Vorhersagen des Modells wurden mit numerischen Simulationen verglichen und zeigen eine gute Übereinstimmung.

[1] A. Podlipensky et al., JOSA B **25**, 2049 (2008)
[2] A. Hause et al., Phys. Rev. A **80**, 063824 (2009)

Q 53.4 Th 14:45 F 128

Small period surface relief gratings based on azobenzene containing layers for thin film distributed feedback lasers — •Sebastian Döring, Torsten Rabe, Regina Rosenhauer, Olga Kulikovska, Niko Hildebrandt, and Joachim Stumpe — Fraunhofer Institut für Angewandte Polymerforschung, Potsdam, Deutschland

Holographic surface relief gratings written in azobenzene containing films were studied for the use as master structures for polymeric thin film DFB lasers. Light induced mass transport driven by E-Z-isomerisation in azobenzene containing materials have shown to be attractive for one-step fabrication of periodic surface structures with varying parameters for different optical applications. Based on new azobenzene materials and their holographic processing deep surface relief gratings with grating pitches in the range of 400 nm as resonant structures for second order distributed feedback lasers were generated emitting light in the VIS range. Nanoimprint techniques enabled multiple duplications of azobenzene in UV-adhesives. Replicas were coated via spin casting with thin films of red light emitting polymer layers to form distributed feedback thin film lasers. For invesigations of laser behavior multiple surface structures with different corrugation depths of up to 100 nm were generated and duplicated.

Q 53.5 Th 15:00 F 128

Selbstähnliche Wechselwirkung von Solitonen in dispersionsalternierenden Glasfasern — •Alexander Hause, Haldor Hartwig und Fedor Mitschke — Universität Rostock, Institut für Physik, Universitätsplatz 3, 18051 Rostock

Lichtpulse in dispersionsalternierenden Glasfasern, die nahezu aber nicht genau die Pulsform eines sogenannten DM-Solitons aufweisen, unterliegen langperiodischen Oszillationen. Die Wechselwirkung eng benachbarter langsam schwingender DM-Solitonen wurde theoretisch und numerisch untersucht.

Neben der Bildung des Solitonenmoleküls[1] kommt es zur Ausbildung selbstähnlicher bzw. fraktaler Strukturen im Parameterraum der Wechselwirkung. Die Entwicklung des Solitonenabstandes während der Ausbreitung ist in diesen Bereichen sehr stark abhängig von den Startbedingungen. Jede noch so kleine Änderung der Startwerte wie Eingangsabstand oder Pulsenergie lässt die Bewegung der DM-Solitonen völlig anders verlaufen.

Ein Resonanzmechanismus zwischen der Solitonenwechselwirkung und der individuellen langsamen Solitonenschwingung konnte als Ursache für dieses Verhalten bestimmt werden. Hier setzt ein störungstheoretisches Modell an, das diesen Mechanismus als auch die stabile Bindung des Solitonenmoleküls erklären kann. Im Vergleich zeigt sich eine gute qualitative Übereinstimmung zwischen Theorie und Simulation.

[1] A. Hause et al., Phys. Rev. A **78**, 063817 (2008)

Q 53.6 Th 15:15 F 128

Modenkonversion durch optisch induzierte Gitter mit großer Periodenlänge — •Martin Schäferling[1], Niklas Andermahr[1,2] und Carsten Fallnich[1] — [1]Institut für Angewandte Physik, WWU Münster, Corrensstr. 2, 48149 Münster, Deutschland — [2]Laserzentrum Hannover, Hollerithallee 8, 30419 Hannover, Deutschland

Durch die unterschiedlichen Ausbreitungsgeschwindigkeiten transversaler Moden in Stufenindexfasern entstehen bei der Propagation eines Modengemisches charakteristische Schwebungsmuster. Wir demonstrieren, wie diese Muster mit Hilfe des Kerr-Effektes zur Erzeugung von Brechungsindexgittern mit Periodenlängen im Bereich weniger Millimeter ausgenutzt werden können. Im Gegensatz zum weit verbreiteten Verfahren, die Gitter in photosensitive Fasern fest einzuschreiben, können mit der vorgestellten (ebenfalls rein optischen) Methode sehr lange temporäre Gitter realisiert werden. Über ein solches Gitter werden transversale Moden passender Schwebungslänge gekoppelt, wodurch eine Modenkonversion erzielt werden kann. Gitter dieser Art können unter anderem zur Dispersionskompensation oder für Sensoren eingesetzt werden.

Mit Hilfe von numerischen Simulationen analysieren wir die Einflüsse von Gitterparametern wie Länge, Stärke oder Reinheit des verwendeten Modengemisches auf das Konversionsverhalten; des Weiteren werden die Auswirkungen äußerer Störungen, wie z. B. makroskopische Biegung der Faser, betrachtet. In ersten Experimenten konnte bereits eine Effizienz von 50% für die Konversion von der Grundmode in die nächsthöhere transversale Mode erreicht werden.

Q 53.7 Th 15:30 F 128

Eine einfache Beschreibung der Dispersionsrelation für die *fundamental space-filling mode* in Photonischen Kristallfasern — •Christoph Mahnke und Fedor Mitschke — Institut für Physik, Universität Rostock, Universitätsplatz 3, 18051 Rostock

Wir stellen eine einfache, heuristische Formel für die Dispersionsrelation $n_{\mathrm{FSM}}(\omega)$ der *fundamental space-filling mode* (FSM) in Photonischen Kristallfasern (PCFs) mit massiven Kern vor. In diesen sogenannten *holey fibers* entspricht n_{FSM} der effektiv wirksamen Brechzahl im Mantelbereich der PCFs. Die Kenntnis dieser Brechzahl ist hilfreich, um aus der geometrischen Struktur des Mantels Eigenschaften wie die Gesamtdispersion oder die Modenanzahl der Faser abzuleiten. Um den Verlauf von n_{FSM} zu bestimmen, werden bisher entweder aufwendige numerische Rechnungen oder in Spezialfällen empirische Relationen verwendet.

In unserem Modell hingegen wird n_{FSM} durch eine einfache Interpolationsformel dargestellt, wobei die Zahl der freien Parameter stark reduziert ist. Die aus dieser Formel erhaltenen Brechzahlverläufe stimmen im gesamten Wellenlängenbereich gut mit numerisch erhaltenen Daten überein. Unser Modell besitzt dabei nur eine geringe Geometrieabhängigkeit und ist somit für die Beschreibung der Dispersion der FSM in verschiedensten Gittergeometrien geeignet. Die physikalische Interpretation der einzelnen Parameter unserer Formel ermöglicht es, das Verhalten der FSM in gegebenen Strukturen zu verstehen und vorherzusagen.

Q 53.8 Th 15:45 F 128

Langsame Oszillationen von Solitonen in Glasfasern mit alternierender Dispersion: Experimentelle Untersuchungen — •Haldor Hartwig und Fedor Mitschke — Universität Rostock, Institut für Physik, Universitätsplatz 3, 18051 Rostock

Glasfaserstrecken mit abwechselnd normaler und anomaler Dispersion werden seit einiger Zeit in der optischen Datenübertragung eingesetzt. Auf kurzen Skalen betrachtet folgt die Impulsform dem Wechsel der Dispersion, während sich auf langen Skalen ein dynamisches Gleichgewicht zwischen mittlerer Dispersion und Nichtlinearität einstellen kann. Da es sich mathematisch um ein nichtintegrables System handelt, muss die Beschreibung dieser sogenannten DM-Solitonen (von engl. dispersion management) durch analytische Näherungsmethoden oder numerische Simulationen erfolgen. Dabei wurde beobachtet, dass Abweichungen von der idealen Impulsform, wie sie in realen Systemen stets vorkommen, langsame Oszillationen der Impulsparameter hervorrufen, die auch nach vielen Dispersionsperioden nicht abklingen. Um eine experimentelle Charakterisierung dieser langsamen Oszillationen vorzunehmen, wurde eine DM-Faserstrecke bestehend aus 10 Dispersionsperioden konstruiert. Die langsamen Oszillationen werden anhand von Veränderungen im optischen Impulsspektrum gemessen. Wir zeigen die Abhängigkeit der Oszillationsperiode von der Impulsenergie. Ein Vergleich mit numerischen Simulationen unter Berücksichtigung unabhängig bestimmter Faserparameter zeigt eine gute Übereinstimmung.

Q 53.9 Th 16:00 F 128

Dynamic silicon photonics in slow light waveguides — •Michel Castellanos, Alexander Petrov, and Manfred Eich — Hamburg University of Technology, Institute of Optical and Electronic Materials.

Theoretical approaches for tunable frequency conversion and time delay of guided light signals in Silicon-on-Insulator (SOI) line-defect waveguides are presented. The band structure of a guided mode in such a waveguide can be manipulated by properly modifying the refractive index of the bulk material. By doing so, while a light signal is present in the device (dynamic process), its properties can be manipulated accordingly. Thus a time delay of broadband signals can be achieved by dynamic flattening of the band structure, which corresponds to a dynamic tuning of the signal's group velocity towards zero. Wavelength conversion is achieved by shifting the frequency position of the band structure while its shape is conserved. A combination of slow light signal and guided fast light pump waves is investigated for ultrafast switching through free carriers generation by two photon absorption of the pump wave.

Q 54: Laser Applications: Optical Measurement Technology I

Time: Thursday 14:00–16:15 Location: F 342

Q 54.1 Th 14:00 F 342

Measurement of submicrometer diameters of tapered optical fibres using harmonic generation — •Ulrich Wiedemann, Konstantin Karapetyan, Dimitri Pritzkau, Cristian Dan, Wolfgang Alt, and Dieter Meschede — Institut für Angewandte Physik, Wegelerstr. 8, 53115 Bonn

For applications of subwavelength-diameter optical fibres in nonlinear optics it is important to know the submicrometer fibre diameter precisely. We demonstrate a new technique for optical measurement of the diameter based on second- and third-harmonic generation with an accuracy of a few percent. In order to obtain the harmonic light, inter-modal phase matching has to be fulfilled. We find that the phase-matching condition allows us to unambiguously deduce the fibre diameter from the wavelength of the harmonic light.

Q 54.2 Th 14:15 F 342

Demonstration of sub-picometer length measurements and sub-nanoradian angular read-out in the millihertz-frequency range — •Christian Diekmann, Michael Tröbs, Frank Steier, Iouri Bykov, Gerhard Heinzel, and Karsten Danzmann — Albert-Einstein-Institut Hannover, Max-Planck-Institut für Gravitationsphysik und Leibniz Universität Hannover

The space-based interferometric gravitational-wave detector Laser Interferometer Space Antenna (LISA) requires interferometry with sub-picometer and nanoradian sensitivity in the frequency range between 3 mHz and 1 Hz. Currently, a first prototype of the optical bench for LISA is being designed. We report on a pre-experiment with the aim to demonstrate the required sensitivities and to thoroughly characterise the equipment. For this purpose, a quasi-monolithic optical setup has been built with two Mach-Zehnder interferometers (MZI) on an optical bench made of zerodur. In a first step the relative length change between these two MZI will be measured with a heterodyne modulation scheme in the kHz-range and the angle between two laser beams will be read out via quadrant photodiodes and a technique called differential wavefront sensing. These techniques have already been used for the LISA predecessor mission LISA Pathfinder and their sensitivity needs to be further improved to fulfill the requirements of the LISA mission. We describe the experiment and the characterization of the basic components. First measurements of the length and angular noise will be presented.

Q 54.3 Th 14:30 F 342

Verification of Optical Diameter Measurement of Subwavelength-Diameter Optical Fibres using Scanning Electron Microscopy — •Dimitri Pritzkau, Konstantin Karapetyan, Ulrich Wiedemann, Cristian Dan, Wolfgang Alt, and Dieter Meschede — Institut für Angewandte Physik, Wegelerstr. 8, 53115 Bonn

Subwavelength-diameter optical fibres (SDOF) are widely used in linear optics and they are a promising tool for nonlinear optical applications. The diameter of an SDOF (300 - 1000 nm) is a main parameter in controlling nonlinear effects. Several optical measurement techniques exist, which are usually verified by scanning electron microscopy (SEM). For submicrometer metrology SEM is a convenient method but typically limited to 10 % uncertainty. We developed a new optical measurement method with improved accuracy. To validate this method, a precision of about 2 % is needed. In this talk we discuss the SEM measurement requirements (including fibre preparation, electron-fibre interaction and advanced analysis software) to achieve this goal.

Q 54.4 Th 14:45 F 342

Measuring small absorptions using the thermal Kerr effect — •Nico Lastzka, Jessica Dück, Sebastian Steinlechner, and Roman Schnabel — Institut für Gravitationsphysik, Leibniz Universität Hannover und Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) Callinstrasse 38 D-30167 Hannover

The precise measurement of small absorption in optical materials is a challenging task. To measure absorption coefficients of some ppm/cm or smaller it is necessary to use indirect methods, which do not measure the power losses but the effect of the absorbed power in the substrate. These are for example calorimetric measurements or methods using the thermal lens effect. The sensitivities of these methods scale with the substrate length and with the input power, and typically high input power is necessary.

We present an absorption measurement scheme based on the shape of the airy peaks of a scanned optical resonator. Due to the heating of the intra-cavity material, the transmitted as well as the reflected airy peaks show a hysteresis depending on the scan direction. A time domain simulation based on the theory of Hello and Vinet is used to fit the measured data. In order to prove the quantitative results of this method the absorption coefficient of a lithium niobate was measured and compared to literature values. An estimation of the lower limit of the measurable absorption coefficient and corresponding error bars is given.

Q 54.5 Th 15:00 F 342

Measurement of complex optical third-order nonlinearities in waveguides and bulk samples — •Anatoly Sherman, Erik Benkler, and Harald R. Telle — Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany

We demonstrate a novel method for measuring real and imaginary parts of the third-order nonlinear optical susceptibility ($\chi(3)$) in waveguides and bulk samples. Here, the unknown nonlinearity of the device under test is compared, under nearly identical experimental circumstances, with the known value of a reference sample. In order to gain information about both amplitude and phase of $\chi(3)$, a four-wave mixing set-up is combined with a phase-sensitive heterodyne detection scheme. The overall phase is calibrated during such measurements using reference sample with negligible two-photon absorption (i. e. fused silica at telecommunication wavelength). From the ratio of both quadrature components of $\chi(3)$, one directly deduces the so-called nonlinear figure of merit, which is an important parameter of all-optical circuits. As a source of error, spurious mixing signals generated from the photodiode are eliminated by all-optical methods.

Q 54.6 Th 15:15 F 342

Online Laser-Raman-Spektroskopie an Tritium für KATRIN — •Magnus Schlösser[1], Michael Sturm[1], Sebastian Fischer[1], Beate Bornschein[2], Richard Lewis[3] und Helmut Telle[3] — [1]Karlsruher Institut für Technologie (KIT), Zentrum Elementarteilchen und Astroteilchenphysik, GER — [2]KIT, Tritiumlabor Karlsruhe, GER — [3]Dep. of Phys., Swansea University, UK

Das KArlsruher TRItium Neutrino-Experiment KATRIN untersucht das Elektronenspektrum des Tritiumzerfalls nahe dem kinematische Endpunkt von 18,6 keV. Mit einer fensterlosen molekularen gasförmigen Tritiumquelle hoher Luminosität und einem hochauflösenden elektrostatischen Filter wird KATRIN eine modellunabhängige Bestimmung der Neutrinomasse mit einer erwarteten Sensitivität von 0,2 eV (90% CL) ermöglichen. Um diese Präzision zu erreichen, ist die präzise Kenntnis der Zusammensetzung des in die Quelle eingespeisten Gases erforderlich. Zur Bestimmung und Überwachung der Anteile der verschiedenen Wasserstoffisotopologe (T2, D2, H2, DT, HT, HD) wird ein Laser-Raman-System verwendet. In diesem Vortrag werden der Aufbau des Laser-Raman-Systems im Tritiumlabor Karlsruhe sowie aktuelle Ergebnisse vorgestellt. Dabei wird gezeigt, dass alle sechs Isotopologe simultan gemessen werden können [1] und eine Präzision von 0.1 % in 250 s erreicht werden kann. Gefördert vom BMBF unter 05A08VK2 und von der DFG im SFB/TR27 "Neutrinos and Beyond".

[1] Sturm et al., Monitoring of All Hydrogen Isotopologues at Tritium Laboratory Karlsruhe Using Raman Spectroscopy, Laser Physics, 2010, Vol. 20, No. 2

Q 54.7 Th 15:30 F 342

New Spectroscopic Techniques for Rydberg Atoms — •Thomas Becker, Pierre Thoumany, Linas Urbonas, and Theodor Hänsch — Max Planck Institute for Quantum Optics, Garching

In this talk, recent experiments about purely optical, Doppler-free spectroscopy of Rydberg atoms in gas cells will be reviewed. All experiments are based on a realization of electron-shelving techniques and allow a non-destructive detection of Rydberg transitions. Two different laser schemes, one single-step Rydberg excitation in he UV and a three-step Rydberg excitation with IR diode lasers will be presented. Possibilities of observing two-photon transitions with a similar setup will be discussed as well. The unexpected frequency stability of the Rydberg lines opens the possibility for laser frequency metrology and coherent control applications. Finally, ideas about extending the presented technology with frequency combs as light sources will be discussed.

Q 54.8 Th 15:45 F 342

Very sensitive *in situ* gas analysis of combustion processes with an Er^{3+}-doped fiber laser — •Benjamin Löden[1], Svetlana Kuznetsova[1], Anatoly Goldmann[2], Sergej Cheskis[2], Klaus Sengstock[1], and Valeri Baev[1] — [1]Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]School of Chemistry, Tel-Aviv University, Tel Aviv 69978, Israel

Intracavity absorption spectroscopy with a broadband Er^{3+}-doped fiber laser is applied for the measurements of several molecular species revealing quantitative information about the gas concentration, temperature and chemical reactions in flames. The spectral range of the measurements extends from 6200 cm^{-1} to 6550 cm^{-1} with the proper choice of the fiber length and by moving an intracavity lens. With a pulsed laser applied in this experiment the sensitivity corresponds to an effective absorption path length of 3 km and does not depend on the broadband cavity losses. Absorption spectra of various molecules such as CO_2, CO, H_2O, H_2S, C_2H_2 and OH were recorded separately in the cell and/or in low pressure methane and propane flames. The presented measurements demonstrate simultaneous *in situ* detection of three molecular products of chemical reactions at different flame locations. The variation of the relative strengths of OH absorption lines with the temperature enables the estimation of the local flame temperature. The presented technique can be applied for various diagnostic purposes, such as environmental, combustion and plasma research, medical applications and measurements of stable isotope ratio.

Q 54.9 Th 16:00 F 342

Laser ablation loading of a linear Paul trap — •Kai Zimmermann, Maxim Okhapkin, Oscar Andrey Herrera Sancho, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, Braunschweig

We present a systematic study of ion production via photoablation using a small, low power nitrogen laser at 337 nm wavelength with $\approx$ 0.1 mJ pulse energy. Yield tests have been done with various metals in a time-of-flight experiment. The method allows to produce ions of elements like Ti or Th that are not easily evaporated and it also yields doubly charged ions. Ions of all elements that are presently considered for optical clocks or quantum logic applications could be produced efficiently. The setup was used to load a linear Paul trap with up to 10^5 ions by a single laser pulse.

Q 55: Poster II

Time: Thursday 16:00–19:00 Location: Lichthof

Q 55.1 Th 16:00 Lichthof

Process-chain approach and its application to bosonic lattice systems — •Dennis Hinrichs, Niklas Teichmann, and Martin Holthaus — Institut für Physik, Carl von Ossietzky Universität, D-26111 Oldenburg, Germany

Using Kato's formulation of the perturbation series we implement a diagrammatic process-chain approach, which enables us to obtain ground state expectation values and phase boundaries for lattice boson models [1]. We study the transition from a Mott insulator to a superfluid in the Bose-Hubbard model for various dimensions and geometries at zero temperature, employing the method of the effective potential. Furthermore, we find a scaling relation that maps critical hopping parameters for different filling factors onto each other [2]. Currently, we are extending this method to other lattice models.

[1] N. Teichmann, D. Hinrichs, M. Holthaus and A. Eckardt, Phys. Rev. B **79**, 224515 (2009)

[2] N. Teichmann, D. Hinrichs, EPJ B **71**, 219 (2009)

Q 55.2 Th 16:00 Lichthof

BEC and atom-optics in optical waveguides — •Johannes Küber, Thomas Lauber, Oliver Wille, Martin Hasch, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

In our experiment we aim to study and control the properties of Bose-Einstein condensates in optical potentials. We use a crossed dipole trap at 1070nm to prepare up to 25000 condensed Rb atoms. This approach gives us the advantage of being independent of the magnetic properties of our atoms.

After previous experiments with ultra-cold thermal atoms in optical waveguide structures we are going to work with condensed matter in optical potentials. Using miniaturized lens structures we are able to implement attractive or repulsive potentials in different geometries.

Our approach allows us to combine multiple potentials to create complex structures like a one-dimensional resonator for guided atoms or a ring shaped waveguide. For controlled manipulation of atoms, such as accelerating and coherent splitting, we use a blue detuned one dimensional optical lattice and achieve a versatile setup for coherent matter wave manipulation.

Q 55.3 Th 16:00 Lichthof

Quantum brownian motion of grey solitons in 1D-condensates — •Philip Walczak and James R. Anglin — Fachbereich Physik, TU Kaiserslautern, D-67663 Kaiserslautern

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

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

Q 55.4 Th 16:00 Lichthof

Parametric Excitation of Bose-Einstein Condensate Modes — Hamid Jabber Haziran Al-Jibbouri[1] and •Axel Pelster[2,3] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Institut für Physik und Astronomie, Karl-Liebknecht-Str. 24 14476 Potsdam, Germany — [3]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

A recent experiment at Rice University studies how the lowest-lying quadrupole mode of a Bose-Einstein condensate of ^{7}Li is excited by modulating periodically the atomic scattering length via a Feshbach resonance [1]. Measuring the amplitude of the quadrupolar oscillation as a function of the excitation frequency Ω reveals both a resonance enhancement at $\Omega = \omega_Q$ and a parametric enhancement at $\Omega = 2\omega_Q$. We investigate theoretically how the heights of these resonance peaks depend on the anisotropy of the harmonic trap. To this end we follow Refs. [2,3] and apply techniques of nonlinear dynamics in order to analyze the coupled set of ordinary differential equations for the widths of a Gaussian function which solves variationally the underlying Gross-Pitaevskii theory.

[1] R.G. Hulet, V.S. Bagnato *et al.* (in preparation)

[2] F.K. Abdullaev, R.M. Galimzyanov, M. Brtka, and R.A. Kraenkel, J. Phys. B **37**, 3535 (2004)

[3] N.N. Bogoliubov, Y.A. Mitropolsky, *Asymptotic Methods in the Theory of Non-Linear Oscillation* (Hindustan P. Corp. Delhi-6, 1961)

Q 55.5 Th 16:00 Lichthof

The Dicke Model Quantum Phase Transition in a Driven Condensate-Cavity System — •Ferdinand Brennecke, Kristian Baumann, Christine Guerlin, Silvan Leinss, Rafael Mottl, and Tilman Esslinger — Quantum Optics Group, ETH Zurich, Switzerland

The Dicke Model describes the collective interaction between an ensemble of two-level atoms and a single electromagnetic field mode, and remains a fundamental theme in quantum optics. In the thermodynamic limit this system was predicted to undergo a quantum phase transition from a normal to a superradiant phase. Here we present an experimental open-system realization of the Dicke model using a Bose-Einstein condensate coupled to a high-finesse optical cavity. The superfluid atoms collectively couple a far-detuned pump field to an empty cavity mode. Above a critical pump power the atoms self-organize into an emergent checkerboard pattern. When entering this self-organized phase, the gas initially maintains phase coherence and can thus be regarded as a supersolid. Over a wide range of parameters, the boundary of this novel quantum phase is mapped out and compared to a theoretical model. This work opens up new aspects of quantum many-body physics with global interactions mediated by the cavity field.

Q 55.6 Th 16:00 Lichthof

Single Atom Detection on Atomchips — •Saskia Kühnhold, Barbara Grüner, Michael Gierling, Philipp Schneeweiss, Gabriela Visanescu, Michael Jag, Alexander Stibor, Michael Häffner, Dieter Kern, Andreas Günther, and József Fortágh — Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen

We present two single atom detection schemes for cold atom experiments on atom chips. The first detector is based on multi-photo-ionization of cold atoms and the adjacent ion-counting with a channel electron multiplier [1]. We present measurements on static and dynamic properties of ultracold atom clouds, ranging from temperatures to correlation measurements. The second detector is based on field-ionization of ground state atoms close to tips of positively charged carbon nanotubes (CNTs) and the detection of the produced ion [2]. We characterize the field strength at the CNT tips and determine the ionising area next to the nanotubes. We demonstrate the nanotube detector by counting atoms from a thermal beam of rubidium atoms and show up an application of the detector as a partial pressure gauge.

[1] Günther et al., Phys. Rev. A 80, 011604(R) (2009) [2] Grüner et al., arXiv:0911.1329 (2009), Phys. Rev. A in print

Q 55.7 Th 16:00 Lichthof

Feshbach resonances in mixtures of ^{6}Li and ^{40}K — •Antje Ludewig[1], Tobias Tiecke[1], Steve Gensemer[1,2], Sebastian Kraft[1,3], and Jook Walraven[1] — [1]Van der Waals-Zeeman Institute of the University of Amsterdam, The Netherlands — [2]Ethel Walker School, Simsbury, United States — [3]PTB, Braunschweig

We report on the measurement of Feshbach resonances in Fermi-Fermi mixtures. For this purpose we have created an ultracold mixture of the fermionic alkali isotopes ^{6}Li and ^{40}K in an optical dipole trap. In the same trap we have realized a three-component degenerate spin mixture of ^{40}K -atoms at T $0.3T_F$. To create the mixture we start by loading a two-species magneto-optical trap (MOT) from two separate 2D-MOT sources. We realized for the first time a 2D-MOT source for lithium, yielding a large cold flux of up to 10^9 s^{-1}. The mixture is then captured in an optically-plugged magnetic quadrupole trap. After sympathetic cooling of ^{6}Li by ^{40}K to T$\sim$10μK the mixture is loaded into optical tweezers. The mixture is optically transported over a distance of 21.5 cm into a science cell where we measure Feshbach resonances using magnetic field coils designed for high homogeneity. We report on our progress measuring the width of Feshbach resonances in ^{6}Li -^{40}K mixtures and locating resonances in mixtures of ^{40}K.

Q 55.8 Th 16:00 Lichthof

Mott insulator phases of spin-3/2 fermions in one-dimensional lattices — Karen Rodriguez, Arturo Arguelles, •Maria Colome-Tatche, Temo Vekua, and Luis Santos — Institut fur Theoretische Physik, Leibniz Universitat Hannover, Appelstr. 2, D-30167, Hannover, Germany

We study the ground state phase diagram of repulsive spin-3/2 fermions at zero magnetization in the presence of quadratic Zeeman effect (QZE). Starting from the Hamiltonian of the 4-component Hubbard model we derive the effective hard-core Hamiltonian, that can be understood as a spin-chain model. This model presents effective coupling constants which show a non-trivial dependence induced by the interplay between QZE and spin-changing collisions. In the absence of QZE the ground state of the system is either in the dimer (spin Peierls) phase or in the spin liquid one. Applying a non-zero QZE the system breaks the degeneracy between 1/2 and 3/2 spin components, resulting in a phase transition into an effective pseudo-spin 1/2 isotropic Heisenberg antiferromagnet for a sufficiently large QZE. We characterize by means of DMRG calculations the ground state properties for the different regimes and determine the boundaries between the different phases. We characterize the transition between dimer phase and effective Heisenberg antiferromagnet by means of exact diagonalization techniques. We shall also discuss, by means of Gutzwiller Ansatz calculations for the particular case of spinor bosons, a resonance occuring between spin-changing collisions and QZE, which may lead to the destruction of the Mott-insulator phase.

Q 55.9 Th 16:00 Lichthof

Low-dimensional Bose-Fermi mixtures and atom chips — •Tim Langen, Michael Gring, Maximilian Kuhnert, Matthias Schreitel, David A. Smith, and Jörg Schmiedmayer — Institute for Atomic and Subatomic Physics, TU Wien, Stadionallee 2, A-1020 Vienna, Austria

We report on our novel experimental setup which aims for the creation of degenerate, low-dimensional Bose-Fermi mixtures on an atom chip. The apparatus is based on a two-species double-MOT system for bosonic ^{87}Rb and fermionic ^{40}K. Using two macroscopic magnetic traps, precooled atoms from the MOT are efficiently transfered onto the atom chip. There, we currently reach Bose-Einstein condensation with up to 10^5 atoms which we will use to rapidly cool the fermions into the degenerate regime [1]. The intrinsic tight confinement and high aspect ratio of the chip traps will then make it possible to prepare individual realizations of low-dimensional gases of bosons, fermions or mixtures of both. For the bosons, we present first results on the preparation, manipulation and probing of these many-body systems using radio-frequency dressed-state potentials [2] and matter-wave interferometry.

[1] Aubin et al., Nature Phys. 2, 384 (2006)
[2] T. Schumm et al., Nature Phys. 1, 57 (2005)

Q 55.10 Th 16:00 Lichthof

Multiband renormalization of Bose-Fermi mixtures in optical lattices — •Alexander Mering and Michael Fleischhauer — Fachbereich Physik and research center OPTIMAS, Technische Universität Kaiserslautern

The physics of ultracold mixtures of bosons and fermions in optical lattices is considered in the framework of the Bose-Fermi-Hubbard model. Starting from the derivation of the full multi-band model by including all couplings from the first Bloch band to all higher bands, we derive an effective single band Hamiltonian. This single band model obeys renormalized model parameters and allows for a consideration of the higher band effects onto the mixture. The most important contribution is shown to arize from inter- and intraspecies nonlinear corrections to the tunneling rate. Including further first-band corrections this approach finally allows to study the influence of the higher bands as well as the fermionic species onto the superfluid to Mott insulator transition of the bosons as recently studied in experiments.

Q 55.11 Th 16:00 Lichthof

"Photon"-assisted tunnelling of ultra-cold atoms — •Martin Esmann, Kirsten Stiebler, Bettina Gertjerenken, Niklas Teichmann, and Christoph Weiss — Institute of Physics, Carl von Ossietzky University, D-26111 Oldenburg, Germany

"Photon"-assisted tunnelling has recently been realised experimentally for a Bose-Einstein condensate in an optical lattice [1]. The focus of this poster are numerical and analytical calculations on the transfer of ultra-cold atoms between neighbouring wells in double-well lattices for which effects like fractional photon resonances are important [2]. Subwavelength lattices are also investigated.

[1] C. Sias, H. Lignier, Y. P. Singh, A. Zenesini, D. Ciampini, O. Morsch, and E. Arimondo, Phys. Rev. Lett. 100, 040404 (2008).
[2] N. Teichmann, M. Esmann, and C. Weiss, Phys. Rev. A 79, 063620 (2009).

Q 55.12 Th 16:00 Lichthof

Three-body bound states in a lattice — •Manuel Valiente[1,2], David Petrosyan[1], and Alejandro Saenz[2] — [1]IESL-FORTH, Heraklion, Greece — [2]Institut für Physik, Humboldt Universität zu Berlin, Berlin, Germany

We investigate the three-boson problem in a deep one-dimensional lattice with nearest neighbor hopping and pairwise on-site interaction. We find that, apart from the trivial bound states of three particles strongly co-localized on the same lattice site, there exist two other bound states essentially composed of a bound pair [1,2]– "dimer" – and a third particle – "monomer" – weakly bound to the pair [2]. The energy of such states can be above or below the continuum of dimer-monomer collisions. We explain these new exotic states in term of an effective model in the strong-coupling regime and find that the binding is induced by an exchange operator between the dimer and the monomer.

References [1] K. Winkler et al., Nature 441, 853 (2006) . [2] M. Valiente and D. Petrosyan, J. Phys. B 41, 161002 (2008); ibid. 42, 121001 (2009). [3] M. Valiente, D. Petrosyan and A. Saenz, Phys. Rev. A (in press); arXiv:0907.3111 .

Q 55.13 Th 16:00 Lichthof

Single site addressability in optical lattices — •Endres Manuel, Christof Weitenberg, Jacob Sherson, Marc Cheneau, Ralf Labouvie, Rosa Glöckner, Immanuel Bloch, and Stefan Kuhr — Max-Planck-Institut für Quantenoptik, Garching

Investigations of ultracold quantum gases in optical lattices are mostly restricted to access global information of the system. By contrast we are developing experimental techniques revealing the local distribution of the trapped gas. The main part of our experiment is an optical imaging system with a spatial resolution better than the lattice spacing of a near-infrared optical lattice. In addition the setup allows for manipulation of the atoms on a local scale.

Collecting the fluorescence light of the trapped atoms, will enable us to observe the local dynamics of the many-body system. With an additional strongly focused laser beam single sites of the optical lattice can be addressed. Possible applications of single site addressability are e.g. single q-bit rotations via local microwave-resonance or perturbation of the many-body system on a local scale.

So far we have taken in trap fluorescence images with a resolution of 700 nm using the 5S1/2 to 5P3/2 transition at 780nm and demonstrated the micro-manipulation of a few atoms with a tightly focused dipole trap. To extract one or a few slices and to remove the atoms that are out of the depth of focus we use microwave transitions in a magnetic field gradient.

Q 55.14 Th 16:00 Lichthof

Equilibrium and out-of-equilibrium properties of ultracold fermions in optical lattices — •Robert Jördens, Leticia Tarruell, Daniel Greif, Thomas Uehlinger, Niels Strohmaier, Henning Moritz, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

We present the results of a combined experimental and theoretical study of repulsively interacting ^{40}K atoms in the Hubbard model. Accurate measurements of the double occupancy provide direct access to the system's properties both in equilibrium and in the linear response regime. By calibrating the equilibrium double occupancy against theoretical models over a wide range of parameters we develop a reliable measure for the entropy in the lattice. We demonstrate the applicability of both high-temperature series and dynamical mean field theory to obtain quantitative agreement with the experimental data.

Additionally, we perform weak lattice modulation and monitor the increase of doublons with time. The observations are well captured by linear response theory and are sensitive to local spin ordering, which can be used to detect anti-ferromagnetic states. For long modulation times the system is driven into a far-from-equilibrium state with many additional doublons. We show that the dominant decay mechanism is a high-order scattering process and the doublon lifetime depends exponentially on the ratio of onsite interaction to tunneling energy.

Q 55.15 Th 16:00 Lichthof

Singlet-triplet oscillations with pairs of neutral atoms in an optical superlattice — •Stefan Trotzky[1], Yu-Ao Chen[1], Ute Schnorrberger[1], and Immanuel Bloch[1,2] — [1]Ludwig-Maximilians-Universität, Schellingstrasse 4, 80799 München — [2]Max-Planck-Institut für Quantenoptik, Hans Kopfermann-Strasse 1, 85748 Garching

We show the creation, detection and manipulation of effective-spin triplet and singlet pairs with ultracold ^{87}Rb atoms in a bichromatic optical superlattice. The system is initialized with two atoms per lattice site being in two different Zeeman states $|F = 1; m_F = -1\rangle \equiv |\downarrow\rangle$ and $|1; +1\rangle \equiv |\uparrow\rangle$. When splitting the lattice sites into symmetric double-wells by means of the superlattice, we create an array of entangled triplet pairs $|\uparrow,\downarrow\rangle + |\downarrow,\uparrow\rangle$. Subsequently, a magnetic-field gradient along the double-well axis is used to induce oscillation between the triplet and the singlet state $|\uparrow,\downarrow\rangle - |\downarrow,\uparrow\rangle$. We detect these singlet-triplet oscillations via the symmetry of the respective wavefunction after merging the double-wells. Our method provides a tool to probe local spin-order emerging in e.g. valence-bond solid type states as well as in Fermi-Hubbard systems at low temperature.

A superexchange coupling between adjacent double-wells is employed to implement a SWAP operation, stretching the entangled pairs over more than one double-well. This operation can be seen as a step towards the creation of a multi-particle entangled state in the optical lattice, which might serve as initial state for one-way quantum computational schemes.

Q 55.16 Th 16:00 Lichthof

Interacting Bose-Fermi Mixtures in Optical Lattices — •Simon Braun[1], Sebastian Will[1], Thorsten Best[2], Philipp Ronzheimer[1], Michael Schreiber[1], Ulrich Schneider[1], Tim Rom[1], Lucia Hackermüller[1], Kin-Chung Fong[1], Dirk-Sören Lühmann[3], and Immanuel Bloch[1] — [1]Ludwig-Maximilians-Universität München — [2]ALU Freiburg — [3]Universität Hamburg

Mixtures of ultracold quantum gases in optical lattices form novel quantum many-body systems, whose properties are governed by an intriguing interplay of quantum statistics, inter- and intraspecies interactions, as well as the relative atom numbers of the constituents.

In our setup, we cool bosonic ^{87}Rb and fermionic ^{40}K to simultaneous quantum degeneracy. We realize a Bose-Fermi Hubbard model (BFHM) by loading the atoms into the combined potential of a blue-detuned three-dimensional optical lattice and a red-detuned dipole trap. The interspecies interactions can be controlled using Feshbach resonances and Raman transitions between different Zeeman sublevels.

Our investigations of the many-body properties of the Bose-Fermi mixture revealed that attractive interspecies interactions cause a marked shift in the superfluid to Mott insulator transition due to self-trapping. In a detailed study of quantum phase diffusion of a BEC in a 3D optical lattice, we were able to measure the bosonic interaction energies with very high precision and observe the influence of a fermionic admixture on both the occupation number statistics and the BFHM parameters. Finally, we present routes towards the realization of polaron physics in atomic Bose-Fermi mixtures.

Q 55.17 Th 16:00 Lichthof

Collisional properties of metastable neon — •Thomas Feldker[1], Holger John[1], Jan Schütz[1], Norbert Herschbach[2], and Gerhard Birkl[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt — [2]QUEST Institute at PTB, Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

We study the collisional interactions of metastable neon (Ne*) in the $^3P_2$ state in a magneto-optical trap and magnetic trap. The remarkable feature of Ne* is its extremely high internal energy which, on the one hand, enables sensitive detection using electron multipliers but, on the other hand, leads to very high two-body losses due to Penning ionization. The bad ratio of elastic to inelastic collisions hampers efficient evaporative cooling and, thus, achievement of quantum degeneracy.

We are therefor investigating possibilities to manipulate the collisional interactions. One objective is to prepare the atoms in certain superposition states of Zeeman sublevels using STIRAP which is proposed to significantly suppress inelastic collisions. Another approach is to exploit inter-isotopic collisions. We are able to trap two-isotope combinations of bosonic ^{20}Ne, bosonic ^{22}Ne, and fermionic ^{21}Ne and are exploring possible schemes for sympathetic cooling. We report on the status of the experiments.

Q 55.18 Th 16:00 Lichthof

A high-flux source of guided ultracold chromium atoms — •Valentin Viktorovich Volchkov, Anoush Aghajani-Talesh, Markus Falkenau, Axel Griesmaier, and Tilman Pfau — Universität Stuttgart, 5. Physikalisches Institut

A continuous source of cold atoms is a vital ingredient for realizing continuous atom lasers. The presented apparatus delivers a magnetically guided, ultracold beam of chromium atoms at a flux of 10^9 atom/s [1]. This beam is obtained by operating a MOT directly inside a magnetic guide. We discuss a proposal to continuously load a deep optical dipole trap from the atomic beam. To this end, a scheme of an atomic diode is presented: a magnetic field barrier within the optical dipole trap removes the kinetic energy of the atoms, while optical pumping into the lowest energy state removes the potential energy and traps the atom at the bottom of the combined trap. This mechanism will allow for continuous trapping and fast loading of the ODT. Recently, transverse laser cooling of the guided atoms has been demonstrated [2]. The resulting radial temperature yields, according to our simulations [3], a much higher loading efficiency of the trap.

[1] A Griesmaier et al. *J. Phys. B.* **42** 145306 (2009).
[2] A Aghajani-Talesh et al. *Submitted to New J. Phys.*
[3] A Aghajani-Talesh et al. *J. Phys. B.* **42** 245302 (2009).

Q 55.19 Th 16:00 Lichthof

Rb MOT system for an advanced lab course at the University of Heidelberg — Silvânia Alves de Carvalho, Marc Repp, Christoph S. Hofmann, Rico Pires, •Kristina Meyer, Dominic Litsch, and Matthias Weidemüller — Physikalisches Institut, Ruprecht-Karls Universität, Philosophenweg 12, 69120 Heidelberg, Germany

We present an improved and compact setup of a Rb magneto-optical trap (MOT) experiment for an advanced student laboratory course. The Rb MOT will be used to introduce the students to topics such as Atomic Physics, laser cooling, spectroscopy and to the experimental techniques relevant in AMO Physics. This poster presents the apparatus and the characterization of the atom cloud (atom number, density, temperature and loading). We are currently working on implementing photoassociation spectroscopy near the dissociation threshold in this sample of cold atoms as an extension of the lab course. Instead of usual printed instructions, the lab manual will be available in the form of a wikipedia, which contains descriptions of the experiment and the topics presented.

Q 55.20 Th 16:00 Lichthof

Cooling caesium atoms in a bad, near-confocal cavity — •Arne Wickenbrock, Piyaphat Phoonthong, Nihal Wahab, and Ferruccio Renzoni — Department of Physics and Astronomy, Univerity College London, WC1 5BT London, UK

Particles in a macroscopic optical cavity have significantly altered optical properties [1]. The presence of the cavity changes the em-mode spectrum and hence scattering rates and spontaneous emission. Inside the cavity the mode density is strongly frequency dependent, which can be used to propose cooling schemes without a closed optical transition [2-4]. This might expand the range of ultracold particles to more complex structured atoms and molecules. We report on experiments conducted on a cold sample of caesium atoms placed in the centre of the optical resonator. Our apparatus includes a 12cm long near-confocal cavity with a finesse of 800.

In a first set of experiments the cavity resonance is positioned with respect to the cycling transition of caesium, while a laser pumps it for a certain time. Measuring the temperature of the expanding cloud in a time of flight measurement over the cavity-atom detuning reveals the effect of the resonator. [1]E.M. Purcell, Phys. Rev. 69, 681 [2]Horak P., Hechenblaikner G., Gheri K. M., Stecher H., Ritsch H., Phys. Rev. Lett.79, 4974 [3]Vuletic V., Chu S., Phys. Rev. Lett. 84, 3787 [4]P. Domokos and H. Ritsch, J. Opt. Soc. Am. B 20, 1089 (2003)

Q 55.21 Th 16:00 Lichthof

Optical Trapping of an Ion — •Thomas Huber[1], Christian Schneider[1], Martin Enderlein[1], Stephan Duewel[1,2], and Tobias Schaetz[1] — [1]Max-Planck-Institut für Quantenoptik, Garching, Deutschland — [2]Ludwig-Maximilians-Universität München, Deutschland

One can gain deeper insight into complex quantum dynamics via experimentally simulating the quantum behaviour of interest in another quantum system, where not all but the relevant parameters and interactions can be controlled and robust effects detected sufficiently well.

We report the trapping of a single ion in an optical dipole trap for a duration on the order of milliseconds. After the dipole trap is loaded by a regular Paul trap, the latter is turned off. Due to the sensitivity of the charged particle to voltages, the dipole forces required are orders of magnitudes above the ones required for atomic dipole traps. We found that we can achieve this by decreasing the detuning from resonance. However, this causes the increase of various heating effects like dipole heating and recoil heating, limiting the trapping duration. Therefore one has to find a trade-off between strong dipole forces and long trapping durations.

We aim to merge the advantages of quantum simulations with atoms and ions by confining them in the identical dipole trap/optical lattice. This renders it possible to investigate for instance atom-ion interactions or to form anharmonic potentials, a tool for scalable quantum simulations.

Q 55.22 Th 16:00 Lichthof

Microwave structures for electron guiding — •Johannes Hoffrogge and Peter Hommelhoff — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching bei München

We present microwave structures for the guiding of electrons in an alternating quadrupole field. These combine the electrode layout of a two dimensional planar Paul trap with that of a microwave transmission line. For longitudinal guide dimensions comparable to the wavelength of the driving field, the microwave guiding properties of these structures have to be considered. A normal mode decomposition of the trapping field shows that the latter consists of a superposition of two different eigenmodes of the electrode structure with differing propagation constants. For a typical structure driven at 10 GHz this leads to a dephasing by 5° after a propagation length of 7 cm. We investigate the consequences of this on the particle dynamics by numerical particle tracking and discuss strategies to minimize the effect.

At the moment, we are setting up a proof of principle experiment, where we will guide electrons in an electrically small structure at 1 GHz. Besides microwave measurements on test substrates, we present the characteristics of a low energy electron source and the current status of the experiment.

Q 55.23 Th 16:00 Lichthof

Design of a hexapole-compensated magneto-optical trap without external fields — •Stefan Jöllenbeck, Jan Mahnke, Jan Arlt, Carsten Klempt, and Wolfgang Ertmer — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

The production of Bose-Einstein condensates with a high repetition rate constitutes a large step towards atom interferometry with coherent matter waves. Our approach is to load atoms into a chain of magnetic traps generated by planar wire structures where they can be transported and cooled to quantum degeneracy. Magnetic offset fields used in a conventional magneto-optical wire trap disturb the parallel trapping of more than one cloud at a time. Here we present a new setup to generate a magnetic quadrupole field with nine planar wires placed outside our vacuum system. By minimizing the hexapole components of the magnetic field, a large effective trapping volume is obtained. We expect large trapping efficiencies for pre-cooled atoms provided by a two-dimensional magneto-optical trap. Such a mesoscopic trap with high particle numbers may serve as an ideal starting point for the production of many Bose-Einstein condensates in fast sequence.

Q 55.24 Th 16:00 Lichthof

Dynamics of a coherently driven atom in a high-finesse optical resonator — •Martin Eckstein, Wolfgang Alt, Stefan Brakhane, Tobias Kampschulte, Sebastian Reick, René Reimann, Artur Widera, and Dieter Meschede — Institut für Angewandte Physik, Universität Bonn

In our experiment we transport a single cold caesium atom into a high-finesse optical resonator using an optical dipole trap [1]. By monitoring the transmission of a probe laser beam resonant with the cavity we measure the atomic spin state [2]. We study the dynamics of a coherently driven two-level atom inside our cavity. The driving source consists of two phase locked diode lasers that connect the atomic states by a two-photon Raman process. We study the influence of the non-destructive measurement on the evolution of the system.

[1] M. Khudaverdyan *et al.*, New J. Phys. **10**, 073023 (2008)
[2] M. Khudaverdyan *et al.*, Phys. Rev. Lett. **103**, 123006 (2009)

Q 55.25 Th 16:00 Lichthof

Coherent Processes in the Presence of Interparticle Interactions — •Hanna Schempp[1], Georg Günter[1], Christoph S. Hofmann[1], Nele Müller[1], Christian Giese[1], Sebastian D. Saliba[1], Brett D. DePaola[1], Sevilay Sevincli[2], Thomas Pohl[2], Thomas Amthor[1], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg — [2]Max-Planck-Institut für Physik Komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden

We report on coherent processes in ultracold Rydberg gases, namely Rabi oscillations between ground and Rydberg state [1], Rapid Adiabatic Passage [2] and Coherent Population Trapping (CPT). In the presence of interparticle interactions the coherence of these processes is reduced and correlations among the particles play a role. Van der Waals interactions between Rydberg atoms can precisely be adjusted by varying the atom density and the principal quantum number. Thus Rydberg atoms provide an excellent tool to systematically tune the interparticle interactions. We show experimental results on CPT with controlled interparticle interactions and present a many-body model that reproduces the measured features [3].

[1] M. Reetz-Lamour et al., Phys. Rev. Lett. 100, 253001 (2008)
[2] J. Deiglmayr et al., Opt. Comm. 264, 293 (2006)
[3] H. Schempp et al., submitted (2009)

Q 55.26 Th 16:00 Lichthof

Drift waves and instabilities in ultracold plasmas — •Cornelia Lechner, Christian Knapp, and Alexander Kendl — Institut für Ionenphysik und Angewandte Physik, Universität Innsbruck, Technikerstraße 25, A-6020 Innsbruck, Austria

Ultracold quasi-neutral plasmas merge the physics of strongly coupled plasmas and of ultracold quantum gases. Recent experiments have been reported on first observations of ultracold plasma waves and instabilities, which are counterparts of well-known drift instabilities in hot plasmas (where they are e.g. responsible for turbulent transport losses in fusion experiments). However, not much attention has yet been devoted to the theory of ultracold plasma instabilities. Here, we present an analysis of possible theoretical approaches to ultracold plasmas, and discuss the influence of strong Coulomb coupling on the drift dynamics of such systems, especially concentrating on the case of a magnetized ultracold plasma.

Q 55.27 Th 16:00 Lichthof

Erzeugung und Nachweis von Bewegungs-Quantenzuständen einzelner kalter Ionen in einer Mikrofalle — •Gerhard Huber[1], Ulrich Poschinger[1], Markus Deiss[2], Frank Ziesel[1], Max Hettrich[1], Daniel Seyfried[1], Michaela Petrich[1] und Ferdinand Schmidt-Kaler[1] — [1]Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, 89069 Ulm — [2]Universität Ulm, Institut für Quantenmaterie, Albert-Einstein-Allee 45, 89081 Ulm

Kalte, in einer Paul-Falle gespeicherte Ionen sind ein ideales Modellsystem zur Untersuchung quantenthermodynamischer Phänomene [1]. Die experimentelle Umsetzung dieser Modellsysteme erfordert ein Höchstmaß an Kontrolle über die Bewegungsfreiheitsgrade einzelner Ionen, um die erforderlichen Quantenzustände zu präparieren und über externe, zeitabhängige Potentiale zu kontrollieren. Darüber hinaus kann der Bewegungszustand durch die Kopplung interner und externer Freiheitsgrade über Lichtfelder mit der Präzision einzelner Vibrationsquanten manipuliert werden [2]. Dazu führen wir Experimente in einer mikrostrukturierten linearen Paul-Falle durch. Insbesondere zeigen wir alle notwendigen Methoden der Zustandsdetektion von der Messung der Phononenverteilung bis hin zur vollständigen Zustandstomographie des Bewegungszustandes [3].

[1] G. Huber *et al.*, Phys. Rev. Lett. **101**, 070403 (2008)
[2] U. G. Poschinger *et al.*, J. Phys. B **42** 154013 (2009)
[3] D. Leibfried *et al.*, Phys. Rev. Lett. **77**, 4281 (1996)

Q 55.28 Th 16:00 Lichthof

Atom Trap Trace Analysis of Argon 39 — •Florian Ritterbusch[1], Joachim Welte[1], Matthias Henrich[1], Werner Aeschbach-Hertig[2], and Markus K. Oberthaler[1] — [1]Kirchhoff-Institute, Heidelberg university — [2]Institute for environmental physics, Heidelberg university

We present our work towards the realization of Atom Trap Trace Analysis for ^{39}Ar, a promising novel method for dating water from the past 50 to 1000 years. This ultra-sensitive detection method for rare isotopes is based on laser cooling mechanisms. We report on the first experimental determination of the hyperfine spectrum of the relevant cooling transition. Furthermore, a high intensity, optically collimated beam of metastable argon atoms has been set up and fluorescence detection of single ^{40}Ar atoms in a magneto-optical trap is realized. Having achieved these essential steps an ATTA table-top apparatus now becomes feasible.

Q 55.29 Th 16:00 Lichthof

Cold atoms inside a hollow core fiber - a novel medium for few-photon nonlinear optics — •Sebastian Hofferberth[1], Thibault Peyronal[2], Michal Bajcsy[2], Alexander Zibrov[2], Vladan Vuletic[1], and Mikhail Lukin[1] — [1]Harvard-MIT Center for Ultracold Atoms, Department of Physics, Harvard University, Cambridge, MA 02138 — [2]Harvard-MIT Center for Ultracold Atoms, Department of Physics, MIT, Cambridge, MA 02139

Typically, interactions of light beams in nonlinear media are very weak at low light levels. Strong interactions between few-photon pulses require a combination of large optical nonlinearity, long interaction time, low photon loss, and tight confinement of the light beams.

Here, we present an approach to overcome these issues that makes use of an optically dense medium containing a few hundred cold atoms trapped inside the hollow core of a photonic crystal fiber. We discuss recent experiments regarding few-photon optical nonlinearities and single atom detection inside the hollow core fiber.

Q 55.30 Th 16:00 Lichthof

Properties of ultracold ground state LiCs molecules — •Marc Repp[1], Johannes Deiglmayr[1,2], Anna Grochola[3], Olivier Dulieu[4], Roland Wester[2], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg — [2]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg — [3]Institute of Experimental Physics, University of Warsaw — [4]Laboratoire Aimé Cotton, CNRS, Orsay

Recently we achieved the formation of LiCs molecules in the lowest levels of the ground state by photoassociation (PA) [1]. These molecules are of particular interest due to their large permanent electric dipole moment. We will present a first experimental measurement of this dipole moment. We will further present the first trapping of ultracold LiCs molecules. The molecules are formed and trapped in a quasi electrostatic trap (QUEST) formed by single-focused CO_2 laser. We determine the lifetime of molecules in the trap to be τ=24(3) s, limited by collisions with background gas. Rate coefficients for inelastic collisions between LiCs molecules and cesium atoms in the QUEST are measured to be between $\beta=1.1\times10^{-10}$cm^3/s and 2.4×10^{-10}cm^3/s, depending on the PA resonance used for the formation of the molecules.

[1] J. Deiglmayr *et al.*, Phys. Rev. Lett. 101, 133004 (2008).

Q 55.31 Th 16:00 Lichthof

Setup of a Li MOT for the study of ultracold molecule production — •Michael Köppinger, Frank Münchow, Florian Baumer, and Axel Görlitz — Institut für Experimentalphysik, HHU Düsseldorf, 40225 Düsseldorf

Quantum gases of ultracold polar molecules offer fascinating prospects for the realization of new forms of quantum matter with possible applications to quantum information and to precision measurements. Recently we have begun to study the photoassociative production of heteronuclear molecules in a mixture of ultracold Yb and Rb atoms and observed molecule production in the excited state.

While a mixture of Yb and Rb allows for the production of boson-boson and boson-fermion molecules, in a mixture of Yb and Li it would also be possible to explore the properties of fermion-fermion molecules. Therefore, we have started to set up a Li MOT in a compact test chamber which will eventually be merged with the Yb-Rb mixture. Here we report on the status of the experiment.

Q 55.32 Th 16:00 Lichthof

Active low- frequency vibration isolation for high precision atom interferometry — •Christian Freier, Alexander Senger, and Achim Peters — Humboldt Universität Berlin

The performance of high precision atom interferometers is often limited by Raman phase noise introduced by vibrations of the interferometers optical components. We present an active low frequency vibration isolation based on a commercial MinusK passive vibration isolation platform which isolates one key component, a retro-reflecting mirror, from environmental vibrations. The system combines an active system with the spring based negative-stiffness passive isolation of a MinusK vibration isolation platform. The active stage measures residual vibrations using a commercial weak-motion seismometer and feeds them back into a voice coil actuator to cancel them out. The passive vibration isolation only, with a resonant frequency of 0.5 Hz, reduces the amount of vibrations by a factor of 100-1000 from 10Hz to 100Hz. We characterize the performance of the platform with the active system enabled and show tests of interferometer fringes with and without active vibration isolation.

Q 55.33 Th 16:00 Lichthof

Degenerate Bose-Fermi Gases in Microgravity — •Christina Rode[1], Ernst Maria Rasel[1], and das QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Quantenoptik, LU Hannover — [2]ZARM, Uni Bremen — [3]Institut für Physik, HU Berlin — [4]Institut für Laserphysik, Uni Hamburg — [5]Institut für Quantenphysik, Uni Ulm — [6]MPQ, München — [7]Institut für angewandte Physik, TU Darmstadt — [8]Midlands Ultracold Atom Research Centre, University of Birmingham, UK — [9]FBH, Berlin

Recent developments in atom optics allow for ultra precise and accurate measurements at the level of Heisenberg limited uncertainty. These measurements can be performed with ultra-cold quantum gases by extending their time of unperturbed evolution. The pioneering experiment QUANTUS has realized a Bose-Einstein condensate in microgravity and subsequently observed it's free evolution for up to 1 second. Our second generation experiment QUANTUS 2 will be more compact, allow for larger numbers of atoms and will enhance the time of microgravity to 9 seconds. ^{87}Rb and ^{40}K will be used as a Bose-Fermi mixture in order to perform matter wave interferometry in microgravity and to test the Weak Equivalence Principle in the quantum domain. This will be possible due to the mass independent confining potentials available in a microgravity environment. An up-to-date progress report of our activities and future prospects will be presented.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50WM0835-0839.

Q 55.34 Th 16:00 Lichthof

Nanoscale scanning probe magnetometer with single spin sensitivity — •Friedemann Reinhard[1], Eike Oliver Schäfer-Nolte[1,2], Markus Ternes[2], Bernhard Grotz[1], Helmut Rathgen[1], Gopalakrishnan Balasubramanian[1], Julia Tisler[1], Klaus Kern[2], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]Universität Stuttgart, 3. Physikalisches Institut — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart

We present our work towards a scanning-probe magnetometer with subnanometre resolution, using the NV center in diamond as a magnetic field sensor. We will discuss technical aspects, such as the construction of dedicated AFMs for this application, as well as studies of the properties of NV centers close to the surface of diamond and in nanodiamonds.

Q 55.35 Th 16:00 Lichthof

Stabilization of the Advanced LIGO 200W laser — •Christina Krämer, Jan Hendrik Pöld, Patrick Kwee, Hyunjoo Kim, Benno Willke, and Karsten Danzmann — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) und Institut für Gravitationsphysik der Leibniz Universität Hannover, Germany

The high power laser which will be operated in the interferometric gravitational wave detector Advanced LIGO has to fulfill strict requirements according to frequency and power stability as well as to the shape of the spatial beam profile. Therefore a demanding active and passive stabilization of this continuous wave 200W Nd:YAG laser at 1064nm is necessary. A key part of this stabilization is a ring cavity, which is used to suppress power noise at radio frequencies and improves the spatial beam quality. For the frequency stabilization the laser system is stabilized to a high finesse reference cavity. The power stability is achieved with a nested control loop to reach a relative power noise of $2\cdot10^{-9}\,\mathrm{Hz}^{-1/2}$ at the interferometer input.

In this contribution the concepts and preliminary results of the stabilization of the Advanced LIGO laser will be presented.

Q 55.36 Th 16:00 Lichthof

Controlling single-molecule dipole-dipole coupling by optical confinement in a $\lambda/2$-microresonator (exchanged with Q 67.1) — •Raphael Gutbrod, Sebastian Bär, Frank Schleifenbaum, Sébastien Peter, Kirstin Elgass, and Alfred J. Meixner — Institute of Physical and Theoretical Chemistry, University of Tübingen

Fluorescence resonance energy transfer (FRET) is a well-known photophysical phenomenon where the excited-state energy from the initially excited donor molecule is transferred to an acceptor molecule via dipole-dipole coupling. The rate of energy transfer depends upon the extent of spectral overlap of the donor emission spectrum with the acceptor absorption spectrum, the quantum yield of the donor, the relative orientation of the donor and acceptor transition dipoles and the distance between donor and acceptor and hence is often used as a molecular ruler in fluorescence microscopy in life-sciences. We present a novel approach to precisely tune the FRET efficiency by the local mode of a subwavelength Fabry-Pérot type microresonator. According to Fermi's golden rule, the spontaneous emission rate depends on the mode density of the electromagnetic field and can be modified in the microresonator. Thus, the fluorescence of the chromophores involved in the FRET-process is varied over a broad range. We demonstrate that a microresonator disentangles coupled FRET systems by gradually varying the energy transfer from donor to acceptor. It is possible to tune the energy transfer rate of a given FRET-pair without chemical or physical manipulation of the dye system by simply varying the mirror separation of the microresonator.

Q 55.37 Th 16:00 Lichthof

Quantum sensors with laser cooled ions — •Karsten Pyka, Norbert Herschbach, and Tanja E. Mehlstäubler — QUEST - Institut, Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

Time and frequency are the most accurately measurable quantities in physics today. In the cluster of excellence QUEST (Center for Quantum Engineering and Space-Time Research) atomic clocks are developed for new kinds of quantum sensors and tests of fundamental theories on a quantum-mechanical level. With an atomic clock with relative frequency inaccuracy of 10^{-18} new applications in geodetic measurements as well as navigation are accessible.

Today's standards in frequency measurement are defined by single-ion clocks and neutral atom optical lattice clocks, which have demonstrated the potential for ultra-high short term stability and ultra-high accuracy, respectively. Our group dedicates its work to the development of new trap geometries for the trapping, manipulation and spectroscopy of many ions to combine the advantages of both and overcome the problems of the current technologies.

We have set up a new experiment to trap ions in microfabricated trap structures. $^{172}Yb^{+}$-ions serve to test and characterize the new trap geometries as well as to sympathetically cool $^{115}In^{+}$-ions for spectroscopy. The first tested ion trap is made out of Rogers4350 printed circuit board, a high-precision ceramic chip trap is built in parallel. We present the status of our experiment together with FEM-simulations of the new trap designs.

Q 55.38 Th 16:00 Lichthof

Michelson interferometer with 3-port grating coupled arm resonators — •Maximilian Wimmer, Michael Britzger, Daniel Friedrich, Oliver Burmeister, Björn Hemb, Karsten Danzmann, and Roman Schnabel — Institut für Gravitationsphysik, Leibniz Universität Hannover und Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) Callinstrasse 38 D-30167 Hannover

The signal to noise ratio in high precision interferometers such as gravitational wave detectors can be increased by maximizing the circulating laser power. In current laserinterferometric gravitational wave detectors partly transmissive optics are used as couplers and beamsplitters. In future detectors stronger light fields will increase thermal effects as the consequence of absorption of the transmitted part and this may lead to a limitation of the sensitivity. One possible solution for this problem is the change to all-reflective optics. Previous experiments have shown that the replacement of single interferometer elements is technically feasible. As the next step towards all-reflective interferometry we present the concept of an interferometer with arm cavities using so-called 3-port gratings as reflective cavity couplers.

Q 55.39 Th 16:00 Lichthof

A fiber-based femtosecond frequency comb for precision measurements in microgravity — •Andreas Resch, Claus Lämmerzahl, and Sven Herrmann — Center of Applied Space Technology and Microgravity (ZARM), Universität Bremen

We use a compact fiber-based femtosecond frequency comb in the microgravity environment of the Bremen drop tower at ZARM to explore possible applications in precision experiments, both earthbound and space-based. To this end we have acquired a frequency comb that was designed specifically for the use in a drop tower experiment.

The prospective application of this frequency comb is in an experiment that tests the universality of free fall from a differential measurement of a dual species atom interferometer. Due to the extended time of free fall available in the microgravity environment of the drop tower, and ultimately on board the International Space Station, the sensitivity of such an atom interferometer will be significantly enhanced as compared to earthbound laboratory experiments. The frequency comb will be used to establish a phase-link between the Raman lasers of the two atom interferometers and thus enable a precision measurement of the differential phase of the atom interferometers.

Here we present the current status of the experiment aiming tophase-link lasers at 780 nm and 767 nm in a drop tower experiment. We also discuss the perspectives for further microgravity applications of optical frequency combs. We acknowledge support by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50 WM 0842.

Q 55.40 Th 16:00 Lichthof

Correction of Phase Damping Errors — •Benjamin Trendelkamp-Schroer, Julius Helm, and Walter T. Strunz — TU Dresden

We study a phase damping channel arising from a quantum optical experiment and focus on the question of how to correct phase errors. These errors allow for a complete correction if and only if the corresponding channel is of random unitary type, i.e., a convex combination of unitary transformations [1]. A successful correction, however, requires sound knowledge of both the system and its dynamics. In this context the role of random unitary versus quantum decoherence will be elucidated.

[1] M. Gregoratti and R.F. Werner, J. Mod. Opt. 50, 915 (2002)

Q 55.41 Th 16:00 Lichthof

Quantum key distribution with finite resources: calculating the min-entropy — •Sylvia Bratzik, Markus Mertz, Hermann Kampermann, Silvestre Abruzzo, and Dagmar Bruss — Heinrich-Heine-Universität, Universitätsstr.1, 40225 Düsseldorf

The min-entropy is an important quantity in quantum key distribution [1]. Recently, a connection between the min- entropy and the minimal-error discrimination problem was found [2]. We use this connection to evaluate the min-entropy for different quantum key distribution setups.

[1]R. Renner. Security of quantum key distribution. International Journal of Quantum Information, 6(1):1-127, 2008.

[2]R. König, R. Renner, and Ch. Schaffner. The operational meaning of min- and max-entropy. IEEE Trans. Inf. Th., 55(9), 2009.

Q 55.42 Th 16:00 Lichthof

Optimal Control of Adiabatic Quantum Search — •Johannes Nehrkorn — Institut für Quanteninformationsverarbeitung, Uni Ulm

The total time of an adiabatic computation depends on the speed by which the Hamiltonian of the system is varied. Cerf and Roland proposed an upper bound for this speed as a function of the instantaneous gap. Here, we propose a different approach, applicable for a much broader range of problems, where only an instantaneous condition is used to determine a maximum speed per timestep without any knowledge of the full instantaneous spectrum of the system. This approach is then tested on the search problem introduced by Roland and Cerf.

Q 55.43 Th 16:00 Lichthof

Optimising Quantum Control Algorithms: Tailored Balance between Sequential and Simultaneous Control Update — •Uwe Sander[1], Shai Machnes[2], Steffen Glaser[1], and Thomas Schulte-Herbrüggen[1] — [1]Department of Chemistry, Technical University of Munich, D-85747 Garching, Germany — [2]School of Physics and Astronomy, Raymond and Beverly Sackler Faculty of Exact Sciences, Tel-Aviv University, Tel-Aviv 69978, Israel

We compare the computational performance of the commonly used unconstrained optimal-control algorithms GRAPE (simultaneous update) and Krotov (sequential update), as well as several hybrid versions. Highly optimised code is used to study their behaviour in terms of computationally demanding operations like matrix multiplications and matrix exponentials. Test cases include unitary gate synthesis and state-to-state transfer for various system sizes, coupling types and topologies. The relative performance of each algorithm varies significantly with problem type and size (factors may be as large as ten). We give paradigmatic scenarios, where either GRAPE or hybrids that are midway or close to Krotov perform best.

Q 55.44 Th 16:00 Lichthof

Quantum Decoherence of Two Qubits — •Julius Helm and Walter T. Strunz — Institut für Theoretische Physik, TU Dresden, 01062 Dresden

A widely accepted explanation of decoherence rests upon growing entanglement between the system and its environment. In practice, however, surprisingly often decoherence may equally well be described by random unitary dynamics without invoking a quantum environment at all. For a single qubit, for instance, pure decoherence (or phase damping) is always of random unitary type [1]. Here, we construct a simple example of true quantum decoherence of two qubits: we present a viable phase damping channel that cannot be understood in terms of random unitary dynamics [2]. We give a very intuitive geometrical measure for the positive distance of our channel to the convex set of random unitary channels, of which we find remarkable agreement with the norm distance based on the norm of complete boundedness [3].

[1] L. Landau and R.F. Streater, Lin. Alg. Appl. 193, 107 (1993).
[2] J. Helm and W.T. Strunz, Phys. Rev. A 80, 042108 (2009).
[3] V.I. Paulsen, Completely Bounded Maps and Operator Algebras (Cambridge University Press, Cambridge, U.K., 2002).

Q 55.45 Th 16:00 Lichthof

Towards quantum networks: integrating fiber cavities and ion traps — •Birgit Brandstätter[1,2], Tracy Northup[1], Maximilian Harlander[1], Piet Schmidt[1,3], and Rainer Blatt[1,4] — [1]Institute of Experimental Physics, University Innsbruck, Technikerstraße 25, A-6020 Innsbruck, Austria — [2]Recipient of a DOC-fFORTE-fellowship of the Austrian Academy of Sciences at the Institute of Experimental Physics, University Innsbruck, A-6020 Innsbruck, Austria — [3]present address: QUEST Institute of Experimental Quantum Metrology, PTB, D-38116 Braunschweig, Germany — [4]Institute of Quantum Optics and Quantum Information, Austrian Academy of Sciences

Quantum networks, in which atoms at quantum nodes are linked by photonic channels, offer a compelling solution to the challenge of scalability in quantum computing. In these networks, optical cavities provide an interface between photons and atoms; however, the technical requirements for such cavities are demanding. We hope to utilize recent advances in mirrors fabricated on fiber facets in order to couple trapped calcium atoms to a high-finesse cavity with small mode volume. Our approach is twofold: first, we are investigating the perturbation of ions in a linear segmented trap by the presence of an optical fiber. This experiment provides a testbed for us to explore little-understood factors such as acceptable ion-fiber distances and the effects of fiber coatings. Second, we are developing and testing curved, coated fiber mirrors and designing an integrated ion-trap cavity setup.

Q 55.46 Th 16:00 Lichthof

Towards Cryogenic Surface Ion Traps — •Regina Lechner[1], Michael Niedermayr[1], Muir Kumph[1], Michael Brownnutt[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Uni. Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, 6020 Innsbruck, Austria

Many future applications of quantum information processes such as quantum simulations and entanglement-enhanced precision measurements require a large number of qubits.

Arrays of miniaturised traps will form an ideal system for trapping large numbers of ionic qubits. Increased ion-heating rates in miniaturised traps due to charging of nearby surfaces can be mitigated by cooling the trap to cryogenic temperatures.

We present the characterisation of a gold-on-sapphire surface microtrap suitable for use at cryogenic temperatures. Furthermore, we discuss the experimental system including the cryostat and investigate the photoionisation loading of microtraps.

Q 55.47 Th 16:00 Lichthof

Entanglement dynamics of three-qubit states in noisy channels — •Michael Siomau[1] and Stephan Fritzsche[2,3] — [1]Max-Planck-Institut fuer Kernphysik, Postfach 103980, D-69117 Heidelberg, Germany — [2]Department of Physical Sciences, P.O.Box 3000, Fin-90014 University of Oulu, Finland — [3]Frankfurt Institute for Advanced Studies, D-60438 Frankfurt am Main, Germany

The implementation of schemes for quantum teleportation requires the quantification of entanglement for states that, in general, are mixed due to the interaction with the environment. We study the entanglement dynamics of three-qubit GHZ and W states under the influence of the environment. As noise models for the influence of the environment we use σ_z, σ_x and σ_y Pauli as well as the depolarizing channel [1]. The entanglement of the states is quantified with the lower bound to the three-qubit concurrence [2]. We show that the GHZ state preserves more entanglement than the W state in transmission through σ_x and σ_y Pauli and the depolarizing channels. For σ_z Pauli channel, in contrast, the W state preserves more entanglement than the GHZ state.

[1] E. Jung *et al.* Phys. Rev. A **78**, 012312 (2008).
[2] M. Li, S.-M. Fei, Z.-X. Wang, J. Phys. A **42**, 145303 (2009).

Q 55.48 Th 16:00 Lichthof

Beam Stabilization for Atmospheric Quantum Communication — •Claudia Dürr[1,3], Bettina Heim[1,2], Dominique Elser[1,2], Christoffer Wittmann[1,2], Denis Sych[1,2], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen — [2]Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg — [3]University of Applied Sciences, Munich

We present a free space quantum communication system using continuous polarization states [1]. Weak coherent signal states are polarization-multiplexed with a bright local oscillator in order to perform homodyne measurements. Our atmospheric channel of length 1.6 km produces spatial beam fluctuations which could lead to detection losses [2]. Since losses can be detrimental for continuous-variable quantum states, we compensate for them by using active beam stabilization. For that purpose, the bright local oscillator generates a control signal on a position-sensitive-detector at the receiver. By using a network connection, we feed this signal back to the receiver in order to control the telescope's tilt.

[1] D. Elser et al., New J. Phys. 11, 045014 (2009)
[2] B. Heim et al., to appear in Appl. Phys. B

Q 55.49 Th 16:00 Lichthof

Experimente zur Typ-II Abwärtskonversion in periodisch gepolten Kristallen — •Sabine Euler, Michael Beier, Karen Siegenthaler, Mathias Sinther und Thomas Walther — IAP, TU Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

In einem periodisch gepolten KTP-Kristall entstehen durch Abwärtskonversion aus einem Photon bei 404 nm in einem Typ-II Prozess zwei Photonen der Wellenlänge 808 nm und unterschiedlicher Polarisation. Wir präsentieren zwei Experimente basierend auf diesem Effekt: Zum einen eine heralded Ein-Photonenquelle, die in einer quantenkryptografischen Schlüsselaustauschstrecke eingesetzt werden soll. Zum anderen eine Zwei-Photonenquelle, die auf Rückkopplung eines der obengenannten Photonen basiert. Der aktuelle Stand der Projekte wird diskutiert.

Q 55.50 Th 16:00 Lichthof

Generation of two-dimensional cluster states using bimodal cavities — •Denis Gonta[1], Thomas Radtke[2], and Stephan Fritzsche[3,4] — [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]Department of Physical Sciences, P.O Box 3000, Fin-9014, University of Oulu, Finland — [4]GSI Helmholtzzentrum für Schwerionenforschung, D-64291 Darmstadt

In the framework of microwave cavity QED, we propose two schemes to generate the two-dimensional 2×N and 3×N cluster states [1]. These states are produced between a chain of two-level Rydberg atoms in a deterministic way by using one or more bimodal cavities within the resonant atom-cavity interaction regime. In contrast to standard (single-mode) cavity schemes, such bimodal cavities possess two independent (orthogonally polarized) modes of the light field. We demonstrate that a 2×N cluster state can be generated efficiently with a single bimodal cavity, while two such cavities are needed to produce a 3×N cluster state. An extension of the scheme to generate two dimensional cluster states of arbitrary size is also possible.

[1] D. Gonta, T. Radtke, and S. Fritzsche, Phys. Rev. A **79**, 062319 (2009).

Q 55.51 Th 16:00 Lichthof

Towards a Loophole-free Test of Bell's Inequality with Entangled Pairs of Neutral Atoms — •Christoph Kurz[1], Julian Hofmann[1], Michael Krug[1], Florian Henkel[1], Wenjamin Rosenfeld[1], Markus Weber[1], and Harald Weinfurter[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität München, D-80799 München, Germany — [2]Max-Planck Institut für Quantenoptik, D-85748 Garching

Experimental tests of Bell's inequality allow to distinguish quantum mechanics from local hidden variable theories. Such tests are performed by measuring correlations of two entangled particles (e.g. spins of atoms). In order to constitute conclusive evidence, two conditions have to be satisfied. First, strict separation of the measurement events in the sense of special relativity is required ("locality loophole"). Second, almost all entangled pairs (for particles in a maximally entangled state the required one-side detector efficiency is 82.8%) have to be detected, which is hard to achieve experimentally ("detection loophole"). By using the recently demonstrated entanglement between single trapped atoms and single photons [1] it becomes possible to entangle two atoms at a large distance via entanglement swapping. Combining the high detection efficiency achieved with atoms with the space-like separation of the atomic state detection events, both loopholes can be closed within the same experiment [2]. In this contribution we present recent experimental progress which shows that such an experiment is feasible.

[1] J. Volz et al., Phys. Rev. Lett. **96**, 030404 (2006). [2] W. Rosenfeld et al., Adv. Sci. Lett. **2**, 469 (2009).

Q 55.52 Th 16:00 Lichthof

Optical nanofibers in ion-traps — •Jan Petersen[1], Rainer Blatt[2], Michael Brownnutt[2], and Arno Rauschenbeutel[1] — [1]QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Institut für Experimentalphysik, Unversität Innsbruck, 6020 Innsbruck, Austria

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

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

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

Q 55.53 Th 16:00 Lichthof

EIT storage for arbitrarily shaped low-intensity light pulses — •Gunnar Langfahl-Klabes[1], Peter Nisbet[1], Jerome Dilley[1], Genko Vasilev[2], Daniel Ljunggren[3], and Axel Kuhn[1] — [1]Clarendon Laboratory, Parks Road, Oxford, OX1 3PU, UK — [2]Dept. of Phys., Sofia University, Bulgaria — [3]Dept. of Appl. Physics, KTH Stockholm, Sweden

Electromagnetically induced transparency (EIT) in hot atomic ensembles allows for the generation, delay, storage and retrieval of light pulses by precisely manipulating an control field that drives one of the branches in a Λ-type level scheme. Recent experiments extended the applicability to the few-photons and single photon level [1].

We aim to store and retrieve single photons which were generated by an atom-cavity-system a.k.a. photon pistol (cf. our other posters and talks) and check the retrieved photons for the preservation of their coherence properties.

The EIT process will utilise a Λ-type scheme connecting two Zeeman sub-levels of the hyperfine ground state $F = 1$ in ^{87}Rb.

We report on the latest status and characterization of our setup including a triple-shielded isotopically enriched ^{87}Rb vapour cell with Ne as buffer gas.

[1] Eisaman, M. *et al.* Nature **438**, 837 (2005)

Q 55.54 Th 16:00 Lichthof

Lossless atomic state detection using the Purcell effect — •Carolin Hahn, Jörg Bochmann, Martin Mücke, Christoph Guhl, Stephan Ritter, David Moehring, and Gerhard Rempe — MPI für Quantenoptik, 85748 Garching

One of the diVincenzo criteria for quantum computation is the efficient read-out of the state of the quantum bit (qubit). In single trapped neutral atoms, qubits are typically encoded in or mapped onto atomic hyperfine states. Detection of these hyperfine states often suffers from loss of the atom. Further, the speed and efficiency in schemes relying on spontaneous emission in free space is limited by the photon collection efficiency. Making use of the Purcell effect in an optical cavity, a controlled coupling between qubit and environment can be established, suitable for in an improved state detection scheme based on cavity-enhanced fluorescence. With this method we achieve a hyperfine state detection fidelity of 99.4% in 85 μs in our experiment with a single trapped ^{87}Rb atom. A result is obtained in every read-out attempt and, most importantly, the qubit can be interrogated many hundred times before the atom is lost from the trap. This presents an essential advancement for the speed and scalability of quantum information protocols based on neutral atoms. Our scheme is applicable to all systems with optically accessible qubits.

Q 55.55 Th 16:00 Lichthof

Quantum Information Processing with Atoms in Arrays of Dipole Potentials — •Malte Schlosser, Jens Kruse, Peter Schauss, Benedikt Baumgarten, Sascha Tichelmann, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

Ultracold neutral atoms confined in two dimensional periodic potentials represent highly controllable quantum information systems with long coherence times. In our experiment, we use sets of optical micropotentials created by micro-fabricated lens arrays as the architecture for a scalable quantum processor. The microtrap array accesses the regime of collisional blockade, which allows us to probe single atoms in a site-selective fashion using advanced detection schemes with high efficiency and reliability. In addition to the stable and reproducible operation of the dipole trap array, employing microoptics ensures single site addressability. We are able to control each potential well separately utilizing a spatial light modulator. The combined system allows for the creation of arbitrary trap configurations as well as for flexible, site-specific, but also parallelized initialization and coherent manipulation of separated small ensembles or single ^{85}Rb atoms. We report on the experimental cancellation of the differential ac Stark shift of the hyperfine clock transition by optical means. The separation of internal and external dynamics results in a strong suppression of the dephasing of atoms occupying different vibrational levels and trapping sites, respectively. This scheme is extendable to all alkali elements where no standard "magic-wavelength" is available.

Q 55.56 Th 16:00 Lichthof

Operational multipartite entanglement classes for symmetric photonic qubit states — Nikolai Kiesel[1,2,3], •Witlef Wieczorek[1,2], Stephanie Krins[4], Thierry Bastin[4], Harald Weinfurter[1,2], and Enrique Solano[5,6] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Department für Physik, Ludwig-Maximilians-Universität, Munich, Germany — [3]permanent address: Faculty of Physics, University of Vienna, Wien, Austria — [4]Institut de Physique Nucléaire, Atomique et de Spectroscopie, Université de Liège, Liège, Belgium — [5]Departamento de Química Física, Universidad del País Vasco, Bilbao, Spain — [6]IKERBASQUE, Basque Foundation for Science, Bilbao, Spain

We present experimental schemes that allow to study the entanglement classes of all symmetric states in multiqubit photonic systems. In addition to comparing the presented schemes in efficiency, we will highlight the relation between the entanglement properties of symmetric Dicke states and a recently proposed entanglement scheme for atoms [1]. In analogy to the latter, we obtain a one-to-one correspondence between well-defined sets of experimental parameters and multiqubit entanglement classes inside the symmetric subspace of the photonic system [2].

[1] T. Bastin, C. Thiel, J. von Zanthier, L. Lamata, E. Solano, and G. S. Agarwal, Phys. Rev. Lett. 102, 053601 (2009). [2] N. Kiesel, W. Wieczorek, S. Krins, T. Bastin, H. Weinfurter, E. Solano, arXiv:0911.5112

Q 55.57 Th 16:00 Lichthof

A single photon source with diamond nanocrystals — •Juliane Hermelbracht[1], James Rabeau[3], Ariane Stiebeiner[4], Ruth Garcia Fernandez[4], Arno Rauschenbeutel[4], and Harald Weinfurter[1,2] — [1]FAkultät für Physik, Ludwig-Maximilians-Universität, München, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany — [3]Macquarie University, Sydney, Australia — [4]Johannes-Gutenberg-Universität, Mainz, Germany

The development of reliable devices to generate single photons is crucial for applications in quantum cryptography, as well as for fundamental quantum optics experiments. With an optical emission centered around 650nm and a fluorescence lifetime of 11.6ns the nitrogen-vacancy (NV) color center in diamond seems well suited for implementing a single photon source which could be used in quantum cryptography experiments. The efficiency of the NV-center is, however, limited by the existence of a shelving level. Additionally the high refractive index of bulk diamond restricts the efficiency to collect the fluorescence light. A more convenient approach is the use of NV-center containing diamond nanocrystals, which - being much smaller than the wavelength of the fluorescence light - are not subject to refraction. Furthermore, diamond nanocrystals can be combined with a wide variety of microstructures and thus e.g. be incorporated into cavity-structures. We describe attempts to apply single NV-containing diamond nanocrystals to the waist of tapered optical fibers in order to manipulate the single photon emission characteristics.

Q 55.58 Th 16:00 Lichthof

Generation of strongly squeezed light in periodically poled KTP — •Sebastian Steinlechner, Jöran Bauchrowitz, Tobias Eberle, Henning Vahlbruch, and Roman Schnabel — Institut für Gravitationsphysik, Leibniz Universität Hannover und Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstrasse 38, 30167 Hannover, Germany

Recent years saw a steady increase in the squeezing strength of continuous-wave light generated by parametric down-conversion. Losses have been reduced significantly by using monolithic nonlinear resonators made from magnesium-doped lithium niobate. However, high second-harmonic pump powers were needed to achieve strong squeezing in magnesium-doped lithium niobate, thus leading to thermal instabilities. Here we report on experimental results with a monolithic, periodically poled KTP resonator and present ultra-strong squeezing at 1064nm.

Q 55.59 Th 16:00 Lichthof

Geometric measure of entanglement compared to measures based on fidelity — •Alexander Streltsov — Heinrich-Heine-Universität Düsseldorf, Institut für Theoretische Physik III, Düsseldorf, Germany

One big problem in quantum information theory is the quantification of entanglement for multipartite mixed states. Different axiomatic and operational measures were proposed so far. In this work connections between the geometric measure of entanglement and measures based on the fidelity are established. Also a useful expression for fidelity is derived.

Q 55.60 Th 16:00 Lichthof

Barrier Control in Tunneling e^+-e^- Photoproduction — •Sebastian Meuren[1], Antonino Di Piazza[1], Erik Lötstedt[1], Alexander I. Milstein[1,2], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany — [2]Budker Institute of Nuclear Physics, 630090 Novosibirsk, Russia

QED predicts that in the collision of a strong laser field and a relativistic nucleus, tunneling electron-positron pair production occurs. This process can be described as the tunneling of an electron from the filled, negative-energy Dirac see to a positive-energy state, under the influence of the external laser and nuclear fields. Since the tunneling barrier is very large (around 1 MeV, corresponding to twice the electron rest energy), this process has never been observed experimentally. In [1] we proposed to add to the above setup a weak, high-frequency laser field with a photon energy in the nucleus rest frame close to the pair production threshold. The absorption of one photon from this laser field significantly reduces the barrier to be still tunneled by the electron to go to the positive levels. In this way one can lower the required intensity of the strong laser field to observe the process. Our calculations show that tunneling electron-positron pair production can in principle be observed in the proposed scheme with currently available laser technology.

[1] A. Di Piazza, E. Lötstedt, A. I. Milstein and C. H. Keitel, Phys. Rev. Lett. **103**, 170403 (2009).

Q 55.61 Th 16:00 Lichthof

Quantum friction for particles near a metal — •Gregor Pieplow, Harald Haakh, Francesco Intravaia, and Carsten Henkel — Universität Potsdam, Germany

Quantum friction refers to the deceleration of a neutral or charged particle moving parallel to a half space filled by a dielectric or metal [1]. This was also investigated with plates moving parallel to each other at constant speed. The existence of this friction force has not yet been agreed upon for the zero temperature case [1,2]. QED calculations require the solution of the Maxwell equations with the respective boundary conditions. For realistic systems, symmetry breaking due to finite conductivity of the reflecting plane plays an important role and the role of longitudinal electric fields must be evaluated carefully. We discuss the consistency of previous approaches and their application to the zero temperature case. Our approach rigorously implements Lorentz covariance parallel to the surface.

[1] A.I. Volokitin, B.N.J. Persson, Rev. Mod. Phys. **79**, 1291 (2007).
[2] T. G. Philbin and U. Leonhardt, New J. Phys. **11**, 033035 (2009).

Q 55.62 Th 16:00 Lichthof

Microwave cavity QED experiment with lower Rydberg atomic state — •Pierre Thoumany, Linas Urbonas, Theodor W. Hänsch, and Thomas Becker — Max Planck Institut für Quantenoptik, Garching, Deutschland

The one atom maser is a unique tool to study light matter interaction at the quantum level. The single mode of a superconductive microwave Nb cavity is interacting with a two level Rb85 Rydberg atomic system. This allows us to produce quantum state of light such as fock states. In a new approach we show the interaction of the cavity field with the lower atomic state of the two level atomic system.

Q 55.63 Th 16:00 Lichthof

Interpretation of Quantum Trajectories Arising from a Stochastic Description of Non-Markovian Open Quantum Systems — •Sven Krönke and Walter T. Strunz — Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

By investigation of a simple non-Markovian open quantum system, we try to illuminate the conditions under which the quantum trajectories corresponding to a nonlinear stochastic Schroedinger equation [L. Diósi, N. Gisin and W. T. Strunz, Phys. Rev. A 58, 1699 (1998)] can be interpreted in terms of a continuous measurement scheme. In particular, we are interested in whether and under which circumstances such a scheme can be realised by only measuring the environment.

Q 55.64 Th 16:00 Lichthof

Short-time vs. long-time dynamics of entanglement in quantum lattice models — •Razmik Unanyan, Dominik Muth, and Michael Fleischhauer — Fachbereich Physik und Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern

We study the short-time evolution of the bipartite entanglement in quantum lattice systems with local interactions in terms of the purity of the reduced density matrix. A lower bound for the purity is derived in terms of the eigenvalue spread of the interaction Hamiltonian between the partitions. Starting from an initially separable state the purity decreases as $1-(t/\tau)^2$, i.e. quadratically in time, with a characteristic time scale τ that is inversly proportional to the boundary size of the subsystem, i.e., as an area–law. For larger times an exponential lower bound is derived corresponding to the well-known linear-in-time bound of the entanglement entropy. The validity of the derived lower bound is illustrated by comparison to the exact dynamics of a 1D spin lattice system as well as a pair of coupled spin ladders obtained from numerical simulations.

Q 55.65 Th 16:00 Lichthof

Crystallization of photons in optical lattices — •Sergey Grishkevich, Hessam Habibian, and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes, 66041 Saarbrücken

Photons can interact with each other in a nonlinear medium. Such a medium could be realized using cold atoms loaded in an one-dimensional optical fibre. In this case the confinement enables the generation of large, tunable optical nonlinearities. In its extreme, the quantum light at the fiber output can behave as it were a gas of fermions [1]. Ultracold atoms in optical lattices (OL) may constitute an alternative system for realizing a similar medium. The OL resembles, in some sense, the periodicity of a crystal potential with interparticle distance of the order of the optical wavelength. In this case, the periodic distribution of atoms modulates the refractive index which may strongly modify the photonic properties.

We study light propagating through a crystal of atoms exhibiting a large Kerr nonlinearity. We show how photon blockade in such a medium, whose index of refraction can be modulated by the atomic spacial density as well as by an external field, may lead to a "crystallization" of photons. We focus on a simple 1D OL with atoms well localized at the lattice minima. For this system we develop a full quantum model for the light-matter interactions. These investigations open up the possibility for quantum simulation of matter Hamiltonians using optical systems. Such a system is also supposed to be of great interest for applications in metrology and for quantum information purposes.

[1] D. E. Chang et al., Nature Physics 4, 884 (2008)

Q 55.66 Th 16:00 Lichthof

Cavity-EIT with single atoms — •Martin Mücke, Eden Figueroa, Joerg Bochmann, Carolin Hahn, Celso Jorge Villas-Boas, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

Coherent dark states, such as electromagnetically induced transparency (EIT), can be used to control nonlinear effects for light fields [1]. So far, these phenomena have been studied in media involving a macroscopic number of atoms. In order to scale down these systems to the single quantum level of matter (single atoms) and light (single photons) one has to enhance the matter-light interaction. We report on a new experiment where we use a high finesse optical cavity in which an exactly defined number of atoms can be coupled to the mode of the cavity. We discuss prospects for cavity-based EIT with single atoms and will present its first experimental observation.

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

Q 55.67 Th 16:00 Lichthof

Artificial magnetic fields for stationary light — •Johannes Otterbach[1], Julius Ruseckas[2], Razmik Unanyan[1], Gediminas Juzeliunas[2], and Michael Fleischhauer[1] — [1]Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Institute of Theoretical Physics and Astronomy, Vilnius University, 01108 Vilnius, Lithuania

The creation and control of effective gauge potentials for electrically neutral particles, such as cold atoms, has attracted lots of interest recently. Here we show how to create a homogeneous magnetic fields for light-matter quasi-particles, so-called dark-state polaritons (DSP). These particles arise in the Raman interaction of a weak probe field with a coherently driven atomic ensemble and form the basis of phenomena such as slow and stopped light. In the limit of a large pulse length they behave as effective Schrödinger particles with an externally controllable mass and velocity. Confinement to lower dimensions is easily done by using standard resonator or wave-guide techniques. By uniformly rotating the medium, an artificial gauge field is created. We show that in this scheme Landau levels with degeneracies well above 100 can be achieved. Thus the system is well suited to study such effects as the action of a Lorentz force on neutral particles or the bosonic analog of the fractional quantum Hall effect.

Q 55.68 Th 16:00 Lichthof

Zeta-States in Phase Space — •Cornelia Feiler, Rüdiger Mack, and Wolfgang P. Schleich — Institute for Quantum Physics, Ulm University

> Wenn ich nach einem tausendjährigen Schlaf aufwachen würde, wäre meine erste Frage: „Wurde die Riemann-Hypothese bewiesen?"
>
> D. Hilbert - Zur Hypothese von Bernhard Riemann

The Riemann hypothesis is a conjecture about the distribution of the so called non-trivial zeros of the Riemann ζ-function which is strongly connected with the distribution of primes [1]. Prime numbers, on the other hand, play a crucial role for example in cryptography or factorization.

We aproach the questions about the behavior of the ζ-function in the whole complex plane from a physical point of view. We construct so-called Zeta-states which contain properties connected to the Riemann ζ-function $\zeta(s)$. For example, the imaginary part t of the argument $s = \sigma + it$ should be proportional to the time if we consider the time-evolution of the Zeta-state. Other properties, like the functional equation, and their influence on the phase space functions of these states are considered.

[1] E. C. Titchmarsh. *The Theory of the Riemann Zeta-Function.* Oxford, Charlendon Press, 1967.

Q 55.69 Th 16:00 Lichthof

Motional effects on the efficiency of excitation transfer — •Ali Asadian[1], Markus Tiersch[1], Jianming Cai[1], Gian Giacomo Guerreschi[1], Hans Briegel[1], and Sandu Popescu[2] — [1]Institut für Theoretische Physik, Universität Innsbruck, Technikerstraße 25, A-6020 Innsbruck, und Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaften, Innsbruck, Austria — [2]Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol BS8 1TL, UK.

Energy transfer plays a vital role in many natural and technological processes. In this work we study the effects of classical motion on the electronic excitation transfer through a chain of interacting molecules. Our investigation demonstrates that for various types of oscillations, in a suitable range of frequencies, the efficiency of the energy transfer is significantly enhanced. This enhancement is a signature of the collaborative interplay between the coherent evolution of the excitation and the classical motion of the molecules. This effect has no analogue in the classical incoherent energy transfer. In addition, we discuss control techniques to optimize the excitation transfer along the chain.

Q 55.70 Th 16:00 Lichthof

Tunable upconversion Pr,Yb:ZBLAN fiber laser from 601 nm to 625 nm — •Benjamin Hermberg, Ortwin Hellmig, Klaus Sengstock, and Valeri Baev — Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Compact coherent light sources at different wavelengths in the visible can be realized with an upconvertion Pr/Yb-doped ZBLAN fiber laser. Selective dielectric mirrors placed to both ends of the fiber are usually used for the selection of the required emission wavelength, e.g. 492, 520, 535, 605, 612, 635, or 717 nm. Since the separation between some of the emission lines is smaller than the spectral broadening of the gain, continuous wavelength tuning between neighboring transitions is possible [1]. We have realized a broadband spectral tuning between 605, 612 and 635 nm transitions with a specially designed nonuniform narrowband spectral filter placed in the open part of the cavity. A spectral filter made out of 19 dielectric layers is highly transparent at the desired wavelength and highly reflecting at small detunings. This requirement is very important because of strong variations of the laser gain. An additional 50% cavity loss is achieved at 0.5 nm detuning. Transmission maximum of the filter can be spectrally shifted over 50 nm by its translation perpendicular to the optical axis. The tuning range demonstrated in this experiment extends from 601 to 625 nm, which is 3 times larger than the tuning achieved with a Bragg grating [1].

1. M Zeller, H. G. Limberger, and T. Lasser, IEEE Photonics Technology Letters 15, 194 (2003).

Q 55.71 Th 16:00 Lichthof

Femtosekunden-Laser geschriebener Kanalwellenleiterlaser in Nd:YAG mit 1,3 W Ausgangsleistung — •Jörg Siebenmorgen, Thomas Calmano, Ortwin Hellmig, Klaus Petermann und Günter Huber — Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Mit fs-Laserpulsen einer Pulsdauer von 140 fs wurden Spurpaare bestehend aus zwei parallelen Zerstörspuren in Nd(1%)- bzw. Nd(0,55%)-dotierte YAG-Kristalle geschrieben. Aufgrund spannungsinduzierter Doppelbrechung konnte Wellenleitung in einem Kanal im Zentrum der Doppelspuren beobachtet werden. Die Brechungsindexänderung betrug etwa 10^{-3}.

Die geringsten Leitungsverluste der Wellenleiterkanäle von 1,2 dB/cm bei einer Wellenlänge von 1063 nm traten zwischen Doppelspuren auf, die einen Abstand von ca. 25 μm hatten.

Unter Verwendung eines Ti:Saphir-Lasers als Pumpquelle konnte Lasertätigkeit des Nd(1%):YAG Wellenleiters bei einer Wellenlänge von 1064 nm für vier verschiedene Auskoppelgrade zwischen 50% und 99% gezeigt werden. Die Ausgangsleistung betrug 1,3 W bei einem Auskoppelgrad von 95%. Dies ist die bisher höchste erzielte Leistung eines fs-strukturierten Wellenleiterlasers. Der differenzielle Wirkungsgrad betrug 59%.

Ein Vergleich der Nd(1%)- und Nd(0,55%)-dotierten Wellenleiterlaser ergab ähnliche Wirkungsgrade.

Q 55.72 Th 16:00 Lichthof

A new laser source for trapping Lithium — •Ulrich Eismann[1], Frédéric Chevy[1], Fabrice Gerbier[1], Gérard Trénec[2], Jacques Vigué[2], and Christophe Salomon[1] — [1]Laboratoire Kastler Brossel, CNRS UMR 8552, UPMC, École Normale Supérieure, 24 rue

Lhomond, 75231 Paris, France — [2]Laboratoire Collisions Agrégats Réactivité, CNRS UMR 5589 - Université Paul Sabatier Toulouse 3, Route de Narbonne, 31062 Toulouse Cedex, France

We present a powerful new laser setup for light-induced manipulation of Lithium atoms which is currently being developed within the framework of the Fermix experiment at ENS.

The design is based on a diode-pumped solid state Nd:YVO_4 ring laser, operating on the $^4F_{3/2} \rightarrow \ ^4I_{13/2}$ transition near 1342 nm. The infrared light is subsequently frequency doubled to the Lithium-6 D2 resonance at 670.977 nm in an enhancement cavity using periodically poled Potassium Titanyl Phosphate (ppKTP). Hereby, a special locking technique is applied.

The results obtained so far indicate a higher performance in terms of power, spatial mode quality and simplicity compared to the existing laser sources in the same wavelength range.

Q 55.73 Th 16:00 Lichthof

High-power solid state laser system at 589 nm — Axel Friedenauer, •Manfred Hager, Bernhard Ernstberger, and Wilhelm Kaenders — TOPTICA Photonics AG, Gräfelfing, Germany

A novel scheme is presented which allows for generating high-power diffraction-limited laser radiation in the yellow spectral region. An extended cavity diode laser (ECDL) emitting at a wavelength of 1178 nm serves as a master oscillator and provides seed signals for two PM fibre Raman amplifiers. The output of these amplifiers is coherently combined and resonantly frequency-doubled to obtain more than 30 W of narrow-band tunable output power to resonantly address the sodium D2 transition at 589 nm.

The results have been obtained in collaboration with MPBC and ESO.

Q 55.74 Th 16:00 Lichthof

Aufbau eines kompakten Dioden-Lasersystems bei 435,9 nm — •Florian Schad, Thorsten Führer und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, AG Laser und Quantenoptik, Schlossgartenstr. 7, 64289 Darmstadt

Zur Anregung des Übergangs $^3P_1$ nach $^3S_1$ in neutralen Quecksilberatomen wird Laserlicht der Wellenlänge 435,9 nm benötigt. Dieser Übergang wird zum optischen Pumpen der metastabilen Niveaus verwendet.

Zur effizienten Frequenzverdopplung kommt ein Leistungsüberhöhungsresonator in bow-tie Konfiguration zum Einsatz, der auf einen ECDL (External Cavity Diode Laser) bei 871 nm gelockt wird. Als nichtlineares Medium wird ein LBO-Kristall unter kritischer Phasenanpassung verwendet. Die Stabilisierung erfolgt nach dem Pound-Drever-Hall-Verfahren, bei dem Seitenbänder mittels Strommodulation erzeugt werden. Durch Überlagerung des heraustretenden und des direkt reflektierten Lichtes vom Resonator kann ein geeignetes Fehlersignal erzeugt werden.

Desweiteren soll der gesamte optische Aufbau kompakt gehalten werden und nicht mehr als die Grösse eines DIN A4 Blattes beanspruchen. Erste Ergebnisse des Projekts werden vorgestellt.

Q 55.75 Th 16:00 Lichthof

Continuous-wave Lyman-α generation by four-wave-mixing in mercury — •Andreas Koglbauer, Martin Scheid, Daniel Kolbe, Ruth Steinborn, Sven Richter, and Jochen Walz — Institut für Physik, Johannes Gutenberg-Universität Mainz, D-55099 Mainz

For future precision measurements on anti-hydrogen, laser-cooling of the magnetically trapped atoms down to a milli-Kelvin range is essential. We present the generation of Lyman-α-light on the cooling-transition at 121.56 nm wavelength by sum-frequency four-wave-mixing (FWM) in mercury-vapor using solid-state fundamental laser systems. In addition to the enhancement utilizing the two-photon $6^1S - 7^1S$ resonance, the tuning range of our fundamental laser system enabled us to investigate the influence of the $6^1S - 6^3P$ resonance on the FWM-process. This also gave rise to the observation of two-photon absorption laser induced stimulated emission (TALISE) on the $6^1P - 7^1S$ transition at 1014 nm.

At slightly shorter wavelength than Lyman-α, the mixing process can use a triple one-photon resonant scheme. This gives a 10^4-fold increase of the nonlinear susceptibility and a total vacuum UV power of 6 μW.

The current status of new projects like Lyman-α generation in a three-color resonator and in hollow-core fibers is presented.

Q 55.76 Th 16:00 Lichthof

Effects of counter-directional mode coupling in a cw PP LN SRO with ring resonator — Sergey Vasilyev[1], Stephan Schiller[1], •Hans-Emanuel Gollnick[1], Alexander Nevsky[1], Arnaud Grisard[2], and Juan Jiménez[3] — [1]Heinrich-Heine Universität, Düsseldorf, Germany — [2]Thales Research and Technology, Palaiseau Cedex, France — [3]Universidad de Valladolid, Valladolid, Spain

The effects of coupling between clockwise and counterclockwise modes in a ring resonator with QPM nonlinear crystals are observed and investigated. We consider back reflection from the QPM grating as an important cause of the counter-directional mode coupling. We used computer simulation to demonstrate that the non-phase-matched back reflection from the QPM grating can be considerably enhanced due to grating imperfections. We developed an analytical model and evaluated parameters of the SRO in presence of the coupling. This is a parasitic effect, and results in increase of the SRO threshold. On the other hand, the asymmetry of coupled clockwise and counterclockwise modes can be used for active stabilization of the cavity. Described effects were observed experimentally. Measured properties are in good agreement with our analysis.

Q 55.77 Th 16:00 Lichthof

Detektor zum Nachweis von Hg für ein EPR-Experiment — •Tobias Beck, Alexander Bertz und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, Laser und Quantenoptik, Schloßgartenstraße 7

Ein Detektor, basierend auf resonanter Ionisationsspektroskopie, wird vorgestellt. Dieser ermöglicht es, mit Hilfe von Channel-Electron- Multipliers Quecksilberatome sowie -dimere nachzuweisen. Zur Ionisation wird ein regeneratives Titan:Saphir-Verstärkersystem verwendet, welches ns-Pulse bei 789 nm und 761 nm simultan emittiert. Mittels Frequenzkonversion wird Strahlung bei $253,7$ nm sowie $197,3$ nm erzeugt. Durch die zweistufige Anregung in einen autoionisierenden Zustand ist die Ionisation besonders effizient. Die geladenen Teilchen werden durch Ring-Elektroden in die CEMs fokussiert. Präsentiert wird der aktuelle Stand der Entwicklung.

Q 55.78 Th 16:00 Lichthof

Optical AC Coupling - Ein neues Konzept für Leistungsstabilisierungen von Lasern — •Patrick Kwee, Benno Willke und Karsten Danzmann — Albert-Einstein-Institut Hannover

Optische Präzisionsexperimente, wie z.B. interferometrische Gravitationswellendetektoren, benötigen häufig eine Laserquelle mit sehr hoher Leistungsstabilität. Traditionell werden Photodioden als Leistungsdetektoren verwendet, um die Laserleistung mithilfe eines Regelkreises aktiv zu stabilisieren. Dabei wird die erreichbare Stabilität durch die Empfindlichkeit des Photodetektors limitiert. Die optische AC Kopplung verwendet einen Photodetektor in Reflektion eines optischen Resonators, um dessen Empfindlichkeit um etwa eine Größenordnung zu erhöhen. Dadurch können Leistungsstabilitäten erzielt werden, die bislang unerreichbar schienen. Ergebnisse einer durch Quantenrauschen limitierten Leistungsstabilisierung eines Nd:YAG Lasers bei 1064 nm werden vorgestellt. Eine Analyse des theoretischen Stabilitätslimits und begrenzender Rauschkopplungen werden präsentiert.

Q 55.79 Th 16:00 Lichthof

Study of nonlinear effects produced by organic molecules adsorbed on subwavelength diameter optical fibres — •Konstantin Karapetyan, Cristian Dan, Ulrich Wiedemann, Dimitri Pritzkau, Wolfgang Alt, and Dieter Meschede — Institut für Angewandte Physik, Wegelerstr. 8, 53115 Bonn

Optical fibres with a diameter smaller than the wavelength of light offer interesting perspective for strong light-matter interaction without using a cavity. Light propagating in such fibres has a strong evanescent component, which can be coupled to molecules close to or adsorbed on the surface of the fibre. Thus, linear (e.g. absorption, fluorescence) and nonlinear (e.g. two photon absorption/fluorescence, second and third harmonic generation) effects can be used to characterize and control the molecules. In this work we study the effects produced on the propagation of light in subwavelength diameter fibres by organic molecules deposited on the surface.

Q 55.80 Th 16:00 Lichthof

Chlorophyll fluorescence measurements with single cells of the photosynthetic model organism *Chlamydomonas*

reinhardtii — •Andreas Garz[1], Stefanie Schlede[2], Heiko Lokstein[2], and Ralf Menzel[1] — [1]Institut für Physik und Astronomie/Photonik — [2]Institut für Biochemie und Biologie/Pflanzenphysiologie, Universität Potsdam, Karl-Liebknecht-Str. 24/25, 14476 Potsdam

A comprehensive systems biology analysis of photosynthesis and its regulation in response to selected environmental factors and at different growth stages in a model algal system, *Chlamydomonas reinhardtii*, and the integration of the obtained insight with research on model higher plants and crop plant species are the aims of the interdisciplinary collaborative Potsdam-Golm (Germany) network GoFORSYS.

Our particular field of interests in this regard is the study of the regulation of photosynthesis in response to environmental factors and at different developmental stages, also at the level of single cells using the principle of puls-amplitude-modulated fluorometry to measure photosynthetic parameters such as photochemical and non-photochemical quenching. The data will be used to gain deeper insight into photosynthesis, its regulation and photoprotective mechanisms by application of systemic modelling.

The employed setup is based on an inverse confocal microscope. For manipulation of single cells during the measurements a home-made optical trap is used. Furthermore, the cells can be manipulated in specifically designed micofluidic assemblies (in the range of twenty microns).

Q 55.81 Th 16:00 Lichthof

THz generation via optical rectification in GaAs and GaP — •Jan-Philipp Negel, Robin Hegenbarth, Andy Steinmann, Bernd Metzger, Felix Hoos, and Harald Giessen — 4th Physics Institute, University of Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany

We develop a compact, high-power and low-cost THz source using optical rectification in GaAs and GaP. We use a home-built 5 W, 230 fs, 1025 nm, 44 MHz Yb:KGW laser as well as a commercial 3 W, sub-500 fs, 1035 nm, 37 MHz fiber laser as the pump source for optical rectification in GaP. Alternatively, GaAs with a much higher electro-optic coefficient is used. In order to avoid two-photon absorption in the GaAs, which would lead to a high THz absorption in the crystal, we use an OPO having a tunable signal wavelength up to 1.9 μm. We expect broadband, ultrashort THz radiation centered around 1 THz and output powers of a few μW. We demonstrate scaling up of the power even further.

Q 55.82 Th 16:00 Lichthof

Realization of a scanning microscope for nonlinear microscopy — •Sebastian Beer[1,2], Petra Gross[1], Carsten Cleff[1], Lisa Kleinschmidt[1], and Carsten Fallnich[1] — [1]Institut für Angewandte Physik, Westfälische Wilhelms-Universität, Corrensstr. 2, 48149 Münster — [2]Fachhochschule Gießen-Friedberg, Wiesenstr. 14, 35390 Gießen

During the last decade, research in biology and the life sciences has inspired and led to major achievements in nonlinear microscopy. This includes the improvement of resolution beyond the diffraction limit as well as advances in and application of different nonlinear microscopy methods like two-photon excited fluorescence, harmonic generation or coherent anti-Stokes Raman scattering (CARS). Typically, these methods require scanning of the focus across the sample.

We have developed a multimodal scanning microscope, where not the focus, but the sample is scanned in order to disturb the focus as little as possible. The easy access to all building blocks and the resulting flexibility made an experimental setup more attractive than a commercial, but expensive microscope. Using a piezo-driven three axis stage, the specimen can be scanned by 150 μm in each direction. We present practical considerations and technical details which one has to keep in mind when constructing a high performance scanning microscope. We also show first results obtained by two-photon excited fluorescence-, second harmonic generation-, and CARS-microscopy, which demonstrate that our microscope is highly suitable for multimodal nonlinear microscopy.

Q 55.83 Th 16:00 Lichthof

Brightness measurement of laser-triggered electrons from field emission tips — •Hanno Kaupp, Max Eisele, Markus Schenk, Michael Krüger, Johannes Hoffrogge, John Breuer, and Peter Hommelhoff — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching bei München, Germany

We have set up a source of laser triggered electrons emitted from sharp metal tips. Currently our group investigates the nature of the diverse emission processes possible [1]. Here we present a method to measure the brightness of laser-triggered electrons emitted from these sources. We employ a method based on Fresnel diffraction that occurs at a sharp edge in close proximity of the tip and observe the far-field diffraction pattern with a micro channel plate detector [2]. This is of high interest for future applications of ultrafast tip-based electron sources. We also focus on the development of alternative field emitters. Materials like gold offer laser-induced plasmon resonances which can greatly enhance the field at the tip apex. Modifications of tip geometry and material are presented and we report on the current status of our experiments. [1] See contributions by Markus Schenk et al. and Michael Krüger et al. [2] N. de Jonge et al., Nature 420, 393-395 (2002)

Q 55.84 Th 16:00 Lichthof

Laser Proton Acceleration with a 150 TW laser system — •Stephan Kraft, Karl Zeil, Josefine Metzkes, Tom Richter, Stefan Bock, Uwe Helbig, Thomas Cowan, and Ulrich Schramm — Forschungszentrum Dresden Rossendorf, Bautzener Landstraße 400, 01328 Dresden

Recent success in laser-driven particle acceleration has increased interest in laser-generated accelerator-quality beams. At the Forschungszentrum Dresden - Rossendorf effords are made to produce and charaterize ion beams suitable for applications. During the last two years the 150 TW laser system DRACO as well as a target site have been commisioned and first experiments on ion acceleration have been performed.

In order to investigate the influence of laser accelerated protons on a cell sample a cell irridation site equioped with an energy filtering system has been setup. In this poster we want to present the experimental setup for proton acceleration as first results on energy scaling.

Q 55.85 Th 16:00 Lichthof

Direct Observation of Structural Dynamics in Graphite Using Ultrafast Electron Diffraction — •Christian Gerbig, Cristian Sarpe-Tudoran, Matthias Wollenhaupt, and Thomas Baumert — University of Kassel, Institute of Physics and Center of Interdisciplinary Nanostructure Science and Technology (CINSaT), D-34132 Kassel, Germany

In the recent past Ultrafast Electron Diffraction (UED) has become one of the most promising techniques to directly provide insights into fundamental physical and chemical dynamics at the microscopic level and on the pico- to subpicosecond timescale [1].
With its nature to form a wide range of bonding networks (sp, sp2, sp3) carbon is well-suited to investigate bond and lattice dynamics. So far time-resolved electron crystallography has been used to study structural dynamics of graphite sub-surfaces providing new insights in processes involving lattice vibrations [2] and coherent lattice motions [3]. In this contribution we present first results on the direct observation of optically induced structural dynamics in graphite *bulk* material using UED. In addition, we show improvements and a new approach of our setup, leading to a better spatial and temporal resolution with the prospect to directly resolve coherent shearing phonons in graphite.

[1] M. Chergui & A. H. Zewail, Chem. Phys. Chem. **10**, 28 (2009)
[2] A. H. Zewail and coworkers, Phys. Rev. Lett. **100**, 035501 (2008)
[3] R. K. Raman *et al.*, Phys. Rev. Lett. **101**, 077401 (2008)

Q 55.86 Th 16:00 Lichthof

OCT and CARS imaging with an ultrashort pulse Ti:sapphire laser — •Claudia Hoffmann[1], Angelika Unterhuber[2], Boris Považay[2], Thomas Binhammer[1], Wolfgang Drexler[2], and Uwe Morgner[1] — [1]Institute of Quantum Optics, Leibniz University Hanover, Germany — [2]Biomedical Imaging Group, School of Optometry and Vision Sciences, Cardiff University, Cardiff, UK

Optical coherence tomography (OCT) is an emerging non-invasive in vivo biomedical imaging modality capable of performing real time, three-dimensional visualization of tissue morphology at micrometer scale resolution. Coherent Anti-Stokes Raman Scattering (CARS) is a nonlinear spectroscopic technique which provides molecular information due to a four wave mixing process. In combination with a microscope, CARS enables chemical selective imaging by scanning the sample with resolutions in the micrometer range.

We present measurements of the same sample with both techniques by using ultrashort pulse Ti:sapphire lasers.

Q 55.87 Th 16:00 Lichthof

Selectively closed liquid-filled photonic crystal fibers — •Timo Gissibl, Marius Vieweg, and Harald Giessen — 4th Physics Institute, University of Stuttgart, Germany

In the past few years periodic and nonlinear systems have been subject of many efforts in optics. Therefore many researchers aim to develop all-optical tunable devices. We use glue to close selectively the holes of photonic crystal fibers. Afterwards we use these selectively closed fibers by filling the unblocked holes with highly-nonlinear fluids. With this method we have the possibility to close microstructured fibers with any desired pattern and produce in this way tunable liquid-filled photonic crystal fibers for both supercontinuum generation and nonlinear light propagation in two-dimensional discrete systems.

Q 55.88 Th 16:00 Lichthof

Numerische Berechnungsverfahren zur Simulation von Brillouin-basierten Slow-Light Systemen — •Andrzej Wiatrek, Ronny Henker, Kambiz Jamshidi, Stefan Preussler und Thomas Schneider — Institut für Hochfrequenztechnik, Hochschule für Telekommunikation Leipzig, Germany

Die gezielte Veränderung der Ausbreitungsgeschwindigkeit optischer Pulse, auch bekannt als Slow-Light, hat in den letzten Jahren viel Aufsehen erregt. Neben der sehr offensichtlichen Anwendungsmöglichkeit als optischer Pufferspeicher in der Telekommunikation eröffnen sich weitere Anwendungsfelder in der zeitlich aufgelösten Spektroskopie, der nichtlinearen Optik und der Signalverarbeitung. Der nichtlineare optische Effekt der stimulierten Brillouin-Streuung (SBS) gilt vor allem in faserbasierten Slow-Light Systemen als sehr vielversprechend, weil eher geringe Pumpleistungen zu hohen Verzögerungszeiten führen und der Effekt im gesamten Transparenzbereich aller Fasern auftritt.

Der Prozess der Verstärkung und Verzögerung der optischen Pulse mittels SBS wird durch ein Gleichungssystem gekoppelter Differentialgleichungen beschrieben. Das aufgrund der Gegenläufigkeit der Wellen entstehende Randwertproblem wird mittels Schießverfahren auf ein Anfangswertproblem zurückgeführt. Die Sättigung des SBS-Prozesses verhindert eine weitere Vereinfachung des Gleichungssystems, jedoch führt sie zu einer signifikanten Pulskompression bei gleichzeitiger Verzögerung der Pulse. In diesem Beitrag werden Runge-Kutta und Split-Step-Fourier Methode zur numerischen Simulation eines gesättigten SBS Slow-Light Systems intensiv untersucht und verglichen.

Q 55.89 Th 16:00 Lichthof

Simulation eines optischen Regenerators für mehrstufige optische Modulationsformate — •Martin Hierold[1], Tobias Röthlingshöfer[1,2,3], Klaus Sponsel[1,2], Georgy Onishchukov[2,3], Bernhard Schmauss[1,3] und Gerd Leuchs[1,2,3] — [1]Universität Erlangen — [2]Max-Planck-Institut für die Physik des Lichts — [3]Graduate School in Advanced Optical Technologies

Bei der Weiterentwicklung optischer Übertragungssysteme finden sich zunehmend mehrstufige optische Modulationsverfahren im Fokus der Untersuchungen, inbesondere zur Erhöhung der spektralen Effizienz. Die Akkumulation von Phasen- und Amplitudenrauschen ist bei diesen jedoch auf Grund der geringen Distanz der Signalzustände im Phasenraum besonders kritisch. Bei der Verwendung einer Phasenkodierung führt dabei das nichtlineare Phasenrauschen durch nichtlineare Effekte in Übertragungsfasern, wie die Erzeugung von nichtlinearem Phasenrauschen aus Amplitudenrauschen durch die Selbstphasenmodulation, zu starken Beeinträchtigungen. Mithilfe eines modifizierten nichtlinearen Faser-Sagnac Interferometers, des nichtlinearen verstärkenden Schleifenspiegels (NALM) kann eine phasenerhaltende Verringerung des Amplitudenrauschens auch bei mehrstufigen Modulationsformaten erricht werden. Durch eine Optimierung der verschiedenen Parameter eines NALM, wie das Teilugnsverhältnis, die Verstärkung und das Profil des nachgeschalteten optischen Bandpassfiltes, kann der NALM für Eingangssignale mit verschieden starkem Eingangsrauschen angepasst werden. Hierbei ist auch eine Optimierung für Modulationsformate mit nicht äquidistanten Amplitudenniveaus möglich.

Q 55.90 Th 16:00 Lichthof

On the brink of causality: Wave propagation in Gödel's Universe — •Michael Samaniego, Endre Kajari, and Wolfgang P. Schleich — Institut für Quantenphysik, Universität Ulm, 89069 Ulm, Germany

In 1949 Kurt Gödel presented a cosmological solution of Einstein's field equations, the so-called Gödel Universe, which is stationary, homogeneous, but anisotropic. A particularly interesting feature of Gödel's Universe is the existence of closed timelike world lines, which allow for time travel. Thus, a well-posed Cauchy initial value problem is only possible when we restrict ourselves to a specific spacetime region in Gödel's Universe. In this work, we examine a special type of wave propagation in Gödel's Universe based on a well-posed Cauchy initial value problem for the Klein-Gordon equation.

Q 55.91 Th 16:00 Lichthof

Optical Properties of the Insulator-On-Silicon-On-Insulator Material System — •Daniel Pergande and Ralf B. Wehrspohn — Martin-Luther-Universität Halle-Wittenberg, 06099 Halle

In the last years great efforts lead to a strong miniaturization of optical components by means of realization of devices within the silicon-on-insulator (SOI) platform which is completely compatible to CMOS technology. The very high refractive index contrast between the Si core (n=3.5) and the oxide cladding (n=1.45) and air (n=1), respectively, leads to a high confinement of light inside a waveguide. To meet the demands of next generation networks an appropriate material system which provides equably propagation of TE and TM-polarization is essential. In addition, to realize photonic crystal (PhC) based polarization sensitive devices a fully symmetrical material system is needed to avoid polarization mixing. For most of the (symmetric) SOI-based structures no transmission for TM-polarized light was reported or for TM-polarization a large deviation between theory and experiment was observed.

We present polarization-dependent optical transmission properties of a completely symmetric SOI-based material system. In contrast to typical SOI structures here an insulator-on-silicon-on-insulator (IOSOI) material system has been fabricated, which features an additional silica top layer. The group index dispersions and absorption coefficients of ridge waveguides will be presented. Furthermore, PhC waveguides were characterized and we present measurements to determine the amount of polarization crosstalk.

Q 55.92 Th 16:00 Lichthof

Optomechanical coupling of ultracold atoms and a membrane — •Maria Korppi, Stephan Camerer, David Hunger, Theodor W. Hänsch, and Philipp Treutlein — Max-Planck-Institut für Quantenoptik und Ludwig-Maximilians-Universität München

We report the progress of our experiment which aims at coupling a single mechanical mode of a high-Q membrane-oscillator to the motion of laser-cooled atoms in an optical lattice. The optical lattice is formed by retroreflection of a laserbeam from the oscillator surface. When the trap frequency of the atoms is matched to the eigenfrequency of the membrane, the coupling leads to resonant energy transfer between the two systems. This should allow to observe the back-action of the atoms onto the membrane. In the long term, such coupling mechanism could be exploited in developing hybrid quantum systems between atoms and solid-state devices.

Q 55.93 Th 16:00 Lichthof

Measuring non-Markovian dynamics using optomechanical systems — •Alexey Trubarov[2], Konrad Kieling[1], Simon Gröblacher[2], Markus Aspelmeyer[2], and Jens Eisert[1] — [1]Universität Potsdam — [2]Universität Wien

We consider a system consisting of a micromechanical harmonic oscillator coupled to a thermal bath. Usually, for reasons of simplicity, the assumption is made that this heat bath is ohmic, i.e. is described by a linear spectral density. However, depending on the geometry of the specific mechanical oscillator at hand, this assumption does not have to be fulfilled. We show that the spectral density of the heat bath of the oscillator*s environment can be extracted from the dynamics of the mechanical system and we present first experimental results.

Q 56: Quantum Information: Quantum Communication II

Time: Friday 10:30–12:15 Location: A 310

Q 56.1 Fr 10:30 A 310

Experimental demonstration of an exploit of detector dead-times in QKD — •Sebastian Nauerth[1], Henning Weier[1], Harald Krauss[1], Martin Fürst[1], Markus Rau[1], and Harald Weinfurter[1,2] — [1]Ludwig-Maximilians-Universität München — [2]Max-Planck-Institut für Quantenoptik Garching

The security of real world quantum key distribution (QKD) systems depends heavily on their thorough implementation. Eavesdroppers can benefit from technical imperfections to gain information on the generated keys. Because some of these attacks are beyond the scope of current security proofs, they possibly will remain unnoticed by the legitimate communicating parties.

One of these imperfections, which is common to almost all QKD systems, is the so called dead time of most single photon detectors (SPD), i. e. the time for which an SPD is rendered inactive after a detection event.

We present our experimental results of a very simple yet highly effective method to exploit this detector imperfection by sending carefully timed blinding pulses into the detectors. Without introducing additional quantum bit errors, thus without being detected by state of the art QKD protocols, an adversary could successfully guess each keybit with a probability greater than 98%. While, in this work, we attack a BB84 system with four detectors, many other schemes are vulnerable to the evesdropping strategy we developed. Yet, we propose an evenly simple and effective countermeasure to inhibit the demonstrated and similar attacks already by the detector electronics.

Q 56.2 Fr 10:45 A 310

Quantum key distribution and 1 Gbit/s data encryption over a single fibre — •Nino Walenta[1], Patrick Eraerds[1], Matthieu Legré[2], Nicolas Gisin[1], and Hugo Zbinden[1] — [1]Group of Applied Physics-Optique, University of Geneva, Rue de l'École-de-Médecine 20, 1205 Geneva, Switzerland — [2]idQuantique SA, Chemin de la Marbrerie 3, 1227, Geneva, Switzerland

Quantum key distribution (QKD) allows highly secure communication based on the laws of quantum mechanics. Until recently, one of the specifics of QKD systems was the need for a dedicated dark optical fibre, exclusively reserved for the quantum channel. Classical signals, assigned to perform key distillation and encrypted communication between the end users, were sent through separate fibres to not compromise the weak quantum signal.

With the aim for scalable and cost effective deployment we demonstrate QKD in the presence of 4 classical channels in a C-band dense wavelength division multiplexing (DWDM) configuration. The classical channels are used for key distillation and 1 Gbps encrypted communication, rendering the entire system independent from any other communication link than a single dedicated fibre. The separation between quantum channel and nearest classical channel is only 200 GHz, while the classical channels are all separated by 100 GHz. We successfully distil secret keys over fibre spans of up to 50 km. In this context we also discuss DWDM configurations with a quantum channel at 1310 nm.

Q 56.3 Fr 11:00 A 310

Quantum Key Distribution on Hannover Campus: Experiment — •Vitus Händchen, Tobias Eberle, and Roman Schnabel — Institut für Gravitationsphysik, Leibniz Universität Hannover und Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstrasse 38, D-30167 Hannover

We currently prepare the experimental implementation of quantum key distribution on the campus of the Leibniz Universität Hannover. In this contribution we report on the entanglement (two-mode squeezing) based setup with continuous-wave light fields at a wavelength of 1550 nm, which provides a low absorption in optical fibers. The communication link will be established between the Albert Einstein Institute and the Institute of Quantum Optics through an existing telecom fiber of approximately 1 km length. The readout of the continuous variables at the two locations will be realized by a homodyne detection scheme.

Q 56.4 Fr 11:15 A 310

Quantum key distribution on Hannover Campus: Theory — •Jörg Duhme, Torsten Franz, and Reinhard Werner — Institut für theoretische Physik, Leibniz Universität Hannover

We report on an upcoming implementation of quantum key distribution on LUH campus, see talk by V. Händchen et al. The theoretical model for the experiment includes different noise sources, e.g. damping and phase noise. We discuss the security and expected secure bit rates and comment on the problem of extending security proofs from collective to coherent attacks for continuous variable key distribution.

Q 56.5 Fr 11:30 A 310

Implementation of an attack scheme on a practical QKD system — Qin Liu[1], Ilja Gerhardt[2], Antia Lamas-Linares[2], Vadim Makarov[1], and •Christian Kurtsiefer[2] — [1]NTNU Trondheim — [2]Centre for Quantum Technologies/Physics Department, Nat. Univ. Singapore

We report on an experimental implementation of an attack of a practical quantum key distribution system [1], based on a vulnerability of single photon detectors [2]. An intercept/resend-like attack has been carried out which revealed 100% of the raw key generated between the legitimate communication partners. No increase of the error ratio was observed, which is usually considered a reliable witness for any eavesdropping attempt. We also present an experiment which shows that this attack is not revealed by key distribution protocols probing for eavesdroppers by testing a Bell inequality [3], and discuss implications for practical quantum key distribution.

[1] I. Marcikic, A. Lamas-Linares, C. Kurtsiefer, Appl. Phys. Lett. **89**, 101122 (2006)
[2] V. Makarov, New J. Phys. **11**, 065003 (2009)
[3] A. Ling et al., Phys. Rev. A **78**, 020301(R), (2008)

Q 56.6 Fr 11:45 A 310

Quantum key distribution with finite resources: Smooth Min entropy vs. Smooth Rényi entropy — •Markus Mertz, Silvestre Abruzzo, Sylvia Bratzik, Hermann Kampermann, and Dagmar Bruss — Institut für Theoretische Physik III, Düsseldorf, Germany

We consider different entropy measures that play an important role in the analysis of the security of QKD with finite resources. The smooth min entropy leads to an optimal bound for the length of a secure key. Another bound on the secure key length was derived by using Rényi entropies. Unfortunately, it is very hard or even impossible to calculate these entropies for realistic QKD scenarios. To estimate the security rate it becomes important to find computable bounds on these entropies. Here, we compare a lower bound for the smooth min entropy with a bound using Rényi entropies. We compare these entropies for the six-state protocol with symmetric attacks.

Q 56.7 Fr 12:00 A 310

Extremal quantum correlations and cryptographic security — •Torsten Franz, Fabian Furrer, David Gross, Jukka Kiukas, Volkher Scholz, and Reinhard Werner — Institut für Theoretische Physik, Leibniz Universität Hannover

Results of quantum experiments are given by correlation tables, i.e. expectation values of joint measurements performed at different locations. We are interested in situations when these correlations are provably secure, i.e. when the measured results can be shown to be independent of any eavesdropper. We show that any extremal quantum correlation table is secure, and provide algebraic criteria for this.

Q 57: Micromechanical Oscillators II

Time: Friday 10:30–12:30 Location: A 320

Q 57.1 Fr 10:30 A 320

Exploring Optomechanics with optically levitating dielectric objects — •Anika C. Pflanzer, Oriol Romero-Isart, and J. Ignacio Cirac — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany

Optomechanical systems hold the promise to facilitate the preparation of superposition states of macroscopic objects. While the main drawback in ground state cooling of the center-of-mass motion in most systems, such as membranes or cantilevers in optical cavities, is their large heating rate, optically levitating sub-wavelength dielectric objects in high-finesse cavities realize a setup with negligible mechanical damping. They do not couple to a thermal reservoir and consequently the main source of heating can be circumvented. The transition to larger objects comes with a coupling of the center-of-mass motion to other modes of the mechanical oscillator, which we take into account by an additional heating rate. Furthermore, the cavity's finesse decreases with the size of the trapped objects. These effects, limiting the maximal size of objects that can be cooled in this cavity system by state-of-the-art quantum optomechanical techniques, are investigated in detail and possible alternatives are discussed.

Q 57.2 Fr 10:45 A 320

Interfacing Opto-mechanics with Atoms — •Klemens Hammerer — University of Innsbruck, Austria

We propose and analyze setups interfacing opto-mechanical systems with single atoms or atomic ensembles. In particular we show that strong, coherent coupling between a single trapped atom and a mechanical oscillator can be mediated via a laser-driven high-finesse cavity. In free space it is still possible to achieve a coherent coupling between a micromirror and an ensemble of atoms trapped in a standing wave field reflected thereof. Finally, in a travelling wave, pulsed scheme allows for a quantum non-demolition measurement of hybrid atomic-micromechanical Einstein-Podolsky-Rosen variables. The wave function of the massive mechanical oscillator and the collective atomic spin is thereby collapsed into an entangled EPR state. These setups provide the basic toolbox for coherent manipulation, preparation and measurement of micro- and nanomechanical oscillators via the tools of atomic physics. Beyond interfaces of optomechanics to AMO systems, I will discuss general perspectives of strong and super-strong optomechanical coupling.

Q 57.3 Fr 11:00 A 320

Cavity-Optomechanics with Silica Microresonators at Helium-3 Temperatures — •Stefan Weis[1], Rémi Rivière[1], Olivier Arcizet[1,2], Albert Schliesser[1], Samuel Deléglise[1], Emanuel Gavartin[3], and Tobias J. Kippenberg[1,3] — [1]MPI für Quantenoptik, 85748 Garching, Germany — [2]Institut Néel, CNRS, 38042 Grenoble, France — [3]Ecole Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland

We present the optical and mechanical properties of toroidal resonators thermalized to Helium-3 (600 mK) temperatures, which exhibit ultra-high optical Q (up to 10^8) whispering gallery mode resonances coupled via radiation pressure to mechanical radial breathing modes.

Recent experiments performed in a Helium-4 cryostat aiming at ground state cooling the mechanical degree of freedom have combined cryogenic precooling with laser cooling. Final phonon occupation numbers of about 60 quanta [1] could be attained, which were however limited by the mechanical losses due to two-level systems at temperatures above 1.6 K. Here, we demonstrate that the mechanical Q dramatically improves at temperatures below 1 K, enabling mechanical Q factor in excess of 10,000.

The large achievable mechanical Q factors, combined with low initial occupancies of < 200 for 75 MHz oscillators, render this system a promising candidate for ground state cooling and a range of experiments pertaining to quantum measurement theory of mechanical oscillators.

[1] A. Schliesser et al., Nature Physics 5, 509 (2009)

Q 57.4 Fr 11:15 A 320

Single-Photon Optomechanics in the Strong Coupling Regime — •Uzma Akram[1], Nikolai Kiesel[2], Markus Aspelmeyer[2], and Gerard Milburn[1] — [1]Department of Physics, School of Mathematics and Physics, The University of Queensland, St. Lucia, QLD 4072, Australia — [2]Faculty of Physics, Quantum Optics, Quantum Nanophysics and Quantum Information, University of Vienna, Austria

We give a theoretical description of a coherently driven opto-mechanical system with a single added photon. The photon source is modeled as a cavity which initially contains one photon and which is irreversibly coupled to the opto-mechanical system. We show that the probability for the additional photon to be emitted by the opto-mechanical cavity will exhibit oscillations under a Lorentzian envelope, when the interaction with the mechanical resonator is strong enough. Our scheme provides a feasible route towards quantum state transfer between optical photons and micromechanical resonators.

Q 57.5 Fr 11:30 A 320

Quantum optomechanics beyond rotating-wave-approximation: Towards optomechanical entanglement — Simon Gröblacher[1,3], •Sebastian Hofer[1], Michael Vanner[1], Klemens Hammerer[2,4], and Markus Aspelmeyer[1] — [1]Fakultät für Physik, Universität Wien, 1090 Wien, Österreich — [2]Institut für Theoretische Physik, Universität Innsbruck, 6020 Innsbruck, Österreich — [3]Institute for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, 1090 Wien, Österreich — [4]Institute for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, 6020 Innsbruck, Österreich

We investigate the dynamics of a mechanical oscillator coupled to an optical cavity by radiation pressure. Going into the strong coupling regime enables us to access dynamics beyond the rotating-wave-approximation. This sets the way for the creation of nonclassical quantum states and optomechanical entanglement.

Q 57.6 Fr 11:45 A 320

Optomechanische Verschränkung im instabilen Regime — Christian Höhne und •Carsten Henkel — Universität Potsdam

Das Kühlen von beweglichen Spiegeln durch rotverstimmtes Laserlicht ist eine erfolgversprechender Weg, um makroskopische Objekte in ihrer Bewegung an die Quantengrenze zu bringen. Wir untersuchen hier den Fall von blauer Verstimmung, wo eine parametrische Resonanz zur Instabilität von Spiegel und Lichtfeld führt ("Heizen"). Es wird eine Beschreibung entwickelt, die dieses Verhalten in Analogie zur Schwelle eines Lasers beschreibt: der Spiegel ist die "Lasermode", das getriebene Lichtfeld im Resonator das "gepumpte Medium". Das System stabilisiert sich nichtlinear durch die Rückwirkung der Spiegelbewegung auf die Resonatorkennlinie. Wir zeigen, dass für geeignet große Kopplung die beiden Oszillatoren sich spontan verschränken, und charakterisieren diese "Verschränkungs-Schwelle" mit Hilfe von Darstellungen der symplektischen Gruppe auf dem Raum der Kovarianzmatrizen.

Q 57.7 Fr 12:00 A 320

Observation of strong coupling between a micromechanical resonator and an optical cavity field — •Simon Gröblacher[1,2], Klemens Hammerer[2,3], Michael Vanner[1,2], and Markus Aspelmeyer[1,2] — [1]Fakultät für Physik, Universität Wien, A-1090 Wien, Österreich — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, A-1090 Wien und A-6020 Innsbruck, Österreich — [3]Institut für theoretische Physik, Universität Innsbruck, A-6020 Innsbruck, Österreich

We report the observation of strong coupling between a macroscopic mechanical resonator and an optical field, which is an essential requirement for the preparation of mechanical quantum states.

Q 57.8 Fr 12:15 A 320

Squeezing optomechanical systems — •Andrea Mari[1] and Jens Eisert[1,2] — [1]Institute of Physics and Astronomy, University of Potsdam, D-14476 Potsdam, Germany — [2]Institute for Advanced Study Berlin, D-14193 Berlin, Germany

We introduce a framework of optomechanical systems that are driven with a mildly amplitude-modulated light field, but that are not subject to classical feedback or squeezed input light. We find that in such a system one can achieve large degrees of squeezing of a mechanical micromirror - signifying quantum properties of optomechanical systems - without the need of any feedback and control, and within parameters reasonable in experimental settings. Entanglement dynamics is shown of states following classical quasiperiodic orbits in their first moments. We discuss the complex time dependence of the modes of a cavity-light field and a mechanical mode in phase space. Such settings give rise to certifiable quantum properties within experimental conditions feasible with present technology.

[1] A. Mari and J. Eisert, Phys. Rev. Lett. 103, 213603 (2009).

Q 58: Quantum Gases: Lattices II

Time: Friday 10:30–12:30 Location: E 001

Q 58.1 Fr 10:30 E 001

Dynamics of Atoms in a Hamiltonian Quantum Ratchet — •Tobias Salger, Carsten Geckeler, Sebastian Kling, Tim Hecking, and Martin Weitz — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn, Germany

Ratchets are devices, that are able to generate a directed motion of particles in a fluctuating environment without gradients or net forces. In order to observe the ratchet effect, one has to break the spatiotemporal symmetry of the system [1]. Here we report on the first realization of a pure "Hamiltonian Quantum Ratchet" in the absence of dissipation [2]. A ^{87}Rb Bose-Einstein condensate is loaded into a sawtooth-like lattice potential, which is realized by superimposing an optical standing wave with $\lambda/2$ spatial periodicity with a four-photon lattice with $\lambda/4$ spatial periodicity [3]. Besides the spatial, also the temporal symmetry is broken by asymmetrically modulating the amplitude of the ratchet potential. We observe a directed motion of atoms arising from Hamiltonian ratchet transport at the quantum limit.
In more recent experiments we have investigated the dynamics of atoms in a Hamiltonian Quantum Ratchet under the influence of weak gradients. Absolute negative mobility, which describes the possibility to transport a particle against an external field, could be observed in the experiment.

[1] S. Denisov et al., Phys. Rev. A **75**, 063424 (2007)
[2] T. Salger et al., Science **326**, 1241 (2009)
[3] T. Salger et al., Phys. Rev. Lett. **99**, 190405 (2007)

Q 58.2 Fr 10:45 E 001

Dynamic localization in optical lattices — •Matthias Langemeyer, Stephan Arlinghaus, and Martin Holthaus — Institut für Physik, Carl von Ossietzky Universität, D-26111 Oldenburg

The concept of dynamic localization is often disussed theoretically within the framework of a single-band tight-binding model. For possible applications with time-periodically shifted optical lattices, the theoretical ideal is endangered by interband transtions. In this talk we demonstrate with the help of numerical model calculations that nonetheless almost perfect dynamic localization of ultracold atoms in optical lattices can be reached for suitably chosen parameters. This allows one, in particular, to exert active control over the Aubry-Andre-like incommensurability transition which occurrs in bichromatic optical lattices.

Q 58.3 Fr 11:00 E 001

Localization of cold atoms in state-dependent optical lattices via a Rabi pulse — •Birger Horstmann[1], Stephan Dürr[1], Ignacio Cirac[1], and Tommaso Roscilde[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Laboratoire de Physique - ENS Lyon, 46 Alle d'Italie, 69007 Lyon, France

We propose a novel realization of Anderson localization in excited states of ultracold atoms trapped in state-dependent optical lattices. The disorder potential leading to localization is generated with a Rabi pulse which transfers a fraction of the atoms into a different internal state for which tunneling between lattice sites is suppressed. These frozen atoms create a quantum superposition of different random potentials, localizing the atoms. We investigate the dynamics of the mobile atoms after the Rabi pulse for non-interacting and weakly interacting bosons, as well as for infinitely repulsive bosons in one dimension.

Q 58.4 Fr 11:15 E 001

Free expansion of ultracold fermions in an optical lattice — •Jens Philipp Ronzheimer[1], Ulrich Schneider[1], Lucia Hackermüller[1], Sebastian Will[1], Simon Braun[1], Thorsten Best[2], Tim Rom[1], Michael Schreiber[1], Kin Chung Fong[1], and Immanuel Bloch[1] — [1]LMU München — [2]ALU Freiburg

We investigate the free expansion of fermionic ^{40}K atoms in an optical lattice. A balanced mixture of atoms in the $|\frac{9}{2},-\frac{9}{2}\rangle$ and $|\frac{9}{2},-\frac{7}{2}\rangle$ hyperfine states is initially prepared in a non-interacting band insulator state in the combination of a blue detuned optical lattice and a red detuned optical dipole trap. Using a Feshbach resonance, the interaction between the species is set to values varying from strongly attractive to strongly repulsive. The atoms are released by quickly ramping down the dipole trap to a strength that only compensates the anticonfinement due to the optical lattice while increasing the depth of the lattice in one direction, thereby creating sheets of homogeneous 2D lattices.

In the case of negligible interactions, the atomic cloud expands ballistically with a speed given by the tunneling rate. For interacting fermions, the expansion becomes diffusive with a density dependent diffusion constant. Independent of the sign of interactions, the outer regions of the cloud still expand ballistically while the expansion of the high density core slows down with increasing interaction strength. Eventually, the core stops expanding and instead starts to dissolve from the outside, shrinking over time.

These measurements demonstrate previously unobserved transport dynamics and give insight into timescales for density redistribution.

Q 58.5 Fr 11:30 E 001

Monomere und Dimere im Bose-Hubbard-Modell — •Mathias Schneider und Michael Fleischhauer — Technische Universität Kaiserslautern

Ein wesentlicher Aspekt von Vielteilchen-Systemen in periodischen Potentialen ist die Existenz repulsiv gebundener Teilchenpaare (Dimere). Diese treten auf, wenn der energetische Unterschied zwischen einem Dimer und zwei einzelnen Teilchen (Monomere), welche räumlich getrennt sind, in einer Bandlücke liegt, so dass der Zerfall dieser Objekte energetisch verboten ist. Kalte Gase in optischen Gittern eignen sich hervorragend für die Beobachtung repulsiv gebundener Paare, da hier - anders als im Festkörper - keine Zerfallskanäle existieren, welche die Lebensdauer dieser Objekte extrem verkürzen würden. Wir untersuchen die effektive Dynamik eines Systems von Dimeren, in Wechselwirkung mit einem thermischen Reservoir von Monomeren. Diese Kopplung führt, je nach Monomerdichte, zu Dimererzeugung und -Vernichtung, die durch Ratengleichungen beschrieben werden. Die möglichen Zerfallsprozesse und Raten von Dimeren unterscheidet sich für isolierte Dimere und zusammenhängende Cluster. Der Zerfall von Clustern führt dabei temporär zu verschränkten Zuständen

Q 58.6 Fr 11:45 E 001

Real-Time Ginzburg-Landau Theory for Ultracold Bosons in Optical Lattices — •Tobias Grass[1], Francisco Ednilson Alves dos Santos[1], and Axel Pelster[2,3] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Institut für Physik und Astronomie, Karl-Liebknecht-Str. 24 14476 Potsdam, Germany — [3]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

Applying the Schwinger-Keldysh formalism to the Bose-Hubbard Model we derive a real-time Ginzburg-Landau theory at zero temperature [1]. Surprisingly, it reduces to the seminal Gross-Pitaevskii theory deep in the superfluid phase although it has been originally determined within a hopping expansion and should, therefore, be only applicable in the immediate vicinity of the quantum phase boundary. Furthermore, in an equilibrium application, we show that the particle-hole excitation spectra in the Mott phase merge continuously into corresponding excitation spectra of the amplitude and the phase of the order parameter in the superfluid phase, once the quantum phase boundary is crossed. Finally, we discuss as a non-equilibrium application that the damping observed within the collapse and revival experiments of Ref. [2] turns out to be due to the overall harmonic potential which confines the atoms inside a finite volume.

[1] B. Bradlyn, F.E.A. dos Santos, and A. Pelster, Phys. Rev. A **79**, 013615 (2009)

[2] M. Greiner, O. Mandel, T. W. Hänsch, and I. Bloch, Nature, **419**, 51 (2002)

Q 58.7 Fr 12:00 E 001

Probing superfluids in optical lattices by momentum-resolved Bragg spectroscopy — •Sören Götze, Philipp T. Ernst, Jasper S. Krauser, Jannes Heinze, Malte Weinberg, Christoph Becker, and Klaus Sengstock — Universität Hamburg, Institut für Laser-Physik, Luruper Chaussee 149, 22761 Hamburg, Germany

By the creation of ultracold quantum gases in optical lattices, superfluids can be realized over a wide range of tunable parameters, with a continuous connection to the regime of strong correlation. However, for full experimental access and a comprehensive comparison with condensed-matter systems, there is a need for new detection techniques to probe their fundamental behaviour, characterized i.e. by the dynamic structure factor. Here we report on a comprehensive study of superfluids in optical lattices by Bragg spectroscopy and present fully momentum-resolved measurements of the band structure and associated interaction effects at several lattice depths. In addition, we directly study the momentum composition of excitations in this system and observe strong indications for Bogoliubov backscattering[1]. Our measurements demonstrate the applicability and limits of the Bogoliubov theory to describe excitation properties of superfluids in periodic potentials and pave the way for further detailed studies of strongly correlated phases, quantum gas mixtures and novel quantum phases.

[1] P. T. Ernst et al., Probing superfluids in optical lattices by momentum-resolved Bragg spectroscopy, Nature Physics advance online publication, 29.11.2009 (DOI: 10.1038/nphys1476)

Q 58.8 Fr 12:15 E 001

Dynamics and stability of Bose-Einstein solitons in tilted optical lattices — •Christopher Gaul[1], Cord A. Müller[1], Elena Díaz[2], Rodrigo Lima[3], and Francisco Domínguez-Adame[2] — [1]Physikalisches Institut, Universität Bayreuth, Deutschland — [2]GISC, Departamento de Física de Materiales, Universidad Complutense, E-28040 Madrid, Spain — [3]Instituto de Física, Universidade Federal de Alagoas, Maceió AL 57072-970, Brazil

We consider a BEC whose mean-field interaction parameter $g(t)$ is modulated harmonically in time via Feshbach-resonance techniques. When the 1d lattice is tilted, the BEC wave packet starts to perform Bloch oscillations. We show that for suitable choices of $g(t)$, these Bloch oscillations are stable [1]. Moreover, solitonic wave packets can be effectively stabilized against certain experimentally relevant perturbations [2].

[1] Gaul et al. PRL 102, 255303 (2009)
[2] Díaz et al. arXiv:0911.5633 (2009)

Q 59: Quantum Information: Atoms and Ions IV / Photons and Nonclassical Light II

Time: Friday 10:30–12:45 Location: E 214

Q 59.1 Fr 10:30 E 214

Storage and recall of single photon level pulses with an efficiency of 25% — •Andreas Walther, Mahmood Sabooni, Felix Beaudoin, Lin Nan, Atia Amari, Maomao Huang, and Stefan Kröll — Department of Physics, Lund University, P.O. Box 118, SE-22100 Lund, Sweden

We demonstrate experimentally a quantum memory scheme for the storage of weak coherent light pulses in an inhomogeneously broadened optical transition in a Pr^{3+}: YSO crystal at 2.1 K. Precise optical pumping using a frequency stable (about 1kHz linewidth) laser is employed to create a highly controllable Atomic Frequency Comb (AFC) structure. We report single photon storage and retrieval efficiencies of 25%, based on coherent photon echo type re-emission in the forward direction. The coherence property of the quantum memory is proved through interference between a super Gaussian pulse and the emitted echo. Backward retrieval of the photon echo emission has potential for increasing storage and recall efficiency.

Q 59.2 Fr 10:45 E 214

Atom-Photon-Interfaces for Single-Photon Generation and Storage — •Gunnar Langfahl-Klabes[1], Peter Nisbet[1], Jerome Dilley[1], Genko Vasilev[2], Daniel Ljunggren[3], and Axel Kuhn[1] — [1]Clarendon Laboratory, Parks Road, Oxford, OX1 3PU, UK — [2]Dept. of Phys., Sofia University, Bulgaria — [3]Dept. of Appl. Physics, KTH Stockholm, Sweden

Single atoms coupled to high-finesse cavities provide a unique way to deterministically generate a stream of single photons with MHz bandwidth and arbitrary pulse shape allowing for reversible state mapping. *Hot atomic ensembles* enable the generation, delay, storage and retrieval of single photons by manipulating an EIT control field.

In our lab we aim to generate single photons from a cavity using vacuum-stimulated Raman scattering, store them in a vapour cell, and check the retrieved photons for the preservation of their coherence properties. Generation and storage will utilise a Λ-type scheme connecting two Zeeman sub-levels in ^{87}Rb.

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

A new scheme for Custom Photon Shaping [1,2] is additionally presented.

[1] Vasilev, G. *et al.* Phys. Rev. A 80, 013417 (2009)
[2] Vasilev, G. *et al.* arXiv:0906.1989v1 [quant-ph]

Q 59.3 Fr 11:00 E 214

Quantum interference of photon pairs emitted by two remotely trapped atoms — •Julian Hofmann[1], Christoph Kurz[1], Michael Krug[1], Florian Henkel[1], Wenjamin Rosenfeld[1], Markus Weber[1], and Harald Weinfurter[1,2] — [1]Fakultät für Physik der Ludwigs-Maximilians-Universität, München — [2]Max-Planck-Institut für Quantenoptik, Garching

Entanglement of two remotely trapped atoms is a key element in long distance quantum communication - leading to applications like quantum repeaters and a future loophole-free test of Bell's inequality. One method to entangle two remote atoms is entanglement-swapping. A basic requirement for this protocol is quantum interference of photon pairs on a beam-splitter, where each photon is entangled with an atom respectively.

So far we demonstrated atom-photon entanglement generation in two independent experiments as well as long distance atom-photon entanglement distribution [1,2]. In order to achieve two photon inference with high fidelity both experiments have to be synchronised on a sub-nanosecond timescale.

Here we report on recent progress towards quantum interference of photon pairs emitted by two independent atoms and progress towards verification of atom-atom entanglement.

Group Report Q 59.4 Fr 11:15 E 214

Einzelphotonenquellen auf Basis von Farbzentren in Diamant — •David Steinmetz, Elke Neu, Christian Hepp, Roland Albrecht, Janine Riedrich-Möller und Christoph Becher — Technische Physik, Universität des Saarlandes, D-66123 Saarbrücken

Unter den Realisierungen praktikabler Einzelphotonenquellen für die Quanteninformation sind Farbzentren in Diamant vielversprechende Kandidaten: Als „künstliche Atome“ bieten sie die Vorteile der Langzeit-Stabilität und schmaler Emissionslinien bei Raumtemperatur, sowie die Möglichkeit zur Kopplung an Resonatorstrukturen zur Verbesserung der Emissionseigenschaften.

Wir stellen Untersuchungen an Si- und Ni-basierten Farbzentren vor. Letztere emittieren bei Raumtemperatur bei einer Wellenlänge von 810 nm mit einer Linienbreite von nur ≈ 2 nm. Dabei werden Sättigungszählraten von 69 kcounts/s erreicht, die Intensitätsautokorrelation bestätigt mit $g^{(2)}(0) = 0{,}1$ zweifelsfrei einzelne Emitter.

Darüber hinaus diskutieren wir zwei Ansätze zur Kopplung einzelner Farbzentren an Mikro-Resonatoren. Zum einen wurden faserbasierte Fabry-Pérot-Resonatoren aus einem Planspiegel und einer beschichteten, laserprozessierten Faserfacette realisiert, deren Vorteil darin besteht, dass sie durchstimmbar und automatisch fasergekoppelt sind. In einem zweiten Ansatz realisieren wir Mikroresonatoren in diamantbasierten photonischen Kristallen. Mittels eines fokussierten Ionenstrahls (FIB) wird die optimierte Resonatorgeometrie in eine nanokristalline

Diamantmembran geätzt. Der gemessene Gütefaktor $Q \approx 100$ ist maßgeblich durch die Absorption des Diamantfilms limitiert.

Q 59.5 Fr 11:45 E 214

Erzeugung gequetschter Lichtfelder mit einer Bandbreite von über 1 GHz — •Stefan Ast, Aiko Samblowski, Henning Vahlbruch und Roman Schnabel — Max-Planck Institut für Gravitationsphysik (Albert-Einstein Institut), Institut für Gravitationsphysik, Leibniz Universität Hannover, Callinstraße 38, D-30167 Hannover

Für die Quantenkommunikation können kontinuierliche Variablen verwendet werden, um einen Quantenschlüssel mittels gequetschter Lichtfelder zu übertragen. In der Quantenkryptographie hängt die erreichbare Datenrate sowohl vom Quetschgrad, als auch von der Bandbreite des Feldes ab. Zur Erzeugung eines breitbandig gequetschten Feldes wurde der Prozess der optisch parametrischen Verstärkung innerhalb eines Resonators verwendet. Dieser Resonator besaß zur Erhöhung der Pumpleistung eine hohe Finesse bei 532 nm. Für eine quasi unbeschränkte Bandbreite des gequetschten Feldes bei 1064 nm hatte der Resonator bei dieser Wellenlänge jedoch eine verschwindende Finesse. Es wurde im Experiment erstmals ein gequetschtes Feld mit mehr als 1 GHz Bandbreite erzeugt und mittels Homodyndetektion detektiert.

Q 59.6 Fr 12:00 E 214

Preparation of high fidelity single photons from waveguided parametric down-conversion — •Kaisa Laiho, Katiuscia N. Cassemiro, and Christine Silberhorn — Max Planck Institute for the Science of Light, Günther-Scharowsky-Straße 1/ Bau 26, D-91058 Erlangen

Single-photon sources play an important role in several quantum optical applications. Practical sources should meet the demands of high brightness, fidelity and efficiency. Parametric down-conversion offers a possibility to prepare and manipulate photonic states in a controlled way through heralding. However, spectral correlations between the twin beams and higher photon-number contributions can decrease the fidelity of the prepared single photon.

We experimentally study the suitability of a conventional waveguided PPKTP source for producing single-photon Fock states in combination with spectral filtering. The employed method enables a direct determination of the fidelity of the prepared state. We examine the spectral overlap between the heralded state and an independent reference with HOM interference. In addition, the contributions of higher photon-number components are characterized by reconstructing the statistics of the heralded state. Our results show that we prepare a single photon state with the fidelity of 78%.

Q 59.7 Fr 12:15 E 214

Radiometrische Kalibrierung von Einzel-Photonen Detektoren — •Waldemar Schmunk, Silke Peters, Mark Rodenberger, Helmuth Hofer und Stefan Kück — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Die rasche technische Weiterentwicklung von Einzelphotonenquellen und -detektoren ist mitverantwortlich für die Fortschritte in der Quantentechnologie innerhalb der letzten Jahre. In diesem Kontext gewinnt eine metrologische Charakterisierung solcher Einzelphotonenemitter und -detektoren sowie eine Rückführung auf bestehende Standards, wie das Kryoradiometer, zunehmend an Bedeutung.

Im folgenden wird eine radiometrische Methode aus dem Bereich der fasergekoppelten Detektoren vorgestellt, mittels derer die relative Quanteneffizienz von Single-Photon Avalanche Dioden (SPAD) kalibriert werden kann. Bei dieser Methode ist die explizite Kalibrierung von optischen Elementen im Strahlengang nicht erforderlich. Die momentan erreichte Standardmessunsicherheit liegt bei ca. 0,02. Für die Kalibrierung werden nicht-klassische Photonenquellen mit verschiedenen $g^2(0)$-Werten (0,1 bis 0,9) und Photonenraten (40000 *cps* bis 450000 *cps*) verwendet, die auf der Basis der laserinduzierten Fluoreszenz von Stickstoff-Fehlstellen-Zentren in Nanodiamanten beruhen. In der vorliegenden Arbeit werden die Messergebnisse präsentiert und das Messunsicherheitsbudget diskutiert. Außerdem wird der Einfluss der Mehrfachphotonenprozesse auf die Kalibrierungsergebnisse und die Reproduzierbarkeit der Messung betrachtet sowie ein Ausblick auf die Realisierung einer absoluten Rückführung gegeben.

Q 59.8 Fr 12:30 E 214

Quantum Combinatorics — •Malte Tichy[1], Markus Tiersch[2], Fernando de Melo[3], Florian Mintert[1], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg im Breisgau, Germany — [2]Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Technikerstr. 21A, A-6020 Innsbruck, Austria — [3]Instituut voor Theoretische Fysica, Katholieke Universiteit Leuven, Celestijnenlaan 200D, B-3001 Heverlee, Belgium

Interference effects relying on the identity of two photons find an important application in linear-optics based quantum information processing. Here we report on the statistical behavior of an arbitrary number of photons which scatter through a (Bell) multiport beam splitter. In doing so, we consider the realization probability of all possible final arrangements of the photons in the output ports. A versatile predictive law for the suppression of output configurations, hence a generalization of the Hong-Ou-Mandel effect of two photons, is derived. It is furthermore shown to apply for the majority of all possible events. Such multiparticle interference effects dominate at the level of single transition amplitudes, while a generic bosonic signature can be observed when the average number of occupied ports and the typical number of photons per port is considered. The results allow to classify in a common approach several recent experiments and theoretical studies and disclose many accessible quantum statistical effects involving many photons.

Q 60: Photonics III

Time: Friday 10:30–12:30 Location: F 128

Q 60.1 Fr 10:30 F 128

Nanophotonic Interactions of Resonant Cesium Atoms with 3D Opal Photonic Crystals — •Pepijn Pinkse[1], Philip Harding[1], Allard Mosk[1], and Willem Vos[1,2] — [1]Mesa+ Institute for Nanotechnology, University of Twente, PO Box 217, 7500 AE Enschede, The Netherlands — [2]FOM-AMOLF, Amsterdam, The Netherlands

We have introduced hot Cs vapor in a silica opal photonic crystal to observe novel nanophotonic properties. In comparison to dyes and quantum dots, gaseous alkali atoms are better understood and have strong and very narrow resonances $\omega/d\omega = 10^7$. As the temperature is increased, we observe shifts of the opals reflectivity peak in excess of 20%, which is attributed to the reduction of the silica to SiOx. This shift tunes the frequency of the photonic bands relative to the near-infrared Cs D1 transition. Simultaneously, the Cs resonances undergo dramatic changes in strength, off-resonance reflectivity, and shape. The results are in good agreement with a transfer-matrix model including the dispersion and absorption of two of the Cs hyperfine transitions.

Q 60.2 Fr 10:45 F 128

Applications of Selectively Filled Photonic Crystal Fibers — •Marius Vieweg, Timo Gissibl, and Harald Giessen — 4th Physics Institute, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Filling the holes of a photonic crystal fiber with different media has gained a lot of interest in the recent past for several different optical applications. With our method we are now able to close and fill the fibers selectively with different liquids. There are numerous possible applications for this new optical device. As two examples we present first a single-strand structure embedded in a standard photonic crystal fiber. Here we could measure spectral broadening due to self-phase modulation. As a second example we present a more complex structure. Several single holes infiltrated with a liquid form a liquid waveguide array, in which the waveguides are separated from each other by unfilled holes. We present here the linear propagation as well as coupling effects. For further applications it is possible to tailor the dispersion properties, the nonlinearity, as well as the spatial arrangement of the waveguides for nonlinear light propagation in two-dimensional discrete optical systems.

Q 60.3 Fr 11:00 F 128

Broadband electro-optic modulation in hybrid silicon-organic photonic crystals — •Stefan Prorok[1], Jan Hendrik Wülbern[1], Jan Hampe[1], Alexander Petrov[1], Manfred Eich[1], Jingdong Luo[2], Alex K.-Y. Jen[2], Andrea Di Falco[3], and Thomas F. Krauss[3] — [1]Hamburg University of Technology, Eissendorfer Str. 38, D-21073 Hamburg, Germany — [2]Department of Materials Science and Engineering, University of Washington, Seattle, Washington 98194-2120, USA — [3]School of Physics and Astronomy, University of St Andrews, North Haugh, St Andrews KY16 9AJ, Scotland

Electrically driven modulation of the optical properties of silicon based photonic devices so far relies on the refractive index change resulting from the modulation of carrier density in silicon either by carrier depletion, injection or accumulation. The achievable modulation speeds using these methods is limited by the time constants by which the carriers can be injected into or removed from the area of the optical mode. In nonlinear optical (NLO) polymers however, the electro-optic effect originates from the electronic hyperpolarisability of the organic molecules, which allows extremely high modulation speeds. Photonic devices based on a hybrid material system merging silicon and polymer are therefore attractive since they combine the strong light confining abilities of silicon with the superior NLO properties of polymers. Here we present a compact and ultra fast electro-optic modulator based on slotted photonic crystal waveguide that can be realized in two dimensional slabs of silicon as core material employing a nonlinear optical polymer as infiltration and cladding material. A Klopfenstein-taper like electrode structure is used to provide an external modulation signal to the slotted waveguide. The taper like structure yields an increased field strength of the modulation signal. The optical field enhancement in the slotted region increases the nonlinear interaction with the external electric field. Using this kind of setup we demonstrate electro-optic modulation up to 40 GHz at a driving voltage of approximately 1 Volt.

Q 60.4 Fr 11:15 F 128

Simulation analysis of one-dimensional photonic crystal Fabry-Perot filters — •Aws Al-Saadi[1], Bülent A. Franke[1], Shaimaa Mahdi[1], Sigurd Schrader[2], Viachaslau Ksianzou[2], Harald Richter[2], Stefan Meister[1], and Hans J. Eichler[1] — [1]Technische Universität Berlin, Institut für Optik und Atomare Physik, Berlin, Germany — [2]Technische Fachhochschule Wildau, Institut für Plasma- und Lasertechnik, Wildau, Germany

We present 3-D FDTD simulation results to specify the relevant parameters of photonic bandgap (PBG) structures in asymmetric strip waveguide. These mandatory simulations act as pre-processing step before CMOS fabricating of a one-dimensional photonic crystal (PhC) Fabry-Perot filters on a Silicon-on-Insulator (SOI) wafer. The microcavity filters were formed by holes inside of the stripe waveguide. Tuning the Fabry-Perot filter parameters (holes diameter, holes number and cavity length) which make effects on the transmission characteristics (center wavelength, spectral bandwidth, maximum transmission) were investigated. Influence of first and higher order cavity length as well as the number of cavities on the filter spectral shape was analyzed. Finally, in order to achieve the desired spectral shape of the filter function for several applications, a number of different cavities were designed and investigated. Simulation spectral results of the designed filters will be compared to the measurement results.

Q 60.5 Fr 11:30 F 128

Low temperature studies of near-infrared single-photon emitters in nanodimonds — •Petr Siyushev[1], Vincent Jacques[1], Igor Aharonovich[2], Florian Kaiser[1], Tina Müller[3], Laurent Lombez[3], Mete Atatüre[3], Stefania Castelletto[2], Steven Prawer[2], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]3.Physikalisches Institut, Universität Stuttgart, D-70550 Stuttgart, Germany — [2]School of Physics, University of Melbourne, VA 3010, Australia — [3]Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, UK

Source of indistinguishable single photons is a key requirement for the development of the linear quantum computing and large distance entanglement protocols. Such sources have been already demonstrated using molecules, single atoms, semiconductor quantum dots, and PDC.

Most of the color centers in diamond, including NV defects, have the strong disadvantage: their spectrally broad emission band. In contrast to them, the near-infrared defects in nanodiamonds under consideration emit light concentrated in the zero-phonon line. Beside that, the radiative lifetime is in the nanosecond range and the emission is perfectly linearly polarized. The spectral stability of infrared defects is then investigated using resonant excitation at the zero-phonon line. Although Fourier-transform emission was not achieved, our results show that it might be possible to use consecutive photons emitted by infrared defects in diamond nanocrystals to perform two photon interference experiments, which is at the heart of linear quantum computing protocols.

Q 60.6 Fr 11:45 F 128

Confocal microscopy and magneto-optical properties of cerium-doped YAG nanoparticles — •Roman Kolesov, Rolf Reuter, Fedor Jelezko, and Jörg Wrachtrup — 3. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, Stuttgart, D-70569

Fluorescent and magneto-optical properties of cerium-doped yttrium aluminium garnet (YAG) nanoparticles are studied by means of confocal microscopy under ambient conditions. It is shown that Ce:YAG nanoparticles exhibit very bright fluorescence which makes them perfect photostable fluorescent biomarkers. In addition, all-optical manupulation and detection of cerium electron spin is confirmed by measuring optically-induced magnetization and fluorescence quantum beats. Photon correlation measurements show that creation of a single emitting cerium center is feasible, therefore, making it a good candidate for all-optically addressable spin qubit.

Q 60.7 Fr 12:00 F 128

Single-Photon Imaging and Efficient Far Field Coupling to Single Plasmons — •Robert Lettow, Philipp Kukura, Michele Celebrano, Mario Agio, Stephan Goetzinger, and Vahid Sandoghdar — Laboratory of Physical Chemistry and optETH, ETH Zurich, CH-8093 Zurich, Switzerland

Coupling of light to a dipolar radiator is one of the most fundamental problems of light-matter interaction. Recent theoretical studies have predicted more than 80% extinction of a focused classical Gaussian beam by a single dipolar radiator [1]. In this talk, we show that single photons can be efficiently coupled to a dipole, realized by a single silver nanoparticle. As single photon sources we used dye molecules at cryogenic temperatures, which emit more than one million Fourier-limited photons per second [2, 3]. We used an interferometric technique in a confocal arrangement to image single silver nanoparticles excited by single photons both in transmission and reflection [4]. Since the scattered photons have been produced via an interaction with plasmons in the nanoparticle, our experimental arrangement provides an efficient way to excite and investigate single quantized plasmons. We discuss the prospects of our experimental arrangement for the efficient coupling of single photons to single molecules.

[1] G. Zumofen, et al., Phys. Rev. Lett. 101, 180404 (2008) [2] R. Lettow, et al., Optics Express 15, 15842 (2007). [3] V. Ahtee, et al., J. Mod.Opt. 56, 161-166 (2009) [4] M. Celebrano, R. Lettow, P. Kukura, M. Agio S. Götzinger, V. Sandoghdar, submitted.

Q 60.8 Fr 12:15 F 128

Assembly and coupling of diamond nanocrytsals to photonic- and plasmonic nanostructures — •Andreas Schell, Thomas Aichele, and Oliver Benson — Humboldt-Universität zu Berlin, Institut für Physik, Nanooptik, Berlin, Germany

The controlled assembly of single quantum emitters, metal nanoantennas, and micro-resonators to nano-photonic structures are attractive for quantum-optical building blocks in integrated photonic circuits. Surface plasmon polaritons (SPPs) in metal nanoparticles and -wires can concentrate and guide electromagnetic energy in volumes much smaller than the corresponding wavelength, providing intense interaction between light and matter.

We have prepared samples with gold and silver nanowires (NWs) as SPP waveguides. Diamond nanocrystals including NV defect centers as single-photon sources where first optically characterized on a separate substrate. Using the tip of an AFM, the emitter was transferred to the NW sample and placed next to a selected NW with high precision. After excitation, single photon emission directly from the emitter, as well as from each end of the NW was observed, confirming the excitation of single SPP in the waveguide. In further steps, the same emitter was moved to various locations with respect to the NW, in order to test the local plasmonic coupling. In this way, the behavior of one emitter in variable model configurations could be studied, while excluding effects arising from inhomogeneous distributions when using several emitters. The composition of more complex systems of metal nanostructures and single quantum-emitters will be discussed, as well.

Q 61: Ultrashort Laser Pulses: Applications IV

Time: Friday 10:30–12:00 Location: F 342

Q 61.1 Fr 10:30 F 342

Full control over the electric field using four liquid crystal arrays — •Fabian Weise and Albrecht Lindinger — Institut für Experimentalphysik, Freie Universität Berlin, Arnimalle 14, 14195 Berlin

Femtosecond pulse shaping is a very powerful technique and has already been successfully applied to a wide range of Systems. Extending the capability of phase and/or amplitude shaping to the modulation of the polarization, the pulses took account of the three dimensionality of physical systems. This results in larger optimization factors and a better understanding of the induced processes.

Initially, we will discuss different concepts of femtosecond polarization shaping and their experimental implementation. Then, we introduce a new setup for pulse shaping which enables us to simultaneously and independently modulate the three parameters phase, amplitude, and polarization [1]. This setup uses four liquid crystal arrays for the modulation and therefore it is able to produce any desired pulse shape with arbitrary polarization states.

Furthermore, we present an analytical approach where the pulse parameters distance, energy, ellipticity, orientation, phase, and chirps can be independently controlled. This parameterization allows to design a sequence of pulses in which the parameters of each sub-pulse can be individually set. Experimentally measured multi-pulses illustrate this method.

[1] Fabian Weise and Albrecht Lindinger Opt. Lett. 34, 1258-1260 (2009)

Q 61.2 Fr 10:45 F 342

Titan:Saphir-gepumptes Superkontinuum als Laserquelle für CARS Mikroskopie — •Lisa Kleinschmidt, Petra Gross, Carsten Cleff, Sebastian Beer und Carsten Fallnich — Institut für Angewandte Physik, Westfälische Wilhelms-Universität, Corrensstr. 2, 48149 Münster

Aufgrund der Möglichkeit, chemische Selektivität ohne eine Manipulation der Probe (beispielsweise durch Markierung mit einem Farbstoff) zu erreichen, ist die Nutzung kohärenter Anti-Stokes Raman-Streuung (CARS) im Bereich der nichtlinearen Mikroskopie besonders für die Lebenswissenschaften von Interesse. Bisher findet die CARS-Mikroskopie wegen der nötigen komplexen und teuren Laserquellen jedoch noch eine geringe Verbreitung.

Wir präsentieren eine neuartige Strahlquelle für die CARS-Mikroskopie. Dabei dient ein Titan:Saphir-Ultrakurzimpulslaser als Quelle für Pump- und Probewelle des CARS-Prozesses, während gleichzeitig ein Teil des Laserlichtes zur Erzeugung der Stokeswelle in eine mikrostrukturierte Faser (MSF) eingekoppelt wird. Während der Propagation des Lichtes in der MSF entsteht ein Soliton, dessen Zentralwellenlänge bei ca. 1040 nm liegt und das anschließend in einem Ytterbium-Faserverstärker nachverstärkt wird. Wir stellen erste Ergebnisse vor, für die die neuartige Laserquelle erfolgreich eingesetzt wurde, um Abbildungen einer Probe zu erstellen, die Informationen über die räumliche Verteilung der chemischen Bestandteile der Probe, z.B. Lipide, enthalten.

Q 61.3 Fr 11:00 F 342

Titan:Saphir-Oszillator mit konstanter Träger-Einhüllenden-Phase — •Stefan Rausch[1], Thomas Binhammer[2] und Uwe Morgner[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [2]VENTEON Laser Technologies GmbH, Garbsen, Germany

Wir präsentieren einen oktavbreiten Titan:Saphir-Laseroszillator, der mit Hilfe eines erweiterten f-zu-2f-Interferometers auf konstante Träger-Einhüllenden-Phase, bzw. Träger-Einhüllenden-Frequenz "null", stabilisiert werden kann. Bei einem so stabilisierten Pulszug weist jeder Puls einen identischen Verlauf des elektrischen Feldes auf. Mit einer solchen Lichtquelle ist es nun möglich, feld-abhängige Prozesse direkt, bei voller Oszillator-Pulswiederholrate und Ausgangsleistung zu untersuchen. Durch das identische Feld der aufeinander folgenden Pulse kann dabei auf kompliziertes, bei der großen Bandbreite nicht rekomprimierbares, Puls-Picking verzichtet, und lange Integrationszeiten umgesetzt werden.

Die weiteren Eigenschaften des Lasersystems sind eine nutzbare Ausgangsleistung von 200 mW bei einer Pulsdauer von 4,5 fs und eine Pulswiederholrate von 100 MHz. Mit diesem System wurde zum ersten Mal die spektrale Interferenz von Oszillator-Pulsen in einem zweiten f-zu-2f-Interferometer mit einem Spektrometer gemessen. Die aufgenommen Interferenzverläufe weisen einen sehr guten Kontrast auf, der den exzellenten Phasen-Lock des Systems beweist - für die aufgenommen Graphen interferieren 10^{11} Pulse. Die stabilisierte Phase des Systems kann über Glaskeile im Ausgangsstrahl eingestellt werden.

Q 61.4 Fr 11:15 F 342

Self-diffraction SPIDER — •Simon Birkholz, Sebastian Koke, Jens Bethge, Christian Grebing, and Günter Steinmeyer — Max Born Institute, Berlin, Germany

We discuss a novel variant of spectral phase interferometry for direct electric field reconstruction (SPIDER). This SPIDER variant relies on the $\chi^{(3)}$-process of self-diffraction (SD), which allows for octave-spanning phase-matching. With three photons on the input side of a $\chi^{(3)}$-process, there are actually two different versions of SD-SPIDER possible: one with two short pulse input photons and one with only one. In both cases, the SPIDER-signals are spectrally collocated with the input pulse. We experimentally demonstrated both of these possible SD-SPIDER variants, using a 500 μm BaF_2-crystal. Using pulses from a 400 nm white-light continuum, we measure a pulse duration of 8.2 fs. Finally, we discuss pros and cons of both novel SPIDER variants.

Q 61.5 Fr 11:30 F 342

Carrier-envelope phase-dependent electron emission from isolated, size-selected SiO_2 nanoparticles — •Jürgen Plenge[1], Egill Antonsson[1], Burkhard Langer[1], Christina Graf[1], Sergey Zherebtsov[2], Irina Znakovskaya[2], Izhar Ahmad[2], Adrian Wirth[2], Oliver Herrwerth[2], Sergei Trushin[2], Volodymyr Pervak[2], Stefan Karsch[2], Mark Stockman[2], Ferenc Krausz[2], Matthias Kling[2], Marc Vrakking[3], Thomas Fennel[4], and Eckart Rühl[1] — [1]Institut für Chemie und Biochemie, Freie Universität Berlin, Takustr. 3, 14195 Berlin — [2]Max-Planck Insti- tut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching — [3]FOM Institute for Atomic and Molecular Physics, Science Park 113, 1098 XG Amsterdam — [4]Institut für Physik, Universität Rostock, Universitätsplatz 3, 18051 Rostock

We report on the ionization of isolated, size-selected SiO_2 nanoparticles (d = 50 - 250 nm) with intense, phase-stabilized laser pulses ($\tau < 5$ fs). The experiments indicate a significant increase of the cut-off in the electron energy spectra of the SiO_2 nanoparticles as compared to xenon atoms for the same laser conditions. The asymmetry of the electron emission along the laser polarization axis shows a pronounced dependence on the carrier-envelope phase of the few-cycle laser field. Model calculations of the electron energy spectra and the emission asymmetry indicate that the high kinetic energy electrons result from electron recollision and rescattering in the enhanced field near the nanoparticle surface, where the penetration depth into the surface is a crucial parameter.

Q 61.6 Fr 11:45 F 342

Towards Nanostructure-Enhanced High-Harmonic Generation — •Murat Sivis[1], Katrin Siefermann[2], Yaxing Liu[2], Bernd Abel[2,3], and Claus Ropers[1] — [1]University of Göttingen, Courant Research Center Nano-Spectroscopy and X-Ray Imaging, Friedrich-Hund-Platz 1, D-37077 Göttingen, Germany — [2]University of Göttingen, Department of Physical Chemistry, Tammannstr. 6, D-37077 Göttingen, Germany — [3]University of Leipzig, Wilhelm-Ostwald-Institute for Physical and Theoretical Chemistry, Linnestr. 2, D-04103 Leipzig, Germany

Recent efforts to utilize optical field enhancements in metallic nanostructures for high-harmonic generation (HHG) have generated significant interest [S. Kim *et al.*, Nature **453**, 575 (2008)]. Using local plasmon resonances, the threshold for HHG can be substantially reduced, allowing for HHG by using unamplified few femtosecond laser oscillators. To date, rather limited information on the characteristics and scaling behavior of the relevant processes is available. Here, we present the first results of our study on harmonic generation with metallic nanostructures in the presence of a noble gas jet. We demonstrate the significant enhancement of harmonic generation of low orders. Experimental limitations and prospects of the approach are discussed.

Q 62: Quantum Control (with MO)

Time: Friday 10:30–12:15 Location: F 102

Q 62.1 Fr 10:30 F 102

Field-free orientation of molecules by femtosecond two-color laser fields — •Matthias Kling[1,2], Irina Znakovskaya[1], Sankar De[2], Dipanwita Ray[2], Fatima Anis[2], Nora Johnson[2], Irina Bocharova[2], Maia Magrakvelidze[2], Brett Esry[2], Charles Lewis Cocke[2], and Igor Litvinyuk[2] — [1]MPQ, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]JRML, K-State University, Manhattan, KS 66506, USA

We report on the first experimental observation of nonadiabatic field-free orientation of a heteronuclear diatomic molecule (CO) induced by an intense two-color (800 and 400 nm) femtosecond laser field [1]. We monitor orientation by measuring fragment ion angular distributions after Coulomb explosion with an 800 nm pulse. The orientation of the molecules is controlled by the relative phase of the two-color field. The results are compared to quantum mechanical rigid rotor calculations. The demonstrated method can be applied to study molecular frame dynamics under field-free conditions in conjunction with a variety of spectroscopy methods, such as high-harmonic generation, electron diffraction, and molecular frame photoelectron emission.

[1] De et al., Phys. Rev. Lett. 103, 153002 (2009)

Q 62.2 Fr 10:45 F 102

Die Rolle der Elektronendynamik in der Quantenkontrolle molekularer Zustände durch intensive Laserfelder — •Robert Simmering[1], Philipp von den Hoff[1], Tim Bayer[2], Matthias Wollenhaupt[2], Thomas Baumert[2] und Regina de Vivie-Riedle[1] — [1]Ludwig-Maximilians-Universität, München, Deutschland — [2]Universität Kassel, Kassel, Deutschland

Intensive phasenmodulierte Kurzpulsfelder ermöglichen neuartige Quantenkontrollszenarien aufgrund ihrer Kohärenz und der AC Starkverschiebung. An atomarem Kalium konnte bereits ein Starkfeldkontrollschema basierend auf der selektiven Besetzung einzelner bekleideter Zustände (Selective Population of Dressed States, SPODS) erfolgreich demonstriert werden [1]. Dieses Kontrollszenarium wurde nun auf das Molekül K_2 übertragen und theoretisch analysiert. Als Kontrollziel wurde die selektive Besetzung der elektronisch angeregten Zustände $4\Sigma_g^+$ und $5\Sigma_g^+$ des K_2 Moleküls über SPODS gewählt. Im speziellen wurde auf zwei Fragen eingegangen: I) Kann man in molekularen System eine ähnliche hohe Selektivität erreichen, also einen Zustand maximaler Kohärenz erzeugen? II) Welchen Einfluss hat dabei die Elektronendynamik? Zur Klärung dieser Fragen ist es notwendig das Wechselspiel von Kern- und Elektronendynamik zu betrachten. Hierzu haben wir unsere ab initio basierte Methode [2] eingesetzt und die Elektronendynamik auf sechs gekoppelten Zuständen verfolgt.

[1] Wollenhaupt et al., J. Opt. B 7 (2005) S270 - S276
[2] D. Geppert, J. Phys. B: At. Mol. Opt. Phys., 41 (2008)

Q 62.3 Fr 11:00 F 102

New studies on photo induced bond breaking in model peptides — •Ihar Shchatsinin, Nickolai Zhavoronkov, Ingolf Volker Hertel, and Claus Peter Schulz — Max Born Institute, Max-Born-Str. 2A, D-12489 Berlin, Germany

Small peptides possessing a -CO-NH-CHR-CO- moiety may be regarded as "model peptides". Recently we have reported the experimental results on specific bond breaking in the one of them (Ac-Phe-NHMe) using the pulse shaping technique [1]. We have shown ability to cleave the peptide bond in this molecule preferentially with shaped femtosecond laser pulses, while keeping other more labile bonds intact [2]. These results demonstrate the potential of the pulse shaping technique and can be considered as a first move toward an analytic tool for protein sequencing. As a step further now we present detailed investigations of selective bond breaking using other model peptides. Studies on different chromophores and backbone structures provide new information about the photo induced bond breaking phenomena in model peptides. The photo physical and photo chemical mechanisms involved in the observed phenomena will be discussed in this contribution.

[1] T. Laarmann, I. Shchatsinin, P. Singh, N. Zhavoronkov, M. Gerhards, C.P. Schulz, I.V. Hertel, J. Chem. Phys. 127, 201101 (2007)
[2] T. Laarmann, I. Shchatsinin, P. Singh, N. Zhavoronkov, C.P. Schulz, I.V. Hertel, J. Phys. B 41, 074005 (2008)

Q 62.4 Fr 11:15 F 102

Control of ionization processes by tailored femtosecond pulses in dielectric materials — •Lars Englert, Dirk Otto, Jutta Mildner, Alexander Horn, Matthias Wollenhaupt, and Thomas Baumert — Universität Kassel, Institut für Physik und CINSaT, Heinrich-Plett-Str. 40, D-34132 Kassel, Germany

Femtosecond laser pulses tailored by spectral phase modulation are successfully used for coherent control of atoms and molecules [1,2]. We present experiments [3] and simulations on the ionization processes in a wide band gap material with tailored femtosecond laser pulses.

On the ultrafast timescale tailored laser pulses are used to excite electrons from the valence band to quasifree states in the conduction band by multiphoton ionization and avalanche ionization. Relaxation back to the valence band or trapping to interbandgap states leads to depopulation of the quasi free states. Reaching a critical quasifree electron density results in material ablation.

The effects of laser pulses with asymmetric intensity and frequency distributions in the time domain are studied with respect to material ablation thresholds and structure morphologies on the nanometer scale.

[1] M. Wollenhaupt *et al.*, Annu. Rev. Phys. Chem. **56**, 25–56 (2005)
[2] T. Brixner *et al.*, Chap. 9, "Femtosecond Laser Spectroscopy", Editor P. Hannaford, Springer (2005)
[3] L. Englert *et al.*, Opt. Express **15**, 17855 (2007)

Q 62.5 Fr 11:30 F 102

Waveform control of the dissociative ionization of D2 with few-cycle pulses — •Irina Znakovskaya[1], Gilad Marcus[1], Sergey Zherebtsov[1], Boris Bergues[1], Xun Gu[1], Yunpei Deng[1], Philipp von den Hoff[2], Marc J.J. Vrakking[3], Reinhard Kienberger[1], Ferenc Krausz[1], Regina de Vivie-Riedle[2], and Matthias Kling[1] — [1]MPQ, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]LMU Department Chemie, Butenandt-Str. 11, 81377 München, Germany — [3]FOM-Institute AMOLF, Science Park 113, 1098 XG Amsterdam, The Netherlands

A first successful example of electron localization and its control by waveform controlled few-cycle pulses (5fs, 760 nm) was demonstrated on the dissociative ionization of the prototype molecules D_2 [1] and HD [2], a high degree of light-waveform control over the directional emission of D^+ fragments was observed. Here we report on the first experimental observation of waveform control of the dissociative ionization of D_2 with recently developed intense CEP stabile few cycle laser pulses at the central wavelength of 2.1 μm. We observed a high degree of asymmetry for D^+ fragments in the low energy range corresponding to bond softening, whereas in the experiments at 760 nm recolision excitation was a vital element in the mechanism responsible for the observed phase control.

[1] Kling et al., Science 312, 246 (2006)
[2] Kling et al., Mol. Phys. 106, 455 (2008)

Q 62.6 Fr 11:45 F 102

Chemoselective quantum control of carbonyl bonds in Grignard reactions. — •Markus Kowalewski[1], Caroline Gollub[2], Sebastian Thallmair[1], and Regina de Vivie-Riedle[1] — [1]Department Chemie und Biochemie, Ludwig-Maximilians-Universität München — [2]Institut für Werkstoffwissenschaft und Max-Bergmann-Zentrum für Biomaterialien, Technische Universität Dresden, Max Planck Institut für Physik Komplexer Systeme, Dresden

Under laboratory conditions Grignard reagents like methyl magnesium bromide do not react selectively with respect to different carbonyl bonds. We investigate theoretically the perspectives of selective laser excitation of CO bonds in mixed systems. As an representative example a mixture of cyclohexanone and cyclopentanone is chosen as reagent. The laser is supposed to provide the activation energy and to adopt the function of a protective group. The control aim is to elongate the CO bond of one compound until the bond length required in the transition state is reached. We optimized picosecond laser pulses in the infra red regime with optimal control theory (OCT) which excite only the desired carbonyl bond. From the theoretical results laser assisted chemo-selectivity seems possible to a large extent. To obtain control not only on the final product but also on the excitation mechanism the behavior of the OCT algorithm for various initial conditions and under frequency restrictions is investigated.

Q 62.7 Fr 12:00 F 102

Accurate generation of polarization-shaped fs laser pulses with application to photoelectron imaging spectroscopy — •Jens Köhler, Marc Krug, Cristian Sarpe-Tudoran, Tim Bayer, 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

Femtosecond polarization pulse shaping is a tool to generate laser pulses with a time-dependent polarization profile on an ultrashort timescale. The realization of such pulses is often affected by undesired polarization-dependent amplitude modulations and phase shifts introduced by the pulse shaper itself as well as other optical elements in the beam. In order to ensure accurate generation of polarizationshaped pulses, these effects have to be taken into account and the optical setup has to be corrected accordingly. Different schemes for detection and compensation of these effects are presented and compared. Recently, realization of accurately generated polarization-shaped laser pulses in the interaction region of a vacuum chamber has been demonstrated by photoelectron imaging spectroscopy [1]. Currently, we extend the application of our polarization shaping capabilities to the generation of complex-shaped free-electron wave packets characterized by three-dimensional tomographic reconstruction methods [2]. First results are presented.

[1] M. Wollenhaupt et al., Applied Physics B, 95(2), 245-259, (2009)
[2] M. Wollenhaupt et al., Applied Physics B, 95(4), 647-651, (2009)

Q 63: Quantum Effects: Entanglement and Decoherence III

Time: Friday 14:00–16:00 Location: A 310

Group Report Q 63.1 Fr 14:00 A 310

Multipartite entanglement: Creation with identical particles and general classification — •Malte Tichy, Benno Salwey, Klaus Mayer, Florian Mintert, and Andreas Buchleitner — Albert-Ludwigs-Universität Freiburg

We study the classification of entanglement in high-dimensional multipartite systems and processes to generate states of distinct entanglement properties by means of linear optics. Two states are said to contain a different kind of entanglement if they cannot be obtained from each other with finite probability just by means of local manipulation. We derive a general framework to discriminate inequivalent entanglement properties in high dimensional multi-partite systems via permutation symmetries of multiple tensor products of the quantum states. Having identified distinct classes of entanglement, we investigate which of those can emerge in multidimensional many-particle quantum walks with bosons and fermions and point out the differences to analogous situations with distinguishable particles. In particular we focus on the generalized n-port beam splitter, easily realizable for photons with linear optics elements only, and the fourpartite qubit case.

Q 63.2 Fr 14:30 A 310

Optimal dynamical control of many-body entanglement — •Felix Platzer, Florian Mintert, and Andreas Buchleitner — Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

We derive time-dependent control fields, which are suitably tailored to maximize a multipartite entanglement measure and thus steer a given system towards highly entangled states. The usage of an entanglement measure as target functional naturally leads to an optimization over the multitude of states with equivalent entanglement properties, and results in the creation of the most suitable highly entangled state, i.e. the state which is most rapidly produced and most robust against the predominant type of decoherence. This rather general framework is then readily applied to nitrogen vacancy centers in diamond, whose permanent and uncontrollable interaction strengths impede the creation of high entanglement. Not only does our control scheme achieve and maintain strong entanglement through local driving only, but it is also intrinsically robust to possible experimental imperfections, e.g. imperfectly estimated coupling constants or imperfect control sequences.

Q 63.3 Fr 14:45 A 310

Entanglement-enhanced energy transport — •Torsten Scholak[1], Fernando de Melo[1,2], Thomas Wellens[1], Florian Mintert[1], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, D-79104 Freiburg, Germany — [2]Instituut voor Theoretische Fysica, Katholieke Universiteit Leuven, Celestijnenlaan 200D, B-3001 Heverlee, Belgium

In many areas of physics we witness dramatic differences between classical and quantum transport. In general, we expect quantum features to fade away on large scales, due to the ever more unavoidable – and detrimental – influence of the environment which scrambles relative phases and damps quantum amplitudes. Recent experimental evidence suggests, however, that the functional efficiency of large biomolecular units may stem from quantum coherence phenomena, despite strong environment coupling. We explain such efficiency, under the assumption that evolution is able to steer finite size three dimensional systems into molecular conformations with optimal coherent transport properties. It turns out that such optimal conformations are characterized by specific, optimal entanglement properties between different sites of the molecular complex.

Q 63.4 Fr 15:00 A 310

Dissipation induced Tonks-Girardeau gas of polaritons — •Martin Kiffner and Michael Hartmann — Technische Universität München, Physik-Department I, James-Franck-Straße, 85748 Garching, Germany

In one-dimensional systems, bosons can behave with respect to many observables as if they were fermions. This strongly correlated regime of a Tonks-Girardeau (TG) gas regime can be reached for strong repulsive interactions between the particles. Recently, an experiment [1] with cold molecules showed that not only elastic interactions, but even two-particle losses alone are able to create a TG gas.

Here we derive a scheme for the generation of a Tonks-Girardeau (TG) gas of polaritons with purely dissipative interaction [2]. We put forward a master equation approach for the description of stationary light in atomic four-level media and show that, under suitable conditions, two-particle decays are the dominant photon loss mechanism. These dissipative two-photon processes increase the interaction strength by at least one order of magnitude as compared to their dispersive counterparts and can drive the polaritons into the TG regime. Our scheme allows to measure local and non-local correlations of the TG gas via quantum optical techniques.

[1] N. Syassen, D. M. Bauer, M. Lettner, T. Volz, D. Dietze, J. J. Garcia-Ripoll, J. I. Cirac, G. Rempe, S. Dürr, Science **320**, 1329 (2009).
[2] M. Kiffner and M. J. Hartmann, arXiv:0908.2055.

Q 63.5 Fr 15:15 A 310

Optimal quantum many-body dynamics — •Felix Platzer[1], Torsten Scholak[1], Fernando de Melo[2], Florian Mintert[1], and Andreas Buchleitner[1] — [1]Albert-Ludwigs-Universität Freiburg — [2]Katholieke Universiteit Leuven

We investigate the evolution of quantum many-body systems with permanent inter-particle interactions and their ability to evolve into highly entangled states. We are following a statistical approach in which we test the dynamics of coupled spins, a random spatial arrangement of which induces randomly distributed coupling elements. Correlating entanglement properties and transport efficiency over many realizations reveal that high multi-partite entanglement is an indispensable catalyst for energy transport. Whereas optimality is of extreme statistical unlikeliness, we argue that evolution could have found exactly such untypical geometries resulting in the astonishing transport efficiency of biological compounds. In the generic case where the natural coupling mechanism does not result in the evolution to high entanglement we can use suitably tailored time-dependent control fields to steer the system towards a desired class of highly entangled states. In our approach to coherent control this is achieved with the help of a multipartite entanglement measure as target functional, what leaves the freedom to find those states with given entanglement properties that have advantageous dynamical properties. Applying our framework to NV-centers, we find rapid evolution into those highly entangled states that are robust to against the prevailing decoherence mechanism.

Q 63.6 Fr 15:30 A 310

Assymptotic multipartite entanglement at finite temperature
— •Simeon Sauer, Florian Mintert, and Andreas Buchleitner — Physikalisches Institut Albert-Ludwigs-Universität Freiburg

When a many-body system is coupled to a noisy, thermal environment, it rapidly loses its coherences. Multipartite entanglement relies on such coherences, and therefore decays accordingly; and it does so, the faster, the larger the system and the hotter the environment is. However, external coherent driving is likely to slow down such decay, and it might even stabilize entanglement at a finite level.

Here, we study the entanglement dynamics in a periodically driven many-body system, embedded in a thermal environment. With the help of the Floquet formalism, we identify steady states and characterize their entanglement properties. With this approach, we look for conditions (such as strength and frequency of the driving, and environmental temperature) that maintain a finite amount of multipartite entanglement for asymptotically large times.

Q 63.7 Fr 15:45 A 310

Attosecond neutron scattering from open quantum systems
— •C. Aris C.-Dreismann — Institute of Chemistry, Technical University of Berlin, D-10623 Berlin, Germany

Neutron Compton scattering (NCS) from single nuclei of atoms in molecules, e.g. H2 (and/or single atoms, e.g. He) is effectuated in the attosecond timescale. The related "scattering time" is considered in detail, in relation with the Uncertainty Relations. It is shown that the entity "scattering time" gives a statistical measure of the length of the time interval during which an elementary neutron-nucleus collision may occur, in the same way that the spatial extent of a particle wavefunction (or wavepacket) gives a statistical measure of the extent of the region in which the particle may be found. Consequently, the elementary neutron-nucleus scattering process represents a time-interference phenomenon over the sub-femtosecond "scattering time" window. Moreover, the very short-range strong interaction of the neutron-nucleus collision implies that the scattering system (e.g. a proton partically "dressed" with electrons) must be considered as an open quantum system. Experimental results from H2, D2 and HD are mentioned and their "anomalous" scattering property [1] in the attosecond timescale is qualitatively discussed, also in connention with the Schulman-Gaveau effect [2].

[1] G. Cooper, A. P. Hitchcock, C. A. Chatzidimitriou-Dreismann, PRL 100, 043204 (2008); and references therein. [2] L. S. Schulman, B. Gaveau, PRL 97, 240405 (2006).

Q 64: Matterwave Optics II

Time: Friday 14:00–16:00 Location: A 320

Q 64.1 Fr 14:00 A 320

Berry phase in atom optics
— •Polina V. Mironova, Maxim A. Efremov, and Wolfgang P. Schleich — Universität Ulm, Ulm, Deutschland

We suggest to use the concept of the Berry phase to create an atomic lens. In particular, we consider the scattering of an atom by a near-resonant standing light wave, assuming an adiabatic turn-on and turn-off of the interaction. Within the rotating wave approximation and the adiabatic approximation on the atomic center-of-mass motion we find that the dynamical phase is cancelled out and the final state of the atom differs from the initial one only by twice the familiar Berry phase, which depends on the atomic external degrees of freedom. Therefore, the scattering process is determined by the atomic center-of-mass position.

Q 64.2 Fr 14:15 A 320

Distinction of structural isomers in molecule interferometry
— •Sandra Eibenberger[1], Stefan Gerlich[1], Jens Tüxen[2], Marcel Mayor[2], and Markus Arndt[1] — [1]University of Vienna, Quantum Optics, Quantum Nanophysics, Quantum Information, Boltzmanngasse 5, 1090 Wien — [2]University of Basel, Department of Chemistry, St. Johannsring 19, CH-4056 Basel

Kapitza-Dirac Talbot-Lau interferometry (KDTLI) has already been established as a well-adapted tool for studying the quantum wave nature of massive and complex particles.

De Broglie coherence is to first order only associated with the center-of-mass motion. In the presence of external perturbations, quantum metrology however also becomes highly sensitive to internal molecular properties, such as electric susceptibilities or dipole moments, which may affect the interference contrast or phase shift without introducing genuine decoherence.

New high-contrast interference measurements now show for the first time the possibility to distinguish two structural isomers, i.e. two sorts of perfluoralkyl-functionalized molecules with the same mass (1592 amu) and the same chemical sum formula.

Q 64.3 Fr 14:30 A 320

High-Precision Matter-Wave Interferometry
— •Naceur Gaaloul[1], Ernst Maria Rasel[1], and das QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Quantenoptik, LU Hannover — [2]ZARM, Uni Bremen — [3]Institut für Physik, HU Berlin — [4]Institut für Laserphysik, Uni Hamburg — [5]Institut für Quantenphysik, Uni Ulm — [6]MPQ, München — [7]Institut für angewandte Physik, TU Darmstadt — [8]Midlands Ultracold Atom Research Centre, University of Birmingham, UK — [9]FBH, Berlin

The recent developments in quantum optics transformed atom interferometry from pure fundamental research to a powerful technique giving birth to a multitude of tools for metrology, gravimetry and fundamental physics. Besides the measurement of fundamental constants (Fine structure constant, gravitational constants) or the tests of fundamental laws (Equivalence principle), the application of atom interferometers for gravimetry or generally for the measurement of inertial forces (Earth rotation, acceleration) became a central focus of research. Indeed, atom interferometers show not only a high sensitivity compared to other techniques but also an intrinsically high accuracy comparable to atomic clocks. Our efforts to advance the field of atom interferometry by carrying out challenging experiments, building networks and identifying the physical limitations as well as the potential applications will be reported in this contribution.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50WM0835-0839.

Q 64.4 Fr 14:45 A 320

Atom Interferometry in a mobile setup to measure local gravity
— •Alexander Senger, Malte Schmidt, Matthias Hauth, Sebastian Grede, Christian Freier, and Achim Peters — Humboldt Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Hausvogteiplatz 5-7, 10117 Berlin

GAIN (Gravimetric Atom Interferometer) is a mobile and robust gravimeter, which is based on interfering ensembles of laser cooled ^{87}Rb atoms in an atomic fountain configuration. With a targeted accuracy of a few parts in 10^{10} for the measurement of local gravity, g, this instrument will offer about an order of magnitude improvement in performance over the best currently available absolute gravimeters. Together with the capability to perform measurements directly at sites of geophysical interest, this opens up the possibility for a number of interesting applications. Furthermore future satellite sensors based on atom interferometry will benefit from GAIN technology and experience.

We introduce the working principle of our interferometer and give an outline of the subsystems needed for a mobile setup. First measurements of local gravity acceleration are presented and the next steps necessary to achieve full accuracy are discussed.

Q 64.5 Fr 15:00 A 320

Space Atom Interferometer (SAI)
— •Malte Schmidt[1], Guglielmo Tino[2], Philippe Bouyer[3], Ernst Rasel[4], Wolfgang Ertmer[4], Klaus Sengstock[5], Arnaud Landragin[6], Massimo Inguscio[7], Wolfgang Schleich[8], Reinhold Walser[8], Claus Laemmerzahl[9], Kai Bongs[10], and Achim Peters[1] — [1]Humboldt-

Universität zu Berlin — [2]Università di Firenze — [3]Institut d'Optique, Orsay — [4]Institut für Quantenoptik, Hannover — [5]Universität Hamburg — [6]SYRTE, Paris — [7]LENS, Firenze — [8]Universität Ulm — [9]ZARM, Bremen — [10]University of Birmingham

Since 1992, matter wave interferometry has been used in many laboratories for a variety of fundamental physics experiments, e.g. measurement of the fine-structure and gravity constants. However, due to the complexity of these experiments, they were confined to laboratory environments. In recent years, however, efforts have been undertaken to develop mobile atom interferometers. These new sensors open up the possibility to perform on-site high-precision measurements of rotations, gravity gradients as well as absolute accelerations.

We present the SAI project (ESA contract 20578/07/NL/VJ) that investigates both experimentally and theoretically the different aspects of placing atom interferometers in space: the equipment needs, the resulting device sensitivities, and what physics might be done using such systems. For these purposes, the project brings together European institutions to share their mutual expertise and to collaborate on the construction of an atom interferometer testbed geared towards future applications in space. We give an overview of the sensor's ultra-compact design and report on the status of its first completed subsystems.

Q 64.6 Fr 15:15 A 320

Towards near-field interferometry with massive metal clusters — •Philipp Haslinger[1], Nadine Dörre[1], Philipp Geyer[1], Stefan Nimmrichter[1], Klaus Hornberger[2], Bernd v. Issendorff[3], and Markus Arndt[1] — [1]Faculty of Physics, University of Vienna, Austria — [2]Max-Planck Institute for the Physics of Complex Systems, Dresden, Germany — [3]Universität Freiburg, Germany

Throughout the last decade quantum interferometry with complex matter has grown from a Gedankenexperiment to a well developed field of research. Here we discuss the merits and draw-backs of far-field diffraction at material [1] and optical [2] gratings as well as a near-field interferometer that allows to increase both the detected flux as well as the mass limits in de Broglie interferometry [3,4]. A most promising instrument, at present, is an all-optical Talbot-Lau interferometer. It promises to shift matter wave interferometry to masses even beyond the limit of a million atomic mass units [5]. We discuss how such an interferometer can become important for exploring fundamental decoherence and dephasing phenomena and how it can become useful as a tool for measuring the electromagnetic or structural properties of nanoparticles [6].

[1] Arndt et al. Nature 401, 680 (1999) [2] O. Nairz et al. Phys. Rev. Lett. 87, 160401 (2001) [3]Brezger et al. Phys. Rev. Lett. 88, 100404 (2002) [4]Gerlich et al. NATURE PHYSICS 3, 711 (2007) [5]Reiger et al. Opt. Comm. 264, 326 332 (2006) [6]Gerlich et al. Angew.Chem.Int.Ed. 47, 6195 (2008)

Q 64.7 Fr 15:30 A 320

Quantum interference lithography with large molecules — •Philipp Geyer, Thomas Juffmann, Stefan Truppe, Sarayut Deachapunya, Andras Major, Hendrik Ulbricht, and Markus Arndt — University of Vienna Austria

Already in the past, Talbot-Lau interferometry had proven to be a suitable tool for testing the wave-particle duality of complex and massive molecules.

We here report the implementation of a new detection scheme for molecule interferometry: the near-field interference pattern is deposited onto an atomically clean Si(111)7x7 surface, immobilized and subsequently imaged using a scanning tunnelling microscope (STM). We present interferograms of C60 buckyballs written onto the reconstructed silicon surface. STM imaging allows to detect every single molecule with nanometer resolution within the interference pattern. Dominantly applied as a detecting tool in quantum interference experiments molecule lithography also opens an interesting perspective on soft and non-contact surface deposition of molecular nanopatterns.

Q 64.8 Fr 15:45 A 320

The weak-coupling master equation of polarizable particles in a pumped cavity — •Stefan Nimmrichter[1], Klemens Hammerer[2], Helmut Ritsch[2], and Markus Arndt[1] — [1]Faculty of Physics, University of Vienna — [2]Institute for Theoretical Physics, University of Innsbruck

We derive a master equation for the motion of a polarizable particle weakly interacting with strongly pumped cavity modes. We follow the analogy to the light-pressure coupling model for the motion of cavity mirrors, while the particle motion is not considered to be deeply trapped in the optical potential. Focussing on massive particles with uncontrollable internal dynamics such as large molecules and clusters, our derivation bases on a phenomenological model of off-resonant particle-light interaction. The resulting friction and diffusion coefficients are in good agreement with former semiclassical calculations for atoms and small molecules in weakly pumped cavities, while the current rigorous quantum treatment is meant to throw light on the feasibility to optically manipulate beams of hot and massive particles.

Q 65: Quantum Gases : Lattices III

Time: Friday 14:00–16:00 Location: E 001

Group Report Q 65.1 Fr 14:00 E 001

Quantum Gases in Hexagonal Optical Lattices — •Parvis Soltan-Panahi, Julian Struck, Georg Meineke, Wiebke Plenkers, Andreas Bick, Christoph Becker, Patrick Windpassinger, and Klaus Sengstock — Luruper Chaussee 149, 22761 Hamburg, Deutschland

The physics of ultracold quantum gases in optical lattices has developed to a fascinating field with many connections to different areas like condensed matter physics, quantum computing or ultracold chemistry. So far, most experiments have been performed in cubic lattice structures with spin-independent potentials. We have realized a "magnetic", optical lattice with hexagonal symmetry, where atoms of different spin quantum number feel different potentials, e.g., having different periodicity. This leads to a specific "magnetic ordering" and state-dependent Mott-insulator transition points or more generally to new options to study "magnetism" in optical lattices.
In particular, we show that in case of a bosonic spin-mixture, interaction induced blocking of tunneling occurs. This manifests in terms of a significant shift of the quantum point of phase transition. To analyze the occupation of different lattice wells by the individual components of the spinor condensate we have developed a microwave spectroscopy technique that allows for unambiguous identification of different components and specific types of lattice sites. This enables us to observe a strong dependency of the atom-distribution due to the existence of several spin-components within the superfluid- and the Mott-insulating regime.

Q 65.2 Fr 14:30 E 001

Linear response thermometry with ultracold fermions in an optical lattice — •Daniel Greif, Leticia Tarruell, Thomas Uehlinger, Robert Jördens, Niels Strohmaier, Henning Moritz, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

The low-temperature Fermi-Hubbard model is expected to capture many fascinating phenomena such as d-wave superfluidity. In our experiment we use a repulsive two-component Fermi gas loaded into a 3D optical lattice to realize this simple model Hamiltonian. Currently several experiments are reaching out to achieve even lower temperatures with novel cooling schemes in order to access and characterize the magnetically ordered state. This requires a temperature sensitive probe in the lattice.

We show how linear response to weak lattice modulation can be used as a thermometer in the lattice. This can also be employed as a detector for local spin ordering.

Q 65.3 Fr 14:45 E 001

Quantitative temperature determination of ultracold fermions in an optical lattice — •Thomas Uehlinger[1], Robert Jördens[1], Daniel Greif[1], Niels Strohmaier[1], Leticia Tarruell[1], Henning Moritz[1], Tilman Esslinger[1], Lorenzo De Leo[2], Corinna Kollath[2], Antoine Georges[2,3], Vito Scarola[4], Lode Pollet[5], Evgeni Burovski[6], Evgeny Kozik[7], and Matthias Troyer[7] — [1]Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland — [2]Centre de Physique Théorique, CNRS, Ecole Polytechnique, 91128 Palaiseau, France — [3]Collège de France, 11 place Marcelin Berthelot, 75231 Paris, France — [4]Department of Physics, Virginia Tech, Blacksburg, Virginia 24061, USA — [5]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA — [6]Laboratoire de Physique Théorique et Modèles Statistiques, Université Paris-Sud, 91405 Orsay, France — [7]Institute for Theoretical Physics, ETH Zurich, 8093 Zurich, Switzerland

While experiments with ultracold fermions in optical lattices are approaching magnetically ordered states of the Fermi Hubbard model, a reliable determination of temperature in the regime of intermediate interaction has yet not been possible. We compare precise measurements of the double occupancy in our system with both DMFT calculations and the high-temperature series expansion. Both methods agree with the experimental data over a wide range of parameters. The entropy per atom in the center of the trap is about twice as large as the entropy required to enter the Néel phase. The corresponding temperature reaches values on the order of the tunneling energy t.

Q 65.4 Fr 15:00 E 001

Multiphoton-like transitions in driven optical lattices — •Stephan Arlinghaus, Matthias Langemeyer, and Martin Holthaus — Institut für Physik, Carl von Ossietzky Universität, D-26111 Oldenburg

Recent experiments with ultracold atoms in time-periodically forced optical lattices performed by the Pisa group have clearly revealed phenomena related to forcing-induced interband transitions. In this talk we will show that theoretical concepts known from laser-induced electronic transitions in atoms or molecules can be transferred to the description of such interband transitions occurring in optical lattices. In particular, we discuss the emergence of multiphoton-like resonances, and outline how these can be detected experimentally. Our results indicate that ultracold atoms in lattices subjected to forcings with slowly varying strength may serve as powerful probes for coherently controlled quantum dynamics.

Q 65.5 Fr 15:15 E 001

The Dicke Quantum Phase Transition in a Superfluid Gas Coupled to an Optical Cavity — •Kristian Baumann, Christine Guerlin, Ferdinand Brennecke, Silvan Leinss, Rafael Mottl, and Tilman Esslinger — IQE, ETH Zürich, Switzerland

A fundamental concept to describe the collective matter-light interaction is the Dicke model which has been predicted to how an intriguing quantum phase transition. We have realize d the Dicke quantum phase transition in an open system formed by a Bose-Einstein condensate coupled to an optical cavity, and observed the emergence of a self-organized supersolid phase. The phase transition is driven by infinitely long-ranged interactions between the condensed atoms. We show that the phase transition is described by the Dicke Hamiltonian, including counter-rotating coupling terms, and that the supersolid phase is associated with a spontaneously broken spatial symmetry. The boundary of the phase transition is mapped out in quantitative agreement with the Dicke model.

Q 65.6 Fr 15:30 E 001

Ginzburg-Landau Theory for the Jaynes-Cummings-Hubbard Model — •Christian Nietner[1] and Axel Pelster[2,3] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Institut für Physik und Astronomie, Karl-Liebknecht-Str. 24 14476 Potsdam, Germany — [3]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

We develop a Ginzburg-Landau theory for the Jaynes-Cummings-Hubbard model which describes the thermodynamics of photons evolving in a lattice of cavities filled with a single two-level atom. To this end we follow Ref. [1] and calculate the effective action to first-order in the hopping expansion. Within this Ginzburg-Landau description we reproduce the finite-temperature mean-field quantum phase boundary of Refs. [2,3] between a Mott-insulating and a superfluid phase of polaritons. Furthermore, we report on our quest to determine the sound velocity of light in the superfluid phase.

[1] B. Bradlyn, F.E.A. dos Santos, and A. Pelster, Phys. Rev. A **79**, 013615 (2009)

[2] J. Koch and K.L. Hur, Phys. Rev. A **80**, 023811 (2009)

[3] S. Schmidt and G. Blatter, Phys. Rev. Lett. **103**, 086403 (2009)

Q 65.7 Fr 15:45 E 001

Pfaffian state(s) simulation in 2D Spin-1 Optical Lattices — Leonardo Mazza[1], •Matteo Rizzi[1], Maciej Lewenstein[2], and J. Ignacio Cirac[1] — [1]Max Planck Institut für Quantenoptik, Garching, Deutscheland — [2]ICREA and ICFO, Barcelona, Spain

We investigate the possibility of simulating bosons subject to an infinite three-body contact repulsion, and to an external magnetic field, with experimentally feasible cold atoms setups. A spin-1 (F=1) atomic Mott insulator with one atom per site provides the required three local degrees of freedom; suitable laser assisted couplings via an auxiliary F=2 ancilla tailor the dynamics of the experimental system to the desired one.

Such a scheme can be used to investigate Pfaffian (Moore-Read) states, arising in the context of Quantum Hall Effect (QHE) if particles are constrained to be not more than two in a single place; their bosonic version displays a QHE filling factor $\nu = 1$, i.e. one particle for each quantum of magnetic flux. One of their most intriguing features is the support of non-abelian topological excitations. Up to now, the long quest for Pfaffian physics has not produced experimental fingerprints: our proposal could open a new way towards this goal.

Finally, we characterize the ground state of the discrete system, demonstrating that for a dilute enough one the well-known topological properties of the continuum QHE are preserved. With the help of Chern numbers and ground state degeneracy, we show that even increasing the magnetic field these properties should not be abruptly washed out.

Q 66: Quantum Information: Photons and Nonclassical Light III

Time: Friday 14:00–16:00 Location: E 214

Q 66.1 Fr 14:00 E 214

Squeezing in Radially and Azimuthally Polarized Doughnut Modes — •Christian Gabriel[1,2], Wenjia Zhong[1,2], Andrea Aiello[1,2], Peter Banzer[1,2], Dominique Elser[1,2], Michael Förtsch[1,2], Ulrik L. Andersen[1,2,3], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Guenther-Scharowsky-Str. 1, 91058 Erlangen, Germany — [2]Institute for Optics, Information and Photonics, University Erlangen-Nuremberg, Staudtstr. 7/B2, 91058 Erlangen, Germany — [3]Department of Physics, Technical University of Denmark, 2800 Kongens Lyngby, Denmark

So far experiments in quantum imaging have solely concentrated on taking advantage of the spatial properties of light. However, exploiting more than one degree of freedom, such as the spatial mode as well as the polarization, offers new opportunities to improve continuous variable quantum information processing protocols. We present a theoretical investigation of squeezed states in an azimuthally and radially polarized doughnut mode. These not only have a complex spatial but also a complex polarization structure. Squeezing in these modes is a manifestation of entanglement between two other spatio-polarization modes which are symmetric and antisymmetric superpositions of the initial modes; for example the vertically polarized TEM01 mode and the horizontally polarized TEM10 mode in the case of a quantum noise reduction of a radially polarized doughnut mode and its counter part.

Q 66.2 Fr 14:15 E 214

Recent Results and Future Challenges of Photonic Quantum Computation — •Stefanie Barz[1,2], Gunther Cronenberg[1,2], Anton Zeilinger[1,2], and Philip Walther[1,2] — [1]Faculty of Physics, University of Vienna, Boltzmanngasse 5, 1090 Vienna, Austria — [2]Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Boltzmanngasse 3, 1090 Vienna, Austria

Entangled photons are a crucial resource for quantum communication and linear optical quantum computation. Therefore the controlled generation of these fundamental states attracts a worldwide effort. The majority of current experiments is based on the production of photon pairs in the process of spontaneous parametric down-conversion, where the entangled photon pair is concluded from post-selection of randomly occurring coincidences. Here we present the heralded generation of photon states that are maximally entangled in polarization with linear optics and standard photon detection from spontaneous parametric down-conversion. We utilize the down-conversion state corresponding to the generation of three pairs of photons, where the coincident detection of four auxiliary photons unambiguously heralds the successful preparation of the entangled state. This controlled generation of entangled photon states is a significant step towards the applicability of a linear optics quantum network, in particular for entanglement distribution, entanglement swapping, quantum teleportation, quantum cryptography and scalable approaches towards photonics-based quantum computing schemes.

Q 66.3 Fr 14:30 E 214

Efficient error-proof Bell measurements for photons by coupling to a single emitter — •Dirk Witthaut[1,2], Mikhail D. Lukin[3], and Anders S. Sørensen[1] — [1]QUANTOP, Niels Bohr Institute, University of Copenhagen, Denmark — [2]Max-Planck-Institute for Dynamics and Self-Organisation, Göttingen, Germany — [3]Department of Physics, Harvard University, Cambridge, USA

We present an efficient error-proof Bell state analyzer composed of linear optical elements and a non-linear element provided by the coupling to a single emitter, which can be realized in a photonic microcavity or a surface plasmon polariton mode on a nanowire. The setup is error-proof in the sense that every detection event projects unambiguously onto one of the Bell states, and losses may lead to inconclusive, but never to wrong measurement outcomes. Even more, a large class of errors results in a full transmission of all photons, so that they can be recycled for another attempt. Efficiencies exceeding the best possible performance with linear optics are shown to be achievable with modest atom-field coupling and a simple optical setup.

Q 66.4 Fr 14:45 E 214

Engineered photon-pair generation in standard birefringent optical fibers — •Christoph Söller[1], Offir Cohen[2], Brian J. Smith[2,3], Ian A. Walmsley[2], and Christine Silberhorn[1] — [1]IQO Group, MPI for the Science of Light, Günther-Scharowsky-Str. 1, 91058 Erlangen, Germany — [2]University of Oxford, Clarendon Laboratory, Parks Road, Oxford, OX1 3PU, UK — [3]Centre for Quantum Technologies, National University of Singapore, 3 Science Drive 2, 117543 Singapore, Singapore

Photon-pair sources are a vital building block for many applications in quantum optics, e.g. quantum-communication and computation schemes. We present a photon-pair source based on spontaneous four-wave mixing in standard birefringent optical fibers. Pumping the fiber source with a pulsed Ti:sapphire laser allows generation of highly non-degenerate pair photons that can be efficiently detected with standard silicon-based single-photon detectors. By changing the bandwidth of the pump pulses we are able to control the amount of spectral entanglement and thus of spectral correlations present between the photons of a pair. This feature offers the possibility of creating completely factorable two-photon states, an important resource for linear optical quantum computing.

Q 66.5 Fr 15:00 E 214

Accessing higher order correlations by time-multiplexing — •Malte Avenhaus[1], Kaisa Laiho[1], Maria V. Chekhova[1,2], and Christine Silberhorn[1] — [1]Max Planck Institute for the Science of Light, Günther-Scharowsky-Straße 1/Bau 24, 91058 Erlangen — [2]Department of Physics, M. V. Lomonosov Moscow State University, Leninskie Gory, 119992 Moscow, Russia

The characterization of optical quantum states poses an important prerequisite for many applications like the security of quantum key distribution or the analysis of quantum sources. Here, we focus on normalized correlation functions which yield information about a state without any assumption about optical losses, rendering an intriguing approach for Fock state measurements with lossy detectors.

We experimentally measured higher order normalized correlation functions of pulsed light with a time-multiplexing-detector. We demonstrate excellent performance of our device by verifying a unity valued up to the eighth order for coherent light, and factorial dependence for pseudo-thermal light. Further, we applied our measurement technique to a type-II parametric downconversion source to investigate mutual two-mode correlation properties and ascertain non-classicality.

Q 66.6 Fr 15:15 E 214

Three-color entanglement — Antonio Coelho[1], Felippe Barbosa[1], Katiuscia Cassemiro[2], •Alessandro Villar[2,3], Marcelo Martinelli[1], and Paulo Nussenzveig[1] — [1]Instituto de Física, Universidade de São Paulo, Post Office Box 66318, São Paulo, SP 05314-970, Brazil — [2]Max Planck Institute for the Science of Light, Günther-Scharowsky-Strasse 1/Bau 24, 91058 Erlangen, Germany — [3]University of Erlangen-Nuremberg, Staudtstrasse 7/B2, 91058 Erlangen, Germany

Entanglement is an essential quantum resource for the acceleration of information processing as well as for sophisticated quantum communication protocols. Quantum information networks are expected to convey information from one place to another by using entangled light beams. We demonstrated the generation of entanglement among three right beams of light, all of different wavelengths (532.251, 1062.102, and 1066.915 nanometers). We also observed disentanglement for finite channel losses, the continuous variable counterpart to entanglement sudden death.

Q 66.7 Fr 15:30 E 214

A versatile source of polarization-entangled photons — Andreas Maser, Ralph Wiegner, Uwe Schilling, Christoph Thiel, and •Joachim von Zanthier — Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, 91058 Erlangen

We propose a method for the generation of a large variety of entangled states, encoded in the polarization degrees of freedom of N photons, within the same experimental setup. Starting with uncorrelated photons, emitted from N arbitrary single photon sources, and using linear optical tools only, we demonstrate the creation of all symmetric states, e.g., GHZ- and W-states, as well as all (symmetric and non-symmetric) total angular momentum eigenstates of the N qubit compound. Amongst others, the scheme also enables to generate all canonical states representing the possible entanglement families of symmetric states inequivalent under SLOCC as recently defined in [1]. The technique thus comes close to the ideal of a single apparatus “that tunes in any wanted multipartite entangled state by simply turning a knob” [2].

[1] T. Bastin, S. Krins, P. Mathonet, M. Godefroid, L. Lamata, and E. Solano, PRL 103, 070503 (2009).
[2] M. Aspelmeyer and J. Eisert, Nature 455, 180 (2008).

Q 66.8 Fr 15:45 E 214

Diffraction at a blazed grating as a tool for characterizing the degree of spatial entanglement of different biphoton sources — •Dirk Puhlmann and Martin Ostermeyer — Universität Potsdam, Institut für Physik und Astronomie, Karl-Liebknecht-Str. 24-25, 14476 Potsdam, Germany

Correlations between photons are interesting for a number of applications and concepts in metrology, in particular for resolution improvements in different methods of quantum imaging. We demonstrate the application of a blazed grating for the characterization of the degree of spatial correlations of biphotons. For spatially correlated biphotons a new order of diffraction (OD) is observed in the far field distribution of the two photon rate behind the grating. This new OD appears at a far field angle, expected for single photons of half the original wavelength [1]. The higher the degree of spatial correlation of the biphotons, the stronger becomes this new OD. Thus the diffraction distribution behind the blazed grating can be used to characterize the spatial correlations of the biphotons. This characterization process is carried out for different biphoton sources, including spontaneous parametric down conversion in bulk crystals as well as in periodically poled MgO doped stoichiometric Lithium Tantalat (PP-MgO:SLT).

[1] M.Ostermeyer, D. Puhlmann, D. Korn, JOSA-B 26, 2347 (2009)

Q 67: Photonics IV

Time: Friday 14:00–15:45 Location: F 128

Q 67.1 Fr 14:00 F 128

Controlling the optical properties of single molecules by optical confinement in a tunable microresonator (exchanged with Q 55.36) — •Raphael Gutbrod, Alexey Chizhik, Anna Chizhik, Dmitry Khoptyar, Sebastian Bär, and Alfred J. Meixner — Institute of Physical and Theoretical Chemistry, University of Tübingen

Optical single-mode microresonators are structures which confine light to a small region in the range of half a wavelength. The broadband fluorescence emission and the decay lifetimes of single molecules are altered by the optical mode structure. In the tunable microresonator we present here, the resonator length can be changed reversibly with piezoelectric elements to a distinct position corresponding to a specific emission wavelength. The local mode structure of the electromagnetic field is changed at this position which results in a redistribution of the fluorescence and a modification of the lifetime for the same single molecule. The results obtained are in good agreement with the semiclassical model we developed for a better understanding of the coupling mechanisms between a single molecule and the cavity. The radiative coupling of the molecule to the electromagnetic field is also determined by the orientation of its transition dipole moment. Focusing a radially polarized doughnut mode laser beam (cylindrical vector beam) via a high NA into such a resonator leads to an inhomogeneous field distribution. By comparing the excitation pattern of a molecule with the calculated vector field distribution, we can determine the position or 3D-orientation of this molecule with high accuracy.

Q 67.2 Fr 14:15 F 128

Addressing single mode in GaAs/AlAs micropillar resonators — •Georgios Ctistis[1,3], Edwin van der Pol[1], Alex Hartsuiker[1], Maela Bazin[2], Julien Claudon[2], Jean-Michel Gérard[2], and Willem L. Vos[1,3] — [1]Center for Nanophotonics, FOM Institute for Atomic and Molecular Physics (AMOLF), Amsterdam, Netherlands — [2]CEA-CNRS Nanophysics and Semiconductors joint laboratory, Grenoble, France — [3]Complex Photonic Systems (COPS), MESA+ Institute for Nanotechnology, University of Twente, Netherlands

In this talk we present broadband white-light reflectivity experiments on micropillar resonators with diameters ranging between 1μm and 20μm. The micropillars consist of a GaAs λ-layer, sandwiched between two Bragg-stacks made of $\lambda/4$ GaAs/AlAs layers, and were fabricated by molecular-beam epitaxy. We are able to spectrally resolve distinct transverse modes in the reflectivity experiments and to address single modes by scanning the probe beam along the top facet of the micropillar. The positioning of the focused laser beam turns out to be crucial for pillar diameters exceeding the beam diameter, since at every position the coupling efficiency to different modes changes. By decreasing the pillar diameter, we are able to resolve single modes, since the spacing between the modes increases.

Q 67.3 Fr 14:30 F 128

Hybrid SOI nonlinear optical polymer racetrack resonator designs for electro-optical modulation — •Jan Hampe, Jan-Hendrik Wülbern, Stefan Prorok, Alexander Petrov, and Manfred Eich — TU Hamburg-Harburg, Eißendorfer Str. 38, 21073 Hamburg

Racetrack resonators based on the silicon-on-insulator (SOI) platform are proposed for modulation of an optical continuous wave (CW) signal by electrical signals.

The resonators are functionalized by a cladding of a second order nonlinear optical (NLO) polymer.

Two different concepts for the racetrack design employing different waveguide geometries for quasi-TE and quasi-TM polarization operation are presented.

The Pockel's coefficients of the in device poled NLO polymers are determined by the shift of the resonance wavelength with applied voltage and the modulation depth with low frequency signals.

In both resonator designs the electrical contact is established by fully etched segmented electrode sections to allow for an easy fabrication process.

Q 67.4 Fr 14:45 F 128

Fabry-Perot microcavities in ultra-small SOI waveguides — •Bülent A. Franke[1], Aws Al-Saadi[1], Shaimaa Mahdi[1], Sigurd Schrader[2], Viachaslau Ksianzou[2], Harald Richter[2], Stefan Meister[1], and Hans J. Eichler[1] — [1]Technische Universität Berlin, Institut für Optik und Atomare Physik, Berlin, Germany — [2]Technische Fachhochschule Wildau, Institut für Plasma- und Lasertechnik, Wildau, Germany

Microcavity filters in ultra-small Silicon on Insulator (SOI) waveguides are investigated. The microcavities are formed by one-dimensional photonic crystals (PhC) in Fabry-Perot structures, which are embedded in planar strip waveguides with 500nm width and 220nm height.

The photonic crystal microcavities are fabricated in a CMOS environment using 248nm DUV lithography. Several types of PhC micorcavities were optically characterized by a measurement setup using an external cavity laser (ECL) (tunable from 1520nm to 1630nm) and a nano-positioning system with an active differential intensity alignment system for the coupling of light.

Results of a number of different cavity filters, for instances multicavity, first and higher order cavities will be presented. Furthermore the measured transmission characteristics will be compared with simulations.

Q 67.5 Fr 15:00 F 128

Frequency Stable Fiber Ring Laser based on Whispering Gallery Modes — •Benjamin Sprenger, Harald G. L. Schwefel, and Lijun Wang — MPI für die Physik des Lichts, Günther-Scharowsky-Str. 1 / Bau 24, D-91058 Erlangen, Deutschland

We use high quality (Q) factor whispering gallery mode resonances in microspheres to stabilize a fiber loop laser. Microspheres are created by melting the tips of standard 1550 nm fibers, and can have Q factors up to 10^8. We evanescently couple into the high Q modes of such a sphere using a tapered fiber, and out using a fiber polished at a sharp angle. By including this frequency selective element into a fiber loop laser we manage to stabilize the laser to single-mode emission. The linewidth is determined to be 170 kHz, limited by the resolution of a heterodyne beat measurement with a grating stabilized diode laser. This corresponds to a Q factor of 10^9, and is five orders of magnitude larger than in the unstabilized regime. Additionally, we observe a red-shift with increasing pump intensity due to the thermo-refractive index inside the microsphere. Further experiments will focus on a more rigid coupling design to prevent the slight drift of the emission, as well as investigation of the linewidth and quantum behavior.

Q 67.6 Fr 15:15 F 128

Directional emission from Terahertz whispering gallery mode resonators — •Harald G. L. Schwefel[1], Sascha Preu[1], Sebastian T. Bauerschmidt[1], Stefan Malzer[1], Gottfried H. Döhler[1], Hong Lu[2], Arthur C. Gossard[2], and Lijun Wang[1] — [1]MPI für die Physik des Lichts, Erlangen — [2]Materials Department, Univ. of California, Santa Barbara, USA

High quality (Q) whispering gallery mode (WGM) resonators are known to feature extremely narrow frequency selectivity. Their azimuthal symmetry dictates however non-directional spatial emission. Theoretical studies predict that an inclusion of a finite scatterer inside the WGM resonator leads to directional emission [1]. In the THz domain, with millimeter wavelength, the accuracy requirements for fabricating such resonators are chiefly relaxed. Resonators in the optical domain, for comparison, require (sub-) nanometer accuracy. We report strong directional emission with a minimal loss in the Q factor from a 10 mm poly-ethylene disk including a 1 mm scatterer. For characterizing the resonator properties and emission pattern we use continuous-wave, room temperature operating Terahertz n-i-pn-i-p superlattice photomixer sources, pumped by two frequency off-set diode lasers operating at the telecommunication wavelength. The THz radiation is coupled into the resonators through the evanescent field of a thin dielectric waveguide and collected in the far-field with a Golay cell. Qualitative agreement of experiment and theoretical expectation will be reported.

[1] J. Wiersig and M. Hentschel, *Phys. Rev. A* **73**, 031802 (2006).

Q 67.7 Fr 15:30 F 128

Optical bistability and all-optical switching in bottle microresonators at very low powers via the Kerr effect —

•Michael Pöllinger and Arno Rauschenbeutel — QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz

We present experimental results on nonlinear, low-power photonics applications of a silica whispering-gallery-mode microresonator. In contrast to microspheres and microtoroidal resonators, where the light is typically guided in a narrow ring along the equator of the structure, the prolate shape of our bottle microresonator gives rise to an advantageous mode structure with two independent coupling points accessible for two nanofiber-couplers. This makes our resonator a real four-port device. Moreover, at a wavelength of 852 nm, the resonator yields an ultra-high intrinsic quality factor Q exceeding 10^8 and a mode volume around $V = 1300\ \mu m^3$. The resulting Q^2/V-ratio is among the highest realized for optical microresonators. The shift of resonance frequency in units of the linewidth scales with this ratio. Therefore, despite the small nonlinear refractive index of silica we observe optical bistability and all-optical switching at thresholds of some 100 μW via the Kerr effect and of some tens of μW for the slower thermo-optical effect. Finally, the possibility of enhancing the Kerr nonlinearity by coating the resonator with thin polymer-films is discussed.

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

Q 68: Laser Applications: Optical Measurement Technology II

Time: Friday 14:00–15:30 Location: F 342

Q 68.1 Fr 14:00 F 342

Neue Konzepte und Ergebnisse bei der Leistungsstabilisierung von Lasern — •Patrick Kwee, Benno Willke und Karsten Danzmann — Albert-Einstein-Institut Hannover

Optische Präzisionsexperimente, unter anderen z.B. interferometrische Gravitationswellendetektoren, benötigen häufig eine Laserquelle mit sehr hoher Leistungsstabilität, die sich nur durch eine aktive Stabilisierung erzielen lässt. Diese Stabilisierungen sind durch die Empfindlichkeit des verwendeten Leistungssensors limitiert. Zwei sich ergänzende Wege werden vorgestellt, um die Empfindlichkeit dieser Leistungssensoren zu steigern: Einerseits wird ein hoch empfindliches Array aus Photodioden mit einer Sensitivität für relatives Leistungsrauschen im Bereich von $2 \times 10^{-9}\,\mathrm{Hz}^{-1/2}$ bei 10 Hz und andererseits eine neuartige Detektionstechnik, die wir *optical ac coupling* nennen, vorgestellt. Diese Detektionstechnik ermöglicht die Empfindlichkeit von Photodetektoren um etwa eine Größenordnung mithilfe eines optischen Resonators zu erhöhen. Damit sind neue Leistungsstabilisierungskonzepte möglich, die neben technischen Vorteilen sogar das theoretische Quantenlimit traditioneller Leistungsstabilisierungen um bis zu 6 dB schlagen können.

Q 68.2 Fr 14:15 F 342

Characterisation and Data Analysis for the LISA Pathfinder Mission — •Martin Hewitson — AEI, Hannover, Germany

The LTP (LISA Technology Package) is the core part of the LISA Pathfinder mission. The main goals of the mission are to study the sources of any disturbances that perturb the motion of the freely-falling test masses from their geodesic trajectories and to test various technologies needed for LISA. The LTP experiment is designed as a sequence of experimental runs in which the performance of the instrument is studied and characterised under different operating conditions.

The software developed for the LTP Data Analysis is a comprehensive data analysis tool which uses an object-oriented approach to data analysis, allowing the user to design and run data analysis pipelines, either graphically or via scripts. The output objects of the analyses contain a full history of the processing that took place; this history tree can be inspected and used to rebuild the objects.

This talk summarises the main experiments of the LISA Pathfinder mission from the point of view of data analysis. In addition, the data analysis software infrastructure will be introduced, together with details of the various test campaigns that are being carried out in order to test the analysis procedures and tools.

Q 68.3 Fr 14:30 F 342

LISA Pathfinder interferometry: Space hardware tests at the AEI — •Heather Audley[1], Antonio Garcia Marin[1], Frank Steier[1], Miquel Nofrarias[1], Gerhard Heinzel[1], Karsten Danzmann[1], Vinzenz Wand[2], Peter Luetzow-Wentzky[2], Gerald Hechenblaikner[2], and Dominico Gerardi[2] — [1]Albert-Einstein-Institut Hannover: Max-Planck-Institut für Gravitationsphysik und Universität Hannover, Deutschland — [2]EADS Astrium Satellites GmbH, Friedrichshafen, Deutschland

The Laser Interferometer Space Antenna (LISA) is a joint ESA-NASA mission for the first space-borne gravitational wave detector, operating in the measurement band from 0.1 mHz to 1 Hz. A precursor satellite, LISA Pathfinder, will be used to demonstrate core LISA technologies that cannot be tested on the ground. Tests of the engineering model of the LISA Pathfinder optical metrology system (OMS) have recently been undertaken in the Albert Einstein Institute, Hannover, in conjunction with ESA and EADS Astrium. Significantly, they represent the first complete integration and testing of the space-qualified hardware. The results and test procedures of this campaign will be utilised directly in the ground-based flight hardware tests, and subsequently within in-flight operations. This talk presents an overview of this test campaign, with specific focus on calibration of the OMS outputs and optimisation of key measurement sensitivities.

Q 68.4 Fr 14:45 F 342

LISA Pathfinder - An interferometric drag-free sensor with picometer accuracy in space — •Frank Steier[1], Antonio Garcia Marin[1], Heather Audley[1], Miquel Nofrarias[1], Gerhard Heinzel[1], Karsten Danzmann[1], Vinzenz Wand[2], Peter Lützow-Wentzky[2], Gerald Hechenblaikner[2], and Domenico Gerardi[2] — [1]Albert-Einstein-Institut Hannover: Max-Planck-Institut für Gravitationsphysik und Universität Hannover, Deutschland — [2]EADS Astrium Satellites GmbH, Friedrichshafen, Deutschland

LISA Pathfinder is a drag-free system that will be able to measure a differential acceleration of two freely falling test masses with an accuracy of a few $\mathrm{fN}/\sqrt{\mathrm{Hz}}$ in the mHz range. It is a technology demonstration mission for the planned gravitational wave detector LISA.

We present the recent progress in the project. The entire optical measurement system has undergone performance tests with so-called Engineering Models that are copies of the real flight hardware. These units have already been verified to be compatible with space applications. The same tests are presently being repeated on the Flight Models at the AEI Hannover.

Q 68.5 Fr 15:00 F 342

Alignment simulations for LISA Pathfinder — •Gudrun Wanner[1], Antonio Garcia[1], Frank Steier[1], Dave Robertson[2], Harry Ward[2], Felipe Guzman[3], Gerhard Heinzel[1], and Karsten Danzmann[1] — [1]Albert-Einstein-Institut, Hannover, D — [2]Institute for Gravitational Research, Glasgow, UK — [3]NASA Goddard Space Flight Center, Greenbelt, USA

LISA Pathfinder, the technology demonstration mission for the space borne gravitational wave detector LISA, will carry two free floating test masses whose position and attitude will be measured by an interferometric readout. The interferometer consists of about 20 elements assembled on one optical bench. Each of these elements will have alignment precisions in the order of 10 μm and 50 μrad. These alignment tolerances influence the measurement precision, cause cross coupling of the heterodyne interferometer signals and contribute to the static test mass attitude in flight. We will present results from various alignment investigations for LISA Pathfinder and experimental results.

Q 68.6 Fr 15:15 F 342

Development of RF Low Noise Quadrant Photo Detectors for Optical Translation and Tilt Metrology — •Steffen Wälde[1,2], Martin Maurer[1,2], Martin Gohlke[1,3], Thilo Schuldt[2,3], Ulrich Johann[1], Dennis Weise[1], and Claus Braxmaier[2] — [1]EADS Astrium — [2]HTWG Konstanz — [3]Humboldt-Universität zu Berlin

The LISA (Laser Interferometer Space Antenna) mission is a space-based gravitational wave detector aiming to detect gravitational waves in a frequency band from 0.1 mHz to 1 Hz. Three satellites arranged in a nearly equilateral triangle with an edge length of about 5 million km will fly in an earth-trailing orbit arround the sun in a distance of 20 °.

The distance between the satellites will be measured with an interferometer setup. During the mission the distance between the satellites vary with about 50000 km. This breathing of the constellation causes a Doppler shift of the Laser frequency in a range of 2 to 19 MHz.

In this context EADS Astrium developed a RF low noise quadrant photo detector which is suited for high precision phase measurements in a sub-Hz LISA measurement band. It uses an Indium Gallium Arsenide (InGaAs) quadrant photodiode with a total diameter of 1 mm. The detector as a position sensitive device can also be used for the technique of differential wavefront sensing. With respect to the mission requirements the detector has a constant frequency response and a linear phase response for frequencies between 2 and 20 MHz. It has also a path for frequencies between DC and 45 kHz for each quadrant.

In the presentation the setup will be explained and the results of our current measurements will be shown.

Q 69: Ultra-Cold Atoms, Ions and BEC IV / Interaction with VUV and X-Ray Light II (with A)

Time: Friday 14:00–15:45 Location: F 303

Q 69.1 Fr 14:00 F 303

Hunting for Efimov trimers in a three-component Fermi gas — •Thomas Lompe[1,2], Timo Ottenstein[1,2], Martin Ries[1,2], Friedhelm Serwane[1,2], Philipp Simon[1,2], Gerhard Zürn[1,2], and Selim Jochim[1,2] — [1]MPI für Kernphysik, Heidelberg — [2]Physikalisches Institut, Universität Heidelberg

In the past years Efimov states have been observed in a multitude of bosonic systems. In contrast, we study Efimov physics in a system of three distinguishable fermions with broad, overlapping Feshbach resonances. For each of these Feshbach resonances there exists a shallow dimer state, which creates a much richer system than a single resonance. So far we have found one loss resonance in three-atom- and two resonances in atom-dimer-scattering, which are caused by two Efimov trimers. This should allow for accurate predictions for the binding energies of these trimers. Additionally the fermionic nature of the atoms greatly enhances the stability of the Feshbach molecules, which makes the preparation of atom-dimer mixtures much easier than in bosonic gases. These properties make our system a promising candidate to attempt spectroscopy of Efimov states by RF-association of Efimov trimers.

Q 69.2 Fr 14:15 F 303

Rydberg atoms in Bose-Einstein condensates and optical lattices — Matthieu Viteau[1], Jagoda Radogostowicz[1], Mark Bason[1], Nicola Malossi[1], Amodsen Chotia[2], Donatella Ciampini[1], •Oliver Morsch[2], and Ennio Arimondo[1,2] — [1]CNISM UdR Pisa, Dipartimento di Fisica, Largo Pontecorvo 3, 56127 Pisa, Italy — [2]CNR-INFM, Largo Pontecorvo 3, 56127 Pisa, Italy

We report on progress in exciting Rydberg states of Rubidium atoms in the Bose condensed phase and inside optical lattices. The high densities achievable in Bose-Einstein condensates give us access to a regime where dipole-dipole interactions between Rydberg atoms are strong, and the spatial order in optical lattices fixes a length scale for the interatomic distance. Both ingredients are essential for implementing controlled Rydberg-Rydberg interactions for quantum gates.

Q 69.3 Fr 14:30 F 303

Optical Trapping of Magnesium — •Matthias Riedmann, Jan Friebe, Temmo Wübbena, André Kulosa, Hrishikesh Kelkar, Sana Amairi, André Pape, Sina Malobabic, Steffen Rühmann, Wolfgang Ertmer, and Ernst-Maria Rasel — Institut für Quantenoptik, Hannover, Germany

Magnesium is an interesting candidate for a future high performance neutral atom optical frequency standard. Long spectroscopy time and therefore high resolution can be reached by confining the atoms in the Lamb-Dicke regime in an optical lattice. Magnesium is challenging because cooling on the strong singlet transition is limited to the Doppler limit of 2 mK. Cooling on narrow lines, a standard technique to reach ultralow temperatures for other alkaline-earth atoms, is not promising for Mg because of a too narrow intercombination line (31 Hz).

Mg atoms are pre-cooled in a two-stage MOT. Atoms are first trapped on the strong singlet cooling transition and then pumped to the triplet system. There, another MOT operating between the ^3P and ^3D states is used to further cool and compress the atomic cloud. Atoms that decay to the $^3P_1$ state are repumped while those that decay to the $^3P_0$ are not and can be optically trapped by a 1064 nm dipole trap, which is superimposed with the second MOT. All cooling stages are running coutinously and atoms are accumulated in the dipole trap. The loss chnannel in the second MOT avoids a density limitation and therefore increases the loading to the dipole trap. With this technique, we are able to load up to $9 \cdot 10^4$ atoms to the dipole trap.

Q 69.4 Fr 14:45 F 303

One-dimensional Anderson localization in correlated random potentials — •Pierre Lugan[1], Alain Aspect[1], Laurent Sanchez-Palencia[1], Dominique Delande[2], Benoit Grémaud[2,3], Cord A. Müller[2,4], and Christian Miniatura[3,5] — [1]Laboratoire Charles Fabry de l'Institut d'Optique, CNRS and Univ. Paris-Sud, Campus Polytechnique, RD 128, F-91127 Palaiseau Cedex, France — [2]Laboratoire Kastler-Brossel, UPMC, ENS, CNRS, 4 Place Jussieu, F-75005 Paris, France — [3]Centre for Quantum Technologies, National University of Singapore, 3 Science Drive 2, Singapore 117543, Singapore — [4]Physikalisches Institut, Universität Bayreuth, D-95440 Bayreuth, Germany — [5]Institut Non Linéaire de Nice, UNS, CNRS, 1361 Route des Lucioles, F-06560 Valbonne, France

The study of disorder with ultracold atomic gases has recently attracted much attention due to the possibility of controlling disorder, interactions, and dimensionality in these systems. In this contribution, we study the Anderson localization of ultracold atoms in weak, correlated one-dimensional potentials, and we discuss how the special long-range correlations present in the speckle potentials used in current experiments affect the localization properties of single particles and non-interacting wave packets. It is known that in one dimension generally all single-particle states are localized. For weak speckle potentials, we show the existence of a series of sharp cross-overs (effective mobility edges) between regions of the single-particle energy spectrum where the localization lengths differ by orders of magnitude [1].

[1] P. Lugan et al., Phys. Rev. A 80, 023605 (2009).

Q 69.5 Fr 15:00 F 303

Aufbau zur Untersuchung freier nanoskopischer Partikel mit Synchrotronstrahlung — •Markus Eritt[1,2], Jan Meinen[1,2], Svetlana Khasminskaya[1,2], Egill Antonsson[3], Burkhard Langer[3], Eckart Rühl[3] und Thomas Leisner[1,2] — [1]Universität Heidelberg, Institut für Umweltphysik — [2]Karlsruher Institut für Technologie, Institute for Meteorology and Climate Research Atmospheric Aerosol Research (IMK-AAF) — [3]Freie Universität Berlin, Institut für Chemie und Biochemie

Es wir eine Apparatur zur Untersuchung freier, funktioneller Nanopartikel im Größenbereich von 3-300nm mit Synchrotronstrahlung vorgestellt. Die zu untersuchenden Partikel werden unter Atmosphärendruck erzeugt und durch ein Einlasssystem aus durchstimmbarer aerodynamischer Linse und RF-Ionenführung ins Vakuum transferiert. Um die zur Untersuchung freier Teilchen mit VUV-Strahlung nötigen hohen Targetdichten zu erreichen, werden die geladenen Nanopartikel in einer linearen Ionenfalle akkumuliert dort moderiert und dann und in dichten Pulsen in den VUV-Wechselwirkungsbereich eingeschossen. In einem ersten Experiment am BESSY II wurden die Photoelektronenspektren von 10nm Siliziumoxid Partikeln mit einem Elektronen-Flugzeitspektrometer aufgenommen. Vorgestellt werden die apparativen Möglichkeiten sowie erste Ergebnisse.

Q 69.6 Fr 15:15 F 303

Collectivity and interference in x-ray scattering on nuclei — •Adriana Pálffy, Christoph H. Keitel, and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Resonant scattering of monochromatized synchrotron radiation or light from upcoming x-ray laser sources can lead to coherent photoexcitation of nuclei. Such an excitation in a nuclear ensemble is of excitonic nature, and the underlying collective effects determine the coherent nuclear reemission in the forward direction or at the Bragg angle. The coherent decay of the collective nuclear excitation is considerably speeded up with respect to the incoherent decay channels and thus to the natural lifetime. It has been shown experimentally [1] that switching abruptly the direction of the magnetic hyperfine fields can control and even completely suppress the coherent decay channel due to destructive interference. With a proper choice of switching parameters, specific transitions between hyperfine levels can be restored thus controlling the polarization of the emitted x-ray light [2].

Based on the results of [1,2], we study here advanced coherent control schemes aimed at the selective population of nuclear states. We show that suppression of the coherent decay in resonant x-ray scattering can be used to control the effective branching ratio in nuclear systems, and thus the population of nuclear states. Prospects for the population of metastable nuclear states are discussed.

[1] Y. V. Shvyd'ko *et al.*, Phys. Rev. Lett. 77, 3232 (1995)
[2] A. Pálffy, C. H. Keitel and J. Evers, Phys. Rev. Lett. 103, 017401 (2009)

Q 69.7 Fr 15:30 F 303

X-ray scattering and ionization of rare gas clusters by superintense pulses from the LCLS FEL — •Tais Gorkhover[1], Marcus Adolph[1], Daniela Rupp[1], Sebastian Schorb[1], Thomas Möller[1], Sascha Epp[3], Robert Hartmann[4], Daniel Rolles[3], Artem Rudenko[3], Ilme Schlichting[3,5], Lothar Strüder[3,4], Joachim Ullrich[6], and Christoph Bostedt[2] — [1]TU Berlin — [2]LCLS, Stanford — [3]ASG — [4]MPI HLL — [5]MPI MF — [6]MPI K

The Linac Coherent Light Source (LCLS) is a new, world wide unique X-ray free electron laser (FEL), which produces ultrashort pulses up to 2keV with unprecedented brightness. One of the most promintent applications of this powerful tool is imaging of unrevealed ultrafast atomic and molecular processes. We report on the first imaging experiment at the LCLS. It was performed on rare gas clusters, which can be applied as simple model systems for interaction between X-ray laser and matter. We used single-photon counting pnCCD detectors for observing scattering and fluorescence. As clusters are destroyed by the ultra intense pulse, the observation of ionisation products is crutial for the understanding of interaction dynamics. They were detected simultaneously with advanced ion /electron spectrometers (VMI). This experiment was performed in the CFEL-ASG Multi-Purpose (CAMP) chamber which contains a unique combination of analysis instruments for exploring the interaction of intense (soft) x-ray radiation and matter.