Fachverband Quantenoptik und Photonik (Q)

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Übersicht der Fachsitzungen

(Hörsäle ESA-A, ESA-B; Audimax-A, Audimax-B; VMP6: HS-A, HS-C, HS-D, HS-E; VMP8: HS, R206; Poster: VMP8 und VMP9)

Preisträgervorträge im Fachverband Quantenoptik

Q 22.1	Di	14:00–14:30	VMP 6 HS-A	**Strong correlations in ultracold fermionic gases** — •Corinna Kollath
Q 33.1	Mi	14:00–14:30	VMP 6 HS-A	**Von der Laserschwelle zum Quantenphasenübergang - und zurück** — •Robert R. F. Graham
Q 43.1	Do	10:30–11:00	VMP 6 HS-A	**Neuer Kurzpulslaser für die Materialbearbeitung** — •Christoph Gerhard

Hauptvorträge des Symposiums Lokalisierung und Verschränkung in photoinduzierten Prozessen (SYLV)

Siehe SYLV für das komplette Programm des Symposiums.

SYLV 1.1	Mo	14:00–14:30	VMP 8 HS	**Coherence, interference and entanglement in the photoionization of homonuclear diatomic molecules** — •Reinhard Dörner, M. Schöffler, T. Jahnke, K. Kreidi, D. Akoury, L.Ph.H. Schmidt, H. Schmidt-Böcking, J. Titze, N. Neumann, T. Weber, M.H. Prior, A. Belkacem, P. Ranitovic, C.L. Cocke, A. Landers, S. Semenov, N. Cherepkov
SYLV 1.2	Mo	14:30–15:00	VMP 8 HS	**Quantum Interfaces between Nanomechanical Systems and Cold Atoms** — •Peter Zoller
SYLV 1.3	Mo	15:00–15:30	VMP 8 HS	**Electron entanglement studied by Dopppler-resolved electron spectroscopy** — •Svante Svensson
SYLV 1.4	Mo	15:30–16:00	VMP 8 HS	**Entanglement-assisted Ramsey Spectroscopy with Atomic Ensembles** — •Eugene Polzik
SYLV 2.1	Mo	16:30–17:00	VMP 8 HS	**Coherent photoelectron emission from diatoms: Influence of scattering, recoil, and dissociation** — •Kiyoshi Ueda
SYLV 2.2	Mo	17:00–17:30	VMP 8 HS	**Atom-Photon Entanglement** — •Harald Weinfurter, Florian Henkel, Julian Hofmann, Michael Krug, Norbert Ortegl, Wenjamin Rosenfeld, Jürgen Volz, Markus Weber
SYLV 2.3	Mo	17:30–18:00	VMP 8 HS	**Space-time entanglement: A realization of EPR's original proposal** — •Burkhard Langer, Uwe Becker
SYLV 2.4	Mo	18:00–18:30	VMP 8 HS	**A long-distance quantum gate between matter qubits** — •P. Maunz, S. Olmschenk, D. Hayes, D. N. Matsukevich, L.-M. Duan, C. Monroe
SYLV 2.5	Mo	18:30–19:00	VMP 8 HS	**Space-QUEST: Experiments with quantum entanglement in space** — •Rupert Ursin, Thomas Jennewein, Anton Zeilinger

Hauptvorträge des Symposiums S-AMOP Dissertationspreis (SYDI)

Siehe SYDI für das komplette Programm des Symposiums.

SYDI 1.1	Di	10:30–11:00	VMP 8 HS	**Experimental manipulation of atoms and photons: the application in quantum information processing** — •Yu-Ao Chen

SYDI 1.2	Di	11:00–11:30	VMP 8 HS	**Cavity QED with a Bose-Einstein Condensate** — •Tobias Donner, Stephan Ritter, Ferdinand Brennecke, Anton Oettl, Thomas Bourdel, Michael Koehl, Tilman Esslinger
SYDI 1.3	Di	11:30–12:00	VMP 8 HS	**Poking and probing strongly correlated gases in optical lattices** — •Simon Fölling, Artur Widera, Stefan Trotzky, Olaf Mandel, Tatjana Gericke, Torben Müller, Fabrice Gerbier, Patrick Cheinet, Immanuel Bloch
SYDI 1.4	Di	12:00–12:30	VMP 8 HS	**Discrete optics in femtosecond-laser written photonic structures** — •Alexander Szameit

Hauptvorträge des Symposiums Photonische Terahertz-Technologien fuer Grundlagenforschung und Anwendung (SYTT)

Siehe SYTT für das komplette Programm des Symposiums.

SYTT 1.1	Di	14:00–14:30	VMP 8 HS	**Terahertz-Wellen: Von der Grundlagenforschung zur industriellen Anwendung** — •Michael Herrmann, Joachim Jonuscheit
SYTT 1.2	Di	14:30–15:00	VMP 8 HS	**THz Zeitbereichsspektroskopie zur Kontrolle von industriellen Prozessen und Produkten** — •Christian Jördens, Steffen Wietzke, Norman Krumbholz, Thomas Hochrein, Maik Scheller, Martin Koch
SYTT 1.4	Di	15:15–15:45	VMP 8 HS	**Biochemical Sensing with THz** — •Peter Haring Bolivar
SYTT 2.1	Di	16:30–17:00	VMP 8 HS	**Photonic Terahertz Technology at 10 GV/m Electric Field Amplitudes** — •Alexander Sell, Rüdiger Scheu, Alfred Leitenstorfer, Rupert Huber
SYTT 2.4	Di	17:30–18:00	VMP 8 HS	**Terahertzspektroskopie der Optischen Antwort eines Zweidimensionalen Elektronengases** — •Sangam Chatterjee, Torben Grunwald, Daniel Golde, Mackillo Kira, Stephan W. Koch
SYTT 2.5	Di	18:00–18:30	VMP 8 HS	**Terahertz (THz) Metamaterials and Transformation Optics** — •Marco Rahm

Hauptvorträge des Symposiums Lichtausbreitung in kohärent präparierten Medien (SYKM)

Siehe SYKM für das komplette Programm des Symposiums.

SYKM 1.1	Do	14:00–14:30	VMP 6 HS-D	**Diffusion of Slow and Stored Light in Vapor** — •N. Davidson, O. Firstenberg, M. Shuker, R. Pugatch, A. Ron
SYKM 1.2	Do	14:30–15:00	VMP 6 HS-D	**EIT and light storage in a Mott insulator** — •Stefan Kuhr, Ute Schnorrberger, Stefan Trotzky, Jeff Thompson, Rami Pugatch, Nir Davidson, Immanuel Bloch
SYKM 1.3	Do	15:00–15:30	VMP 6 HS-D	**Light interactions in Rydberg ensembles** — •Charles Adams
SYKM 2.1	Do	16:30–17:00	VMP 6 HS-D	**Quantum fluid properties of coherently prepared microcavity polaritons** — •E. Giacobino, A. Amo, J. Lefrère, S. Pigeon, C. Adrados, C. Ciuti, I. Carusotto, R. Houdré, A. Bramati
SYKM 2.2	Do	17:00–17:30	VMP 6 HS-D	**3D metamaterials: from simple to complex - coupling matters!** — •Harald Giessen
SYKM 2.3	Do	17:30–18:00	VMP 6 HS-D	**Optically Driven Atomic Coherences : From the Gas Phase to the Solid State** — •F. Beil, J. Klein, G. Heinze, T. Halfmann

Hauptvorträge des Symposiums Defect centers in diamond for applications in quantum optics and nanophotonics (SYDD)

Siehe SYDD für das komplette Programm des Symposiums.

SYDD 1.1	Fr	10:30–11:00	Audi-B	**Manipulation and nanopositioning of single NV centers** — •Ronald Hanson
SYDD 1.2	Fr	11:00–11:30	Audi-B	**Fabrication strategies for diamond based quantum devices** — •Steven Prawer
SYDD 1.3	Fr	11:30–12:00	Audi-B	**Controlling nonclassical emission of light in diamond** — •H. Weinfurter, J. Bahe, C.L. Wang, X.Q. Zhou, T. Kippenberg, A. Stiebeiner, A. Rauschenbeutel, J. Meijer

SYDD 2.1	Fr	14:00–14:30	Audi-B	**Experimental investigation of optically detected magnetic resonance of multiple and single NV spin in diamond** — Ngoc Diep Lai, Dingwei Zheng, Fedor Jelezko, •François Treussart, Jean-François Roch
SYDD 2.2	Fr	14:30–15:00	Audi-B	**Photonic crystal cavities - A basic element for scalable quantum electrodynamics with diamond N-V centers** — •Joseph Salzman, Igal Bayn
SYDD 2.3	Fr	15:00–15:30	Audi-B	**Engineered CVD diamond for spintronic applications** — •Daniel Twitchen, Matthew Markham

Fachsitzungen

Q 1.1–1.5	Mo	10:45–12:00	ESA-A	**Mikromechanische Oszillatoren**
Q 2.1–2.6	Mo	10:45–12:15	ESA-B	**Quanteninformation: Atome und Ionen I**
Q 3.1–3.7	Mo	10:45–12:30	VMP 6 HS-A	**Quantengase: Dynamik in Gittern**
Q 4.1–4.7	Mo	10:45–12:30	VMP 6 HS-C	**Laserentwicklung: Festkörperlaser I**
Q 5.1–5.7	Mo	10:45–12:30	VMP 6 HS-D	**Quanteninformation: Konzepte I**
Q 6.1–6.6	Mo	10:45–12:15	VMP 8 HS	**Ultrakalte Moleküle (mit MO)**
Q 7.1–7.8	Mo	14:00–16:00	VMP 6 HS-A	**Quantengase: Bosonen im Gitter I**
Q 8.1–8.8	Mo	14:00–16:00	VMP 6 HS-C	**Laserentwicklung: Festkörperlaser II**
Q 9.1–9.8	Mo	14:00–16:00	VMP 6 HS-D	**Quanteninformation: Konzepte II**
Q 10.1–10.7	Mo	14:00–15:45	VMP 8 R206	**Ultrakurze Pulse: Erzeugung I**
Q 11.1–11.6	Mo	16:30–18:00	VMP 6 HS-A	**Quantengase: Bosonen im Gitter II**
Q 12.1–12.6	Mo	16:30–18:00	VMP 6 HS-C	**Laserentwicklung: Festkörperlaser III**
Q 13.1–13.6	Mo	16:30–18:00	VMP 6 HS-D	**Quanteninformation: Konzepte III**
Q 14.1–14.9	Mo	16:30–18:45	VMP 8 R206	**Ultrakurze Pulse: Erzeugung II**
Q 15.1–15.8	Di	10:30–12:30	Audi-A	**Ultrakurze Pulse: Erzeugung III**
Q 16.1–16.8	Di	10:30–12:30	Audi-B	**Ultrakalte Atome: Fallen und Kühlung I (mit A)**
Q 17.1–17.8	Di	10:30–12:30	VMP 6 HS-A	**Quantengase: Bosonen Dynamik / Disorder**
Q 18.1–18.8	Di	10:30–12:30	VMP 6 HS-D	**Quanteninformation: Photonen I**
Q 19	Di	13:15–14:00	VMP 6 HS-A	**Mitgliederversammlung Quantenoptik**
Q 20.1–20.8	Di	14:00–16:00	Audi-A	**Präzisionsmessungen I**
Q 21.1–21.6	Di	14:00–15:45	Audi-B	**Ultrakalte Atome: Fallen und Kühlung II / Einzelne Atome (mit A)**
Q 22.1–22.7	Di	14:00–16:00	VMP 6 HS-A	**Quantengase: Fermionen im Gitter**
Q 23.1–23.8	Di	14:00–16:00	VMP 6 HS-D	**Quanteninformation: Photonen II**
Q 24.1–24.10	Di	16:30–19:00	Audi-A	**Präzisionsmessungen II**
Q 25	Di	16:30–18:30	Audi-B	**post deadline**
Q 26.1–26.6	Di	16:30–18:00	VMP 6 HS-A	**Quantengase: Fermionen**
Q 27	Di	16:30–18:00	VMP 6 HS-C	**Ultrakalte Atome, Ionen und BEC I (mit A)**
Q 28.1–28.6	Di	16:30–18:00	VMP 6 HS-D	**Quanteninformation: Photonen III**
Q 29.1–29.30	Di	16:30–19:00	VMP 8 Foyer	**Poster I**
Q 30.1–30.65	Di	16:30–19:00	VMP 9 Poster	**Poster II**
Q 31.1–31.8	Mi	14:00–16:00	Audi-A	**Laseranwendungen: Optische Messtechnik**
Q 32.1–32.5	Mi	14:00–15:15	Audi-B	**Materiewellenoptik**
Q 33.1–33.6	Mi	14:00–16:00	VMP 6 HS-A	**Quantengase: Bosonen**
Q 34.1–34.7	Mi	14:00–15:45	VMP 6 HS-D	**Quanteninformation: Konzepte IV**
Q 35.1–35.8	Mi	14:00–16:00	VMP 6 HS-E	**Quanteneffekte: QED / Interferenz und Korrelationen I**
Q 36.1–36.8	Mi	16:30–18:30	Audi-A	**Laseranwendungen**
Q 37.1–37.9	Mi	16:30–18:45	Audi-B	**Ultrakalte Atome: Manipulation und Detektion / Rydbergatome (mit A)**
Q 38.1–38.6	Mi	16:30–18:00	VMP 6 HS-A	**Quantengase: Gemische**
Q 39.1–39.6	Mi	16:30–18:00	VMP 6 HS-D	**Quanteninformation: Konzepte V**
Q 40.1–40.6	Mi	16:30–18:00	VMP 6 HS-E	**Quanteneffekte: Interferenz und Korrelationen II**
Q 41.1–41.8	Do	10:30–12:30	Audi-A	**Quantengase: Dipolare Gase**
Q 42.1–42.8	Do	10:30–12:30	Audi-B	**Quanteninformation: Atome und Ionen II**
Q 43.1–43.7	Do	10:30–12:30	VMP 6 HS-A	**Ultrakurze Pulse: Anwendungen I**
Q 44	Do	10:30–12:15	VMP 6 HS-C	**Ultrakalte Atome, Ionen und BEC II (mit A)**
Q 45.1–45.8	Do	10:30–12:30	VMP 6 HS-D	**Laserentwicklung: Nichtlineare Effekte**
Q 46.1–46.7	Do	10:30–12:15	VMP 6 HS-E	**Quanteneffekte: Lichtstreuung und Ausbreitung**
Q 47.1–47.8	Do	14:00–16:00	Audi-A	**Quantengase: Gitter und Tunneln I**

Q 48.1–48.8	Do	14:00–16:00	Audi-B	**Quanteninformation: Quantenkommunikation I**
Q 49.1–49.8	Do	14:00–16:00	VMP 6 HS-A	**Ultrakurze Pulse: Anwendungen II**
Q 50	Do	14:00–16:00	VMP 6 HS-C	**Ultrakalte Atome, Ionen und BEC III (mit A)**
Q 51.1–51.8	Do	16:30–18:30	Audi-A	**Quantengase: Gitter und Tunneln II**
Q 52.1–52.10	Do	16:30–19:00	Audi-B	**Quanteninformation: Quantenkommunikation II**
Q 53.1–53.5	Do	16:30–17:45	VMP 6 HS-A	**Ultrakurze Pulse: Anwendungen III**
Q 54	Do	16:30–18:00	VMP 6 HS-C	**Ultrakalte Atome, Ionen und BEC IV (mit A)**
Q 55.1–55.50	Do	16:30–19:00	VMP 8 Foyer	**Poster III**
Q 56.1–56.51	Do	16:30–19:00	VMP 9 Poster	**Poster IV**
Q 57.1–57.8	Fr	10:30–12:30	Audi-A	**Photonik I**
Q 58.1–58.6	Fr	10:30–12:00	VMP 6 HS-A	**Quanteninformation: Atome und Ionen III**
Q 59	Fr	10:30–12:30	VMP 6 HS-C	**Ultrakalte Atome, Ionen und BEC V (mit A)**
Q 60.1–60.8	Fr	10:30–12:30	VMP 6 HS-D	**Quanteneffekte: Dekohärenz**
Q 61.1–61.8	Fr	10:30–12:30	VMP 8 HS	**Laserentwicklung: Halbleiterlaser**
Q 62.1–62.10	Fr	14:00–16:30	Audi-A	**Photonik II**
Q 63.1–63.9	Fr	14:00–16:15	VMP 6 HS-A	**Quanteninformation: Quantencomputer**
Q 64.1–64.10	Fr	14:00–16:30	VMP 6 HS-D	**Quanteneffekte: Verschränkung**
Q 65.1–65.10	Fr	14:00–16:30	VMP 8 HS	**Laseranwendungen: Lebenswissenschaften**

Mitgliederversammlung Fachverband Quantenoptik und Photonik

Dienstag 13:15–14:00 VMP 6 HS-A

- Bericht
- Verschiedenes

Sitzung des Deutschen Optischen Komitees (DOK)

Mittwoch 12:30–14:00 R208

Q 1: Mikromechanische Oszillatoren

Zeit: Montag 10:45–12:00 Raum: ESA-A

Q 1.1 Mo 10:45 ESA-A

Ultralow-dissipation optomechanical resonators on a chip — •Georg Anetsberger[1], Rémi Rivière[1], Albert Schliesser[1], Olivier Arcizet[1] und Tobias Kippenberg[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str.1, 85748, Garching, Germany — [2]EPFL Lausanne, 1015, Lausanne, Switzerland

Cavity-enhanced radiation-pressure coupling of optical and mechanical degrees of freedom gives rise to a range of optomechanical phenomena, in particular providing a route to the quantum regime of mesoscopic mechanical oscillators. A prime challenge in cavity optomechanics[1] has been to realize systems that simultaneously maximize optical finesse and mechanical quality. Here we demonstrate, for the first time, independent control over both mechanical and optical degrees of freedom within the same on-chip resonator[2]. The first direct observation of mechanical normal mode coupling in a micromechanical system allows for a quantitative understanding of mechanical dissipation. Subsequent optimization of the resonator geometry enables intrinsic material loss limited mechanical Q-factors, rivalling the best values reported in the high megahertz frequency range, while simultaneously preserving the resonators' ultrahigh optical finesse. As well as providing a complete understanding of mechanical dissipation in microresonator-based optomechanical systems, our results provide a promising setting for cavity optomechanics[1].

[1] T.J. Kippenberg, K.J. Vahala. Science 321, 1172-1176 (2008).

[2] G. Anetsberger, R. Rivière, A. Schliesser, O. Arcizet, T. J. Kippenberg. Nature Photonics 2, 627-633 (2008)

Q 1.2 Mo 11:00 ESA-A

Resolved-sideband laser cooling and measurement of a micromechanical oscillator close to the quantum limit — •Albert Schliesser[1], Remi Riviere[1], Georg Anetsberger[1], Olivier Arcizet[1], and Tobias Kippenberg[1,2] — [1]Max-Planck-Institute of Quantum Optics, Garching, Germany — [2]Ecole Polytechnique Federale de Lausanne, Lausanne, Switzerland

The observation of quantum effects in the mechanics of mesoscale objects has been of interest since the inception of quantum mechanics. It would provide new insights in the quantum-classical boundary, opportunities for experimental investigation of the postulates of quantum theory of measurements, and access to the regime of nonclassical states of mechanical motion. Here we closely approach the quantum regime of a mechanical oscillator, discernable by bare eye, and more than three orders of magnitude more massive than typical nanomechanical resonators used in prior work: A silica toroidal optical microcavity, which simultaneously supports a high-quality mechanical radial breathing mode (RBM). Using modest cryogenic pre-cooling to 1.65K, we apply resolved-sideband laser cooling to the RBM and reduce its thermal occupation to 63 ± 20 quanta. Simultaneously, highly sensitive optical interferometric measurements allow approaching the standard quantum limit to within a factor of 5 ± 1.5. Taking measurement backaction into account, this represents the closest approach to the Heisenberg uncertainty relation for continuous position measurements yet demonstrated for mesoscopic oscillators.

Q 1.3 Mo 11:15 ESA-A

Coupling of laser-cooled atoms to a mechanical resonator via an optical lattice — •Stephan Camerer[1], David Hunger[1], Margareta Wallquist[2], Claudiu Genes[2], Klemens Hammerer[2], Peter Zoller[2], Theodor W. Hänsch[1], and Philipp Treutlein[1] — [1]MPQ Garching und LMU München — [2]Universität Innsbruck, Österreich

We investigate ultracold atoms in a 1D optical lattice that is formed by a laser beam retroreflected from a mechanical resonator. The optical lattice serves as a transfer rod which couples vibrations of the cantilever to the atoms and vice versa. As the mechanical resonator oscillates, the center of mass mode of the atoms in the lattice is excited. By applying laser cooling to the atoms, the motion of the mechanical resonator can be sympathetically cooled. We present theoretical investigations of this system and the current status of our experiment.

In combination with cryogenic precooling our system can provide ground state cooling of a single mode of the mechanical resonator. In this limit, the system is an example of a hybrid quantum system. A hybrid quantum system is composed of individual quantum subsystems which are coupled in the sense that information is transferred in both directions. Our system would provide a coherent link between the mechanical motion of ultracold atomic gases and the motion of a massive solid-state object.

Q 1.4 Mo 11:30 ESA-A

Coupling of Bose-Einstein condensates to a micromechanical cantilever via atom-surface forces — •David Hunger[1,2], Stephan Camerer[1,2], Daniel König[2], Jörg P. Kotthaus[2], Jakob Reichel[3], Theodor W. Hänsch[1,2], and Philipp Treutlein[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Ludwig-Maximilians-Universität München — [3]Laboratoire Kastler Brossel, E.N.S., Paris

Micro- and nanostructured mechanical oscillators are presently approaching the quantum regime, driven by the continuous improvement of techniques to read out and cool mechanical motion. By coupling mechanical oscillators to ultracold atoms, hybrid quantum systems could be formed, in which the atoms are used to cool, read out, and coherently manipulate the oscillators' state. For the experimental realization of such systems it is important to investigate different coupling mechanisms.

Here we report experiments in which the vibrations of a classically driven micromechanical oscillator are coupled to the motion of a Bose-Einstein condensate in a magnetic microtrap on a chip. The coupling relies on surface forces experienced by atoms at (sub-) micrometer distance from the mechanical structure. We observe parametric resonances induced by the coupling, corresponding to different mechanical modes of the atoms. Coupling via surface forces does not require functionalization of the oscillator with magnets, electrodes, or mirrors, and could thus be employed to strongly couple atoms to carbon nanotubes or other molecular-scale oscillators.

Q 1.5 Mo 11:45 ESA-A

Cavity optomechanics with a Bose-Einstein condensate — •Christine Guerlin, Ferdinand Brennecke, Stephan Ritter, Kristian Baumann, Tobias Donner, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zürich, CH-8093, Switzerland

In our experiment we study the coupling between a Bose-Einstein condensate and an ultrahigh-finesse optical cavity. The tremendous degree of control over atomic gases achieved in Bose-Einstein condensates combined with the rich field of cavity quantum electrodynamics opens access to a wealth of new physics, ranging from studies of the coupling between quantized light and coherent matter to the implementation of tools for quantum communication.

In the dispersive regime, our system realizes a model of cavity optomechanics. This research field typically studies the coupling of the mechanical degree of freedom of one of the cavity mirrors to the light field via radiation pressure. In our case, the mechanical oscillation is given by a coherent and periodic density modulation of the atomic cloud driven by dipole forces due to the cavity light field. We have observed this density modulation and very strong optical nonlinearities, present even at the single photon level. Furthermore our micromechanical oscillator naturally starts in its ground state, from which a single motional excitation can cause a shift of the cavity resonance on the order of the cavity linewidth. Our system is therefore promising to study the quantum regime of cavity optomechanics. We hope to reveal signatures of the quantum nature of the light and matter fields in further experiments.

Q 2: Quanteninformation: Atome und Ionen I

Zeit: Montag 10:45–12:15 Raum: ESA-B

Q 2.1 Mo 10:45 ESA-B

Optimierte Initialisierung eines $^{171}\mathrm{Yb}^{+}$-Ions in den Zustand $^{2}\mathrm{S}_{1/2}$,F=0 — •Ingo Baumgart, Nuala Timoney und Christof Wunderlich — Fachbereich Physik, Universität Siegen,Walter-Flex-Straße 3, 57072 Siegen

Schnelle und effektive Initialisierung eines Anfangszustandes ist im Hinblick auf die Realisierung eines Quantenrechners oder für Quanten-Simulation eine wichtige Voraussetzung.

Die als quantenmechanisches Zwei-Niveau-System genutzten Hyperfeinstruktur-Zustände $^{2}S_{1/2}, F = 0$ und $^{2}S_{1/2}, F = 1, m_F = 0$ eines in einer Paul-Falle gespeicherten $^{171}\mathrm{Yb}^{+}$-Ions können durch ein resonantes Mikrowellenfeld bei einer Frequenz von 12,6 GHz kohärent manipuliert werden. Zum Dopplerkühlen des Ions wird auf den Übergang $^{2}S_{1/2}, F = 1 \leftrightarrow {}^{2}P_{1/2}, F = 0$ Licht bei 369 nm eingestrahlt. Um für die Zustandspräparation den Übergang $^{2}S_{1/2}, F = 1 \leftrightarrow {}^{2}P_{1/2}, F = 1$, mit dem anschließenden Zerfall in den Zustand $^{2}S_{1/2}, F = 0$ resonant anzuregen, wird das Licht bei 369 nm um 2,1 GHz mit einem Sechsfach-Durchgang durch einen akustooptischen Modulator zu größeren Frequenzen hin verstimmt.

Im Vergleich zur bisherigen Methode wird so eine wesentliche Verbesserung der Präparationseffizienz erreicht. Dafür wird eine minimale Lichtleistung von $0{,}02\,\mathrm{W/(mm)^2}$ im Fallenzentrum benötigt und eine kürzere Präparationszeit von bisher minimal $25\,\mu$s erzielt. Die so erlangte Präparationseffizienz von annähernd 100 % stimmt gut mit den durchgeführten Simulationen überein.

Q 2.2 Mo 11:00 ESA-B

Single-photon spectroscopy on a single ion — •Carsten Schuck, Nicolas Piro, Felix Rohde, Marc Almendros, Jan Huwer, Morgan W. Mitchell, Markus Hennrich, Francois Dubin, Albrecht Haase, and Jürgen Eschner — ICFO - The Institute of Photonic Sciences, Mediterranean Technology Park, 08860 Castelldefels (Barcelona), Spain

The realization of a quantum network requires the distribution of entanglement between its nodes. For some of the most promising implementations this requires the interaction of single atoms with single photons. Here we investigate the interaction of a single calcium ion with heralded single photons generated by a spontaneous parametric down-conversion source whose emission is tailored to coincide with the 20MHz bandwidth of the atomic resonance [1]. We focus these photons onto the atom with a high numerical aperture lens and monitor the rate of fluorescence photons continuously emitted by the laser-cooled ion. On absorption of a photon from the pair-source the ion may subsequently decay to a metastable state outside the cooling cycle, i.e. we observe a quantum jump in the fluorescence rate. We perform single-photon spectroscopy of a single atom by measuring the rate of these quantum jumps as a function of the photon pair generation rate and the detuning of the down conversion source from the atomic transition. In both cases we observe clear evidence for the interaction between heralded down-conversion photons and a single trapped ion.

[1] A. Haase et al., Opt. Lett. in print (arXiv:0808.1988)

Q 2.3 Mo 11:15 ESA-B

High fidelity entanglement of $^{43}\mathrm{Ca}^{+}$ hyperfine clock states — •Gerhard Kirchmair[1,2], Rene Gerritsma[1,2], Florian Zähringer[1,2], Jan Benhelm[1,2], Christian Roos[1,2], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, A-6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, A-6020 Innsbruck, Austria

In an experiment using the odd calcium isotope $^{43}\mathrm{Ca}^{+}$ we combine the merits of a high fidelity entangling operation on an optical transition (optical qubit) with the long coherence times offered by two "clock"states in the hyperfine ground state (hyperfine qubit) by mapping between these two qubits. We achieve state initialization, state detection, global qubit rotations and mapping operations with errors smaller than 1%, whereas the Mølmer-Sørensen entangling gate adds errors of 2.3%. We create Bell states with a fidelity of 96.9(3)% in the optical qubit and a fidelity of 96.7(3)% when mapped to the hyperfine states. In the latter case the entanglement is preserved for 96(3) ms, exceeding the gate duration by three orders of magnitude. The Bell state stored in the hyperfine qubit can be mapped back to the optical qubit and additional gate operations disentangle/entangle the ions again. In addition we present results on entangling three $^{40}\mathrm{Ca}^{+}$ ions in a GHZ state with a fidelity of 98%.

Q 2.4 Mo 11:30 ESA-B

Photon-Photon Entanglement with an Atom-Cavity System — •Martin Mücke, Bernhard Weber, Holger Specht, Tobias Müller, Joerg Bochmann, David Moehring, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

We report on the implementation of a deterministic protocol where a single rubidium atom trapped within a high-finesse optical cavity is entangled with an emitted photon [1]. After a chosen time, the atomic state is mapped onto a second photon, thus generating an entangled photon pair. Compared to previous experiments with falling atoms [2], the long trapping times of exactly one atom in the mode of the cavity allow for $\sim 10^5$ times more entangled photons per atom and also for a measurement of the coherence time of the atomic qubit. The entanglement is verified by a Bell inequality measurement that is in clear violation of classical physics. Furthermore, the two-photon state is characterized via quantum state tomography.

[1] B. Weber *et al.*, accepted by PRL, arXiv:0811.3612v1
[2] T. Wilk *et al.*, Science **317**, 488 (2007)

Q 2.5 Mo 11:45 ESA-B

Electromagnetically induced transparency involving Rydberg states in a rubidium microcell — •Harald Kübler[1], James Shaffer[2], Alex Charnukha[1], Thomas Baluktsian[1], Christian Urban[1], 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

Small glass cells filled with rubidium vapor are promising candidates for quantum information processing using Rydberg states. 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 called "dipole blockade", provides a nonlinearity that is an essential tool for proposals to entangle atoms using Rydberg states. Similarly, atomic vapor confined on a length scale comparable to the blockade radius can be used like quantum wells (2D), quantum wires (1D) and quantum dots (0D) e.g. to realize a single photon source. We present measurements in rubidium vapor cells with thicknesses on the order of the blockade radius. We observed EIT with Rydberg states and investigated the effects of the confinement in these vapor cells. These experiments show that coherent dynamics involving Rydberg states are possible in micro cells above room temperature.

Q 2.6 Mo 12:00 ESA-B

Towards entanglement of two individual atoms using the Rydberg blockade — •Tatjana Wilk, Alpha Gaëtan, Yevhen Miroshnychenko, Charles Evellin, Antoine Browaeys, and Philippe Grangier — Laboratoire Charles Fabry, Institut d'Optique, Palaiseau, France

The Rydberg blockade is of great interest for many quantum information processing schemes, since it provides a way to deterministically entangle two or more atoms and to drive fast quantum gates [1]. First experimental efforts into this direction recently succeeded in the observation of the Rydberg blockade between two ^{87}Rb atoms individually trapped in two neighboring dipole traps [2,3]. Furthermore, in the two atom system the Rabi frequency for oscillations between the ground state $|gg\rangle$ and *one* atom in the Rydberg state is enhanced by $\sqrt{2}$ with respect to the Rabi frequency for a single atom [3]. This indicates the production of an entangled state $(|gr\rangle + |rg\rangle)/\sqrt{2}$. To be able to quantify the entanglement between the two atoms in a Bell test or a state tomography, the Rydberg state is mapped onto another ground state $|g'\rangle$. Rotations of the measurement basis are done with a pair of Raman lasers coupling $|g\rangle$ and $|g'\rangle$. The atomic state is read out observing the fluorescence of the remaining atoms after ejecting atoms in state $|g\rangle$ from the trap. We report on the current status of the experiment. [1] D. Jaksch et al., *Phys. Rev. Lett.* **85**, 2208 (2000). M.D. Lukin et al., *Phys. Rev. Lett.* **87**, 037901 (2001). [2] E. Urban et

al., *arxiv:0805.0758.* [3] A. Gaëtan et al., *Nature Phys.* (accepted, see also *arxiv:0810.2960*).

Q 3: Quantengase: Dynamik in Gittern

Zeit: Montag 10:45–12:30 Raum: VMP 6 HS-A

Q 3.1 Mo 10:45 VMP 6 HS-A

Magnetism, coherent many-particle dynamics, and relaxation with ultracold bosons in optical superlattices — Thomas Barthel[1], •Christian Kasztelan[1], Ian P. McCulloch[2], and Ulrich Schollwöck[1] — [1]Institute for Theoretical Physics C, RWTH Aachen University, 52056 Aachen, Germany — [2]School of Physical Sciences, The University of Queensland. Brisbane, QLD 4072, Australia

We study a particular setup of an ultracold two-species boson gas in an optical superlattice. This realizes in a certain parameter regime actually the physics of spin-1/2 Heisenberg magnets describing the second order hopping processes. Tuning of the superlattice allows for controlling the effect of fast first order processes versus the slower second order ones. We provide the evolution of typical experimentally available observables by the density-matrix renormalization-group method. The validity of the description via the Heisenberg model is studied numerically and analytically. Contrary to the case of recently realized coherent two-particle dynamics (isolated double wells), relaxation of local observables can be observed. The tunability between the Bose-Hubbard model and the Heisenberg model in this setup could be used to study experimentally the differences in equilibration processes for nonintegrable and Bethe ansatz integrable models.

[1] T. Barthel, C. Kasztelan, I. P. McCulloch and U. Schollwöck, arXiv:0809.5141 (2008)

Q 3.2 Mo 11:00 VMP 6 HS-A

Relaxation dynamics in quasi one-dimensional cold gases — •Dominik Muth and Michael Fleischhauer — Fachbereich Physik, Technische Universität Kaiserslautern, Germany

Since the first realisation of a Bose-Einstein condensate in cold atomic gases, experimental methods have been much improved. Today also the dynamics of quantum degenerate gases can be observed and deep optical lattices or atom chips provide access to the quasi one-dimensional regime. While one-dimensional quantum gases with local interactions are integrable even for finite interaction strength, experiments necessarily contain small distortions due to transversal excitations in the confinement or coupling between different one-dimensional cells. These destroy integrability and make the system relax into a thermal state, given by the usual canonical ensemble. We investigate theoretically the connection between the strength of the distortions and the rate of thermalization. The analytical results are complemented with numerical simulations using the Time Evolving Block Decimation algorithm, a powerful tool for one-dimensional quantum systems, that allows us to go beyond the regime covered by perturbation theory.

Q 3.3 Mo 11:15 VMP 6 HS-A

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

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 $\mathcal{N}$, where $\mathcal{N}$ is the number of spin 1/2 fermion flavors. The dynamic equations are derived in next-to-leading order of this expansion for a single flavor Fermi gas. This approach reaches far beyond mean-field theory and includes quantum statistical aspects of equilibration dynamics. It enables to describe, e.g., the dynamical evolution of trapped Fermi gases in optical lattices, as well as the BEC-BCS crossover dynamics. We present results on the dynamics of a 1D Fermi gas initally prepared far away from equilibrium.

Q 3.4 Mo 11:30 VMP 6 HS-A

Dynamical properties of solitonic eigenstates of the Bose-Hubbard Hamiltonian — •Hannah Venzl[1], Tobias Zech[1], Bartłomiej Oleś[2], Moritz Hiller[1], Florian Mintert[1], and Andreas Buchleitner[1] — [1]Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany — [2]Marian Smoluchowski Institute of Physics and Mark Kac Complex Systems Research Center, Jagiellonian University, Reymonta 4, 30-059 Kraków, Poland

We show the emergence of solitonic eigenstates in the Bose-Hubbard Hamiltonian with an additional tilt in a regime where the spectrum obeys chaotic level statistics. Those states show robust behavior in the sense that they couple weakly to the chaotic background. By driving the system with a time-dependent tilt we investigate the dynamical behavior of those solitonic eigenstates and show that their stability is strongly enhanced as compared to states from the chaotic background. We discuss the analogy of the solitonic submanifold to regular islands embedded in a chaotic sea.

Q 3.5 Mo 11:45 VMP 6 HS-A

Collapse and Revival of Matter Waves in Bosonic Optical Lattices — •Francisco Ednilson Alves dos Santos[1] and Axel Pelster[1,2] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

Within the Ginzburg-Landau theory of the Bose-Hubbard model [1], we derive the underlying equation of motion which describes the dynamics of the condensate wave function. With this we describe theoretically the experimental results of Ref. [2], in particular the apparent damping effect which completely extinguishes the matter wave after a characteristic time scale. We show that, due to the overall harmonic potential which confines the atoms inside a finite volume, the condensate wave function oscillates with frequencies which vary slightly from site to site. As time elapses, the values of the matter wave at two spatially separated points in the lattice become out of phase. This destroys the coherence of the condensate after a certain damping time which is associated with the harmonic frequency of the external magnetic trap.

[1] B. Bradlyn, F.E.A. dos Santos, and A. Pelster, Phys. Rev. A (in press), eprint: `arXiv:0809.0706`.

[2] M. Greiner, O. Mandel, T. W. Hänsch, and I. Bloch, Nature, **419**, 51 (2002).

Q 3.6 Mo 12:00 VMP 6 HS-A

Exact local relaxation in a class of quantum lattice systems: Central limit theorems and experimentally accessible signatures — •Marcus Cramer[1], Andreas Flesch[2], Ulrich Schollwöck[2], and Jens Eisert[3] — [1]Imperial College London, UK — [2]RWTH Aachen, Germany — [3]Universität Potsdam, Germany

A reasonable physical intuition in the study of interacting quantum systems says that, independent of the initial state, the system will tend to equilibrate. We present a setting in which relaxation to a steady state is provably exact, namely for the Bose-Hubbard model where the system is quenched from a Mott quantum phase to the strong superfluid regime. We find that the evolving state locally relaxes to a steady state with maximum entropy constrained by the constants of motion [1]. Our argument includes a quantum central limit theorem and exploits the finite speed of information propagation. In addition, we present a setting—atoms in optical super-lattices—in which one can experimentally probe signatures of this local relaxation without the need of addressing single sites [2]. This opens up a way to explore the convergence of subsystems to maximum entropy states in quenched quantum many-body systems with present technology. We also outline generalizations to arbitrary initial states and quasi-free dynamics.

[1] M. Cramer, C.M. Dawson, J. Eisert, T.J. Osborne, Phys. Rev. Lett. **100**, 030602 (2008).

[2] M. Cramer, A. Flesch, I.P. McCulloch, U. Schollwoeck, J. Eisert, Phys. Rev. Lett. **101**, 063001 (2008).

Q 3.7 Mo 12:15 VMP 6 HS-A

Statistics of Schmidt coefficients and the simulability of complex quantum systems — •Hannah Venzl[1], Andrew J.

Daley[2,3], Florian Mintert[1], and Andreas Buchleitner[1] — [1]Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany — [2]Institut für Theoretische Physik, Universität Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria — [3]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, 6020 Innsbruck, Austria

We show that the transition from regular to chaotic spectral statistics in interacting many-body quantum systems has an unambiguous signature in the distribution of Schmidt coefficients dynamically generated from generic initial states. The characteristic redistribution that is observed on the transition to chaotic dynamics confirms that chaotic many body systems can not be described efficiently by local bases [1] what implies that techniques like the time-dependent Density Matrix Renormalization Group algorithm [2] loose their efficiency. We investigate these mechanisms on the tilted Bose-Hubbard model. However, the emergence of universal spectral properties allows to translate our conclusions to generic many-body quantum systems.

[1] H. Venzl, A. J. Daley, F. Mintert, and A. Buchleitner, arXiv:0808.3911

[2] G. Vidal, Phys. Rev. Lett. **91**, 147902 (2003)

Q 4: Laserentwicklung: Festkörperlaser I

Zeit: Montag 10:45–12:30 Raum: VMP 6 HS-C

Q 4.1 Mo 10:45 VMP 6 HS-C

Kristallzüchtung und Charakterisierung von Yb:Y_2O_3 als aktives Medium im Scheibenlaser — •Kerstin Schenk, Rigo Peters, Klaus Petermann und Günter Huber — Universität Hamburg, Institut für Laser-Physik, Luruper Chaussee 149, 22761 Hamburg

Yb-dotierte Sesquioxide bieten auf Grund ihrer hervorragenden thermischen Eigenschaften und des geringen Quantendefekts gute Voraussetzungen für den Einsatz als Hochleistungs-Festkörperlaser.

Nachdem bereits mit Yb:Lu_2O_3 und Yb:Sc_2O_3 erfolgreich hocheffizienter Laserbetrieb demonstriert werden konnte [1,2], beschäftigt sich diese Arbeit mit der Herstellung und Charakterisierung von Yb:Y_2O_3. Dieses zeigt mit etwa 0,2 dB/cm im Vergleich zu Lu_2O_3 und Sc_2O_3 deutlich größere Streuverluste. Die Ursache hierfür ist vermutlich eine Phasenumwandlung knapp unterhalb des Schmelzpunktes während der Kristallzüchtung.

Um dieses Verhalten zu verstehen, wird der Einfluss der Züchtungsparameter auf das Streuverhalten untersucht. Anhand von weiterführenden Laserexperimenten werden die Auswirkungen auf die Lasereigenschaften diskutiert.

[1] R. Peters, C. Kränkel, K. Petermann, G. Huber, Opt. Express 15, 7075-7082 (2007)

[2] R. Peters, C. Kränkel, K. Petermann, G. Huber, CLEO2008, Beitrag CTuKK4, San Jose, USA (2008)

Q 4.2 Mo 11:00 VMP 6 HS-C

Yb:LuAG als Scheibenlasermaterial im hohen Leistungsbereich — •Kolja Beil, Susanne T. Fredrich-Thornton, Christian Kränkel, Rigo Peters, Klaus Petermann und Günter Huber — Universität Hamburg, Institut für Laser-Physik, Luruper Chaussee 149, 22761 Hamburg

Aufgrund der geringen Dicke des aktiven Mediums im Scheibenlaser wird auch bei hohen Laserleistungen eine effiziente Kühlung des Lasermediums ermöglicht, wodurch negative thermische Effekte stark reduziert werden. Um die Vorteile des Scheibenlasers nutzen zu können, ist eine hohe Dotierung sowie eine hohe Wärmeleitfähigkeit des Lasermaterials unerlässlich. Yb:YAG ist aufgrund seiner guten thermomechanischen Eigenschaften derzeit das Standardmaterial für die Verwendung im Scheibenlaser.

Yb:LuAG, welches im Vergleich zu Yb:YAG nahezu identische spektroskopische Eigenschaften aufweist, zeigt bei Yb-Dotierung im Gegensatz zu Yb:YAG nur eine geringe Abnahme der Wärmeleitfähigkeit. So wird bei einer Dotierung von 10 at.% für Yb:YAG bereits eine Reduzierung der Wärmeleitfähigkeit um etwa 35% beobachtet, während sich diese bei Yb:LuAG lediglich um 6% verringert. Dadurch ergibt sich ein etwa 20% höherer Wert im Vergleich zu Yb:YAG. In Laserexperimenten mit 10 at.% Yb-dotiertem LuAG konnten bei mittleren Ausgangsleistungen von bis zu 25 W differentielle Wirkungsgrade von mehr als 70% erzielt werden. Die höhere Wärmeleitfähigkeit bei nahezu identischen Lasereigenschaften lässt vermuten, dass sich Yb:LuAG besser für den Hochleistungsbetrieb im Scheibenlaser eignet als Yb:YAG.

Q 4.3 Mo 11:15 VMP 6 HS-C

888 nm gepumpterNd:YVO_4-Hochleistungslaser im TEM_{00}-Mode bei 1342 nm — •Florian Lenhardt[1], Thorsten Bauer[2], Martin Nittmann[2], Jürgen Bartschke[2] und Johannes L'huillier[1] — [1]Technische Universität Kaiserslautern, Fachbereich Physik, Erwin-Schrödinger-Strasse 46, 67663 Kaiserslautern — [2]Xiton Photonics GmbH, Kohlenhofstrasse 10, 67663 Kaiserslautern

Kompakte und effiziente diodengepumpte Festkörperlaser im Spektralbereich um $1,3\ \mu$m besitzen wichtige Anwendungen in der Faseroptik, Medizin und Forschung. Aufgrund des sehr großen Wärmeeintrags in den Kristall bei diesem Laserübergang, verursacht durch den großen Quantendefekt und die "exited state absorption"(ESA), wird im Kristall eine sehr starke thermische Linse induziert. Daher hatten alle bisher veröffentlichten Systeme mit hoher Ausgangsleistung eine schlechte Strahlqualität und alle Systeme mit beugungsbegrenzter Strahlqualität eine vergleichsweise niedrige Ausgangsleistung. In diesem Vortrag wird ein Lasersystem vorgestellt, das in einem TEM_{00}-Strahl eine Ausgangsleistung von 24 W liefert. Die Leistungsschwankungen σ sind geringer als 1 %. Bei einer absorbierten Pumpleistung von 84 W entspricht die erzeugte Leistung einer optischen Effizienz von 29 %. Die Strahlung besitzt ein gaußförmiges Strahlprofil und eine Beugungsmaßzahl von $M^2 < 1,1$. Soweit uns bekannt wurde mit diesem Laser die höchste bisher veröffentlichte Ausgangsleistung in einem 1342 nm TEM_{00}-Strahl erreicht. Diese Ergebnisse wurden durch eine gezielte Optimierung der Wärmeverteilung im Laserkristall und des Resonatordesigns sowie durch Pumplicht mit einer Wellenlänge von 888 nm ermöglicht.

Q 4.4 Mo 11:30 VMP 6 HS-C

Regenerativer Nd:YVO_4 Hochleistungsverstärker mit langen Pikosekunden Impulsen und effizienter Erzeugung der zweiten Harmonische — •Markus Lührmann, Christian Theobald, Richard Wallenstein und Johannes A. L'huillier — TU Kaiserslautern, 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 Intensität der so verstärkten fs-Impulse ist gut geeignet um hohe Harmonische oder Röntgenstrahlung zu erzeugen. Diese Strahlung ist interessant für verschiedene Anwendungen wie Photoelektronen Spektroskopie oder die Verbrennungsdiagnose. Diese Anwendungen würden allerdings stark von Wiederholraten höher als 10 kHz profitieren.

Wir haben daher, basierend auf einem 100 W, 888 nm Diodengepumpten Nd:YVO_4 regenerativen Hochleistungsverstärker, eine Pumpquelle für einen OPCPA mit 20 kHz Wiederholrate entwickelt. Das Gesamtsystem besteht aus einem Masteroszillator, dem rgenerativen Verstärker und einem winkelphasenangepassten LBO Kristall zur externen Frequenzverdoppelung der verstärkten Impulse. Die erzeugten nahezu Fourier limitierten Impulse bei 532 nm besitzen eine Impulsenergie von über 1,2 mJ bei einer Wiederholrate von 20 kHz mit frei einstellbaren Impulsdauern von 180 ps bis etwa 1 ns sowie eine annähernd beugungsbegrenzte Strahlqualität $M^2 < 1,2$.

Q 4.5 Mo 11:45 VMP 6 HS-C

Ein hochrepetierender durchstimmbarer Chrom:Forsterit Laser für die Resonanz-Ionisations-Spektroskopie — •Sebastian Rothe[1], Christoph Mattolat[1], Sebastian Raeder[1], Jens Lassen[2] und Klaus Wendt[1] — [1]Johannes-Gutenberg-Universität, 55128 Mainz — [2]TRIUMF, Vancouver, Kanada

Die resonante Laserionisation wird sehr erfolgreich in der effizienten und selektiven Produktion radioaktiver Ionenstrahlen an on-line Massenseparatoreinrichtungen, z.B. ISOLDE am CERN, eingesetzt. Inzwischen werden an entsprechenden Anlagen, aufgrund ihrer Zuverlässigkeit und Stabilität, verstärkt hochrepetierende Titan:Saphir Laser (Ti:Sa) mit Frequenzvervielfachung und damit einem sehr weiten

Abstimmbereich verwendet. Als Ergänzung zu unserem bestehenden Ti:Sa Lasersystem wurde analog dazu ein Laser mit Chrom:Forsterit als aktivem Medium konzipiert und aufgebaut. Der Kristall hat einen Abstimmbereich von 1150 nm bis 1350 nm. Mittels nachfolgender Frequenzverdopplung kann ein Wellenlängenbereich im orange-roten erreicht werden, dieser fügt sich in die spektrale Lücke zwischen fundamentaler und frequenzverdoppelter Ti:Sa Strahlung. Als Anwendung wurden verschiedene mehrstufig-resonante Anregungsschemata in Nickel, Scandium und Silizium erfolgreich getestet; letzteres wurde dabei der Resonanzionisation durch Festkörperlaser generell erstmals zugänglich gemacht.

Q 4.6 Mo 12:00 VMP 6 HS-C

Highly efficient 4 W, 160 fs Yb:KGW laser oscillator pumped by a single broad area diode and its application for high-power femtosecond supercontinuum generation — •Felix Hoos[1], Todd Meyrath[1], Sai Li[1], Bernd Braun[2], and Harald Giessen[1] — [1]4. Physikalisches Institut, Universität Stuttgart, 70550 Stuttgart — [2]Georg-Simon-Ohm Hochschule, Keßlerplatz 12, 90489 Nürnberg

We present a novel and very simple design for a highly efficient femtosecond Yb:KGW laser oscillator. The laser is capable to generate femtosecond laser pulses at a repetition rate of 44 MHz. An average power of nearly 5 W was obtained for a pulse width of 224 fs, resulting in an optical-to-optical efficiency of more than 28%. With a pulse width of 161 fs, more than 4 W at an optical-to-optical efficiency of 23% were achieved. The laser is based on slab laser crystal geometry and is pumped by a single broad area diode. The progress in efficiency and simplicity is due to the high beam quality of the employed pump diode and to a thorough consideration of the thermal effects that are induced in the gain medium. Concerning thermal lensing, these diodes show some differences compared to other high-power diodes due to their particular beam profile. We present experimental investigations and results of numerical modeling of the thermal effects that are caused by these diodes.

Furthermore we are going to present results of supercontinuum generation in tapered fibers with this laser. Femtosecond supercontinua with more than 1W overall average power could be obtained.

Q 4.7 Mo 12:15 VMP 6 HS-C

Erzeugung von UV-Strahlung im Dauerstrichbetrieb bei 261 nm über resonatorinterne Frequenzverdopplung von diodengepumpten, grün emittierenden Praseodym-Lasern — •Teoman Gün, André Richter, Ernst Heumann und Günter Huber — Institut für Laser-Physik, Universität Hamburg, Germany

Ultraviolette (UV) kohärente Dauerstrich-Strahlung unterhalb einer Wellenlänge von 300 nm wird üblicherweise durch zweifache Frequenzkonversion von Infrarot-Lasern generiert. Diese Methode ist im Allgemeinen sehr aufwendig und kompliziert. In Rahmen dieses Beitrages wird die resonatorinterne Frequenzverdopplung eines Festkörperlasers zur Erzeugung von UV-Strahlung bei einer Wellenlänge von 261 nm demonstriert. Dabei werden Praseodym-dotierte Fluoridkristalle, $LiYF_4$ (YLF) und $LiLuF_4$ (LLF), über eine GaN-Laserdiode mit einer Ausgangsleistung von 1 W und der Emissionswellenlänge von 444 nm gepumpt. Die emittierte Grundwelle des Praseodym-Lasers mit der Wellenlänge von 523 nm wird in dem zweiten Arm des einfach gefalteten Resonators über einen nichtlinearen Kristall resonatorintern frequenzverdoppelt und die UV-Strahlung ausgekoppelt. Die Frequenzkonversion erfolgt über einen für 523 nm antireflexions-beschichteten Beta-Barium-Borat (β-BaB_2O_4 oder BBO)-Kristall unter kritischer Phasenanpassung vom Typ I. Unter Verwendung eines 5 mm langen BBO-Kristalls wurde eine maximale UV-Leistung von bis zu 0,6 mW generiert. Weitere Experimente zur Leistungsskalierung durch Verwendung geeigneter Spiegel, Kristalle und Resonatoranordnungen sind geplant und werden im Vortrag vorgestellt.

Q 5: Quanteninformation: Konzepte I

Zeit: Montag 10:45–12:30 Raum: VMP 6 HS-D

Q 5.1 Mo 10:45 VMP 6 HS-D

Copies with high fidelity from a simple quantum cloning machine — •Michael Siomau[1] and Stephan Fritzsche[1,2,3] — [1]Max-Planck-Institut für Kernphysik, Postfach 103980, D-69117 Heidelberg, Germany — [2]Gesellschaft für Schwerionenforschung, D-64291 Darmstadt, Germany — [3]Frankfurt Institute for Advanced Studies, D-60438 Frankfurt am Main, Germany

We investigate theoretically a symmetric quantum cloning machine (QCM) which provides two identical copies for any given input qubit. When compared with the Universal QCM [1], that produces copies with constant fidelity $F = 5/6 \approx 0.83$ for any given input state, and the Equatorial QCM [2] (copies with fidelity $F \approx 0.85$ for states on the equator of the Bloch sphere), our suggested scheme produces copies with fidelity $0.95 \geq F \geq 0.90$ for some selected region of the Bloch sphere. The properties of the new transformation are discussed along with possible applications of this scheme.

[1] V. Bužek and M. Hillery, Phys.Rev.A. 54, 1844 (1996)
[2] D. Bruß, M. Cinchetti, G.M. D'Ariano and C. Macchiavell, Phys.Rew.A 62, 012302 (2000)

Q 5.2 Mo 11:00 VMP 6 HS-D

Deterministic purification of an entangled state using a single copy — •Matthias Kleinmann, Oleg Gittsovich, and Otfried Gühne — Institut für Quantenoptik und Quanteninformation, Technikerstraße 21a, 6020 Innsbruck, Austria

Two remote parties cannot prepare any entangled quantum state if the communication between them is limited to be classical. However, if both parties initially share an entangled state it is possible to prepare with a probability of one any state from a certain family of entangled states. While –by definition– the entanglement cannot increase in such a scenario, it might well be possible to achieve a pure final state, even if starting from a mixed initial state [1]. We consider conditions and examples for such purification protocols and study the interlink to the entanglement-preserving distinction of pure states [2].

[1] E. Chitambar *et al.*, `arXiv:0811.3739`
[2] S. Cohen, Phys. Rev. A **75**, 052313 (2007)

Q 5.3 Mo 11:15 VMP 6 HS-D

Manipulating entanglement sudden death of two-qubit X-states in zero- and finite-temperature reservoirs — •Mazhar Ali[1], Gernot Alber[1], and Ravi Rau[2] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289, Germany — [2]Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana 70803, USA

The finite-time end of quantum entanglement or *entanglement sudden death* (ESD) has been investigated both theoretically and experimentally. In many situations however it is of interest to stabilize quantum states against ESD. Recently, we have shown that, it is possible to hasten, delay or even avert ESD in zero-temperature reservoirs [1]. Generalizing these first results it is demonstrated that ESD of two qubits interacting with statistically uncorrelated thermal reservoirs can also be controlled by application of simple local unitary transformations. In particular, for initially prepared X-states of two qubits a simple (necessary and sufficient) criterion for ESD can be derived with the help of the Peres-Horodecki criterion. Based on this criterion it is possible to prove that, in contrast to the zero-temperature case, at finite temperatures of at least one of the reservoirs all initially prepared two-qubit X-states exhibit ESD. General conditions are derived under which ESD can be hastened, delayed, or averted [2].

[1] A. R. P. Rau, M. Ali, and G. Alber, Eur. Phys. Lett. 82, 40002 (2008).
[2] M. Ali, G. Alber, and A. R. P. Rau, arXiv: quant-ph/0810.2936 (To appear in J. Phys. B)

Q 5.4 Mo 11:30 VMP 6 HS-D

Post-selection technique for quantum channels with applications to quantum cryptography — •Matthias Christandl[1], Robert Koenig[2], and Renato Renner[3] — [1]University of Munich, Germany — [2]California Institute of Technology, Pasadena, CA, United States of America — [3]ETH Zurich, Switzerland

We propose a general method for studying properties of quantum channels acting on an n-partite system, whose action is invariant under permutations of the subsystems. Our main result is that, in order to prove that a certain property holds for any arbitrary input, it is sufficient to consider the special case where the input is a particular de Finetti-type state, i.e., a state which consists of n identical and independent copies of an (unknown) state on a single subsystem. A similar statement holds for more general channels which are covariant with respect to the action of an arbitrary finite or locally compact group.

Our technique can be applied to the analysis of information-theoretic problems. For example, in quantum cryptography, we get a simple proof for the fact that security of a discrete-variable quantum key distribution protocol against collective attacks implies security of the protocol against the most general attacks. The resulting security bounds are tighter than previously known bounds obtained by proofs relying on the exponential de Finetti theorem [Renner, Nature Physics 3,645(2007)].

Q 5.5 Mo 11:45 VMP 6 HS-D

Models of continuous-variable quantum computing — •Matthias Ohliger und Jens Eisert — Institut für Physik und Astronomie, Universität Potsdam, Karl-Liebknecht-Straße 24/25, 14476 Potsdam, Germany

We discuss strictly efficient models for measurement-based quantum computing using physical continuous variables, such as field modes of light. Such measurement-based quantum computing (MBQC) provides a promising paradigm for quantum computation as it does not require performing unitary gates during the computation, but rather appropriate readout. Here, we introduce novel schemes for which the resource state can be reasonably and efficiently prepared, and which notably do not require having infinite squeezing or mean energy available. What is more, error correction techniques are implementable, as the logical information is stored in finite-dimensional objects grasping correlations of the quantum states. Using the ideas of computational tensor networks we discuss how to sequentially prepare suitable physical resource states with cavity QED or with non-linear optics and how to efficiently implement a computational universal set of quantum operations with feasible optical measurements like homodyne detection and photon counting.

Q 5.6 Mo 12:00 VMP 6 HS-D

Analysis of fermionic gaussian states by non-commutative phase space techniques — •Dirk-Michael Schlingemann, Michael Keyl, and Lorenzo Campos Venuti — ISI Foundation Torino, Quantum information group

The basic constituents of the matter that surrounds us in daily life are fermions. Therefore it is needless to say that theoretical investigation of fermion systems play an essential role in almost all areas of quantum physics. A particular class of states of fermion systems are quasi-free states or Gaussian fermionic states. On one hand, this class of states can be treated analytically even for very large systems, on the other hand, these states are complex enough to describe ground states of interacting spin chain systems.

We present an approach to non-commutative phase space which allows to analyze Gaussian fermionic states in complete analogy to Gaussian bosonic states. The used mathematical tools are based on a novel algebraic structure which combines the Grassmann algebra with the fermion algebra of canonical anti-commutation relations (GAR algebra).

As a new application, the corresponding theory provides an elegant tool for calculating the fidelity of two fermionic gaussian states which is needed for the study of entanglement distillation within fermionic systems.

Q 5.7 Mo 12:15 VMP 6 HS-D

On Quantum Qudit Gate Constructions — •Colin Wilmott — School of Mathematical Sciences, University College Dublin, Dublin, Ireland — Institut für Theoretische Physik III, Heinrich-Heine-Universität, Düsseldorf, Deutschland

Most often it is assumed that quantum computations are predicated on a collection of 2-level quantum mechanical systems called qubits. However, there is a view to generalise to d-level, or qudit, quantum mechanical systems. Furthermore, it is becoming increasingly evident that much effort continues to be made into finding efficient quantum networks in the sense that for the given gate library there is no smaller network that achieves the same task.

The qubit SWAP gate has been illustrated to be a cornerstone in the networkability of quantum computation based on qubits. We introduce a quantum gate construction that generalises the qubit SWAP gate to higher dimensions. This construction makes extensive use of binomial summations and yields a quantum qudit SWAP gate determined only in the CNOT gate. In addition, the task of constructing generalised SWAP gates based on transpositions of qudit states is argued in terms of the signature of a permutation.

Q 6: Ultrakalte Moleküle (mit MO)

Zeit: Montag 10:45–12:15 Raum: VMP 8 HS

Q 6.1 Mo 10:45 VMP 8 HS

Two-photon coherent control of femtosecond photoassociation — •Mamadou Ndong[1], Ronnie Kosloff[2], and Christiane P. Koch[1] — [1]Freie Universität Berlin, Institut für Theoretische Physik, Arnimallee 14, 14195 Berlin — [2]Hebrew University, Dept. of Physical Chemistry, Jerusalem 91904, Israel

Photoassociation with short laser pulses has been proposed as a technique to create ultracold ground state molecules. A broad-band excitation seems the natural choice to drive the series of excitation and deexcitation steps required to form a molecule in its vibronic ground state from two scattering atoms. However, one of the main obstacles with broad-band excitations is to eliminate the atomic excitation which hampered first attempts at femtosecond photoassociation. To overcome the ostensible conflict of driving a narrow transition by a broad-band laser, we propose a two-photon photoassociation scheme. When the excitation is carried out by more than one photon, different pathways in the field can be interfered constructively or destructively. Using the idea of rational phase shaping in two-photon transitions, we derive analytical solutions to suppress atomic transitions in both the weak-field and strong-field regime. Two-photon excitation may thus pave the way toward coherent control of photoassociation. We explore the possibility of two-photon femtosecond photoassociation for alkali and alkaline-earth metal dimers and present a detailed study for the example of calcium.

Q 6.2 Mo 11:00 VMP 8 HS

Heteronuclear molecules in an ultracold Bose-Fermi Mixture — •Oliver Topic, Manuel Scherer, Thorsten Henninger, Carsten Klempt, Eberhard Tiemann, Wolfgang Ertmer, and Jan Arlt — Institut für Quantenoptik, Leibniz Universität Hannover, Germany

The prospect of investigating quantum degenerate molecules with a large dipole moment has driven the field of molecular physics for the past decade. The use of Feshbach resonances now allows for precise control of the interactions in heteronuclear mixtures of two atomic species and provides a new path towards such molecular ensembles.

Within our experiments, bosonic 87Rb atoms are used to cool an ensemble of fermionic 40K atoms to joint quantum degeneracy. This mixture provides the starting point for the detailed analysis and manipulation of the interactions. Applying a homogeneous magnetic field up to 700G allows for the investigation of heteronuclear Feshbach resonances in this mixture. We have been able to observe 28 resonances in ten different spin combinations. Together with results from molecular spectroscopy, this allowed for a large improvement of the interaction model. One of the observed resonances is used for the production of weakly bound heteronuclear Feshbach molecules. We report on a precise characterization of the production efficiency of ultracold Feshbach molecules and its dependence on critical parameters such as temperature and binding energy. Our analysis provides the first full theoretical understanding of this production efficiency and thus paves the way towards the optimised production of deeply bound molecular ensembles.

Q 6.3 Mo 11:15 VMP 8 HS

Preparation of HD^+-Ions in the Ro-vibrational Ground State — •Tobias Schneider, Bernhard Roth, Hannes Duncker, Michael Hansen, Sergey Vasilyev, Ingo Ernsting, and Stephan Schiller — Institut für Experimentalphysik, Universität Düsseldorf, Universitätsstr.1, 40225 Düsseldorf

Being the most simple heteronuclear molecule, the HD^+ molecular ion is an ideal model system for testing the predictions of ab-initio theoretical molecular structure calculations using high precision laser spectroscopy. Two interesting perspectives are improved tests of QED effects in molecules and an alternative determination of the electron to proton mass ration m_e/m_p.

One important prerequisite for high precision spectroscopic measurements is the ability to control the translational as well as internal degrees of freedom of the molecules. 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 the sympathetic cooling does not affect the internal degrees of freedom and in non-cryogenic environments interaction with black body radiation will distribute the molecular population over several ro-vibrational states.

For HD^+ we developed an optical pumping scheme that allows to prepare most of the molecular ions in the ro-vibrational ground state. We present first experimental results.

Q 6.4 Mo 11:30 VMP 8 HS

Formation of dipolar molecules in the absolute ground-state — •Johannes Deiglmayr[1,2], Anna Grochola[1], Marc Repp[3], Olivier Dulieu[2], Roland Wester[1], and Matthias Weidemüller[3] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg — [2]Laboratoire Aimé Cotton, CNRS, Orsay, France — [3]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg

Dipolar molecules in the absolute ground state are promising candidates for the exploration of quantum phases in dipolar gases, the control of ultracold chemical reaction, and a wide range of further systems [1]. In this talk we will report on the formation of ultracold LiCs molecules in the rovibrational ground state $X^1\Sigma^+, v''=0, J''=0$ [2] using photoassociation (PA). The formed molecules are detected in a setup combining resonant-enhanced multi-photon ionization and a high resolution time-of-flight mass spectrometer. Additionally, we employ depletion spectroscopy to determine the rotational state of the formed molecules and to measure the dipole moment of the ground state molecules by Stark spectroscopy. Combining the results of PA and depletion spectroscopy, we also improve the value of the dissociation energy for the $X^1\Sigma^+$ ground state.

[1] O. Dulieu, M. Raoult, and E. Tiemann, E., Introductory review, Special Issue on cold molecules, J. Phys. B **39**, (2006)
[2] J. Deiglmayr *et al.*, PRL **101**, 133004 (2008)

Q 6.5 Mo 11:45 VMP 8 HS

Ultracold Heteronuclear Fermi-Fermi Molecules — •Arne-Christian Voigt[1,2], Matthias Taglieber[1,2], Louis Costa[1,2], Takatoshi Aoki[1,2], Wolfgang Wieser[1,2], Theodor W. Hänsch[1,2], and Kai Dieckmann[1,2] — [1]Department für Physik der Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching

Spin mixtures of quantum-degenerate fermionic gases exhibit long lifetimes in the strongly-interacting regime near a Feshbach resonance. This has opened the door for numerous key experiments like the creation of Fermi-Fermi molecules, the realization of molecular BEC, the observation of a pairing gap and of superfluidity in a fermionic gas in the BEC-BCS cross-over region near a Feshbach resonance.

We present the production of ^{6}Li-^{40}K heteronuclear molecules based on our experimental platform for the production of a two-species mixture of quantum-degenerate Fermi gases [1]. We studied two s-wave Feshbach resonances between lithium and potassium at 155 G and 168 G. By magnetic field sweeps we created about 4×10^4 ^{6}Li-^{40}K molecules at conversion efficiencies of up to 50 % [2]. With a Stern-Gerlach purification technique we are able to image molecules and atoms spatially separated from each other. We show an increased molecule lifetime close to resonance of more than 100 ms in the molecule-atom mixture.

[1] M. Taglieber *et al.*, Phys. Rev. Lett. **100**, 010401 (2008).
[2] A.-C. Voigt *et al.*, accepted for publication in Phys. Rev. Lett.

Q 6.6 Mo 12:00 VMP 8 HS

Observation of a resonant exchange reaction in an ultracold mixture of cesium atoms and dimers — •Martin Berninger[1], Francesca Ferlaino[1], Steven Knoop[1], Walter Harm[1], Michael Mark[1,2], Hanns-Christoph Nägerl[1], and Rudolf Grimm[1,3] — [1]Institut für Experimentalphysik, Universität Innbruck, Austria — [2]Swinburne University of Technology, Melbourne, Australia — [3]Institut für Quantenoptik und Quanteninformation, Innsbruck, Austria

An ultracold atomic gas of cesium is a versatile system to study few-body phenomena because of the extreme tunability of its scattering length. We have studied interactions in an optically trapped mixture of Feshbach molecules with atoms, realized in a Cs gas at nanokelvin temperatures. We start with a sample of atoms in the lowest hyperfine state A and produce molecules AA by means of Feshbach association. Then we transfer the remaining atoms A to a hyperfine state B that is distinct from that of the Feshbach molecule's constituents. We study the exchange reaction B + AA → A + AB, which is resonantly enhanced when the binding energies of AA and AB are equal. The reaction rate is prominent and magnetically tunable, thus showing all properties of controllable ultracold chemistry.

Q 7: Quantengase: Bosonen im Gitter I

Zeit: Montag 14:00–16:00 Raum: VMP 6 HS-A

Q 7.1 Mo 14:00 VMP 6 HS-A

Light Scattering by Ultracold Atoms in Optical Lattices — •Stefan Rist[1], Giovanna Morigi[1], and Chiara Menotti[2] — [1]Departament de Fisica, Universitat Autonoma de Barcelona — [2]BEC-INFM Dipartimento di Fisica, Università di Trento

Light scattering by an ultracold atomic gas in a one-dimensional optical lattice is theoretically studied, when the atoms are probed by a weak laser. We analyze the intensity of the scattered light as a function of the angle of emission for different values of the tunneling rate, spanning from the superfluid to the Mott-insulator phase. We show how the excitation spectrum of the many body system can be measured by observing of the scattered light intensity as a function of the scattering angle and photon frequency. We identify different features in the first order coherence of the scattered light, depending on whether the atoms are in the Mott-insulator or superfluid state. We discuss our results with respect to previous studies, where the structure form factor was evaluated by a time-of-flight measurement [1] and where light scattering by ultracold atoms in an optical lattice was determined, neglecting the tunneling rate [2].

[1] A.M. Rey et al., Phys. Rev. A 72, 023407 (2005)
[2] I.B.Mekhov et al., Phys. Rev. Lett. 98, 100402 (2007)

Q 7.2 Mo 14:15 VMP 6 HS-A

Bose-Hubbard phase diagram with arbitrary integer filling — •Niklas Teichmann[1], Dennis Hinrichs[1], Martin Holthaus[1], and Andre Eckardt[2] — [1]Institut für Physik, Carl von Ossietzky Universität, D-26111 Oldenburg, Germany — [2]ICFO-Institut de Ciències Fotòniques, E-08860 Castelldefels (Barcelona), Spain

We study the transition from a Mott insulator to a superfluid in the Bose-Hubbard model for a square (2D) and cubic (3D) lattice at zero temperature, employing the method of the effective potential. Converting Kato's perturbation series into a numerical algorithm capable of reaching high orders, we obtain accurate critical parameters – also for high integer filling factors, which have remained hard to obtain with other methods. Our technique allows us to monitor both the approach to the mean-field limit by considering spatial dimensionalities $d > 3$, and to the limit of high filling, which refers to an array of Josephson junctions.

Q 7.3 Mo 14:30 VMP 6 HS-A

Bosons in 1D Optical Superlattices: Computing the Phase Diagram from Experimental Parameters — •Felix Schmitt, Markus Hild, and Robert Roth — Institut fuer Kernphysik, Technische Universitaet Darmstadt

We determine the exact zero-temperature phase-diagram of bosonic atoms in a one-dimensional optical superlattice for different experimental setups [T. Stoeferle et al., Phys. Rev. Lett. 92 130403 (2004); J. E. Lye et al., Phys. Rev. A 75 061603 (2007)] directly using the experimental superlattice amplitudes as control parameters. To this end the site-dependent Hubbard parameters, i.e. hopping, two-particle interaction, and on-site energy, are extracted via a single-particle band-structure calculation from the amplitudes of the standing waves forming the two-color superlattice potential. The many-particle problem is then solved with the finite-size density matrix renormalization group (DMRG) technique. This procedure offers the possibility to study observables like the visibility of the interference fringes directly as function of the experimental parameters.

Q 7.4 Mo 14:45 VMP 6 HS-A

Attractively bound pairs in the Bose-Hubbard model and anti-ferromagnetism — •Bernd Schmidt[1], Michael Bortz[1], Sebastian Eggert[1], David Petrosyan[2], and Michael Fleischhauer[1] — [1]Fachbereich Physik, Technische Universität Kaiserslautern, D-67663 Kaiserslautern, Germany — [2]Institute of Electronic Structure & Laser, FORTH, 71110 Heraklion, Crete, Greece

We consider a periodic lattice loaded with pairs of bosonic atoms tightly bound to each other via a strong attractive on-site interaction that exceeds the inter-site tunneling rate. An ensemble of such lattice-dimers is accurately described by an effective Hamiltonian corresponding to the extended Hubbard model with strong repulsive interaction between the nearest neighbor sites corresponding to the anisotropic XXZ model. We calculate numerically and analytically the ground-state phase diagram for this system exhibiting incompressible phases, corresponding to an empty and a fully filled lattice (ferromagnetic phases) and a half-filled alternating density crystal (anti-ferromagnetic phase), separated from each other by compressible phases. In a 1D finite lattice the compressible phases show characteristic oscillatory modulations on top of the anti-ferromagnetic density profile and in density-density correlations. A kink model is derived which provides a simple and quantitative explanation of these features. The large-wavelength properties of the system can be described in terms of a Luttinger liquid.The relevant Luttinger parameter K is obtained exactly using the Bethe Ansatz. Density-density as well as first-order correlations are calculated and shown to be in excellent agreement with numerical results obtained with density matrix renormalization group methods.

Q 7.5 Mo 15:00 VMP 6 HS-A

Ginzburg-Landau Theory for Quantum Phase Transitions in Bosonic Lattices — Barry Bradlyn[1], •Francisco Ednilson Alves dos Santos[2], and Axel Pelster[2,3] — [1]Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA — [2]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [3]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

We work out a Ginzburg-Landau theory for investigating quantum phase transitions in lattice Bose systems at arbitrary temperature [1]. To this end we expand the grand-canonical free energy as a double power series in both the tunneling and a symmetry breaking source term. Then an order parameter field is introduced, and the underlying effective action is derived via a Legendre transformation. Determining the Ginzburg-Landau expansion to first order in the tunneling term, expressions for the Mott insulator–superfluid phase boundary, condensate density, average particle number, and compressibility are derived. Additionally, excitation spectra in the ordered phase are found by considering both longitudinal and transverse variations of the order parameter. Although our effective action approach yields the same Mott insulator - superfluid phase boundary to first order in the tunneling than standard mean-field theory, our predictions turn out to be superior to the mean-field results deeper into the superfluid phase.

[1] B. Bradlyn, F.E.A. dos Santos, and A. Pelster, Phys. Rev. A (in press), eprint: `arXiv:0809.0706`.

Q 7.6 Mo 15:15 VMP 6 HS-A

Quantum chaos and entanglement in the Bose-Hubbard model — •Michael Lubasch[1] and Sandro Wimberger[1,2] — [1]Institute for Theoretical Physics, Philosophenweg 19, 69120 Heidelberg — [2]Graduate School of Fundamental Physics, Albert-Ueberle Str. 3-5, 69120 Heidelberg

It was first shown by *Kolovsky and Buchleitner* in [Europhys. Lett. 68 (2004), 632-638] that the spectral statistics of the Bose-Hubbard model can exhibit quantum chaos. In their work they investigated the distribution of energy level spacings in the spectrum. We derive a reliable method to differentiate between the regular and the chaotic regime via complete detection of avoided-crossings. These are energy levels that come very close to each other but never touch and their presence is characteristic for the chaotic regime.

Quantum entanglement also allows to separate the two regimes. However for a correct description the indistinguishability of the bosons and a superselection rule for constant global particle number have to be taken into account.

Q 7.7 Mo 15:30 VMP 6 HS-A

Valence Bond States : Link models and scattering experiments — Enrique Rico[1], •Robert Hübener[2,3], Simone Montangero[4,5], Niall Moran[6], Bogdan Pirvu[1], Jiri Vala[6,7], and Hans Briegel[2,3] — [1]Fakultät für Physik, Universität Wien, Austria — [2]ITP, Universität Innsbruck, Austria — [3]IQOQI Innsbruck, Austria — [4]Institut für Quanteninformationsverarbeitung, Universität Ulm, Germany — [5]NEST-CNR-INFM and Scuola Normale Superiore, Pisa, Italy — [6]National University of Ireland, Maynooth, Ireland — [7]Dublin Institute for Advanced Studies, Ireland

An isotropic anti-ferromagnetic quantum state on a two-dimensional square lattice is characterized by symmetry arguments only. By construction, this quantum state is the result of an underlying valence bond structure without breaking any symmetry in the lattice or spin spaces. The physical relevance of the model is motivated. A comparison of the model to known anti-ferromagnetic Mott-Hubbard insulators is given by means of the two-point equal-time correlation function obtained i) numerically from the suggested state and ii) experimentally from neutron scattering on cuprates in the anti-ferromagnetic insulator phase. Ref: arXiv:0811.1049

Q 7.8 Mo 15:45 VMP 6 HS-A

Phase diagram of the two-dimensional spin-1/2 XY anisotropic triangular lattice — •Roman Schmied[1], Philipp Hauke[1], Tommaso Roscilde[2], and J. Ignacio Cirac[1] — [1]MPI für Quantenoptik, Garching, Germany — [2]Ecole Normale Supérieure de Lyon, France

Quantum simulators promise to further our understanding of condensed-matter systems which are currently at or beyond the limits of computational methods. One such system is the two-dimensional spin-1/2 XY anisotropic triangular lattice [1], which we have studied using several techniques (Lanczos diagonalization, spin waves, and PEPS [2]). We present its proposed temperature-dependent phase diagram, which includes 1D and 2D Néel ordered phases, a 2D spiraling ordered phase, and several spin-liquid phases. The zero-temperature quantum phase transitions between ordered phases appear to acquire a universal discontinuous structure, passing through a short-range spin-liquid phase similar to what has been predicted for the analogous Heisenberg model. At finite temperatures, Kosterlitz-Thouless and spin-melting transitions complete the picture. We also present preliminary results on the J1-J2-J3 model.

[1] R. Schmied et al., NJP 10 (2008) 045017
[2] F. Verstraete and J. I. Cirac, arXiv:cond-mat/0407066v1

Q 8: Laserentwicklung: Festkörperlaser II

Zeit: Montag 14:00–16:00 Raum: VMP 6 HS-C

Q 8.1 Mo 14:00 VMP 6 HS-C

Untersuchung von Energietransferprozessen in Er^{3+}, Yb^{3+}:Sc_2O_3 — •Henning Kühn, Matthias Fechner, Andreas Kahn, Hanno Scheife und Günter Huber — Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, D-22761 Hamburg

Die Codotierung von Er^{3+}-dotierten Lasermaterialien mit Yb^{3+}-Ionen ist wegen der hohen Yb^{3+}-Absorptionswirkungsquerschnitte ein gebräuchliches Verfahren zur Erhöhung der Pumpabsorption. Um einen effizienten Laserbetrieb zu erzielen, ist ein guter Energietransfer zwischen den Yb^{3+}- und Er^{3+}-Ionen erforderlich. Im Rahmen dieses Beitrages wurden die Energietransferparameter zur Beschreibung der Energietransferprozesse zwischen Er^{3+} und Yb^{3+} in Sc_2O_3 mit zwei verschiedenen Methoden bestimmt. Hierzu wurden einerseits Messungen der Lebensdauer der Yb^{3+}-Ionen in den codotierten Proben durchgeführt, andererseits konnte der Transferparameter durch den relativen Anteil der emittierten Photonen der Wellenlänge 1,55 μm durch Er^{3+}-Ionen unter cw-Anregung der Yb^{3+}-Ionen bestimmt werden. Laser-Experimente wurden durchgeführt, um die Eignung von Er^{3+},Yb^{3+}:Sc_2O_3 als Laser-Material zu untersuchen.

Q 8.2 Mo 14:15 VMP 6 HS-C

Photoleitungsexperimente zur Klärung nichtlinearer Verlustmechanismen in hoch Yb-dotierten oxidischen Lasermaterialien — •Ulrike Wolters, Susanne T. Fredrich-Thornton, Christian Hirt, Friedjof Tellkamp, Klaus Petermann und Günter Huber — Universität Hamburg, Institut für Laser-Physik, Luruper Chaussee 149, 22761 Hamburg

Aufgrund ihres vorteilhaften Energieniveauschemas werden Yb-dotierte Oxide häufig in Hochleistungslasern verwendet, da interne Verlustprozesse wie Kreuzrelaxation, Upconversion oder ESA nicht zu erwarten sind. Dennoch treten in Yb-dotierten Oxiden nichtlineare Verluste auf, die von Dotierungskonzentration, Anregungsdichte sowie der Temperatur abhängen[1] und die Lasertätigkeit stark einschränken. Bei Konzentrationen über 15% erschweren sie den Scheibenlaserbetrieb deutlich. Photoleitungsmessungen bestätigen die Existenz eines Upconversion-Prozesses, der Ladungsträger mit 2 bis 3 Yb-Anregungen kooperativ in ein stromführendes Band anhebt.
Mögliche Ursache für die beobachteten Photoströme ist die Bildung von Yb^{3+}/Yb^{2+} Charge-Transfer-Zuständen, die in der Bandlücke von YAG liegen und mit 2 bis 3 Anregungen erreichbar sind. Es werden Messungen vorgestellt zur Konzentrationsabhängigkeit, zum Einfluss von Kodotierungen von Yb:YAG mit z.B. Eisen als Verunreinigung sowie zum unterschiedlichen Verhalten von einkristallinem Yb:YAG und Yb:YAG-Keramiken.

[1] M. Larionov et al., OSA Trends in Optics and Photonics, Advanced Solid-State Photonics, paper TuB49 (2005)

Q 8.3 Mo 14:30 VMP 6 HS-C

Intrinsische Reduktion von Depolarisationsverlusten in Nd:YAG Kristallen — •Henrik Tünnermann, Oliver Puncken, Maik Frede, Peter Wessels und Dietmar Kracht — Laser Zentrum Hannover e.V., Hollerithallee 8, D-30419 Hannover

Die beim Pumpen in einem Laserkristall deponierte Heizleistung führt zu Spannungen im Kristall, welche über den photoelastischen Effekt zu einer Variation des Brechungsindizes und damit zur Depolarisation linear polarisierter Strahlung führen. Neben den Standardmethoden zur Doppelbrechungskompensation bietet die Abhängigkeit der thermisch induzierten Doppelbrechung von dem Kristallschnitt eine Möglichkeit, die Depolarisation zu verringern. Theoretische Betrachtungen zum photoelastischen Effekt unter Berücksichtigung von Kristallgeometrie und Pumplichtverteilung wurden experimentell mit niedrig dotierten, zylindrischen Nd:YAG Laserstäben überprüft. Dafür wurden neben den konventionell erhältlichen [111]-Schnitten auch Kristalle auf ihre Depolarisationseigenschaften untersucht, die in [110]- bzw. [100]-Richtung geschnitten sind. Die Depolarisation ist dann nicht nur von der Heizleistung, sondern auch von der Polarisationsrichtung abhängig. Zur Messung der Effekte wurde ein Nd:YLF Seedlaser verwendet. Dieser emittiert linear polarisierte Strahlung, die in dem YAG Kristall nicht verstärkt wird. Die Depolarisation dieser Seedstrahlung wurde nach einem Durchgang durch die gepumpten Nd:YAG Kristalle analysiert. Depolarisationsgrad und Depolarisationsmuster wurden für verschiedene Seedstrahlgrößen und Pumplichtverteilungen innerhalb der Kristalle gemessen und mit dem theoretischen Modell verglichen.

Q 8.4 Mo 14:45 VMP 6 HS-C

Hocheffizienter Laserbetrieb von Tm:Lu_2O_3 bei einer Wellenlänge von 2 μm — •Philipp Koopmann, Rigo Peters, Klaus Petermann und Günter Huber — Universität Hamburg, Institut für Laser-Physik, Luruper Chausses 149, 22761 Hamburg

Aufgrund seiner thermischen und spektroskopischen Eigenschaften ist Tm:Lu_2O_3 ein vielversprechendes Lasermaterial für Anwendungen im Wellenlängenbereich um 2 μm. Zur Ermittlung der Lasereigenschaften wurden Tm:Lu_2O_3-Kristalle mit unterschiedlichen Dotierungskonzentrationen hergestellt. Messungen der thermischen Leitfähigkeit zeigen auch bei hohen Dotierungskonzentrationen bis 10 at.% Tm eine lediglich geringfügig reduzierte Wärmeleitfähigkeit gegenüber dem undotierten Material. Dies stellt im Vergleich zu Tm:YAG einen signifikanten Vorteil für die Skalierbarkeit zu hohen Ausgangsleistungen dar. Spektroskopische Untersuchungen ergaben hohe Emissionswirkungsquerschnitte von $9 \cdot 10^{-21}\,cm^2$ und eine nur geringe Verkürzung der Fluoreszenz-Lebensdauer des oberen Laserniveaus bei zunehmender Dotierungskonzentration. Erste Laserexperimente wurden mit einem Ti:Saphir-Laser bei einer Pumpwellenlänge im Bereich von 800 nm durchgeführt. Über einen Kreuzrelaxationsprozess wird das obere Laserniveau effizient bevölkert. Erstmals konnte cw-Laserbetrieb von Tm:Lu_2O_3 gezeigt werden. Differentielle Wirkungsgrade von bis zu 61% sowie niedrige Schwellpumpleistungen im Bereich von 30 mW bestätigen die ausgezeichneten Eigenschaften des Wirtsmaterials. Unter Verwendung eines doppelbrechenden Filters konnte der Laser in einem Bereich von 1900 nm bis 2110 nm durchgestimmt werden.

Q 8.5 Mo 15:00 VMP 6 HS-C

Optische Verstärkung in einkristallinen Er:$(Gd,Lu)_2O_3$ Rippenwellenleitern — •Sebastian Heinrich, Andreas Kahn, Henning Kühn, Klaus Petermann und Günter Huber — Institut für Laser-Physik, Universität Hamburg

Die Wellenleitergeometrie ist vielversprechend im Hinblick auf die Entwicklung kompakter Lasersysteme. Infolge der hervorragenden thermomechanischen und optischen Eigenschaften stellen optisch aktive Sesquioxid-Wellenleiter schmale Emissionslinien, hohe Frequenzstabilität und eine hohe optische Verstärkung in Aussicht.

Daher wurden mit dem Pulsed Laser Deposition Verfahren einkristalline gitterangepasste Er:$(Gd,Lu)_2O_3$-Schichten auf Y_2O_3-Substraten hergestellt. Spektroskopische Untersuchungen zeigten, dass die Emissionsspektren, bis auf eine geringe Verbreiterung, gut mit den Spektren von Er:Y_2O_3-Volumenkristallen übereinstimmen. Auch die gemessene Lebensdauer $\tau = 6,3$ms des $^4I_{13/2}$-Niveaus entspricht annähernd dem Vergleichswert einer Er:Y_2O_3-Schicht.

In einem 7mm langen (0,6at%) Erbium dotierten Wellenleiter konnte bei einer Wellenlänge von 1535nm eine Verstärkung von 5,9dB/cm gemessen werden. Bei der Messung an einer vergleichbaren Schicht ergab sich für die Verluste eine obere Grenze von 4,4dB bei einer Wellenlänge von 633nm. Bei höheren Wellenlängen werden wesentlich geringere Verluste erwartet. So konnte bei erst kürzlich durchgeführten Experimenten mit einer Nd:$(Gd,Lu)_2O_3$-Schicht Lasertätigkeit bei 1079nm gezeigt werden [1].

[1] A. Kahn et al., eingereicht bei OpticsExpress.

Q 8.6 Mo 15:15 VMP 6 HS-C

Subharmonische Fourier Domänen Modenkopplung (shFDML) — •Christoph Eigenwillig, Wolfgang Wieser, Benjamin Biedermann und Robert Huber — Lehrstuhl für biomolekulare Optik, Fakultät für Physik, LMU München

Fourier Domänen modengekoppelte Laser (FDML) sind instantan schmalbandige, schnell wellenlängenabstimmbare Laser, die unter anderem in der biomedizinischen Bildgebung zur optischen Kohärenztomographie (OCT) Anwendung finden. Hier konnte durch den Einsatz von FDML-Lasern die Abtastrate um ein Vielfaches vergrößert werden. Abstimmgeschwindigkeiten von bis zu 370 kHz über einen Abstimmbereich von 100 nm wurden demonstriert. Das FDML-Prinzip basiert darauf, dass ein optischer Bandpass-Filter im Laserresonator resonant zur Lichtumlaufzeit verstimmt wird. Eine Voraussetzung hierfür ist eine optische Verzögerungsstrecke in der Form von mehreren Kilometern Glasfaser. Insbesondere bei Verwendung von teurer Spezialfaser kann die Länge jedoch einen Nachteil darstellen. Hier wird ein neuartiger FDML-Laser (subharmonic FDML) vorgestellt, bei dem Licht die optische Verzögerungsstrecke mehrmals durchläuft und somit die Faserlänge reduziert werden kann. Durch Auskoppeln des Lichts in der Verzögerungsstrecke besteht zudem die Möglichkeit, die Frequenzdurchläufe optisch zu vervielfältigen und damit die Abtastrate für OCT zu vergrößern. Einschränkungen der Abstimmbandbreite und mögliche Lösungsansätze werden diskutiert. Die Anwendung des Lasers für OCT-Bildgebung wird demonstriert.

Q 8.7 Mo 15:30 VMP 6 HS-C

Frequency stabilization of a Q-switched Nd:YAG oscillator following a radio-frequency sideband scheme modified by a sample and hold circuit — •Robert Elsner, Martin Ostermeyer, Thomas Waltinger, and Markus Gregor — Institute for Physics and Astronomy, University of Potsdam, Karl-Liebknecht-Str 24/25, 14476 Potsdam, Germany

Frequency stabilized laser sources in the pulsed domain are of interest for a number of applications - in particular for advanced LIDAR measurements. We present a modified Pound-Drever-Hall [1] technique applied to a Q-switched Nd:YAG ring oscillator [2]. The PDH-technique relies on a reasonably high Q of the resonator. The main limitation of the PDH-method for Q-switched operation is the low Q during the pump period of the gain material. During this period the PDH-scheme is blind and an ill-defined error signal is produced. This problem can be avoided by introducing a sample and hold controller to the scheme that is triggered by the Q-switch. Applying this technique to the injection seeded oscillator a frequency stability of better than 285kHz (rms) is obtained. The oscillator emits pulses of 23ns duration and 20mJ energy at a repetition rate of 400Hz.

[1] R. W. P. Drever et al., Appl. Phys. B **31** 97*105 (1983)
[2] A. Sträßer et al., Applied Optics **46** 8358-8363 (2007)

Q 8.8 Mo 15:45 VMP 6 HS-C

Erzeugung flexibler Pulszüge zur effizienten Materialbearbeitung mit Hochleistungslasern — •Oliver Lux und Thomas Riesbeck — TU Berlin, Deutschland

Hochleistungsfestkörperlaser sind von großer Bedeutung für zahlreiche Anwendungen in der Industrie und Wissenschaft. Dabei bedürfen diese Systeme speziell für das breite Gebiet der Materialbearbeitung neben einer hohen Ausgangsleistung auch einer sehr guten Strahlqualität. Hierzu wurde ein blitzlampengepumptes, aktiv gütegeschaltetes Nd:YAG-Oszillator-Verstärker-System mit einer Ausgangsleistung von über 100 W und einer Strahlqualität von $M^2 < 2{,}5$ entwickelt. Das System operiert mit einer Repetitionsrate von 100 Hz, wobei während jedes Pumppulses eine flexibel einstellbare Zahl an so genannten Burst-Pulsen erzeugt wird. Auf diese Weise gelingt es die Intensität des Laserstrahls unter Beibehaltung seiner geometrischen Parameter variabel einzustellen. Die Pulsbreiten lassen sich ebenso in einem Bereich von 25 bis 150 ns steuern. Die hohe Strahlqualität des verstärkten Strahls wird durch eine Anordnung zur Kompensation der thermisch induzierten Doppelbrechung realisiert, so dass ein linear polarisierter Laserstrahl mit Depolarisationsverlusten von unter 2 % erzielt wird.

Q 9: Quanteninformation: Konzepte II

Zeit: Montag 14:00–16:00 Raum: VMP 6 HS-D

Q 9.1 Mo 14:00 VMP 6 HS-D

Sequentially generated states for the study of two dimensional systems — •Mari-Carmen Banuls[1], David Perez-Garcia[2], Michael M. Wolf[3], Frank Verstraete[4], and J. Ignacio Cirac[1] — [1]Max-Planck-Institut fuer Quantenoptik, 85748 Garching, Germany — [2]Depto. Analisis Matematico, Universidad Complutense de Madrid, 28040 Madrid, Spain — [3]Niels Bohr Institut, 2100 Copenhagen , Denmark — [4]Fakultaet fuer Physik, Universitaet Wien, A-1090 Wien, Austria

The family of Matrix Product States represents a powerful tool for the study of physical one-dimensional quantum many-body systems, such as spin chains. Besides, Matrix Product States can be defined as the family of quantum states that can be sequentially generated in a one-dimensional system. We have introduced a new family of states which extends this sequential definition to two dimensions. Like in Matrix Product States, expectation values of few body observables can be efficiently evaluated and, for the case of translationally invariant systems, the correlation functions decay exponentially with the distance. We show that such states are a subclass of Projected Entangled Pair States and investigate their suitability for approximating the ground states of local Hamiltonians.

Q 9.2 Mo 14:15 VMP 6 HS-D

Random states with an energy constraint — •Markus Müller[1,2], Jens Eisert[1], and David Gross[3] — [1]Institut für Physik, Universität Potsdam, 14476 Potsdam — [2]Institut für Mathematik, TU Berlin, 10623 Berlin — [3]Institut für Mathematische Physik, TU Braunschweig, 38106 Braunschweig

We consider the question of how and whether thermal states emerge in parts of quantum systems if joint systems are in some random state of fixed energy. It is known that if one draws a random state according to the unitarily invariant measure in a composite system, then states of subsystems will with high probability be very close to being maximally mixed, if the environment is large enough. Here we consider the physically motivated question of looking at properties of random states under a meaningful energy constraint. To discuss this, we invoke techniques from concentration of measure and exploit a weak coupling limit, in an argument that is inspired by quantum information ideas. We outline ideas of how Gibbs states emerge in a weak coupling limit.

Q 9.3 Mo 14:30 VMP 6 HS-D

Real Space Renormalization Group Approach for Systems with Random Couplings. — •Oleg Gittsovich[1,2], Enrique Rico[3], and Hans J. Briegel[1,2] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Technikerstrasse 21a, A-6020 Innsbruck, Österreich — [2]Institut für Theoretische Physik, Universität Innsbruck, Technikerstrasse 25, A-6020 Innsbruck, Österreich — [3]Fakultät für Physik, Universität Wien, Boltzmanngasse 5, A-1090 Wien, Österreich

We present a real-space renormalization group (RG) approach for disordered systems. The Hamiltonian of the systems is defined on a rectangular two-dimensional lattice and has only nearest-neighbor interactions. The merits of presented method are twofold. On the one hand we preserve the symmetries of the system, i.e. at each step of the renormalization the system is self-similar. On the other hand the renormalization of the whole quantum system can be seen as a classical sequence of the renormalizations of the coarse-grained system. We provide several examples where the renormalization procedure leads to reliable results for random transverse field Ising model (RTFIM) on a two-dimensional rectangular lattice.

Q 9.4 Mo 14:45 VMP 6 HS-D

Pairing in fermionic systems: A quantum information perspective — •Christina Kraus[1], Michael Wolf[1,2], Ignacio Cirac[1], and Geza Giedke[1] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Niels-Bohr–Institut, Kopenhagen

The notion of "paired" fermions is central to important condensed matter phenomena such as superconductivity and superfluidity. While the concept is widely used and its physical meaning is clear there exists no systematic and mathematical theory of pairing which would allow to unambiguously characterize and systematically detect paired states. We propose a definition of pairing and develop methods for its detection and quantification applicable to current experimental setups. Pairing is shown to be a quantum correlation different from entanglement, giving further understanding in the structure of highly correlated quantum systems. In addition, we will show the resource character of paired states for precision metrology, proving that the BCS states allow phase measurements at the Heisenberg limit.

Q 9.5 Mo 15:00 VMP 6 HS-D

Adiabatic Preparation with Nonlinear Paths — •Gernot Schaller — Institut für Theoretische Physik, Technische Universität Berlin

Many interesting physical models show a quantum phase transition when a single parameter is varied through a critical point. For finite-size counterparts, there is usually a non-vanishing excitation gap at the critical point. This opens the possibility to adiabatically prepare the ground state of one phase from the ground state of another phase. When the parameter appears as a coupling constant (or as e.g. an external field) one may view this process as a straight line interpolation between two Hamiltonians. Unfortunately, the minimum excitation gap along this straight line trajectory often scales inversely with the system size. This does not only affect the adiabatic runtime but for systems coupled to a reservoir, also thermal excitations become likely.

For some simple models it will be demonstrated that with a nonlinear interpolation path a constant lower bound on the minimum energy gap can be proven. An interesting consequence is that the two-dimensional cluster state – encoded in the ground state of a Hamiltonian – can be prepared adiabatically in constant time.

[1] G. Schaller, Phys. Rev. A **78**, 032328 (2008).

Q 9.6 Mo 15:15 VMP 6 HS-D

Measuring mixed-state entanglement via antilinear operators — •Oliver Viehmann[1], Jens Siewert[1], Andreas Osterloh[2], and Armin Uhlmann[3] — [1]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg — [2]Institut für Theoretische Physik, Universität Hannover, 30167 Hannover — [3]Institut für Theoretische Physik, Universität Leipzig, 04109 Leipzig

The amount of entanglement in mixed quantum states is commonly defined via the convex-roof extension of a certain pure state entanglement measure, e.g., a polynomial invariant such as the concurrence [1]. For a pair of qubits, the convex roof of the pure-state concurrence can be obtained analytically [2].

The Wootters-Uhlmann method depends crucially on the properties of antilinear operators. In this contribution, we investigate a possible generalization of the Wootters-Uhlmann method for invariants which can be written as expectation values of antilinear operators with respect to multiple copies of a given pure state. In particular, we try to apply this method to invariants of polynomial degree 4 such as the three-way tangle.

[1] W. K. Wootters, Phys. Rev. Lett. **80**, 2245 (1998).
[2] A. Uhlmann, Phys. Rev. A **62**, 032307 (2000).

Q 9.7 Mo 15:30 VMP 6 HS-D

Entanglement Generation in Clifford Quantum Cellular Automata — •Johannes Gütschow[1], Zoltán Zimborás[2], and Reinhard Werner[1] — [1]Institut für Mathematische Physik, TU Braunschweig, www.imaph.tu-bs.de — [2]Theoretische Physik, Universität des Saarlands, www.uni-saarland.de/fak7/rieger

Clifford Quantum Cellular Automata (CQCA) are a special kind of Quantum Cellular Automata that incorporate Clifford group operations for the time evolution automorphism. Despite being classically simulable, they can be used as basic building blocks for universal quantum computation. This is due to the connection to translation-invariant stabilizer states and their entanglement properties. We investigate the generation of entanglement under CQCA action and show analytical and numerical results for the growth of entanglement for different classes of states and CQCA.

Q 9.8 Mo 15:45 VMP 6 HS-D

Factorization with Gauss Sums — •Sabine Wölk, Wolfgang Merkel, and Wolfgang Schleich — Institute of Quantum Physics, Ulm, Germany

Factoring large numbers N is one of the problems, for which analogue computers need exponential time. Quantum computers on the other hand, can do this in polynomial time. In 1994 P. Shor introduced his famous quantum algorithm for this problem, but it is still difficult to realize it experimentally. As a consequence so far only the number $N = 15$ was factored with this algorithm.

For this reason we study the alternative route to factorization using Gauss sums. Our previous results have led to experimental factorizations of numbers N with up to 17 digits. However, our algorithm is slow because it checks every prime number $l < \sqrt{N}$ if it is a factor or not. Nevertheless there is still an enormous potential in Gauss sums for factoring numbers. In our talk we introduce some new ideainvolvingng entanglement.

Q 10: Ultrakurze Pulse: Erzeugung I

Zeit: Montag 14:00–15:45 Raum: VMP 8 R206

Q 10.1 Mo 14:00 VMP 8 R206

Effect of feedback on femtosecond supercontinuum generation: numerical investigation on nonlinear dynamics — •Michael Kues, Nicoletta Brauckmann, Till Walbaum, Petra Gross, and Carsten Fallnich — Institut für Angewandte Physik Westfälische Wilhelms-Universität, Münster, Deutschland

Since the development of photonic crystal fibers (PCFs), numerous investigations have been made to improve the phase stability and coherence of supercontinua generated in PCFs. As a possible method to achieve this goal, we investigate the effect of feedback on supercontinuum (SC) generation in PCFs. For this, we numerically study the supercontinuum evolution in a ring cavity synchronously pumped with fs-pulses from a titanium:sapphire laser. The generalized nonlinear Schrödinger equation is solved numerically using a split-step Fourier algorithm, and feedback is employed by superimposing the calculated SC with the following pump pulses. Here, we present results of these simulations, which exhibit a strong influence of feedback on the SC evolution. Depending on input parameters, a convergence of consecutive SC spectra to a steady state can be observed, as well as period doubling, limit cycles, and chaos. Finally, we include noise in our simulations in order to pave the way for an experimental demonstration. From these results, we expect a parameter range where the phase stability as well as the coherence should be improved.

Q 10.2 Mo 14:15 VMP 8 R206

Femtosecond supercontinuum generation in a feedback cavity: Experimental investigations on nonlinear dynamics — •Nicoletta Brauckmann, Michael Kues, Till Walbaum, Petra Gross, and Carsten Fallnich — Institut für Angewandte Physik Westfälische Wilhelms-Universität, Münster, Deutschland

Supercontinuum generation is a highly nonlinear optical phenomenon where narrow bandwidth light becomes spectrally broadband due to, e.g., self-phase modulation, four-wave mixing, soliton fission and Raman scattering. For a high degree of pulse-to-pulse coherence in supercontinua typically short pulses with only a few tens of femtoseconds are used. Currently we are investigating how an optical feedback allows to relax the experimental conditions for low-noise supercontinuum generation. In our experimental feedback system, the supercontinuum is generated in a photonic crystal fiber within a ring cavity. This leads to an interaction of the supercontinuum with the following pulses of the titanium:sapphire pump laser. Here, we present the nonlinear dynamical behaviour of this system which includes, e.g., regimes of period doubling, which means that the system state is not reproduced after every cavity roundtrip, but after every second roundtrip. In our experiments, we also observe system state reproductions after three and four roundtrips and more complex regimes of operation up to chaos. With our investigations we want to identify regimes of operation where parts of supercontinuum show improved pulse-to-pulse coherence related to self-stabilisation mechanisms.

Q 10.3 Mo 14:30 VMP 8 R206

Investigation and optimization of continuum generation in crystals - white-light beyond sapphire — •Maximilian Bradler, Peter Baum, and Eberhard Riedle — Lehrstuhl für BioMolekulare Optik, LMU München

Focusing intense ultrashort pulses into nonlinear media leads to one of the most fascinating phenomena in ultrafast optics - white-light generation. The resulting supercontinua are used for many applications such as optical parametric amplification, femtosecond spectroscopy or CEP measurements. The standard bulk material for white-light generation is sapphire, which allows the generation of a high quality single filament. We now find that sapphire is not always the best choice. We report a comprehensive investigation and the optimization of femtosecond continuum generation in single crystals of several common laser host materials. The absolute spectral energy density, pulse-to-pulse stability, pump threshold and beam profile are studied in dependence on the crystal thickness, focusing conditions, pump pulse energy and pump wavelength. Lower thresholds, plateau-like visible and infrared spectra and higher infrared photon flux as compared to conventional materials are found in yttrium aluminum garnet (YAG), yttrium vanadate (YVO4), gadolinium vanadate (GdVO4) and potassium-gadolinium tungstate (KGW). We discuss the particular advantages of each material and show the potential of the new crystals for advanced applications.

Q 10.4 Mo 14:45 VMP 8 R206

Erzeugung von intensiven, ultrakurzen Laserpulsen durch Weißlichtfilamentation in Argongas - Simulation und Experiment — •Robert Irsig[1], Nguyen Xuan Truong[1], Thomas Fennel[1], Tilo Döppner[2], Josef Tiggesbäumker[1] und Karl-Heinz Meiwes-Broer[1] — [1]Institut für Physik, Universität Rostock, Universitätsplatz 3, 18051 Rostock — [2]Lawrence Livermore National Laboratory, Livermore, CA 94551 USA

Durch die Fokussierung von kurzen, intensiven Laserpulsen (40 fs, 2.5 mJ) in eine mit Argon gefüllte Gaszelle werden Weißlichtfilamente erzeugt. In diesen Filamenten kommt es durch Selbstphasenmodulation zu einer spektralen Verbreiterung der Pulse. Die Ionisation des Gases und nichtlineare Effekte wie Self-Steepening führen zu einer Verringerung der Pulslänge [1].
Es wird gezeigt, wie die Filamente experimentell durch Variation von Gasdruck und Fokuslänge beeinflußt werden können. In einer Simulation wird die Propagation der Laserpulse im Filament durch Lösung der nichtlinearen Schrödingergleichung beschrieben. Der Einfluß von Selbstphasenmodulation, Self-Steepening und Plasmabildung wird diskutiert.

[1] G. Stibenz, N. Zhavoronkov, and G. Steinmeyer, Opt. Lett. 31, 274 (2006)

Q 10.5 Mo 15:00 VMP 8 R206

Quasi-hydrodynamic spatio-temporal shaping in filamentary propagation of femtosecond pulses — •Carsten Bree[1,4], Ayhan Demircan[1], Stefan Skupin[2], Luc Berge[3], and Günter Steinmeyer[4] — [1]Weierstraß-Institut für Angewandte Analysis und Stochastik — [2]Max-Planck-Institut für Physik komplexer Systeme — [3]CEA-DAM, DIF, Arpajon, France — [4]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie

Filament self-compression is a remarkably simple new way for generating intense laser pulses with sub-10 fs pulse duration. Despite the experimental simplicity, the physical situation in femtosecond filaments is quite involved. In fact, the filamentary dynamics is governed by a complex interplay of about ten linear and nonlinear optical effects. We will show, however, that the formation of short pulses in the filamentary channel can already be well understood in a reduced model that isolates three major mechanisms. In particular, this model implies vanishing flow of energy between adjacent temporal slices of the pulse. In this quasi-hydrodynamic scenario, a pronounced self-induced pinching of the photon density is observed, leading to the characteristic spatio-temporal inhomogeneity of filamentary pulses. We will show, both by analytical arguments and numerical simulations that it is this spatial concentration of energy that gives rise to the experimentally observed self-compression. In addition, we show that the experimentally observed asymmetric temporal shape of self-compressed pulses, consisting of a small leading subpulse followed by an intense trailing pulse, can be understood within the framework of our analytical model.

Q 10.6 Mo 15:15 VMP 8 R206

Self-healing mechanism of compressed femtosecond filaments — •Stefan Skupin[1], Luc Bergé[2], and Günter Steinmeyer[3] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden — [2]CEA-DAM, DIF, F91297 Arpajon, France — [3]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie

In self-generated filaments, femtosecond pulses experience strong spatial and temporal shaping effects. The dynamical balance between Kerr self-focusing and plasma-induced defocusing gives rise to a self-guiding mechanism, which involves a complex time dependent radial energy flow (dynamical spatial replenishment). This energy flow strongly links spatial and temporal dynamics.

One of the most surprising properties of femtosecond filaments is on-axis self-compression, i. e., pulse shortening in the center of the beam during filamentary propagation. For examining the self-compression regime, experimental set-ups use windowed cells, allowing for careful optimization of the pressure that gives rise to maximum self-compression. Here we will investigate numerically the influence of these exit windows on pulse propagation, which distort the spatio-temporal shape of the exiting pulse considerably and seem to destroy self-compression. However, upon subsequent propagation in, e. g., the atmosphere, a self-healing mechanism takes place. We find that again, as the self-compression mechanism itself, this self-healing process is a result of a time dependent radial energy flow.

Q 10.7 Mo 15:30 VMP 8 R206

Fourfold self-compression of 120-fs pulses in a white-light filament — •J. Bethge[1], G. Stibenz[2], P. Staudt[2], H. Redlin[3], S. Düsterer[3], C. Brée[4,1], A. Demircan[4], and G. Steinmeyer[1] — [1]Max-Born-Institut, Berlin — [2]Angewandte Physik und Elektronik GmbH (APE), Berlin — [3]Deutsches Elektronen-Synchrotron (DESY), Hamburg — [4]Weierstraß-Institut für Angewandte Analysis und Stochastik (WIAS), Berlin

Self-compression in whitelight filaments has opened remarkable new opportunities for compressing energetic pulses from a few ten femtosecond duration down into the sub-10 fs range [1]. Other than hollow fiber compressors, filament compression is neither limited by optical damage to the guiding structure nor does it require external dispersion compensation. However, so far self-compression has only been demonstrated with rather short input pulses. Moreover, this scheme was found to work only in a small parameter range and showed an increased sensitivity towards fluctuations of the input pulses. We use a 10 Hz Ti:sapphire laser system with 3.5 mJ pulse energy at the DESY FLASH facility. Using this laser we demonstrate a fourfold self-compression from 120 fs before filamentary propagation into 30 fs pulses after the filament, clearly indicating the universality of the self-compression mechanism in filaments. The self-compression measured with LX-SPIDER complies with the predictions of an improved analytical model [2].

[1] C. P. Hauri, et al., Appl. Phys. B **79**, 673 (2004).
[2] C. Brée, et al., submitted to Phys. Rev. Lett. (2008).

Q 11: Quantengase: Bosonen im Gitter II

Zeit: Montag 16:30–18:00 Raum: VMP 6 HS-A

Q 11.1 Mo 16:30 VMP 6 HS-A

Bragg Spectroscopy in Optical Lattices — •Philipp T. Ernst, Sören Götze, Jasper S. Krauser, Karsten Pyka, and Klaus Sengstock — Insitut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Physics with quantum gases in optical lattices is a dynamically evolving field of fundamental research and particularly well suited to provide an experimental interface between quantum optics and solid state physics. Many novel quantum phases have been predicted in these systems. However, their detection and analysis, especially the characterization of their excitation spectrum, still remains challenging.

Here we report on high resolution momentum-resolved spectroscopy of the excitation spectrum of an ultracold bosonic gas in an optical lattice for the first time. Using Bragg diffraction in 2D and 3D lattice geometries, we show systematic measurements of the dispersion relation of the first and second band over the whole first Brillouin zone varying the lattice depth. The results clearly show the influence of interaction on the excitation spectrum as well as the sensitivity to density and particle numbers. Changing pulse area and probing time provides an insight into the dynamics of these systems.

Our measurements demonstrate high resolution Bragg spectroscopy in optical lattices to be a powerful technique which offers a wide range of applications, from perspectives on detecting new phases to the preparation of specific momentum states as a starting point for further investigations.

Q 11.2 Mo 16:45 VMP 6 HS-A

RPA Studies of Dynamic Response of Ultracold Bose Gases in 1D Optical Lattices — •Markus Hild, Panagiota Papakonstantinou, Felix Schmitt, and Robert Roth — Institut für Kernphysik, Technische Universität Darmstadt, 64289 Darmstadt

We study the dynamic response of ultracold Bose gases in one-dimensional optical lattices based on the Bose-Hubbard model (BHM) using a generalized random-phase approximation. Our aim is to simulate Bragg-spectroscopy experiments using modulated optical lattice potentials to probe the system [PRL 92 (2004) 130403, PRL 98 (2007) 130404]. We compare the response function obtained at different levels of the RPA scheme with results from a linear response analysis based on the full eigenspectrum of the BHM. The evolution of the response as a function of interaction strength and lattice size is investigated. The results are in very good agreement with experiments and due to the minimal numerical effort RPA emerges as a powerfull tool to gain insights on the dynamics of bosonic lattice systems at experimentally relevant system sizes.

Q 11.3 Mo 17:00 VMP 6 HS-A

Direct Observation of Multi-Band Physics using Quantum Phase Diffusion in 3D Optical Lattices — •Sebastian Will[1], Thorsten Best[1], Simon Braun[1], Ulrich Schneider[1], Lucia Hackermüller[1], Dirk-Sören Lühmann[2], and Immanuel Bloch[1] — [1]Johannes Gutenberg-Universität Mainz — [2]Universität Hamburg

In recent years ultracold bosonic atoms in optical lattices have proven their potential to simulate quantum systems, that are known from condensed matter physics. This was prominently demonstrated by the realisation of the superfluid to Mott insulator transition and has been theoretically described by the Bose-Hubbard model. Its underlying Hamiltonian is restricted to the single, energetically lowest band. However, recent theoretical studies have emphasized, that the interatomic interaction may bring multi-band effects into play and considerably modify the behaviour of the system. In our experiment we have trapped a Bose-Einstein condensate of ^{87}Rb atoms in a 3D optical lattice with minimal underlying harmonic confinement. Through rapid increase of the lattice depth, we have been able to prepare coherent superpositions of atom number states on each site. While tunnelling is strongly suppressed, the dynamical evolution of the system shows a continuous collapse and revival of the phase of the matterwave field, the period of which is determined by the onsite interaction energy. Up to 80 revivals of the matterwave field have been detectable. The observed dynamics give clear indication of multi-band physics beyond the single-band Hubbard model, our data being in excellent agreement with theoretical calculations obtained with the method of exact diagonalization.

Q 11.4 Mo 17:15 VMP 6 HS-A

Quantitative measurement of the downshift of the critical temperature for Bose-Einstein condensation in an optical lattice — •Trotzky Stefan, Schnorrberger Ute, Thompson Jeff, and Bloch Immanuel — Universität Mainz

In the last years, experiments with ultracold quantum gases in optical lattices have developed in many directions, while various theoretical and numerical approaches have been proposed. The variety of Hamiltonians realizable in the experiments shows a large overlap with condensed matter systems. Therefore, the possibility to simulate large-scale quantum systems in the laboratory and to extract observables relevant for condensed matter physics provides a strong motivation for the work in this field. Full quantitative understanding of the usually inhomogeneous experimental systems, however, is extremely demanding for realistic system sizes.

Here, we present a quantitative measurement of the critical temperature T_c for Bose-Einstein condensation in a periodic potential and reveal the downshift of T_c upon approaching the critical interaction strenght for the transition from a superfluid to a Mott insulator. A direct comparison to ab initio quantum Monte-Carlo simulations for our trap parameters and particle numbers is used to verify the evaluation method. This comparison also enables us to check the adiabaticity of the loading process and to quantify non-adiabatic heating in the experimental system.

Q 11.5 Mo 17:30 VMP 6 HS-A

An Optical Microscope for 2D Quantum Gases — •Simon Fölling, Jonathon Gillen, Waseem Bakr, Amy Peng, Peter Unterwaditzer, and Markus Greiner — Department of Physics, Harvard University and Harvard-MIT Center for Ultracold Atoms, Cambridge, MA 02138, USA

Ultracold quantum gases are used as models for studying fundamental questions of modern condensed matter physics with atomic physics experiments. They allow for creating very clean implementations of complex many-body systems, and can enable the realization of tools for manipulating and probing the gas which are not available for classical condensed matter systems. We will present the implementation of an experiment that enables the preparation of a cold quantum gas in a single, strongly two-dimensional trapping potential. The atoms are located a few micrometers from a glass surface, allowing for optical access with a very high numerical aperture of NA=0.8. This enables us to image and manipulate the quantum gas with a resolution on the scale of 500 nm, for example by generating optical lattices by direct projection through the lens and flourescence imaging inside the trap.

Q 11.6 Mo 17:45 VMP 6 HS-A

Coherent control of dressed matter waves in strongly driven periodic potentials — •Oliver Morsch[1], Alessandro Zenesini[1], Hans Lignier[1,2], Donatella Ciampini[1], and Ennio Arimondo[1] — [1]CNR-INFM and Università di Pisa, Largo Pontecorvo 3, 51267 Pisa, Italy — [2]PhLAM, Université de Lille, 59655 Villeneuve d'Ascq cedex, France

We demonstrate experimentally that matter waves in one-, two- and three-dimensional optical lattices can be "dressed" and thus given new properties by strongly driving the periodic potentials. In the driven lattices the tunneling probability and the tunneling phase between adjacent lattice sites become a function of the driving parameters [1]. We identify regimes in which the parameters of the driving can be changed in time without exciting the system, thus allowing coherent and adiabatic following. This coherent control is then used in order to reversibly induce the superfluid-Mott insulator phase transition by changing the strength of the driving [2]. Our findings pave the way towards detailed studies of driven quantum systems, in particular the conditions for adiabatic following, and suggest new methods for controlling matter waves.

[1] H. Lignier et al., Phys. Rev. Lett. 99, 220403 (2007). [2] A. Eckardt et al., Phys. Rev. Lett. 95, 260404 (2005).

Q 12: Laserentwicklung: Festkörperlaser III

Zeit: Montag 16:30–18:00 Raum: VMP 6 HS-C

Q 12.1 Mo 16:30 VMP 6 HS-C

Stabilitätsuntersuchungen an Hochleistungs-CW-Faser-Lasern mit fs-Laser geschriebenen FBGs — •Fabian Stutzki, Cesar Jauregui, Jens Thomas, Christian Voigtländer, Stefan Nolte, Jens Limpert und Andreas Tünnermann — Friedrich-Schiller-Universität Jena Institut für Angewandte Physik (IAP)

Die Stabilität von monolithischen Faser-Lasern zeigt im Hochleistungs-CW-Betrieb einen gravierender Unterschied zwischen Single-Mode-(SM) und Large Mode Area-Fasern (LMA). Während SM-Fasern nur den Grundmode führen und einen stabilen Laserbetrieb ermöglichen, kann die Modenkonkurrenz in LMA-Fasern eine ungewünschte Instabilität hervorrufen.

In ersten Experimenten konnten einzelne Moden charakterisiert und ihre Entstehung erklärt werden. Durch einen geringen Biegeradius konnte ein einfacher Modenfilter realisiert und eine Stabilisierung erzielt werden. Eine Stabilisierung durch unterschiedliche Modenverluste ist demnach möglich.

Basierend auf den bisherigen Experimenten sollen effizientere Moden-Filter und neue Cavity-Designs untersucht werden. Als vielversprechende Idee soll ein Modenfilter nach Vorbild eines Fabry-Perot-Interferometers realisiert werden. Auch ein neuartiges Cavity-Design, das eine gezielte Modenkonvertierung zur Stabilisierung des Lasers ausnutzt, soll untersucht werden.

Q 12.2 Mo 16:45 VMP 6 HS-C

Ein leistungsstarkes, schmalbandiges, kontinuierliches Ytterbium-Faserverstärkersystem bei 1091 nm — •Ruth Steinborn, Frank Markert, Daniel Kolbe, Martin Scheid, Andreas Müllers und Jochen Walz — Institut für Physik, Universität Mainz, D-55128 Mainz

Ein stabiler leistungsstarker Laser bei einer Wellenlänge von 545,5 nm ist ein entscheidender Bestandteil zur Erzeugung von kohärenter kontinuierlicher Strahlung bei 121,56 nm, dem 1S – 2P-Übergang in Antiwasserstoff [1]. Eine solche Lichtquelle kann über die Frequenzverdopplung eines Festkörper-Lasersystems bei 1091 nm realisiert werden. Hierzu sollen 50 mW Ausgangsleistung einer gitterstabilisierten Laserdiode in einem Ytterbium-Faserverstärker auf mehrere Watt verstärkt werden.

Im Vortrag werden erste Ergebnisse vorgestellt. Es soll der Einfluss von verschiedenen Faserlängen und -typen behandelt werden.

[1] M. Scheid, D. Kolbe, F. Markert, J. Walz, T. W. Hänsch, Continuous-Wave Lyman-α Generation using Solid-State Lasers, To be published

Q 12.3 Mo 17:00 VMP 6 HS-C

Einfrequenter Erbium-Faserverstärker als Laserquelle für Gravitationswellendetektoren — •Markus Wiessell[1,2], Vincent Kuhn[1,2], Peter Wessels[1,2] und Jörg Neumann[1,2] — [1]Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover — [2]Centre for Quantum Engineering and Space-Time Research - QUEST, Welfengarten 1, 30167 Hannover

Thermisches Rauschen stellt eine Limitierung der Empfindlichkeit der derzeitigen Generation erdgebundener Gravitationswellendetektoren (GWD) dar, welche durch Kühlen der Testmassen sowie eine geeignete Materialwahl bei zukünftigen Generationen verringert werden soll. Silizium ist vielversprechend, setzt allerdings einen Wechsel von 1064 nm zu längeren Wellenlängen voraus. Hierfür erscheinen 1550 nm geeignet, für die zudem aufgrund von Anwendungen z.B. in der Telekommunikation weitreichende Grundlagen zur Realisierung geeigneter Laserquellen geschaffen wurden. Für GWD ergeben sich allerdings hinsichtlich Ausgangsleistung und Stabilität besondere Anforderungen.

Wir präsentieren das Konzept sowie erste Ergebnisse eines einfrequenten Erbium-Faserverstärkersystems mit in der Vorverstärkerstufe erreichten Ausgangsleistungen von bis zu 874 mW. Messungen zur Optical Noise Figure, sowie zu Intensitäts- und Phasenrauschen, welches mit einem unbalancierten Mach-Zehnder-Interferometer analysiert wurde, werden vorgestellt, sowie verschiedene Pumpkonfigurationen gegeneinander abgewogen. Zudem wird der Einfluss der Erbium-Dotierung auf den Verstärkerbetrieb diskutiert und eine Abschätzung der Linienbreite gegeben.

Q 12.4 Mo 17:15 VMP 6 HS-C

Faserverstärkersystem mit arbiträren und festen Pulsformen im ns- und und ps-Bereich — •Georg Herink, Sebastian Büsche, Thomas Theeg, Matthias Hildebrandt, Maik Frede, Jörg Neumann und Dietmar Kracht — Laser Zentrum Hannover e.V., Hollerithallee 8, D-30419 Hannover

Die Entwicklung eines Faserverstärkersystems für Pulsquellen bei 1064 nm mit arbiträren Pulsdauern von einigen 10-100 ns und festen Pulsdauern von 50 ps bei Wiederholraten von 10 kHz bis MHz wird präsentiert. In den vorgestellten Experimenten wird die Integration unterschiedlicher Seedquellen in Ytterbium und Neodym dotierte, vollständig faserbasierte Verstärker untersucht. Diodenlaser-basierte Seedquellen bieten eine große Pulsvariabilität durch direkte Strommodulation oder externe elektro-optische Modulatoren. Nahezu beliebige zeitliche Laserpulsformen mit Pulslängen von unter 3 ns werden erzeugt und in nachfolgenden Faserverstärkerstufen zu mittleren Ausgangsleistungen von einigen Watt verstärkt. Die Pulsformung infolge von Verstärkungssättigung und die Entwicklung des optischen Spektrums infolge von verstärkter spontaner Emission, sowie nichtlinearer Effekte werden untersucht. In einem weiteren Betriebsmodus mit extrem kurzen, aber festen Pulsdauern von 50 ps können mit faserverstärkten Laserdioden zusätzliche Applikationsfelder in der optischen Messtechnik und Materialbearbeitung erschlossen werden.

Q 12.5 Mo 17:30 VMP 6 HS-C

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

Mit Laserpulsen im Femtosekunden-Bereich können durch nichtlineare Absorption Materialveränderungen in transparenten dielektrischen Medien erzeugt werden. In Nd-dotierten und undotierten YAG-Kristallen führt diese Materialveränderung zur Zerstörung der kristallinen Struktur im Fokus der fs-Pulse.

Aufgrund des elasto-optischen Effekts bewirken Spuren aus zerstörtem Material eine lokale spannungsinduzierte Erhöhung des Brechungsindexes im umgebenden 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 geringen Verlusten hergestellt.

Lasertätigkeit der Wellenleiter konnte über die Rückkopplung an den Endflächen aufgrund der Fresnel-Reflexion von $R \approx 9\%$ gezeigt werden. Es wurde eine maximale Ausgangsleistung von 336 mW bei 690 mW eingekoppelter Pumpleistung bei einer Schwelle von 75 mW und einem differentiellen Wirkungsgrad von $\eta_s = 54\%$ erreicht. Weiterhin werden Ergebnisse mit direkt verspiegelten Endflächen bei verschiedenen Auskoppelgraden diskutiert.

Q 12.6 Mo 17:45 VMP 6 HS-C

Spatially resolved x-ray diffraction measurements of stress-induced fs-laser written YAG waveguides — •Oliver Henneberg[1], Ralf Menzel[1], Robert Elsner[1], Dietmar Korn[1], Jörg Siebenmorgen[2], and Günter Huber[2] — [1]Universität Potsdam, Institut für Physik und Astronomie, Potsdam, Deutschland — [2]Universität Hamburg, Institut für Laser-Physik, Hamburg, Deutschland

Homogeneous Nd:YAG crystals are widely used as an active medium in solid state lasers. Tracks of material damage were inscribed in YAG crystals using a fs-laser system. Due to a stress-induced change of the refractive index waveguiding is possible in different channels in the surrounding region of the written tracks. The diameter of the waveguides is about 20 μm.

In order to get more detailed information about the waveguide and its surrounding area spatially resolved x-ray diffraction measurements have been performed at the synchrotron HASYLAB. YAG with its cubic symmetry has a lattice constant of a = 1.2 nm. Selecting a bragg peak from the diffraction pattern, we compared the distorted and undistorted material. First results show a slightly shifted position of that bragg peak in the waveguide compared to undistorted YAG, indicating a change of the lattice constant of the material. A detailed discussion of the results will be given at the conference.

Q 13: Quanteninformation: Konzepte III

Zeit: Montag 16:30–18:00 Raum: VMP 6 HS-D

Q 13.1 Mo 16:30 VMP 6 HS-D

Quantitative verification of entanglement from incomplete measurement data — •Harald Wunderlich[1,2] and Martin B. Plenio[2,3] — [1]Fachbereich Physik, Universität Siegen, Siegen — [2]Institute for Mathematical Sciences, Imperial College London, London, UK — [3]QOLS, Blackett Laboratory, Imperial College London, London, UK

Many experiments in quantum information aim at creating multipartite entangled states. Quantifying the amount of actually generated entanglement can, in principle, be accomplished using full-state tomography. However, this method requires a number of measurement settings growing exponentially in the number of qubits. Non-trivial bounds on experimentally achieved entanglement can also be obtained from partial information on the density matrix. The fundamental question is then formulated as: What is the entanglement content of the least entangled quantum state that is compatible with the available measurement data?

We formulate the problem mathematically employing methods from the theory of semi-definite programming and then address this problem for the case, where the goal of the experiment is the creation of graph states. The observables that we consider are the generators of the stabilizer group, thus the number of measurement settings grows only linearly in the number of qubits. We provide analytical solutions as well as numerical methods that may be applied directly to experiments, and compare the obtained bounds with results from full-state tomography for simulated data.

Q 13.2 Mo 16:45 VMP 6 HS-D

Detection of entanglement with high statistical significance — •Sönke Niekamp, Bastian Jungnitsch, Matthias Kleinmann, and Otfried Gühne — Institut für Quantenoptik und Quanteninformation, Technikerstraße 21a, 6020 Innsbruck, Austria

A witness operator is a tool which allows to verify whether a given state is entangled. In a typical experiment, only a limited number of copies of the entangled state is available for this task. In order to detect entanglement with high certainty, it is therefore of advantage to decrease the statistical error involved in the measurement of the witness.

We investigate strategies to improve witness operators in order to minimize the error, focusing on experiments with trapped ions.

Q 13.3 Mo 17:00 VMP 6 HS-D

Detector-level entanglement of identical particles — •Malte Christopher Tichy[1], Fernando de Melo[1], Florian Mintert[1], Marek Kuś[2], and Andreas Buchleitner[1] — [1]Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg im Breisgau — [2]Center for Theoretical Physics, Polish Academy of Sciences, Aleja Lotników 32/46, 02-668 Warszawa, Poland

We study the impact of the (anti)symmetrization of the wave function of two identical bosons (fermions) on the entanglement measured at two spatially separated detectors.

Ambiguous spatial detector settings induce uncertainty on the outcome of spin-measurements of two spatially overlapping particles. We show that this uncertainty manifests itself as classical entropy in the case of distinguishable particles and as entanglement in the case of identical particles. We explore the transition between distinguishable and indistinguishable particles by tuning of the *effective indistinguishability*, a quantity which depends on the physical arrangement of the detectors. Due to two-particle interference, initially entangled particles may gain or loose correlations when detected in a certain setting and show strong quantum statistical effects.

Q 13.4 Mo 17:15 VMP 6 HS-D

Triplet-like correlation symmetry of 2-mode continuous variable entangled states — •Gerd Leuchs, Ruifang Dong, and Denis Sych — Institute for Optics, Information and Photonics, Max-Planck Institute for Science of Light, University Erlangen-Nuernberg, Guenther-Scharowsky-Str. 1, 91058, Erlangen, Germany

We report on a remarkable similarity of arbitrary two-mode continuous variable entangled states and two-qubit triplet Bell states. Both are shown to have the similar "mirror-reflection" correlation symmetry. By analogy with the qubit language we refer to the two-mode continuous variable entangled states as being triplet-like. The geometry of these quantum states is closely related to the so-called UxU* symmetry and these states show corresponding correlations. This triplet-like geometrical correlation property is demonstrated experimentally in the continuous variable regime for the first time.

Q 13.5 Mo 17:30 VMP 6 HS-D

Global Effects of Locally Noneffective Unitary Operations — •Hermann Kampermann[1], Sevag Gharibian[1,2], and Dagmar Bruss[1] — [1]Theoretische Physik III, Universität Düsseldorf, Germany — [2]Institute for Quantum Computing, University of Waterloo, Canada

We study the effect of locally noneffective unitary operations on bipartite quantum states, i.e. unitary operations applied to one party which leave the reduced density operator invariant. We investigate the distance between the bipartite state before and after such a local operation as an indicator for entanglement and non-locality [L.B. Fu, Europhys. Lett., vol. 75, 1 (2006)]. Closed formulae for the maximal distance induced by such operations (Fu-distance) are derived for pseudo pure quantum states, Werner states, and two-qubit states. The capabilities and limitations of the Fu-distance for entanglement detection is discussed as well as the connection to the CHSH inequality for specific classes of two-qubit states.

Q 13.6 Mo 17:45 VMP 6 HS-D

Concepts of simultaneity in quantum measurements — •Michael Busshardt and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, 89069 Ulm, Germany

The concept of simultaneous measurements of conjugate variables is reviewed. We especially focus on setups in the optical domain, where the quadratures of the electromagnetic field do not commute and, therefore, cannot be precisely measured simultaneously. However, by allowing the system under investigation to interact with certain classes of additional ruler systems, we can still obtain information about noncommuting observables in a simultaneous measurement. The question arises, which kinds of ruler states are optimal to gain specific knowledge about the system at hand. We focus on the advantage of entangled ruler states, as well as on the possibility to use such setups for state preparation. Moreover, in order to understand the true meaning of simultaneity, we explicitely consider time-dependent interactions.

Q 14: Ultrakurze Pulse: Erzeugung II

Zeit: Montag 16:30–18:45 Raum: VMP 8 R206

Q 14.1 Mo 16:30 VMP 8 R206

Large bandwidth highly efficient dielectric gratings through high index materials — •Helmut Rathgen — 3. Physikalisches Institut, Uni Stuttgart

Possible dielectric optical grating designs for a chirped pulse amplification scheme are investigated through numerical simulations, with focus on large spectral bandwidth. Grating geometries are considered (i) in transmission, (ii) buried grating between two glass bodies, (iii) TIR grating geometry. The effect of a high refractive index grating layer (n=2–4) is studied. An increase of the spectral bandwidth is observed. The -0.5dB bandwidth around the design wavelength is shown to increase by 1.5–3x (as compared to a fused silica grating). The short wavelength efficiency is found to exceed -3dB. Grating designs that provide a flat -1dB bandwidth over one octave are suggested.

Q 14.2 Mo 16:45 VMP 8 R206

Neuartige Transmissionsgitterkonzepte mit verminderten Reflexionsverlusten — •Tina Clausnitzer[1], Marcel Schulze[1], Ernst- Bernhard Kley[1] und Andreas Tünnermann[1,2] — [1]Institut für Angewandte Physik, Friedrich-Schiller Universität Jena — [2]Fraunhofer Institut für Angewandte Optik und Feinmechanik Jena

Dielektrische Beugungsgitter haben in den letzten Jahren, in verschiedensten Anwendungsgebieten, weit über die klassische Spektroskopie hinaus, Verbreitung gefunden. Vor allem in Ultrakurzpulslasersystemen bilden Sie wichtige Schlüsselkomponenten, die leistungslimitierend für den gesamten Aufbau sein können. Neben dielektrischen Reflexionsgittern, welche ähnlich zu klassischen metallischen Gittern eingesetzt werden, stieg in den letzten Jahren zunehmend die Nachfrage nach Transmissionsgittern, die sehr hohen Laserleistungen standhalten und Beugungseffizienzen bis nahe 100% aufweisen können. Ein wichtiger Aspekt bei der Optimierung von Transmissionsgittern ist die Minimierung störender Reflexionsverluste, welche insbesondere bei der Forderung nach hoher Dispersion zu einer beträchtlichen Verminderung der Effizienz führen können. Obwohl solche Gitter Strukturabmessungen im Submikrometerbereich besitzen und darum klassische Antireflexbeschichtungen nicht mehr anwendbar sind, gibt es doch verschiedene Ansätze zur Unterdrückung der Reflexion, welche hier vorgestellt werden. Neben der anschaulichen Erklärung der Konzepte werden auch theoretische Designs und experimentelle Ergebnisse diskutiert, die die reproduzierbare Realisierung von hocheffizienten hochdispersiven Gittern versprechen, die höchsten Laserleistungen standhalten.

Q 14.3 Mo 17:00 VMP 8 R206

All-fiber control of the repetition rate of an erbium fiber laser — Markus Löser[1,2], •Till Walbaum[1], Petra Gross[1], and Carsten Fallnich[1] — [1]Institut für Angewandte Physik, Westfälische Wilhelm-Universität Münster, Münster, Deutschland — [2]Westsächsische Hochschule Zwickau (FH), Fachbereich Physikalische Technik, PF 201037, Zwickau, Deutschland

Stabilization of the repetition frequency of mode-locked lasers is an important issue for synchronisation purposes. Fiber optical means are of special interest in this context due to their low cost and high environmental stability. In order to realize an all-fiber control of the repetition rate, we have developed a fiber stretcher based on low-bending loss single mode fiber. Our device is capable of changing the repetition rate of an erbium fiber laser by more than 1.1kHz at a fundamental frequency of 47.66MHz, which is to our knowledge the largest difference yet achieved by fiber stretching. With this novel stretcher, repetition rate stabilization has been established, fully neutralizing thermal drift. Frequency noise could be reduced to 57mHz RMS, limited by the available RF-reference. Stress-induced changes of polarization have been charaterized and were shown to be negligible. While being stabilized, the pulse repetition rate could still be tuned within several hundred Hertz without affecting pulse duration or optical spectrum significantly, while the output power remained constant within ±2% and the pulse duration within ±2fs over the whole tuning range. The work will be continued including investigations for the transfer of repetition rate stability to a second laser by optical means only.

Q 14.4 Mo 17:15 VMP 8 R206

A chirped photonic crystal fiber for high-fidelity guiding of sub-100 fs pluses — •J. Bethge[1], M. Bock[1], D. Fischer[1], J. S. Skibina[2], V. I. Beloglasov[2], S. Burger[3], R. Iliew[4], and G. Steinmeyer[1] — [1]Max Born Institute, Berlin — [2]Saratov State University, Saratov (Russia) — [3]Konrad Zuse Institute, Berlin — [4]Friedrich-Schiller-Universität, Jena

Photonic crystal fibers usually confine the light by means of a periodic cladding, consisting of several layers of identical cells [1]. This design resonantly decreases the transmission losses of such fibers to values of a few dB/km in a narrow wavelength range. However, the rather narrowband transmission bands and the detrimental third order dispersion characteristics of this single-cell design generally render application of such hollow-core fibers difficult in the femtosecond range. Therefore, no fiber-based concept can currently provide guiding of sub-100 fs pulses over extended distances. By introducing a radial chirp into the photonic crystal [2] we here demonstrate a novel concept for photonic crystal fibers that breaks with the paradigm of lattice homogeneity and enables a new degree of freedom in photonic crystal fiber design, eliminating much of the pulse duration restriction of earlier approaches. We demonstrate that the small GVD of chirped photonic crystal fibers allows for surprisingly weak stretching of 13 fs pulses, which only double their duration within 1 m of guided propagation.

[1] P. Russell, Science **299**, 358-362 (2003)
[2] J. Skibina, Nature Phot. **2**, 679-683 (2008)

Q 14.5 Mo 17:30 VMP 8 R206

Optical Parametric Amplification in the NIR in a gaseous medium by use of a hollow fibre — •Alexander Grün[1], Daniele Faccio[1,3], Arnaud Couairon[4], Philip K. Bates[1], Olivier Chalus[1], and Jens Biegert[1,2] — [1]ICFO-Institut de Cienciès Fotóniques, Mediterranean Technology Park, 08860 Castelldefels (Barcelona), Spain — [2]ICREA-Institució Catalana de Recerca i Estudis Avançats, 08010 Barcelona, Spain — [3]CNISM-Dipartimento di Fisica e Matematica, Università dell'Insubria, IT-22100 Como, Italy — [4]CNRS-Centre de Physique Théorique, École Polytechnique, F-91128, Palaiseau, France

Nonlinear optical interactions in gas-filled hollow fibres are currently widely employed for the generation of intense, few-cycle laser pulses, playing a particularly important role in strong field physics applications such as attosecond pulse generation. Shifting the center wavelength of such few-cycle pulses toward the MIR is of great importance for the generation of shorter attosecond pulses, and allow improved efficiency in extreme ultraviolet (EUV) generation.

Here we report for the first time, to the best of our knowledge, efficient optical parametric amplification (OPA) of ultrashort intense laser pulses in a gaseous medium in the near infrared (NIR). By properly exciting the modes of the capillary and by further optimization of the gas pressure we show broadband phase-matched OPA with a gain exceeding 30 dB at the input seed wavelength of 400 nm and generation of high energy 4 μJ NIR pulses that are also expected to be passively carrier-envelope phase (CEP) locked.

Q 14.6 Mo 17:45 VMP 8 R206

Infrared generation beyond BBO: easy tuning from 850 nm to above 5 μm with novel optical parametric amplifiers — •Maximilian Bradler, Christian Homann, Markus Breuer, and Eberhard Riedle — LS für BioMolekulare Optik, LMU München

Ultrashort few-cycle pulses in the Mid-Infrared (MIR) 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 signal and idler of an optical parametric amplifier (OPA). However, this renders a relatively narrow bandwidth, pulse lengths not much below 100 fs and low overall conversion efficiency in the 1 % range. Here we present a hybrid approach that yields ultrashort carrier-envelope-phase stable MIR pulses up to 5 μm directly as the output of an OPA. We first preamplify selected parts of a white-light supercontinuum generated in yttrium aluminum garnet (YAG) in BBO. As pump we use the second harmonic of a Ti:Sa regenerative amplifier for tunability in the wavelength range between 850 nm and 1550 nm. In a second stage we further amplify these pulses in a LiNbO3 crystal pumped by the 775 nm fundamental output of the Ti:Sa laser. This directly renders idler pulses in the desired wavelength range from 1550 nm to about 5.3 μm. With 240 μJ total pump energy we achieve pulse energies of more than 5 μJ up to 4 μm corresponding to an overall efficiency of more than 8% over a wide tuning range. The transform limit of the pulse widths is as low as 25 fs. An autocorrelation measurement confirms a pulse width of 42 fs at 3.8 μm, equivalent to just 3.5 optical cycles.

Q 14.7 Mo 18:00 VMP 8 R206

Micro-Joule energy, mid-IR pulses with 9-cycle duration from a 100 kHz OPCPA source — •Alexander Grün[1], Olivier Chalus[1], Philip K. Bates[1], Mathias Smolarski[1], and Jens Biegert[1,2] — [1]ICFO-Institut de Ciencièს Fotóniques, Mediterranean Technology Park, 08860 Castelldefels (Barcelona), Spain — [2]ICREA-Institució Catalana de Recerca i Estudis Avançats, 08010 Barcelona, Spain

Ultrashort pulsed light sources in the mid-IR are sought for numerous different fields, e.g. strong field physics, which demands high repetition-rate few-cycle pulses with stable carrier envelope phase (CEP). Generating such pulses in the mid-IR should result in shorter attosecond pulses, while broad bandwidth mid-IR pulses also cover many vibrational transitions in important molecules, opening a wide range of spectroscopic applications, e.g. medical breath monitoring.

Here we present such a completely new, scalable and potentially CEP stable source based on OPCPA, generating 9 cycle pulses at 3.2 μm with 1.2 μJ energy at a repetition rate of 100 kHz.

Q 14.8 Mo 18:15 VMP 8 R206

Generation of 8 fs, 125 mJ Pulses by use of Optical Parametric Chirped Pulse Amplification — Daniel Herrmann[1], Laszlo Veisz[1], Raphael Tautz[1], Franz Tavella[2], Karl Schmid[1,3], Alexander Buck[1], Vladimir Pervak[3], Michael Scharrer[4], Philip Russell[4], and •Ferenc Krausz[1,3] — [1]Max-Planck Institut für Quantenoptik, Garching, Deutschland — [2]HASYLAB/DESY, Hamburg, Germany — [3]Department für Physik Ludwigs-Maximilian-Universität München, Garching — [4]Max-Planck Forschungsgruppe Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, Erlangen, Deutschland

We report generation of three-cycle, 8 fs, 125 mJ optical pulses in a noncollinear optical parametric chirped-pulse amplifier (NOPCPA). These 16 TW laser pulses are compressed to within 6% of their Fourier limit. Our system starts with a broad-bandwidth frontend with improved hollow-core fiber, which delivers seed pulses with an energy of 0.4 mJ at 1 kHz repetition rate. It is optically synchronized with a Nd:YAG laser, which provides 532 nm pump pulses of 1.2 J energy and 80 ps duration at 10 Hz repetition rate. We use a negative-dispersive grism pair and an acousto-optic modulator to stretch the seed pulse to 30 ps with 3 microjoules energy for seeding the single-pass two-stage NOPCPA. After amplification, the signal energy is 150 mJ. Subsequently, the amplified signal pulse is compressed by use of glass bulks and chirped mirrors, and is characterized by using a home-built autocorrelator and a FROG device. This laser system permits exploring attosecond and high-field physics in a so far inaccessible regime.

Q 14.9 Mo 18:30 VMP 8 R206

Modeling Non-collinear Optical Parametric Chirped-Pulse Amplification — •Jiaan Zheng and Helmut Zacharias — Physikalisches Institut, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str.10, 48149 Münster, Germany

Due to the extremely broad spectral acceptance bandwidth non-collinear optical parametric chirped-pulse amplification (NOPCPA) is a promising technique to generate intense pulses with few-cycle pulse duration [1]. In this talk, a new model to describe the parametric process of three-wave interaction in the non-collinear optical parametric chirped-pulse amplification (NOPCPA) is presented, in which the effects from the non-collinear configuration have been taken into account. By utilizing this new model, a two-stage NOPCA system based on BBO with type I phase matching is numerically calculated with a split-step Fourier transform algorithm. Tracing the dynamic process of pump, signal and idler in the crystal reveals that in the beginning stage gain narrowing occurs due to the weak input signal intensity and the non-uniform temporal distribution of the pump light. However, in the saturation regime the spectrum of the signal will be broadened as a consequence of the back conversion process. The simulation shows that it is crucial to correctly control the experimental parameters to balance both processes. [1] F. Tavella, Y. Nomura, L. Veisz, V. Pervak, A. Marcinkevičius and F. Krausz, Opt. Lett. 32, 2227 (2007)

Q 15: Ultrakurze Pulse: Erzeugung III

Zeit: Dienstag 10:30–12:30 Raum: Audi-A

Q 15.1 Di 10:30 Audi-A

Generation and characterization of ultrashort laser pulses — •Alexander Sperl, Konstantinos Simeonidis, and Ullrich Joachim — MPI für Kernphysik, 69117 Heidelberg

In atomic and molecular physics experiments extremely short laser pulses, mostly in the sub ten-femtosecond range, are required. The shorter the pulses are and correspondingly their bandwidth grows, the more important dispersion management and control becomes.

A new setup for spectral broadening involving self phase modulation (SPM) via filamentation and subsequent recompression as well as pulse characterization through an interferometric autocorrelation setup with low dispersion properties are presented. While the so called SPIDER and FROG techniques yield more or less complete information about the pulse parameters, however, they are difficult to implement and their handling is not as easy as often desired. In contrast the interferometric autocorrelation is a comparatively fast measurement, which is helpful in terms of day-to-day adjustments. Even though the information is incomplete, one can retrieve semiquantitative hints towards the pulse chirp by simulating the complete autocorrelation signal, including the GDD parameter.

Q 15.2 Di 10:45 Audi-A

Generation, Phase modulation and Characterization of femtosecond UV pulses — •Jens Möhring, Tiago Buckup, and Marcus Motzkus — Physikalische Chemie, Universität Marburg, Hans-Meerwein-Straße, D-35032 Marburg

The extension of coherent control in the UV requires a flexible, ultrashort source of phase modulated pulses. To cover molecular systems absorbing in this spectral range we present an improved setup around our micromechanical, direct UV femtosecond spatial light modulator. The possibility of combined phase and amplitude modulation, an optimized duty cycle and a simple pulse characterization upgrades significantly the shaping setup for coherent control. The applied sub 30 fs UV pulses, tunable between 300 to 350 nm, are generated by sum frequency mixing of a noncollinear parametric amplifier with NIR pulses. Phase modulation based on a 2D micro mirror array enables then full phase control directly in the UV. Diffractive shaping on this 2D MEMS (micro electromecanical System) device makes possible amplitude control on a phase only modulator by exploiting two dimensional phase structures. In addition, a simple UV autocorrelator based on two photon absorption in a solar blind photomultiplier tube, was constructed. The combination of diffractive shaping and the autocorrelator setup facilitates powerful cross correlation techniques to characterize e.g. linear time delays and double pulse structures.

Q 15.3 Di 11:00 Audi-A

Titan-Saphir Laseroszillator mit Mikrojoule Pulsenergie — •Martin Siegel, Nils Pfullmann, Guido Palmer, Florian Schewe und Uwe Morgner — Institut für Quantenoptik, Universität Hannover, Welfengarten 1, 30167 Hannover

Durch die Kombination eines Cavity-Dumping Konzeptes mit einem Chirped-Pulse Laseroszillator ist es erstmals möglich Pulsenergien von mehr als einem Mikrojoule direkt aus einem Titan-Saphir Laseroszillator zu erzeugen. Durch den Betrieb im Bereich positiver Gesamtdispersion und den dadurch resultierenden Chirp des Pulses ist es möglich zu hohe Nichtlinearitäten zu vermeiden, was auch bei sehr hohen internen Pulsenergien einen stabilen Pulsbetrieb ermöglicht. Auf der anderen Seite werden durch Cavity-Dumping mittels eines AOM sehr hohe Auskoppelgrade im Bereich von 40% ermöglicht. Der hier präsentierte Laser erreicht dadurch Pulsenergien von 1,1 Mikrojoule bei einer Repetitionsrate von einem Megahertz und einem Fourierlimit von 74 fs. Die Pulsdauer der gechirpten Pulse direkt nach dem Resonator beträgt etwa 5 ps, da diese noch im Rahmen eines weiteren Experiments nachverstärkt werden sind sie bisher nicht komprimiert worden. Die nun erreichbaren extrem hohen Spitzenintensitäten machen den vorgestellten Laser zu einer interessanten Lichtquelle vor allem im Bereich der Erzeugung hoher harmonischer Strahlung.

Q 15.4 Di 11:15 Audi-A

Skalierung der Spitzenleistung von ultrakurzen Pulsen bei hohen Wiederholfrequenzen — •Thomas Gottschall, Steffen Hädrich, Jan Rothhardt, Tino Eidam, Damian N. Schimpf, Fabian Röser, Jens Limpert und Andreas Tünnermann — Friedrich Schiller Universität Jena, Institut für Angewandte Physik

Die Erzeugung ultrakurzer Pulse in Laseroszillatoren gehört heutzutage zum Stand der Technik. Werden sie auf Pulsenergien von mJ verstärkt, können sie zur Untersuchung fundamentaler Wechselwirkungen eingesetzt werden. Einer der interessantesten Effekte, die Erzeugung hoher Harmonischer, erweitert den Spektralbereich kohärenter Lichtquellen in den der Röntgenstrahlung. Da dieser Effekt nur eine geringe Konversionseffizienz besitzen, sind empfindliche Detektoren nötig. Mit einer Erhöhung der Pulsfolgerate und so auch der Durchschnittsleistung, würde dies eine genauere Untersuchung bestimmter fundamentaler Wechselwirkungen ermöglichen. Faserlaser besitzen bezüglich der Pulsfolgefrequenz eine große Skalierbarkeit bei höchster Strahlqualität. Durch nichtlineare Effekte beim Verstärken und durch die eingeschränkte Verstärkungsbandbreite, stellt sich das Skalieren von Pulsenergie und Pulslänge als Herausforderung dar. Es werden zwei Konzepte zur Erzeugung ultrakurzer Pulse auf Basis eines Faserlasersystems vorgestellt. Dabei wird auf die nichtlineare Komprimierung in edelgasgefüllten Hohlkernfasern (105μJ mit 68fs bei 30kHz $\geq$ 1GW Spitzenleistung) und auf die optische parametrische Verstärkung gechirpter Pulse (16,2μJ mit 51fs bei 80kHz = 180MW Spitzenleistung) eingegangen.

Q 15.5 Di 11:30 Audi-A

Kryogene Nachverstärkung von μJ-Laserpulsen — •Nils Pfullmann[1,2], Martin Siegel[1,2] und Uwe Morgner[1,2] — [1]Centre for Quantum Engineering and Space-Time Research (QUEST) — [2]Institut für Quantenoptik, Leibniz Universität Hannover

Zur Erzeugung von hoher harmonischer Strahlung werden aktuell mehrheitlich Verstärkersysteme mit Pulsenergien im mJ-Bereich eingesetzt. Diese haben typischerweise eine Pulswiederholrate im Bereich einiger kHz. Der hier präsentierte kontinuierliche Nachverstärker basiert auf einer Kombination eines Seed-Oszillators mit Mikrojoule-Pulsenergien und einem kryogen gekühltem Verstärker. Mit dem System ist es möglich Pulse mit einer Pulsenergie von bis zu 1,46 μJ, einem Fourier-Limit von 95 fs und einer Pulswiederholrate von 1 MHz zu erzeugen. Durch die Kühlung wird eine Steigerung der Verstärkung um einen Faktor von drei bis vier erreicht. Die Pulsenergie kann durch eine Erhöhung der Pumpleistung sowie durch mehrfache Durchgänge durch das Verstärkungsmedium weiter erhöht werden. Abschätzungen auf Grund von Simulationen lassen Pulsenergien im Bereich von 3 μJ realistisch erscheinen. Die mit diesen Pulsenergien erreichbaren Intensitäten oberhalb von 10^{14} W/cm^2 eröffnen neue Möglichkeiten zur Erzeugung von hohen Harmonischen mit Megahertz-Repetitionsraten.

Q 15.6 Di 11:45 Audi-A

227-fs-Pulse aus einem SESAM-modengekoppelten Yb:LuScO$_3$-Scheibenlaser — •Christian Kränkel[1], Cyrill R. E. Baer[1], Oliver H. Heckl[1], Matthias Golling[1], Thomas Südmeyer[1], Ursula Keller[1], Rigo Peters[2], Klaus Petermann[2] und Günter Huber[2] — [1]Institut für Quantenelektronik, ETH Zürich, Wolfgang-Pauli-Str. 16, 8093 Zürich, Schweiz — [2]Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Deutschland

Wir präsentieren unsere Resultate zum SESAM-Modenkoppeln im Scheibenlaser unter Verwendung des Misch-Sesquioxids Yb:$LuScO_3$ als aktives Material. Aufgrund seiner ungeordneten Gitterstruktur vereint dieses Material die Bandbreiten der beiden effizienten Scheibenlasermaterialien Yb:Lu_2O_3 und Yb:Sc_2O_3 und ermöglichte so bei einer mittleren Ausgangsleistung von 7,2 W und einer Repetitionsrate von 66,5 MHz die Erzeugung von nahezu bandbreitenbegrenzten 227-fs-Pulsen. Dies stellt die kürzeste bisher im modengekoppelten Scheibenlaser realisierte Pulsdauer dar und unterbietet die mit dem Standard-Scheibenlasermaterial Yb:YAG erzielbaren Pulsdauern von rund 700 fs um ein Vielfaches. In einer veränderten Konfiguration mit leicht erhöhten Pulsdauern konnten sogar mehr als 10 W mittlere Ausgangsleistung erzielt werden.

Q 15.7 Di 12:00 Audi-A

Single crystal Yb:$LuScO_3$ laser mode-locked by a single-walled carbon nanotube saturable absorber

— •Andreas Schmidt[1], Günter Steinmeyer[1], Valentin Petrov[1], Uwe Griebner[1], Jong Hyuk Yim[2], Won Bae Cho[2], Soonil Lee[2], Fabian Rotermund[2], Rigo Peters[3], Klaus Petermann[3], and Günter Huber[3] — [1]Max-Born-Institut, D-12489 Berlin, Germany — [2]Ajou University, 443-749 Suwon, Korea — [3]Institut für Laser-Physik, Universität Hamburg, D-22761 Hamburg, Germany

Mode-locking of the disordered cubic sesquioxide crystal Yb:$LuScO_3$ using a single-walled carbon nanotube saturable absorber (SWCNT-SA) is demonstrated under diode pumping and compared with passive mode-locking by a commercial semiconductor saturable absorber mirror (SESAM). Around 1 μm, passive mode-locking using SWCNT-SAs was demonstrated for Yb-doped double tungstate lasers (Yb:KLuW, Yb:KYW) [1]. Using a SWCNT-SA directly deposited on a dielectric mirror for passive mode-locking of an Yb:$LuScO_3$ laser, nearly transform-limited pulses with a duration of 306 fs were achieved. The comparison with SESAM mode-locking indicates the directions for future optimization of the SWCNT-SA parameters. The shortest pulse duration of 125 fs for Yb-doped SESAM mode-locked sesquioxide lasers confirms our approach of introducing mixed sesquioxide hosts to profit from their increased gain bandwidth compared to the sesquioxide crystals without compositional disorder.

[1] A. Schmidt, et. al., Opt. Lett. **33**, 729 (2008).

Q 15.8 Di 12:15 Audi-A

Modelocked Integrated External-Cavity Surface Emitting Laser (MIXSEL) — •T. Südmeyer, D.J.H.C. Maas, A.-R. Bellancourt, B. Rudin, M. Hoffmann, M. Golling, Y. Barbarin, and U. Keller — Department of Physics, Institute of Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

Vertical external cavity surface emitting lasers (VECSELs) combine the benefits from diode-pumped solid state and semiconductor laser technologies with wavelength flexibility, high power and excellent beam quality. Previously, ultrafast VECSELs required a folded cavity with a separate semiconductor saturable absorber mirror (SESAM) for passive modelocking. Recently, we demonstrated that SESAM and VECSEL gain structure can be integrated into a single semiconductor structure, which is referred to as modelocked integrated external-cavity surface emitting laser (MIXSEL). The compact and simple MIXSEL platform has a high potential for numerous applications such as the optical clocking of multi-core microprocessors. In this presentation, we illustrate the VECSEL advantages by presenting a continuous wave VECSEL generating a record-high output power of 20.2 W in fundamental transverse mode operation with an overall optical-optical efficiency of 43%. We discuss the integration challenges and present a MIXSEL generating an average output power of 185 mW at 2.86 GHz in 32-ps pulses. Moreover, we discuss novel MIXSEL designs for achieving higher average output power and shorter pulse duration.

Q 16: Ultrakalte Atome: Fallen und Kühlung I (mit A)

Zeit: Dienstag 10:30–12:30 Raum: Audi-B

Q 16.1 Di 10:30 Audi-B

Sympathetic cooling towards a mixed quantum degenerate Gas of Yb and Rb — Florian Baumer, •Frank Münchow, Nils Nemitz, and Axel Görlitz — Institut für Experimentalphysik, Universität 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. Our approach is photoassociative production of YbRb molecules in a mixture of ultracold atomic Yb and Rb, where the special feature of our particular system is that in the ground state YbRb possesses an electric as well as a magnetic dipole moment.

An important step towards efficient molecule production using photoassociation is the realization of a quantum degenerate mixture of Yb and Rb. In our experimental setup the Yb atoms are held in a bichromatic optical dipole trap designed to have minimal effect on the evaporatively cooled ^{87}Rb atoms which are held in a Ioffe-Pritchard type magnetic trap. Through interspecies collisions by ^{87}Rb we have reached temperatures of 1μK at ^{174}Yb atom numbers of $2 \cdot 10^5$. While sympathetic cooling works without loss of Yb atoms down into this temperature regime, quantum degeneracy in the mixed system has not yet been observed possibly due to excessive heating of the atoms due to technical noise. Currently, the nature of the heating mechanisms is under investigation and we will report on the latest results.

Q 16.2 Di 10:45 Audi-B

Auf dem Weg zum Calcium-BEC — •Oliver Appel, Felix Vogt, Uwe Sterr und Fritz Riehle — PTB, Braunschweig

Calcium bietet aufgrund seiner Elektronenstruktur interessante Möglichkeiten zur Untersuchung ultrakalter Stöße und zur Atominterferometrie. Zudem ist es ein aussichtsreicher Kandidat zum Erreichen der Quantenentartung. Aufgrund fehlender magnetischer Substruktur im Grundzustand muss das BEC mit ausschließlich optischen Methoden verwirklicht werden.

Die Calciumatome werden in einer zweistufigen MOT vorgekühlt und in eine eindimensionale oder gekreuzte Dipolfalle umgeladen. Die so erreichten Phasenraumdichten von etwa 0,01 sollen durch Verdampfungskühlung in der Dipolfalle weiter erhöht werden. Die bisherigen Experimente deuten auf starke Dreikörperverluste im Kreuzungsbereich der Dipolfalle hin. Es wird diskutiert welchen Einfluss das Ladeverhalten und die Dreikörperstöße auf eine erfolgreiche Verdampfungskühlung haben.

Q 16.3 Di 11:00 Audi-B

Kalte neutrale Quecksilberatome in einer MOT — •Patrick Villwock, Arne Schönhut, 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 fermionischen Isotope eignen sich zur Untersuchung eines neuen optischen Zeitstandards. In einer magneto-optischen Falle gefangene Quecksilberatome bieten zusätzlich die Möglichkeit der Erzeugung translatorisch kalter Moleküle durch Photoassoziation, sowie deren Laserkühlung in den vibratorischen Grundzustand.

Die Sättigungsintensität des Kühlübergangs bei 253,7 nm beträgt 10,2 mW/cm^2, bei einer natürlichen Linienbreite von 1,27 MHz. Eine UV-Leistung von über 250 mW wird mit einer zweistufigen externen Frequenzverdopplung eines Yb:YAG Scheibenlasers bei 1014,8 nm bereitgestellt. Zur Frequenzstabilisierung des Lasers wird mit Sättigungsspektroskopie ein entsprechendes Fehlersignal im Lock-In Verfahren generiert.

Erste Ergebnisse zur erfolgreichen Realisierung der magneto-optischen Falle werden diskutiert.

Q 16.4 Di 11:15 Audi-B

Laser cooling by collisional redistribution of fluorescence — •Ulrich Vogl and Martin Weitz — Institut für Angewandte Physik, Wegelerstraße 8, 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, culminating in the optical refrigeration of solids. Collisional redistribution of fluorescence is a proposed different cooling mechanism that involves atomic two-level systems, though experimental investigations in gases with moderate density have so far reached the cooling regime. Here we experimentally demonstrate cooling of an atomic gas based on collisional redistribution of fluorescence, using rubidium atoms subject to several hundreds of bars of buffer 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_BT is extracted from the dense atomic sample. In a proof of principle experiment with a thermally not isolated sample, we experimentally demonstrate relative cooling by 33 K. 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 16.5 Di 11:30 Audi-B

EIT Kühlen von $^{40}Ca^+$ Ketten in einer segmentierten Ionenfalle — •Johannes F. Eble, G. Schütz, F. Schmidt-Kaler und K. Singer — Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, D-89069 Ulm

Mittels elektromagnetisch induzierter Transparenz (EIT) können gefangene Ionen bis nahe dem quantenmechanischen Grundzustand abgekühlt werden. Dabei wird eine zusätzliche schmale Absorptionslinie auf der blau verstimmten Seite eines natürlichen Übergangs erzeugt [1]. Ein Vorteil dieser Methode gegenüber anderen Laserkühlverfahren ist, dass mehrere Schwingungsmoden simultan gekühlt werden können und somit besonders für Ionenketten geeignet ist, bei denen verschiedene Schwingungsmoden auftreten.

Wir verwenden die Zeeman Struktur des $S_{1/2}$ - $P_{1/2}$ Dipol Übergangs von Ca^+-Ionen um ein EIT Spektrum zu generieren. Um die Linienform spektroskopisch zugänglich machen zu können scannen wir die Resonanz in gepulstem Lasermodus. Dadurch können wir das EIT Profil charakterisieren und bezüglich optimaler Kühleigenschaften formen. Kühlergebnisse mit einzelnen Ionen und Ionenketten werden vorgestellt.

An diesen kalten Ionenketten wollen wir die Wechselwirkung zwischen Phononen studieren. Diese Wechselwirkung wird durch ein anharmonisches optisches Potential erzeugt [2].

[1] C. F. Roos, D. Leibfried, A. Mundt, F. Schmidt-Kaler, J. Eschner, R. Blatt, Phys. Rev. Lett. **85**, 5547 (2000).
[2] X.-L. Deng et al, Phys. Rev. A **77**, 033403 (2008)

Q 16.6 Di 11:45 Audi-B

Quantum Catcher - Stopping Particles of unknown velocities — •Sönke Schmidt[1], J. Gonzalo Muga[2], and Andreas Ruschhaupt[1] — [1]Institut für Mathematische Physik, TU Braunschweig, Mendelssohnstrasse 3, 38106 Braunschweig — [2]Departamento de Quimica-Fisica, Universidad del Pais Vasco, Apartado 644, 48080 Bilbao, Spain

We propose a method to stop particles of unknown velocities. We present a classical and a quantum mechanical description of the setting. Using numerical simulations with realistic and experimentally accessible parameters, we show the efficiency of the method and discuss its bounds.

Q 16.7 Di 12:00 Audi-B

Trapping neutral Cs-atoms using ultra-thin optical fibres — •Eugen Vetsch, Daniel Reitz, Guillem Sagué, Regine Schmidt, and Arno Rauschenbeutel — Abteilung QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz

We present our recent results on trapping cold neutral Caesium atoms close to the surface of an ultra-thin optical fibre. The atoms are captured by a two-colour trap which is based on light-induced dipole forces exerted on the atoms by a blue- and red-detuned evanescent light field, created by launching two co-propagating laser beams through the fibre. This results in a cylindrically symmetric trap around the fibre that exhibits a trapping minimum about two hundred nanometres above the surface. By launching an additional, counter-propagating red-detuned laser beam through the fibre, a red-detuned standing wave is realized, confining the atoms in all three dimensions.

We are currently able to trap more than 10^3 atoms with a lifetime of about 50 ms. We probe the atoms by measuring the absorption of a weak resonant probe field which is sent through the fibre and which couples to the atoms via the evanescent field. Remarkably, the atomic ensemble is optically dense for this probe field. This opens the route towards non-linear optics applications like electromagnetically induced transparency, slow and stopped light processes, deterministic single photon sources, and quantum memories with fibre-coupled atomic ensembles.

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

Q 16.8 Di 12:15 Audi-B

Mikrostrukturierte Ionenfalle mit integrierten Magnetfeldspulen — •Delia Brüser, Thomas Collath, Michael Johanning und Christof Wunderlich — Fachbereich Physik, Universität Siegen, 57072 Siegen, Deutschland

Es wurde eine mikrostrukturierte Ionenfalle (Mikrofalle) entwickelt, gefertigt und gebaut, welche intern einen hohen Magnetfeldgradienten erzeugen kann. Die Mikrofalle ist eine dreidimensionale Paul-Falle mit segmentierten DC-Elektroden. Sie ist sandwichförmig aus drei übereinander plazierten Lagen aufgebaut. Die beiden äußeren Lagen führen dem Fallenschlitz jeweils 33 DC-Elektroden und eine RF-Elektrode zu. Die mittlere Lage ist so geformt, dass durch vergoldete Strukturen effektiv ein Anti-Helmholtz Spulenpaar gebildet wird. Aufgrund der großen Nähe der Spulen zu den Ionen kann so ein Magnetfeldgradient von erwarteten 100 T/m erzeugt werden. Dieser Gradient ist für Adressierung und Kopplung der Ionen von großer Bedeutung [1].

Der Aufbau des Mikrofallensystems wird beschrieben. Es werden zudem erste Ergebnisse präsentiert und mit vorhergegangenen Simulationen verglichen.

[1] M. Johanning, A. Braun, N. Timoney, V. Elman, W. Neuhauser, Chr. Wunderlich, arXiv:0801.0078v1 [quant-ph]

Q 17: Quantengase: Bosonen Dynamik / Disorder

Zeit: Dienstag 10:30–12:30 Raum: VMP 6 HS-A

Q 17.1 Di 10:30 VMP 6 HS-A

Bose-Einstein condensates in time dependent rotating traps — •Endre Kajari, Daniela Denot, Reinhold Walser, and Wolfgang P. Schleich — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

Recent experiments on the time evolution of Bose-Einstein condensates in free fall, accomplished by the QUANTUS collaboration [1] at the drop tower facility in Bremen (ZARM), revealed a rotation of the harmonic trap at very small trapping frequencies. Since the scaling approach provided in the seminal articles [2,3] is not applicable to time dependent rotating traps, an extension of their formalism is necessary.

We recall a natural generalization [4] of their scaling approach, which allows for an efficient description of the macroscopic wave function in time dependent rotating traps. The limitations of this generalization are explored by comparison to three-dimensional numerical simulations of the time dependent Gross-Pitaevskii equation.

[1] A. Vogel et al., Appl. Phys. B **84**, 664 (2006).
[2] Yu. Kagan et al., Phys. Rev. A. **54**, R1753 (1996).
[3] Y. Castin and R. Dum, Phys. Rev. Lett. **77**, 5315 (1996).
[4] P. Storey and M. Olshanii, Phys. Rev. A **62**, 033604 (2000).

Q 17.2 Di 10:45 VMP 6 HS-A

Dynamical aspects of Bose-Einstein condensation — •Alexej Schelle[1,2], Thomas Wellens[1], Dominique Delande[2], and Andreas Buchleitner[1] — [1]Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]Laboratoire Kastler-Brossel, Université Pierre et Marie Curie-Paris 6, ENS, CNRS; 4 Place Jussieu, F-75005 Paris, France

We present a non-phenomenological, particle number conserving quantum master equation theory for trapped Bose-Einstein condensates out of thermal equilibrium. Based on the separation of time scales between the condensate and non-condensate dynamics, the condensate master equation is derived taking into account all possible two-particle interaction processes. We study the so obtained times scales for non-equilibrium dynamics in the dilute gas limit, and show that they are determined with negligible corrections by properties of a non-interacting gas. As a fundamental application, we study the process of Bose-Einstein condensation quantitatively, which reduces to an evolution equation for the condensate particle number distribution in a gas of exactly N particles.

Q 17.3 Di 11:00 VMP 6 HS-A

Dynamics of Solitons in Bose-Einstein condensates — •Eva-Maria Richter[1], Christoph Becker[1], Parvis Soltan-Panahi[1], Mathis Baumert[2], Sören Dörscher[1], Simon Stellmer[3], Jochen Kronjäger[2], Kai Bongs[2], and Klaus Sengstock[1] — [1]Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]MUARC, School of Physics and Astronomy, University of Birmingham, Edgbaston, Birmingham B15 2TT, United Kingdom — [3]Institut für Quantenoptik und Quanteninformation Technikerstr. 21a A-6020 Innsbruck Austria, Europe

We present the results of numerical calculations solving the 1D Gross-Pitaevskii equation and discuss the dynamics of dark and dark-bright solitons in Bose-Einstein condensates, particularly with regard to their collisions [1,2]. By tracing phase and densitydistribution of the condensate during the interaction, several types of collisions, depending on the depths of the solitons, can be distinguished. We compared these simulations with our results of the experimental observations of dark and dark-bright solitons in Bose-Einstein condensates. [1] C. Becker et. al., Nature Physics 4, 496-501 (2008); [2] S. Stellmer et. al., Phys. Rev. Lett. 101, 120406 (2008)

Q 17.4 Di 11:15 VMP 6 HS-A

Comparison of stochastic theories for the dynamics of Bose gases — Stuart Cockburn[1], •Carsten Henkel[2], Antonio Negretti[3], and Nikolaos Proukakis[1] — [1]School of Mathematics and Statistics, Newcastle University, United Kingdom — [2]Institut für Physik und Astronomie, Universität Potsdam, Germany — [3]Institut für Quanten-Informationsverarbeitung, Universität Ulm, Germany

Theoretical modelling of ultracold Bose gases at finite temperature is based on a variety of different techniques, and the precise relation between these approaches is not yet established [1]. In this work, we compare two numerical simulation schemes that combine propagation according to the Gross-Pitaevskii equation with different initial states: the number-conserving Bogoliubov method [2] and the stochastic Gross-Pitaevskii equation [3,4]. In the latter method, the state is prepared by coupling a heat bath to the atomic quantum field. We compare the initial data, looking at diagnostics such as condensate statistics. Dynamical observables after releasing the initial state at different temperatures are analyzed: we focus on the cases that the heat bath is removed [5] or not.

[1] N.P. Proukakis and B. Jackson, J. Phys. B 41, 203002 (2008).
[2] Y. Castin and R. Dum, Phys. Rev. A 57, 3008 (1998); A. Sinatra, C. Lobo and Y. Castin, J. Phys. B 35, 3599 (2002).
[3] H.T.C. Stoof, J. Low Temp. Phys. 114, 11 (1999).
[4] C.W. Gardiner and M.J. Davis, J. Phys. B 36, 4731 (2003).
[5] N.P. Proukakis, J. Schmiedmayer and H.T.C. Stoof, Phys. Rev. A 73, 053603 (2006).

Q 17.5 Di 11:30 VMP 6 HS-A

BEC's in disordered potentials: from weak to strong localization — •Felix Eckert, Thomas Wellens, Viola Droujinina, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3a, 79104 Freiburg

Recent numerical studies of BEC's scattered from 2-D disordered potentials reveal a reduction (or even inversion) of the coherent back scattering (CBS) cone induced by the atomic mean-field interactions [1]. Since, at least in the linear case, enhanced backscattering corresponds to a reduction of the diffusion coefficient (weak localization), we now investigate whether this correspondence still holds in presence of atomic interactions. Employing a generalization of the self consistent approach of Vollhardt and Wölfle [2] in connection with the non-linear diagrammatic theory developed in [3], we calculate the diffusion coefficient for a BEC in a random finite medium, and study the transition from the weakly to the Anderson localized regime for different coupling constants of the interacting atoms in the BEC.

[1] M. Hartung *et al.*, Phys. Rev. Lett. **101**, 020603 (2008)
[2] D. Vollhardt and P. Wölfle, Phys. Rev. B **22**, 4666 (1980)
[3] T. Wellens and B. Grémaud, Phys. Rev. Lett. **100**, 033902 (2008)

Q 17.6 Di 11:45 VMP 6 HS-A

Transport and depletion of Bose-Einstein condensates in the presence of disorder — Thomas Ernst[1], •Tobias Paul[2], and Peter Schlagheck[3,4] — [1]Center for Theoretical Chemistry and Physics, Massey University Auckland, New Zealand — [2]Institut für Theoretische Physik, Universität Heidelberg — [3]Institut für Theoretische Physik, Universität Regensburg — [4]Division of Mathematical Physics, Lund Institute of Technology, Sweden

We explore transport processes of ultracold Bose-condensed atomic vapors within guided atom lasers beyond the Gross-Pitaevskii Mean-Field approach. For this purpose we generalize the microscopic quantum dynamics approach introduced by Köhler and Burnett to compute the time evolution of the condensate wavefunction as well as the amount of quantum excitations and depletion. Applying this method to flows of ultracold bosonic atoms through quasi 1D waveguides with disorder, we find that the onset of permanently time-dependent scattering of the condensate on the Gross-Pitaevskii level [2,3] corresponds to the appearance of strong depletion of the condensate on the microscopic level.

[1] T. Köhler and K. Burnett, Phys. Rev. A 65, 033601 (2002)
[2] Tobias Paul et al, Phys. Rev. A 72, 063621 (2005)
[3] T. Paul, P. Schlagheck, P. Leboeuf, and N. Pavloff, Phys. Rev. Lett. 98, 210602 (2007)

Q 17.7 Di 12:00 VMP 6 HS-A

Critical velocity of a Bose-Einstein condensate in presence of disorder — •Tobias Paul[1] and Mathias Albert[2] — [1]Institut für Theoretische Physik, Universität Heidelberg — [2]Laboratoire de Physique Théorique et Modèles Statistiques, Université Paris Sud, Orsay

We investigate the breakdown and the critical velocity of the superfluid motion of a quasi-one-dimensional Bose-Einstein condensate in presence of disordered potentials. We present an analytical approach that relates the critical velocity beyond which the superflow breaks down with the statistical properties of the disorder potential. In particular, we study a) smoothly varying disordered potentials like the experimentally relevant case of an optical speckle potential, b) disordered potentials which consists of a series of individual scatterers. We compare our analytical results to full numerical computations which simulate the flow of the condensate through the disordered region.

Q 17.8 Di 12:15 VMP 6 HS-A

Speed of Sound in Interacting Disordered Bose-Einstein Condensates — •Nina Renner, Christopher Gaul, and Cord A. Müller — Physikalisches Institut, Universität Bayreuth, Germany

Elementary excitations of interacting Bose-Einstein condensates are sound-wave like at low energies. The dispersion relation of these excitations is changed by an external disorder potential, for which we consider spatially correlated Gaussian and speckle potentials. To begin with we treat the many-particle Hamiltonian in the Gross-Pitaevskii mean-field framework. After performing a saddle-point expansion of the energy functional followed by a Bogoliubov transformation we arrive at the Bogoliubov Hamiltonian [1]. Its self energy in the disorder-averaged effective medium describes the correction to the dispersion relation and notably to the speed of sound. In several limiting cases for 1D propagation we find very simple analytical expressions for these corrections. Our analytical results agree with numerical simulations of the propagation of sound waves.

[1] C. Gaul and C. A. Müller, Europhys. Lett. **83**, 10006 (2008)

Q 18: Quanteninformation: Photonen I

Zeit: Dienstag 10:30–12:30 Raum: VMP 6 HS-D

Q 18.1 Di 10:30 VMP 6 HS-D

Experimental Demonstration of a Heralded Entanglement Source — •Claudia Wagenknecht, Che-Ming Li, Alexander Goebel, Yu-Ao Chen, Xiao-Hui Bao, Qiang Zhang, and Jian-Wei Pan — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg, Germany

We present the realisation of a linear optics experiment for heralded preparation of polarisation entangled photon pairs. Our experiment relies on three pair emission from a single parametric down-conversion source, where the conditioned detection of a four photon trigger unambiguously heralds successful preparation of a maximally polarisation entangled photon pair in the output mode, ready to be used in an event ready manner. Since parametric down-conversion is a highly probabilistic process the development of a heralded source of photons will be a important step forward to overcome the randomness in all photon based experiments in quantum information processing.

Q 18.2 Di 10:45 VMP 6 HS-D

Heralded Single Photons from Cavity-Enhanced Parametric Down-Conversion — •Lars Koch, Matthias Scholz, and Oliver Benson — Humboldt-Universität zu Berlin, Institut für Physik, AG Nano Optik, Hausvogteiplatz 5-7, 10117 Berlin

A promising scheme for quantum networks uses single photons and atomic ensembles to interconvert between flying and stationary photonic qubits. Thus, single-photon sources with spectral bandwidths of only a few MHz are required that efficiently couple to atomic resonances.
We demonstrate the generation of narrow-band single photons with a spectral width of only 3 MHz by cavity-enhanced parametric down-conversion in PPKTP. A compensating KTP crystal allows triple-resonance of pump, signal, and idler fields. Locking the cavity via the Hänsch-Couillaud method, we achieve long-term stability and an ultra-high brightness of 14000 biphotons/s per mW pump power and MHz signal bandwidth in the TEM_{00} mode on the cesium D1 line (894.3 nm). Moreover, we give proof of the single-photon character by detection of heralding idler photons that trigger a Hanbury-Brown and Twiss setup for the signal field. Compared to a Poissonian source, the multi-photon emission probability is reduced by a factor of 100.

Q 18.3 Di 11:00 VMP 6 HS-D

Shaping the Phase of a Single Photon — •Holger Specht, Jörg Bochmann, Eden Figueroa, David Moehring, Martin Mücke, Christian Nölleke, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Garching

We report on the controlled phase shaping of a light pulse containing a single photon. The single photon is sent through a fiber electro-optical modulator, and the applied phase change is confirmed via interference with a second unmodulated reference photon. According to Hong et al. [1], coalescence is expected for indistinguishable photons. This effect is insensitive to shot-to-shot phase changes but depends on phase changes that occur during the evolution of the light pulse [2]. For instance, the application of a sudden pi-phase change in the middle of the photon wave packet results in maximally distinguishable photons and, hence, a disappearance of the interference effect. However, a time-resolved evaluation proves that this is caused by averaging over two subgroups that show clear photon coalescence and anticoalescence, respectively. Moreover, our scheme allows for arbitrary phase shapes. For example, a linear phase ramp represents a change in the frequency of the photon, and results in characteristic oscillations in the time-resolved two-photon interference [2].

[1] C. K. Hong et al. Phys. Rev. Lett. 59, 2044 - 2046 (1987)
[2] T. Legero et al. Adv. At., Mol., Opt. Phys. 53, 253 - 289 (2006)

Q 18.4 Di 11:15 VMP 6 HS-D

A High-Temperature Single-Photon Source from Nanowire Quantum Dots — •Thomas Aichele[1], Adrien Tribu[2], Gregory Sallen[2], Catherine Bougerol[2], Régis André[2], Jean-Philippe Poizat[2], Serge Tatarenko[2], and Kuntheak Kheng[2] — [1]Humboldt-Universität zu Berlin, Inst. Physik, Nanooptik, Berlin, Germany — [2]Institut Néel, CEA/CNRS/Univ. J. Fourier, Grenoble, France

We present a high-temperature single-photon source based on a quantum dot inside a nanowire. The nanowires were grown by molecular beam epitaxy in the vapor-liquid-solid growth mode. We utilize a two-step growth process that allows a thin, defect-free ZnSe nanowire to grow on top of a broader, cone-shaped nanowire. Quantum dots are formed by incorporating a narrow zone of CdSe into the nanowire. We observe intense and highly polarized photoluminescence even from a single emitter. Efficient photon antibunching is observed up to 220 K, while conserving a normalized antibunching dip of 7 to at most 36%. This is the highest reported temperature for single-photon emission from a nonblinking quantum-dot source and principally allows compact and cheap operation by using Peltier cooling.

Q 18.5 Di 11:30 VMP 6 HS-D

Characterisation of single photons by photon counting — •Kaisa Laiho, Malte Avenhaus, Katiuscia N. Cassemiro, and Christine Silberhorn — Max Planck Research Group, Günther-Scharowsky-Str. 1/Bau 24, 91058 Erlangen, Germany

Photon counting offers a possibility for direct characterisation of quantum states, and it can be utilised especially in the study of non-Gaussian states. This method is based on the measurement of the averaged photon number parity. The information about the coherences of the state is recovered by investigating the behaviour of the displaced states.

We study the direct characterisation of single photons with recently developed time-multiplexed detection (TMD) of photon statistics. According to our numerical simulations TMD is suitable for state characterisation even in the regime of low detection efficiency and the state reconstruction is possible with good accuracy [1].

We study the preparation of single photons in a waveguided parametric down conversion source in the ultrafast regime. Our experimental results indicate tight spectral correlations between signal and idler. Due to simultaneous excitation of several broadband spectral modes we apply filtering at the state preparation. In order to decorrelate the state and to meet the high demands set by the sensitivity of the characterisation method we employ a filter with 0.7nm bandwidth at the trigger arm. At low power regime our heralded statistics show one photon component of 95% with the preparation rate of 60Hz.

[1] K. Laiho *et al.*, arXiv:quant-ph/0811.0284 (2008).

Q 18.6 Di 11:45 VMP 6 HS-D

Single Photon Source for an Ion Trap Quantum Network — •Jan Huwer, Marc Almendros, Felix Rohde, Carsten Schuck, Nicolas Piro, Markus Hennrich, Francois Dubin, and Jürgen Eschner — ICFO - The Institute of Photonic Sciences, Mediterranean Technology Park, 08860 Castelldefels (Barcelona), Spain

On the way towards the realisation of entanglement between two distantly trapped ions we report the implementation of a high efficiency single photon source based on one of the two ions.

This is achieved by triggering a spontaneous Raman transition between two electronic states of a single $^{40}Ca^{+}$ ion. The ion is trapped in a linear Paul trap which is surrounded by two high numerical aperture laser objectives, allowing us to achieve high photon scattering rates into a single optical mode with detection efficiencies comparable to atom-cavity based systems. By adjusting the triggering laser pulses we can engineer the coherence properties of the generated single photons which thus provide a powerful tool for establishing entanglement between remote particles based on different types of protocols.

Q 18.7 Di 12:00 VMP 6 HS-D

Ion-trap single-photon source for quantum networks — •Helena G. Barros[1,2], Andreas Stute[1,2], Tracy Northup[1], Carlos Russo[1], Piet O. Schmidt[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, A-6020 Innsbruck — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, A-6020 Innsbruck

A deterministic source of single photons represents both a fundamentally nonclassical device and a resource for quantum information protocols. In the setting of cavity QED, the coherent generation of single photons provides an atom-photon interface, the basis for quantum networks. Such an interface could be used to realize atom-photon entanglement or entanglement between distant trapped atoms.

We demonstrate and characterize a single-photon source in a new

ion-trap cavity-QED experiment in which a single trapped $^{40}Ca^+$ ion is coupled to the mode of a high-finesse optical cavity. After preparation of the atom in a single Zeeman state, a vacuum-stimulated Raman process transfers the atom to a second Zeeman state, generating one photon in the cavity mode. We evaluate the photon statistics of the source by measurements of the second-order correlation function $g^{(2)}(\tau)$. Furthermore, the temporal profile of the photon exiting the cavity allows us to investigate the dynamics of the Raman transfer. We find strong quantitative agreement with numerical simulations and are thus able to evaluate the coherence of the process.

Q 18.8 Di 12:15 VMP 6 HS-D

A bright source of indistinguishable triggered single photons — •Yves Rezus, Robert Lettow, Alois Renn, Stephan Götzinger, and Vahid Sandoghdar — ETH Zürich, Laboratory of Physical Chemistry (LPC), 8093 Zürich, Switzerland

At cryogenic temperatures (<2 K) single fluorescent dye molecules embedded in an organic matrix display a number of interesting properties, which make them ideally suited to be used as single photon sources for quantum optical experiments. These properties include a quantum yield of nearly 100 %, a lifetime-limited optical linewidth and an almost infinite photo-stability. We demonstrate that by using pulsed laser excitation it is possible to create a triggered stream of bandwidth-limited single photons with a brightness exceeding 10^6 cps. By using the Stark effect we are able to shift the emission frequency of our single photon source and bring it into resonance with a second molecule, which is located in a different cryostat. This makes it possible to produce indistinguishable photons using two independent sources. We discuss the possibilities of employing these indistinguishable photons in two-photon interference experiments. Finally we discuss an experiment in which single photons are channeled from one molecule to a second, thereby using one of the molecules as a source and the second as a detector. This effectively provides a scheme for coupling two single molecules that are separated by a macroscopic distance.

Q 19: Mitgliederversammlung Quantenoptik

Zeit: Dienstag 13:15–14:00 Raum: VMP 6 HS-A

Mitgliederversammlung FV Q

Q 20: Präzisionsmessungen I

Zeit: Dienstag 14:00–16:00 Raum: Audi-A

Q 20.1 Di 14:00 Audi-A

Digitales Phasenmeßsystem für die interferometrische Messung von Gravitationswellen — •Joachim Kullmann, Iouri Bykov, Juan Jose Esteban, Antonio Francisco Garcia Marin, Gerhard Heinzel und Karsten Danzmann — Albert-Einstein-Institut Hannover: Max-Planck-Institut für Gravitationsphysik und Leibniz Universität Hannover, Callinstr.38, 30167 Hannover

LISA (Laser Interferometer Space Antenna) ist eine Weltraummission von ESA und NASA zum direkten experimentellen Nachweis von Gravitationswellen im Frequenzbereich von 0.1 bis 100 mHz. Die durch Gravitationswellen hervorgerufene relative Abstandsänderung zwischen sich auf Satelliten befindlichen, frei fallenden Testmassen soll hierbei mittels Laserinterferometrie gemessen werden. Dazu muß die Phase des dabei entstehenden Heterodynsignals bzgl. eines stabilen Referenzoszillators bestimmt werden.

Die vorgesehene Methode, diese Phase zu bestimmen, stellt ein auf FPGA(Field Programmable Gate Array)-Technologie basierendes, digitales Phasenmeßsystem dar, das nach dem Prinzip des DPLL (Digital Phase Lock Loop) arbeitet. Dieses System wird im Weiteren zur Frequenzstabilisierung und zum Phasenlock der Laser auf den Satelliten, sowie zur Abstandsbestimmung der Satelliten und zum Datentransfer mittels Auslesung von Seitenbändern, verwendet werden.

Ziel ist es, eine Sensitivität von $5\,\mathrm{pm}/\sqrt{\mathrm{Hz}}$ über einen Frequenzbereich des Heterodynsignals von 2 bis 20 MHz zu erreichen.

Der Vortrag stellt ein entsprechendes Phasenmeßsystem sowie erste Meßergebnisse vor.

Q 20.2 Di 14:15 Audi-A

Optical ranging and data communication for the Laser Interferometer Space Antenna (LISA) — •Johannes Eichholz, Juan Jose Esteban Delgado, Antonio Francisco García Marín, Iouri Bykov, Joachim Kullmann, Benjamin Sheard, Gerhard Heinzel, and Karsten Danzmann — Albert-Einstein-Institut, Hannover, Deutschland

The Laser Interferometer Space Antenna (LISA) is a spaceborne gravitational wave detector, an international project aimed at the detection and observation of gravitational waves in the frequency regime from 0.1 to 100 mHz. LISA consists of three identical spacecraft forming an equilateral triangle of about five million kilometers arm length, communicating via bidirectional laser links.

The inter-spacecraft interferometry signal will be obtained by the means of time-delayed interferometry (TDI). For this technique it is necessary to know the arm lengths up to an absolute error of 10 meters at most. The ranging scheme of choice is a spread spectrum modulation of the main science signal. This concept also allows clock synchronization by generating additional sidebands and data transfer between the spacecraft.

We present an experimental setup to determine the functionality of the proposed scheme, a lab-sized version of one arm, providing tests of the used devices under the LISA conditions of low light intensity and realistic noise sources.

Q 20.3 Di 14:30 Audi-A

Status des GEO600-Projekts — •Mirko Prijatelj und das GEO600-Team — Institut für Gravitationsphysik, Albert-Einstein-Institut, Hannover, Germany

Der deutsch-britische Gravitationswellen-Detektor GEO600 kann bereits heute Längenänderungen im Bereich von Zeptometern ($10^{-21}\,\frac{\mathrm{m}}{\sqrt{\mathrm{Hz}}}$) messen. Dies ermöglicht es Gravitationswellen von astrophysikalischen Ereignissen in einer Entfernung von mehr als 15 Millionen Lichtjahren zu beobachten. GEO600 wird als erster Gravitationswellen-Detektor in naher Zukunft gequetschtes Licht zur Steigerung seiner Empfindlichkeit einsetzen.
Der Vortrag wird die Funktionsweise des Detektors darstellen, und einen Ausblick auf die geplanten Verbesserungen geben.

Q 20.4 Di 14:45 Audi-A

Gequetschtes Licht für den Gravitationswellendetektor GEO 600. — •Alexander Khalaidovski, Henning Vahlbruch, Hartmut Grote, Benno Willke, Harald Lück, Karsten Danzmann und Roman Schnabel — Institut für Gravitationsphysik der Leibniz Universität Hannover, Albert Einstein Institut (AEI)

Eine der großen Herausforderungen der modernen Experimentalphysik ist der direkte Nachweis der im Jahre 1916 von Albert Einstein vorhergesagten Gravitationswellen. Im Laufe der letzten Jahre hat daher ein weltweites Netzwerk interferometrischer Detektoren den Betrieb aufgenommen, um eine direkte Messung der durch Gravitationswellen bedingten winzigen Längenänderungen zu erbringen. Zukünftige Detektoren werden in ihrer Empfindlichkeit im wesentlichen durch Quantenrauschen limitiert sein. Einen Ansatz, dieses zu verringern und somit die Sensitivität der Interferometer weiter zu erhöhen, bietet der Einsatz gequetschter Zustände des elektromagnetischen Feldes mit nichtklassischer Rauschdistribution. Der Beitrag diskutiert die weltweit erste Implementierung nichtklassischer Konzepte in den britisch/deutschen Gravitationswellendetektor GEO600, welche bereits vorbereitet wird und im Jahre 2009 realisiert werden soll.

Q 20.5 Di 15:00 Audi-A

Das Einstein Teleskop (ET): ein Gravitationswellenobservatorium der dritten Generation — •Harald Lück — MPI f. Gravitationsphysik und Leibniz Universität Hannover

Die erste Generation des weltweiten Netzwerkes von interferometrischen Gravitationswellendetektoren (LIGO, Virgo und GEO600) hat eine gemeinsame, lange Beobachtungsphase abgeschlossen. Nun werden diese Detektoren zu einer besseren Empfindlichkeit ausgebaut (siehe Vortrag zu GEO600). Spätestens mit Inbetriebnahme der zweiten Ausbaustufe, den sogenannten 'advanced' Detektoren, im Jahr 2015 mit einer zehnfach besseren Empfindlichkeit gegenüber dem vergangenen Datenlauf, kann die Detektion von Gravitationswellen erwartet werden. Um zur routinemäßigen Beobachtung von Gravitationswellen überzugehen, und die Instrumente als astronomische Observatorien betreiben zu können, wird eine weitere Verbesserung der Empfindlichkeit um einen Faktor zehn und damit einer Erweiterung des beobachtbaren Volumens um einen Faktor 1000 nötig sein. Pläne dazu werden in einer europaweiten Design Studie zu ET, dem Einstein Teleskop, erarbeitet. Dieser Bericht wird die Anforderungen und Möglichkeiten eines solchen Detektors, wie den unterirdischen, cryogenen Betrieb mit MW umlaufender Lichtleistung und der Nutzung gequetschten Lichtes, erläutern.

Q 20.6 Di 15:15 Audi-A

The AEI 10m Prototype Interferometer — •Stefan Gossler[1], Alessandro Bertolini[1], Michael Born[1], Jens Breyer[1], Yanbei Chen[2], Fumiko Kawazoe[1], Oliver Kranz[1], Gerrit Kühn[1], Harald Lück[1], Kasem Mossavi[1], Henning Ryll[1], Kentaro Somiya[2], Ken Strain[1], Bob Taylor[1], Benno Willke[1], Alexander Wanner[1], and Karsten Danzmann[1] — [1]Max-Plank-Institut für Gravitationsphysik (AEI), Institut für Gravitationsphysik, Leibniz Universität Hannover, Callinstr. 38, 30167 Hannover — [2]California Institute of Technology, LIGO Project-MS 18-34, Pasadena, CA 91125

A 10m prototype interferometer is currently being set up at the AEI Hannover. One of the main goals in this experiment is to probe at and beyond the so called Standard Quantum Limit (SQL) of interferometry. In order to reach the required sensitivity it is mandatory to minimise the influence of all classical noise contributions to a level well below the SQL. The layout of the interferometer and the road towards sub-SQL measurements will be presented.

Q 20.7 Di 15:30 Audi-A

Seismically isolated optical benches for the AEI 10 m prototype interferometer — •Katrin Dahl[1], Alessandro Bertolini[1], Michael Born[1], Jens Breyer[1], Yanbei Chen[2], Stefan Gossler[1], Fumiko Kawazoe[1], Oliver Kranz[1], Gerrit Kühn[1], Harald Lück[1], Kasem Mossavi[1], Henning Ryll[1], Kentaro Somiya[2], Kenneth A. Strain[1], Bob Taylor[1], Benno Willke[1], Alexander Wanner[1], and Karsten Danzmann[1] — [1]Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Institut für Gravitationsphysik, Leibniz Universität Hannover, Callinstr. 38, D-30167 Hannover — [2]California Institute of Technology, LIGO Project - MS 18-34, Pasadena, CA 91125, USA

The AEI 10 m prototype interferometer will not only develop and test new techniques for the third generation of gravitational wave detectors, but furthermore it will probe at and beyond the standard quantum limit of interferomtry. The experiments will be set up on top of in-vacuum suspended optical tables, instead of commercial tables on the floor.

Three 1.75 m by 1.75 m optical tables will be suspended inside an ultra-high vacuum envelope in an L-shaped configuration of 10 m arm length. To provide active isolation in all 6 degrees of freedom, inertial sensors (3 horizontal and 3 vertical) will be installed inside each table. Relative longitudinal and angular motion between the tables will be monitored by an inter-table interferometer. Coil-magnet actuators will provide feedback to the tables. In this way an excellent seismic isolation - covering also low frequencies - will be achieved.

Q 20.8 Di 15:45 Audi-A

Laser frequency stabilization for the AEI 10 m prototype interferometer — •Fumiko Kawazoe[1], Alessandro Bertolini[1], Michael Born[1], Jens Breyer[1], Yanbei Chen[1], Stefan Gossler[1], Katrin Dahl[1], Oliver Kranz[1], Gerrit Kuehn[1], Harald Lueck[1], Kasem Mossavi[1], Henning Ryll[1], Kentaro Somiya[2], Ken Strain[1], Bob Taylor[1], Benno Willke[1], Alexander Wanner[1], Tobias Westphal[1], and Karsten Danzmann[1] — [1]Max-Planck-Institut fr Gravitationsphysik (Albert-Einstein-Institut), Institut fr Gravitationsphysik, Leibniz Universitt Hannover, Callinstr. 38, 30167 Hannover — [2]California Institute of Technology, LIGO Project-MS 18-34, Pasadena, CA 91125

The AEI 10m prototype interferometer will provide a test bed for various experiments techniques needed for the third generation of gravitational-wave detectors. One such experiment will test the techniques required to improve the sensitivity once it is limited by the Standard Quantum Limit (SQL). In order to achieve sub-SQL sensitivity, it is essential to suppress the sum of all classical noise sourses well below the SQL. To meet this requirement, e.g. the relative laser frequency variations have to be smaller than $5 \cdot 10^{-19}/\sqrt{Hz}$ at Fourier frequencies around 100Hz. This will be achieved by preparing a suspended triangular cavity serving as a length reference to stabilise the laser frequency to. The optical design as well as the suspension design will be presented.

Q 21: Ultrakalte Atome: Fallen und Kühlung II / Einzelne Atome (mit A)

Zeit: Dienstag 14:00–15:45 Raum: Audi-B

Q 21.1 Di 14:00 Audi-B

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

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

We report on a series of experiment exploring cavity cooling in the bad-cavity limit. We prepare a cloud of ultracold cesium atoms in the centre of a leaky, near-confocal cavity. Then we pump the cavity with resonant laser light for a certain time and measure the achieved temperature as a function of atom-cavity detuning and laser intensity. [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 21.2 Di 14:15 Audi-B

Towards a guided atom interferometer based on a superconducting atom chip — Tobias Mueller, Xing Wu, •Anushyam Mohan, Azar Eyvazov, Yu Wu, and Rainer Dumke — Division of Physics & Applied Physics, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore

We evaluate the realization of a novel geometry of a guided atom interferometer based on a high temperature superconducting microstructure [1]. The interferometer type structure is obtained with a guiding potential realized by two current carrying superconducting wires in combination with a closed superconducting loop sustaining a persistent current. We present the layout and realization of our superconducting atom chip. By employing simulations we discuss the critical parameters of the interferometer guide in particular near the splitting regions of the matter waves. In the talk, we present the actual status of the experiment.

[1]: T. Müller et al, New J. Phys.10, 073006, (2008)

Gruppenbericht Q 21.3 Di 14:30 Audi-B

Quantum jumps and continuous spin measurement in a strongly coupled atom-cavity system — •Tobias Kampschulte, Wolfgang Alt, Mkrtych Khudaverdyan, Sebastian Reick, Alexander Thobe, Artur Widera, and Dieter Meschede — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, D-53115 Bonn

In our experiment we transport a predetermined small number of cold caesium atoms into a high-finesse optical resonator using an optical dipole trap. By monitoring the transmission of a probe laser beam resonant with the cavity we are able to measure the atomic spin continuously and observe quantum jumps between the two hyperfine ground states.

Utilizing this non-destructive method, we measure the single atom vacuum Rabi splitting via detection of the atomic state. Moreover, we experimentally demonstrate conditional dynamics of the internal states of two atoms, simultaneously coupled to the cavity field.

A reduction of the intra-cavity scattering rate would enable a quantum nondemolition measurement of the atom number as is required for probabilistic multi-atom entanglement schemes.

Q 21.4 Di 15:00 Audi-B

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

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

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

Q 21.5 Di 15:15 Audi-B

Efimov states in atom-molecular collisions — •Maxim A. Efremov[1], Lev Plimak[1], Misha Yu. Ivanov[2], Gora V. Shlyapnikov[3], and Wolfgang P. Schleich[1] — [1]Institut für Quantenphysik, Universität Ulm, D-89069, Germany — [2]Steacie Institute for Molecular Sciences, NRC Canada, ON Ottawa, K1A 0R6 Canada — [3]Laboratoire de Physique Theorique et Modeles Statistiques, CNRS, Universite Paris Sud, 91405 Orsay, France

Scattering of a heavy atom off a weakly bound molecule comprising an identical heavy and a light atom is considered. We focus on the experimentally favorable situation in which the heavy atoms are bosons and the light ones are fermions, and the molecules exist in a cold boson-fermion mixture due to an interspecies Feshbach resonance. The total cross section of atom-molecular scattering is calculated in the Born-Oppenheimer approximation. In the limit of slow incident atom the total cross section as a function of the heavy-light s-wave scattering length (in experimental terms, as a function of the applied magnetic field) is shown to exhibit a series of resonances, providing a physically clear manifestation of the Efimov states in the three-body collision. Measurement of the cross section can therefore be an efficient and precise tool for scanning the effective potential in the three-body problem.

Q 21.6 Di 15:30 Audi-B

Deterministische ultrakalte Ionenquelle nahe dem Heisenberg Limit — •Wolfgang Schnitzler, R. Fickler, N. M. Linke, F. Schmidt-Kaler und K. Singer — Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, D-89069 Ulm

Wir haben mittels einer Ionenfalle eine universelle deterministische Einzelionenquelle realisiert [1,2]. In einer segmentierten Falle werden kalte $^{40}Ca^{+}$ Ionenkristalle gefangen, anschließend deterministisch aus der Falle extrahiert und mit einer Erfolgsquote von 90% in einem Abstand von 29cm detektiert. Die absolute Geschwindigkeitsfluktuation liegt unter 6.3m/s bei einer mittleren Geschwindigkeit von 19.47km/s und einer Strahldivergenz von 600μrad. Wir zeigen anhand von numerischen Simulationen, dass unsere Quelle in Kombination mit einer elektrostatischen Einzellinse in der Lage sein wird, einzelne Ionen mit nm Auflösung in Festkörper zu implantieren. Diese können dann zur Implantation von P in Si oder zur Erzeugung von NV-Farbzentren in Diamant genutzt werden, welche optisch manipuliert werden können. Solche Systeme stellen Kandidaten zur Realisierung eines skalierbaren Festkörper-Quantencomputers dar [3,4]. Die elektrischen Eigenschaften von Halbleiterbauelementen können durch die deterministische Implantation einzelner Ionen ebenfalls verbessert werden [5].

[1] J. Meijer et al., Appl. Phys. A **83**, 321 (2006)
[2] J. Meijer et al., Appl. Phys. A **91**, 567 (2008)
[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 22: Quantengase: Fermionen im Gitter

Zeit: Dienstag 14:00–16:00 Raum: VMP 6 HS-A

Preisträgervortrag Q 22.1 Di 14:00 VMP 6 HS-A

Strong correlations in ultracold fermionic gases — •Corinna Kollath — CPHT, Ecole Polytechnique, CNRS, 91128 Palaiseau, France — Trägerin des Hertha-Sponer-Preises

Atomic gases cooled to Nanokelvin temperatures are a new exciting tool to study a broad range of quantum phenomena. In particular, the outstanding degree of control which has been achieved over these quantum systems facilitates access to strongly correlated quantum many body physics. For example, optical lattices have been created to mimic condensed matter systems. We perform a theoretical study of a fermionic gas with two repulsively interacting hyperfine states confined to an optical lattice. We determine a generic state diagram in the presence of a harmonic confining potential. We further discuss implications for current experiments.

Q 22.2 Di 14:30 VMP 6 HS-A

Theoretical study of the anomalous expansion of increasingly attractive fermionic atoms in an optical lattice — Lucia Hackermüller[1], Ulrich Schneider[1], Takuya Kitagawa[2], •Maria Moreno-Cardoner[1], Thorsten Best[1], Sebastian Will[1], Simon Braun[1], Eugene Demler[2], Immanuel Bloch[1], and Belén Paredes[1] — [1]Institut für Physik, Johannes Gutenberg-University, 55099 Mainz, Germany — [2]Physics Department, Harvard University, Cambridge, MA02138, USA

We study theoretically and compare with the experimental result the size behaviour of an ultracold spin mixture of fermions in an optical lattice when adiabatically entering the strongly correlated regime. The size of the cloud, directly measured in the experiment using insitu imaging, behaves as expected for weak interactions, decreasing (increasing) for an attractive (repulsive) gas. However, in the strongly interacting regime entropy is redistributed among the lattice sites in a dramatically different way leading to unexpected phenomena like an anomalous expansion of the gas on the attractive side.

Q 22.3 Di 14:45 VMP 6 HS-A

A Mott insulator of ultracold fermions in an optical lattice — •Robert Jördens, Niels Strohmaier, Daniel Greif, Leticia Tarruell, Henning Moritz, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

Strong interactions between electrons in a solid material lead to surprising effects such as the Mott insulator, where a suppression of conductivity occurs due to interactions rather than due to a filled Bloch band. Proximity to the Mott insulating phase is the origin of many intriguing phenomena in condensed matter physics, most notably high-temperature superconductivity.

We implement the Fermi-Hubbard model, which encompasses the physics of the Mott insulator, by trapping a repulsively interacting two-component Fermi gas in an optical lattice. In agreement with theoretical models, the double occupancy provides a versatile and sensitive probe to the system's properties and signals the formation of a Mott insulator by three features: a drastic suppression of doubly occupied lattice sites, a strong reduction of the compressibility, and the appearance of an excitation mode corresponding to the creation of double occupancies. In the regime of strong interactions, this mode establishes a direct measurement of the Hubbard U and allows us to study the process of creation and decay of double occupancies.

Q 22.4 Di 15:00 VMP 6 HS-A

Attractively Interacting Fermionic Mixtures in Optical Lattices — •Lucia Hackermueller[1], Ulrich Schneider[1], Maria Moreno Cardoner[1], Takuya Kitagawa[2], Thorsten Best[1], Sebastian Will[1], Simon Braun[1], Eugene Demler[2], Belen Paredes[1], and Immanuel Bloch[1] — [1]Staudingerweg 7, Universität Mainz, 55099 Mainz — [2]Physics Department, Harvard University, Cambridge, MA 02138, USA

We present an experimental study of a balanced spin mixture of ultracold fermionic ^{40}K in $|F, m_F\rangle = |\frac{9}{2}, -\frac{9}{2}\rangle$ and $|F, m_F\rangle = |\frac{9}{2}, -\frac{7}{2}\rangle$. The mixture is loaded into the combination of a three dimensional blue detuned optical lattice with a red detuned optical dipole trap, which allows an independent control of lattice depth and trapping potential. A Feshbach resonance located at 202.1G can be used to change the interaction strength and to create molecules by ramping adiabatically over the resonance. When the interaction is tuned from repulsive to attractive we measure a continuous decrease in cloud size and observe a minimum for intermediate attractive interactions, while for strong attractive interactions the size increases again. The increase in size coincides with a large fraction of the atomic cloud residing on doubly occupied sites and can be compared with the predictions of high temperature expansion theory. In addition we present measurements on the mobility of bound pairs in the optical lattice.

Q 22.5 Di 15:15 VMP 6 HS-A

Static and dynamic properties of repulsivly interacting fermions in optical lattices — •Ulrich Schneider, Lucia Hackermüller, Thorsten Best, Sebastian Will, Simon Braun, and Immanuel Bloch — Johannes Gutenberg-Universität Mainz

Fermionic atoms in optical lattices can serve as a model system for condensed matter physics: They implement the Hubbard model with high experimental control of the relevant parameters. We study static and dynamic properties of ultracold Fermions in different regimes, ranging from metallic and band-insulating states in the non-interacting case to complex metals and the Fermionic-Mott-Insulator for strongly repulsive systems.

In the experiment, spin mixtures of fermionic ^{40}K are loaded into a combination of a blue detuned three dimensional optical lattice and a red detuned dipole trap. This combination of optical potentials allows an independent control of lattice depth and harmonic confinement, thus enabling us to explore different regimes. In addition to measurements of the in-situ cloud size and the doublon fraction we present measurements of the dynamic response of the system to changes in the external parameters.

Q 22.6 Di 15:30 VMP 6 HS-A

Spin waves in spin-3/2 1D optical lattices — •Arturo Argüelles and Luis Santos — Leibniz Universität Hannover, D-30167 Hannover, Germany

The dynamics of the Hubbard Hamiltonian in 1D optical lattices is very rich. For instance, by taking only spinless particles, it is possible to observe how a hole can propagate throughout the lattice with a certain velocity. If additionally, the spin is taken into account it shows the spin-charge separation phenomenon. For higher spins, the super-exchange collisions allow the system to have several different spin-wave velocities and therefore one can see more general separation of the modes. Our calculations are performed using the Matrix Product State ansatz.

Q 22.7 Di 15:45 VMP 6 HS-A

Doublon relaxation in the Fermi-Hubbard model — •Niels Strohmaier, Daniel Greif, Robert Jördens, Leticia Tarruell, Henning Moritz, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zürich, Switzerland

The investigation of interacting quantum many-particle systems in non-equilibrium has recently attracted a lot of attention. However, a theoretical understanding of experimental results remains challenging due to the complexity of the systems. Ultracold atoms in optical lattices, well described by the Hubbard model, offer a new approach. Their cleanliness and the unique tunability of parameters make them well suited for the emulation of condensed matter systems.

We report on our latest experiments with repulsively interacting Fermions in a 3D optical lattice. Starting either from a Mott insulator or from a metallic state, we perturb the sample by generating a significant amount of doubly occupied lattice sites. The following relaxation of the system back to its thermal equilibrium is monitored in time-resolved manner. We study this decay of doublons for a wide range of parameters of the Fermi-Hubbard Hamiltonian and observe a clear dependence on the ratio of interaction energy and kinetic energy.

Q 23: Quanteninformation: Photonen II

Zeit: Dienstag 14:00–16:00 Raum: VMP 6 HS-D

Q 23.1 Di 14:00 VMP 6 HS-D

Violation of Bell's inequalities by light radiated from two independent sources — •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, Germany — [2]Department of Physics, Oklahoma State University, Stillwater, OK, USA

We study quantum interference effects of light scattered by two uncorrelated single photon sources, e.g. two trapped ions. By looking at the far-field region of the emitters we find non-classical signatures in the second order correlation function of the emitted light. First, we obtain a two-photon signal with a visibility greater than 50% [1] and, second, we can proof that our signal violates Bell-type (CH74') inequalities [2]. Since both emitters scatter incoherently, this violation gives rise to some stunning questions which we will adress.

[1] L. Mandel, Phys. Rev. A **28**, 929 (1983).
[2] J. F. Clauser, M. A. Horne, Phys. Rev. D **10**, 526 (1974).

Q 23.2 Di 14:15 VMP 6 HS-D

Experimental observation of an entire family of four-photon entangled states — •Witlef Wieczorek[1,2], Christian Schmid[1,2], Nikolai Kiesel[1,2], Reinhold Pohlner[1,2], Otfried Gühne[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]Institut für Quantenoptik und Quanteninformation, A-6020 Innsbruck — [4]Institut für Theoretische Physik, Universität Innsbruck, A-6020 Innsbruck

The experimental observation and characterization of multi-partite entangled states aids the development of quantum information applications and helps to gain a deeper understanding of quantum mechanical systems. Spontaneous parametric down conversion in combination with linear optics is widely and successfully used for observing these states. However, so far, experimental set-ups based on that approach were usually tailored for a single state only, see e.g. [1]. Here, we report on the experimental observation and analysis of an entire family of highly entangled four-photon states, which is given by the superposition of a four photon GHZ state and the product of two Bell states. We demonstrate how these states can be obtained within a single set-up by the tuning of a single, experimentally easily accessible parameter and analyze particular entanglement properties [2].

[1] D. Bouwmeester *et al.*, Phys. Rev. Lett. 82, 1345 (1999); Z. Zhao *et al.*, Nature 430, 54 (2004); P. Walther *et al.*, Nature 434, 169 (2005); B. P. Lanyon *et al.*, Phys. Rev. Lett. 100, 060504 (2008)
[2] W. Wieczorek *et al.*, Phys. Rev. Lett. 101, 010503 (2008)

Q 23.3 Di 14:30 VMP 6 HS-D

A Novel Method for Polarization Squeezing and Polarization Entanglement with Photonic Crystal Fibers — •Josip Milanovic[1], Mikael Lassen[1,2], Christoph Marquardt[1], Ulrik L. Andersen[1,2], and Gerd Leuchs[1] — [1]Max Planck Institute for the Science of Light, University of Erlangen-Nuremberg, Guenther-Scharowsky-Str. 1, 91058 Erlangen, Germany — [2]Department of

Physics, Technical University of Denmark, 2800 Kongens Lyngby, Denmark

Photonic Crystal Fibers (PCF) can be tailored to introduce a high nonlinear Kerr effect likewise showing that it is possible to create lower amounts of excess noise compared to standard fibers. Taking advantage of these features and using ultrashort pulses we create polarization squeezed states with notably higher purity than obtained in standard fibers. The squeezed states are produced by pulses of equal polarization counter propagating along the same fiber axis undergoing nearly identical spectral and temporal changes. Overlapping these pulses in modes of mutually orthogonal polarization enables the production of polarization squeezing. By exploiting both polarization axes of the polarization maintaining PCF we can generate two independent polarization squeezed beams thereby creating polarization entanglement. We present results of the PCF squeezer and discuss the progress in creating entanglement with this novel setup.

Q 23.4 Di 14:45 VMP 6 HS-D

Photon Pair Generation in Photonic Crystal Fibres — •Benjamin Brecht, Christoph Söller, Peter J. Mosley, Leyun Zang, Alexander Podlipensky, Philip St.J. Russell, and Christine Silberhorn — Max Planck Research Group IOIP, Günther-Scharowsky-Strasse 1 / Bau 24, 91058 Erlangen

Spontaneous four-wave mixing in Photonic Crystal Fibres (PCF) is a promising approach to creating a heralded single photon source suitable for quantum computation and communication. The possibility of tailoring the dispersion profile of a PCF allows for a high degree of control over the spectral properties of the generated photons.

We are working on a fibre-based heralded single photon source. The heralding signal photon is emitted in the visible wavelength regime, thus allowing for an efficient detection utilising silicon avalanche photodiodes (APDs). The idler photon is generated at 1.55μm and is therefore suitable for a low-loss transmission by standard telecommunication fibres. Spectral decorrelation of the photon pair ensures the indistinguishability of corresponding photons emitted from different sources and permits quantum interference without narrow bandpass filtering.

We report on the current state of the project.

Q 23.5 Di 15:00 VMP 6 HS-D

Erzeugung gequetschter Lichtfelder mit hoher Bandbreite — •Stefan Ast, Aiko Samblowski, Boris Hage, Nicolai Grosse, Nico Lastzka und Roman Schnabel — Institut für Gravitationsphysik, Leibniz Universität Hannover, Albert-Einstein-Institut, Callinstraße 38, 30167 Hannover

Gequetschte Lichtfelder liefern die nichtklassische Resource der Quantenkommunikation mit kontinuierlichen Variablen. Mögliche Anwendungen von 1-Moden gequetschten wie auch 2-Moden gequetschten Feldern, z.B. in der Quantenkryptographie, sind bereits häufig diskutiert worden. Zur Übertragung von Quanteninformation mit hohen Datenraten mittels gequetschter Lichtfelder ist es erforderlich, eine Lichtquelle mit breitbandig gequetschtem Spektrum zu realisieren. Anders als bei der diskreten Detektion von Photonen, bei denen die Bandbreite typischerweise nur einige 10 MHz beträgt, kann bei der Detektion von kontinuierlichen Variablen, also Amplituden- und Phasenquadratur, eine sehr viel höhere Bandbreite erreicht werden. Darauf aufbauend, werden erste Ergebnisse zur breitbandigen Quetschung des Lichtfeldes von mehreren 100 MHz diskutiert. Die Detektion der kontinuierlichen Variablen des gequetschten Feldes wird mittels Homodyndetektion realisiert.

Q 23.6 Di 15:15 VMP 6 HS-D

Gequetschtes Licht bei 1550 nm — •Sebastian Steinlechner, Jessica Dück, Tobias Eberle, Moritz Mehmet, Karsten Danzmann und Roman Schnabel — Max-Planck-Institut für Gravitationsphysik (AEI) und Institut für Gravitationsphysik, Leibniz Universität Hannover

Ein weltweites Netzwerk interferometrischer Detektoren versucht den direkten Nachweis von Gravitationswellen zu erbringen. Verbesserungen der ersten Detektorengeneration werden derzeit installiert, während sich die nächste Generation bereits in der Entwicklung befindet. Die Nachweisgrenze wird durch thermisches Rauschen sowie durch Quantenrauschen limitiert und kann durch Kühlung der Interferometer-Testmassen bzw. den Einsatz von gequetschtem Licht verbessert werden. Silizium ist aussichtsreichster Kandidat für kryogene Testmassen, benötigt jedoch einen Wechsel der Laserwellenlänge von 1064 nm hin zur Telekommunikationswellenlänge 1550 nm. Wir stellen eine PPKTP-Quetschlichtquelle bei 1550 nm vor, mit der eine nichtlineare Rauschunterdrückung von 5,3 dB erzielt wurde. Damit steht gequetschtes Licht als Schlüsseltechnologie zum Erreichen von Empfindlichkeiten jenseits des Schrotrauschlimits für zukünftige, kryogene Gravitationswellendetektoren zur Verfügung.

Q 23.7 Di 15:30 VMP 6 HS-D

Fs-pulsed UV enhancement cavity used as a high power entanglement 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, Germany — [2]Departement für Physik, Ludwig-Maximilians-Universität München, D-80799 München, Germany

The process of pulsed spontaneous parametric down conversion in combination with linear optics is successfully used for observing polarization entangled multi-photon states. However, when using commercial high power mode locked lasers, such experiments are limited by very low count rates resulting in very long measurement times for six-photon states already.

Here, we present the first UV femtosecond enhancement cavity designed to boost the photon count rate of down conversion experiments. To this end, the circulating pulses inside the cavity are resonantly enhanced by up to a factor of 18, which gives more than 10W UV power (at lambda = 390nm). Compared to today's available mode locked lasers this is one order of magnitude improvement. Due to the relatively low detection efficiency, our experiments are now only limited by additional noise from higher order emissions. The next step is thus to utilize the intrinsic spatial mode filter of the cavity to improve the collection efficiency above current state of the art values. We demonstrate the performance of our experiment with first results on the Dicke-state with six-photons.

Q 23.8 Di 15:45 VMP 6 HS-D

Noise properties of a whispering gallery mode resonator — •Christoph Marquardt[1], Dmitry Strekalov[1,2], Mikael Lassen[1], Dominique Elser[1], Ulrik L. Andersen[1,3], and Gerd Leuchs[1] — [1]Max-Planck-Institut für die Physik des Lichts, Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, Günther-Scharowsky-Str. 1, Bau 24, 91058 Erlangen, Deutschland — [2]Jet Propulsion Laboratory, California lnstitute of Technology, MS 296100, 4800 Oak Grove Drive, Pasadena,CA 91109-8099, USA — [3]DTU Physics, Department of Physics, Technical University of Denmark, Building 309, 2800 Kgs. Lyngby, Dänemark

We investigate nonlinear interactions in a Lithium Niobate whispering gallery mode (WGM) resonator. The WGM resonator has very high Q-factors as well as small optical mode volume. This greatly enhances the effective nonlinearity. Therefore nonlinear processes become very efficient for very low optical powers and ultimately for individual photons, e.g. in second harmonic generation and parametric down-conversion. In this regime, the non-classical nature of the generated light fields is revealed. We present our latest results with frequency conversion and noise measurements.

Q 24: Präzisionsmessungen II

Zeit: Dienstag 16:30–19:00 Raum: Audi-A

Q 24.1 Di 16:30 Audi-A

Laserinterferometer für eine satellitengestützte Aufzeichnung des Erdgravitationsfeldes — •Marina Dehne, Felipe Guzmán Cervantes, Gerhard Heinzel und Karsten Danzmann — Albert-Einstein-Institut Hannover, Max-Planck-Institut für Gravitationsphysik und Leibniz Universität Hannover, Callinstr. 38, D-30167 Hannover

Eine derzeitige Mission zur Erfassung des Gravitaionsfeldes der Erde ist das *Gravity Recovery and Climate Experiment* (GRACE). Das Ziel

einer zukünftigen GRACE Nachfolgemission wird es sein, das Erdgravitationsfeld mit einer höheren Auflösung über einen Zeitraum von mindestens 6 Jahren aufzunehmen.

Ein möglicher Detektor für diesen Zweck besteht aus zwei identischen Satelliten, die Testmassen in einem Low-Earth Orbit in etwa 300 km Höhe ohne äußere Einflüsse tragen. Diese beiden mit einem Abstand in der Größenordnung von 10 bis 100 km hintereinander fliegenden Satelliten reagieren empfindlich auf kleinste Änderungen in der Gravitationsbeschleunigung. Die resultierenden Längenänderungen zwischen den beiden Testmassen sollen im Frequenzbereich von 1 bis 100 mHz von einem Laser-Interferometer mit Nanometer-Präzision beobachtet werden.

Es wird ein mögliches Interferometerkonzept vorgestellt, welches mit dem Ziel entwickelt wurde, die Anforderungen ($2.5\,\mathrm{nm}/\sqrt{\mathrm{Hz}}$ von 10 bis 100 mHz mit einem 1/f-Anstieg zwischen 10 und 1 mHz) unter den gegebenen Randbedingungen zu erfüllen.

Q 24.2 Di 16:45 Audi-A

Siliziumnitrid-Membran als optomechanischer Koppler — •Tobias Westphal, Daniel Friedrich, Kazuhiro Yamamoto, Karsten Danzmann und Roman Schnabel — Max-Planck-Institut für Gravitationsphysik (AEI) und Institut für Gravitationsphysik der Leibniz Universität Hannover, Callinstraße 38, 30167 Hannover

Das Quantenrückwirkungsrauschen setzt der Positionsbestimmung von Testmassen in Laserinterferometern, wie z.B. in Gravitationswellendetektoren, ein bislang unerreichtes Limit. Es wird ein neuartiges Interferometerdesign zur Bestätigung der theoretischen Modelle vorgestellt. Die Stabilisierung dieses kombinierten Michelson-Sagnac Interferometers und aktuelle Ergebnisse werden präsentiert. In diesem Interferometer wird eine Siliziumnitrid-Membran hoher Güte (10^6) sowie geringer Masse (50 ng) als optomechanischer Koppler verwendet. Erste Ergebnisse weisen darauf hin, dass das Experiment durch thermisches Rauschen limitiert ist, so dass eine Kühlung der Membran unerlässlich wird, um das Quantenrückwirkungsrauschen tatsächlich beobachten zu können.

Q 24.3 Di 17:00 Audi-A

Long-term test of the isotropy of the speed of light using an optical-resonator-based apparatus — •Christian Eisele, Alexander Yu. Nevsky, and Stephan Schiller — Institut für Experimentalphysik, Heinrich-Heine-Universität, 40225 Düsseldorf

The isotropy of the speed of light is one of the best known invariance principles in physics. It is one aspect of Lorentz Invariance, which is a basic assumption of all theories of the fundamental forces. In the course of the past 120 years the isotropy has been tested with ever increasing precision.

We have developed a highly sensitive laser Michelson-Morley apparatus [1] and performed an extensive search for violation of the isotropy of c. The apparatus contains two orthogonal optical high-finesse resonators (F=180 000) to which two waves obtained from a monolithic 1064 nm Nd:YAG laser are frequency-stabilised. The resonators are embedded in a monolithic structure made of ultra low thermal expansion coefficient glass (ULE). The apparatus is continuously rotated using a highly accurate air bearing rotation table. The difference frequency between the resonators is measured as a function of the orientation in space. The apparatus is also actively stabilized from mechanical vibrations, tilt variations and temperature fluctuations.

We will report about the results of a measurement campaign of approximately one year duration. From the data we obtain coefficients describing a possible violation of Lorentz Invariance within two test theories, the standard model extension (SME) and the Mansouri-Sexl test theory. [1] Eisele et al., Opt. Comm. 281, 1189 (2008)

Q 24.4 Di 17:15 Audi-A

Testing Lorentz Invariance in Vacuum and Matter Using Optical Resonators — •Moritz Nagel[1], Katharina Möhle[1], Evgeny V. Kovalchuk[1], Holger Müller[2], and Achim Peters[1] — [1]Humboldt Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Hausvogteiplatz 5-7, 10117 Berlin — [2]University of California, Berkeley, Department of Physics, Berkeley, CA 94720-7300

We present a new setup of a Michelson-Morley type experiment in which we compare light propagation in vacuum and matter to search for possible violations of local Lorentz invariance in the Maxwell and Dirac equations. Modern experiments that use optical resonators to probe for Lorentz invariance violations are based on measuring the resonance frequencies $\nu = qc/(2nL)$ of the resonator (q is an integer, c is the speed of light, n the index of refraction of the medium, and L the length of the resonator). In our setup, we compare the eigenfrequencies of two crossed fused silica vacuum resonators with the eigenfrequency of a third resonator in which the light is propagating in matter. Thus, any type of Lorentz invariance violation that affects the isotropy of c, L, or n can potentially be detected. Experiments performed in the past did not each by themselves provide enough information to distinguish between the different influences and therefore the results of two experiments had to be combined to obtain separate limits. Our new setup, however, enables us to give independent, simultaneous bounds on a broad range of Lorentz invariance violating coefficients in the Maxwell and Dirac sector in the framework of the Lorentz and CPT violating extension of the standard model of particle physics (SME).

Q 24.5 Di 17:30 Audi-A

Ein kompaktes Diodenlasersystem für die Atominterferometrie mit zwei Spezies — •Christina Rode, Maic Zaiser, Velte Ullrich und Rasel Ernst Maria — Institut für Quantenoptik, Leibniz Universität Hannover

Wir stellen ein Diodenlasersystem zum simultanen Kühlen und Fangen von Kalium (K) und Rubidium (Rb) vor, welches außerdem auch zur Anregung kohärenter Raman-Übergänge in diesen beiden atomaren Spezies für die Atominterferometrie verwendet wird. Das Lasersystem zeichnet sich durch sehr gute spektrale Eigenschaften und eine hohe Ausgangsleistung von bis zu 3 W, sowie eine sehr hohe Stabilität, Flexibilität, Kompaktheit und Transportabilität aus. Es besteht aus je zwei Linearresonatorlasern bei einer Wellenlänge von $\lambda_K \simeq 767$ nm bzw. $\lambda_{Rb} \simeq 780$ nm, deren Laserfelder zunächst entsprechend überlagert und anschließend mittels Trapezverstärkerchips auf jeweils $\simeq 1$ W Lichtleistung zum Betrieb eines 2D/3D MOT-Systems verstärkt werden. Zusätzlich existieren noch jeweils ein Referenzlaser, die beide mittels Frequenzmodulationsspektroskopie auf die jeweilige D_2-Linie von K bzw. Rb stabilisiert werden. Die Frequenz- und Phasenstabilisierung der restlichen Laser erfolgt jeweils mittels Schwebungsmessung an einer schnellen Photodiode und anschließender entsprechender Signalaufbereitung. Das vorgestellte Lasersystem soll in Zukunft zur Erzeugung quantenentarteter Bose-Fermi-Mischungen als Quelle für die Atominterferometrie benutzt werden und bildet einen wichtigen Bestandteil für einen geplanten Test des Äquivalenzprinzips auf Quantenebene.

Q 24.6 Di 17:45 Audi-A

Microcavity spectroscopy and chip-scale frequency combs — •Pascal Del'Haye[1], Olivier Arcizet[1], Ronald Holzwarth[1], and Tobias Kippenberg[1,2] — [1]Max-Planck-Institut für Qantenoptik, Garching bei München, Deutschland — [2]Ecole Polytechnique Federale de Lausanne, Lausanne, Switzerland

Optical frequency combs have revolutionized the ability to measure optical frequencies and posses a variety of applications ranging from molecular gas sensing to atomic clocks. In this talk, a novel, monolithic type of optical frequency comb generator is presented. The broadband frequency combs are generated in fused silica microtoroids, which can confine light for long times in extremely small mode volumes. High optical quality factors ($Q > 10^8$) give rise to a power enhancement that enables the comb generation via four-wave mixing. The frequency combs are generated from a single CW laser source and exhibit mode spacings in the range of 1 THz down to less than 100 GHz, corresponding to the free spectral range of the resonator. Additionally, we demonstrate control over both offset frequency and mode spacing of the comb, enabling full stabilization of the comb to a microwave frequency reference. Owing to their large mode separation, microcavity combs are a perfect tool for applications like high capacity telecommunication and calibration of astrophysical spectrometers. Additionally, a novel spectroscopy method using an external cavity diode laser and a frequency comb is presented, enabling fast measurement of microcavity mode spectra at sub-MHz accuracy over a bandwidth exceeding 30 nm in the 1550 nm range.

Q 24.7 Di 18:00 Audi-A

Calibration of Astronomical Spectrometers with Frequency Combs — •Tobias Wilken[1], Tilo Steinmetz[1], Phillip Vilar-Welter[1], Constanza Araujo-Hauck[2], Ronald Holzwarth[1], Theodor W. Hänsch[1], and Thomas Udem[1] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]European Southern Observatory, Garching

In astronomy the need for ever more precise measurements of spectral lines has led to a point where the traditional calibration sources - spectral lamps - are not sufficient any longer. For the next generation of telescopes new calibration techniques have to be developed to increase the precision with which stellar light can be measured.

Frequency combs - limited in their precision only by the atomic clock they are locked to - have the ability to achieve calibrations with virtually unlimited accuracy. A level of better than 10^{-9} would be needed e.g. to detect extrasolar earthlike planets or directly observe the (accelerating) expansion of the universe.

We have set up a frequency comb based on a previously unreported Yb-doped fiber laser. For the indiviual modes to be resolvable with a spectrometer the mode spacing has been increased up to several GHz with a Fabry-Perot cavity. First test measurements at a solar telescope on Tenerife have been successfully performed and the next campaign at the HARPS spectrometer in Chile are in preparation.

Q 24.8 Di 18:15 Audi-A

Hochauflösende Innertialsensor basierend auf kalten Atomen — •Thijs Wendrich, Christian Schubert, Michael Gilowski, Gunnar Tackmann, Peter Berg, Ernst Rasel und Wolfgang Ertmer — Institut für Quantenoptik, Leibniz Universität Hannover

Materiewelleninterferometrie hat durch ihr hohes Potential in der präzisen Messung von Inertialkräften einen festen Platz in der fundamentalen Physik und Metrologie eingenommen. Im Rahmen des Projekts CASI (Cold Atom Sagnac Interferometer) wird ein duales Atominterferometer, basierend auf optischen Ramanübergängen zur kohärenten Strahlteilung, für hochpräzise Messungen von Rotationen realisiert. Eine differentielle Messung zweier Atominterferometer, in der zwei Ensembles von kalten Rubidium-Atomen gegenläufig in die gemeinsame Interferometrieregion propagieren, ermöglicht die Diskriminierung von Rotationen und Beschleunigungen. Die Topologie des Atom Interferometers ähnelt der eines Mach-Zehnder-Interferometers: Die atomaren Ensembles werden mit Hilfe dreier Atom-wechselwirkungszonen geteilt, umgelenkt und wieder rekombiniert, sodass sich das Interferometer über 15 cm erstreckt und eine Fläche von 22 mm^2 umfasst. In dem Vortrag werden neueste interferometrische Messungen präsentiert, aus denen sich Rückschlüsse auf die Limitierungen des Quantensensors ableiten lassen. Hierbei werden zentrale Elemente des Sensors, die zum Kühlen und Manipulieren der Atome verwendet werden, näher beleuchtet. Ziel ist eine Sensitivität des Quantensensors von einigen 10^{-9} rad/s/$\sqrt{Hz}$ für 10^8 Atome/s zu erreichen. Diese Arbeit ist unterstützt von DFG SFB407, QUEST, und FINAQS.

Q 24.9 Di 18:30 Audi-A

High-order modes for reference cavities in optical clocks — •Björn Stein, Tanja E. Mehlstäubler, Ivan Sherstov, Maksim Okhapkin, Burghard Lipphardt, Christian Tamm, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Optical clocks have reached a performance level where the thermal noise of ULE reference cavities becomes a limitation to the observed instability. Options for improvement include cooling, low mechanical loss materials, elongating the resonator and enlarging the on-mirror spot area: By sampling a larger area, thermally driven mechanical fluctuations of the mirror surface are averaged down. Practical considerations of resonator size and fabrication tolerances prohibit a significant increase of the TEM_{00} spot size. We investigate the use of high-order $TEM_{m,n}$ modes to increase the effective spot area.

In existing reference resonators made from ULE, the mirror substrate is the dominant source of thermal noise. An improvement of the short-term instability by at least a factor of two seems feasible. Several new resonators now use different materials and the noise of the mirror coating is expected to be the future limitation in short term stability. Since the mirror coating noise is spatially uncorrelated, a much larger improvement in stability can be expected from using a high-order mode in such future ultra-stable resonators.

We present calculations on coating and substrate noise suppression for high-order Gauss-Hermite modes and report on the selective excitation of such modes in an optical resonator.

Q 24.10 Di 18:45 Audi-A

Trapped Atom Clock on a Chip - TACC — Clement Lacroute[1], Friedemann Reinhard[2], Christian Deutsch[2], Fernando Ramirez-Martinez[1], Jakob Reichel[2], and •Peter Rosenbusch[1] — [1]SYRTE, Observatoire de Paris, FRANCE — [2]LKB, Ecole Normale Superieure, Paris, FRANCE

We present a new project of a microwave clock interogating magnetically trapped atoms using the atom chip technology. The project builds on the demonstration experiment [P. Treutlein *et al.*, Phys. Rev. Lett., vol. 92, 203005 (2004)] but aims at an improved stability of a few 10^{-13} at 1 s while remaining of breadboard size. TACC will be able to operate with magnetically trapped thermal atoms or a Bose-Einstein condensate, thereby being one of the first experiments to use condensates in a metrological apparatus. We present the current status of the experiment.

Q 25: post deadline

Zeit: Dienstag 16:30–18:30 Raum: Audi-B

Programm siehe Aushang

Q 26: Quantengase: Fermionen

Zeit: Dienstag 16:30–18:00 Raum: VMP 6 HS-A

Q 26.1 Di 16:30 VMP 6 HS-A

Rotating Fermi Gases in an Anharmonic Trap — Kiel Howe[1], •Aristeu Rosendo Pontes Lima[2], and Axel Pelster[2,3] — [1]Department of Physics, University of Arizona, Tucson, AZ 85721, USA — [2]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [3]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

Motivated by recent experiments on rotating Bose-Einstein condensates, we investigate a rotating, polarized Fermi gas trapped in an anharmonic potential [1]. We apply a semiclassical expansion of the density of states in order to determine how the thermodynamic properties depend on the rotation frequency. The accuracy of the semiclassical approximation is tested and shown to be sufficient for describing typical experiments. At zero temperature, rotating the gas above a given frequency Ω_{DO} leads to a 'donut'-shaped cloud which is analogous to the hole found in two-dimensional Bose-Einstein condensates. The free expansion of the gas after suddenly turning off the trap is considered and characterized by the time and rotation frequency dependence of the aspect ratio. Temperature effects are also taken into account and both low- and high-temperature expansions are presented for the relevant thermodynamical quantities. In the high-temperature regime a virial theorem approach is used to study the delicate interplay between rotation and anharmonicity.

[1] K. Howe, A. R. P. Lima, and A. Pelster, `arXiv:0810.4983`

Q 26.2 Di 16:45 VMP 6 HS-A

Interference of Two Molecular Bose-Einstein Condensates — •Christoph Kohstall[1,2], Stefan Riedl[1,2], Edmundo R. Sánchez Guajardo[1,2], Leonid A. Sidorenkov[1], Johannes Hecker Denschlag[1], and Rudolf Grimm[1,2] — [1]Inst. of Experimental Physics and Center for Quantum Physics, Univ. Innsbruck, 6020 Innsbruck, Austria — [2]Inst. for Quantum Optics and Quantum Information, Acad. of Science, 6020 Innsbruck, Austria

Interference of Bose-Einstein condensates (BEC) strikingly demonstrates the wave nature of matter. In this talk, we present the observation of interference of BECs made of molecules. Our starting point is a BEC of weakly bound Feshbach dimers consisting of fermionic lithium atoms in two different spin states. The condensate is split by slowly changing the trapping potential into a double well. Then, the two clouds are released and overlap. We record high-contrast interference fringes by absorption imaging. We explore different scenarios that affect the contrast of the interference fringes. First, contrast is lost when the interaction strength between the molecules is increased. The mean field of one cloud repels the other and the overlap is disturbed. Second, the contrast periodically changes when we excite collective modes along the line of sight. We attribute the change in contrast to the spatial change of the relative phase between the two clouds.

Q 26.3 Di 17:00 VMP 6 HS-A

Thermodynamic and Dynamic Properties of a Dipolar Fermi Gas — •Aristeu Rosendo Pontes Lima[1] and Axel Pelster[1,2] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

We present a variational Hartree-Fock approach to treat a Fermi gas of fully polarized particles interacting through a dipole-dipole potential. Starting from a Thomas-Fermi approximation for the Wigner function, we obtain analytical information on this system from a parabolic ansatz, which is exact in the non-interacting limit and discuss the resulting equilibrium properties of the cloud. For example, we analyze the how the Thomas-Fermi radii, the aspect ratio and the release energy depend on the dipolar interaction strength. We confirm the numerically indicated nonexistence of absolute stability [1] and attribute it to the incapability of the Fermi pressure to suppress the attractive part of the dipole-dipole interaction. This is in contradiction to the dipolar Bose gas [2], which is stabilized by the contact interaction. Furthermore, we analyze the frequencies of the collective oscillations of a dipolar Fermi gas within a variational sum-rule approach.

[1] L. He, J.-N. Zhang, Y. Zhang, and S. Yi, Phys. Rev. A **77**, 031605(R) (2007)

[2] C. Eberlein, S. Giovanazzi, and D.H.J. O'Dell, Phys. Rev. A **71**, 033618 (2005)

Q 26.4 Di 17:15 VMP 6 HS-A

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

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

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

Q 26.5 Di 17:30 VMP 6 HS-A

Stability of the three-component ^{6}Li^{40}K Fermi mixture with a single resonant interaction — •Andreas Trenkwalder[1], Frederik Spiegelhalder[1], Eric Wille[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

We report on the stability of a strongly interacting ^{6}Li two-component mixture in presence of weakly interacting ^{40}K. The sample consists of ^{6}Li in the two lowest spin states and ^{40}K in the ground state held in an optical dipole trap. The temperature of ^{40}K is close to the Fermi temperature, ^{6}Li is degenerate. We measure loss rate coefficients of this mixture for different magnetic fields around the 834 Gauss ^{6}Li Feshbach resonance. Despite the mixture consisting of three distinguishable particles, we observe stability against three-body recombination. On the resonance as well as on the BCS side the mixture is very stable. On the molecular side losses increase due to atom-dimer collisions. The stability around the Feshbach resonance will allow to use ^{40}K as a probe for the BEC-BCS crossover of ^{6}Li.

Q 26.6 Di 17:45 VMP 6 HS-A

Exact numerical simulations of interacting fermions in 1D trapping potentials — •Bernd Schmidt, Dominik Muth, Alexander Mering, and Michael Fleischhauer — Fachbereich Physik, Technische Universität Kaiserslautern, Germany

We discuss p-wave interacting spin-polarized fermions in a 1D trapping potential for arbitrary interaction strength. Using a boson-fermion mapping in 1D, interacting fermions with p-wave interaction strength g^F_{1D} can be mapped to bosons with s-wave interaction strength $g^B_{1D} = -1/g^F_{1D}$. As a consequence a weakly interacting Fermi gas behaves in local properties like a strongly interacting Bose gas and vice versa. We derive a proper discretized model for the interacting fermions and compare its predictions with that obtained by the Bose-Fermi mapping using DMRG simulations. We calculate the realspace and momentum distributions of the fermions for arbitrary interaction strength starting at a weakly interacting gas to the Fermi-Tonks limit. and compare the results to predictions from field theoretical approaches.

Q 27: Ultrakalte Atome, Ionen und BEC I (mit A)

Zeit: Dienstag 16:30–18:00 Raum: VMP 6 HS-C

Das Programm der Sitzung ist unter A 14 zu finden.

Q 28: Quanteninformation: Photonen III

Zeit: Dienstag 16:30–18:00 Raum: VMP 6 HS-D

Q 28.1 Di 16:30 VMP 6 HS-D

A quantum interface between light and nuclear spins in quantum dots — •Heike Schwager, Geza Giedke, and Ignacio Cirac — Max-Planck Institut für Quantenoptik, Hans-Kopfermann Str. 1, 85748 Garching

The coherent coupling of flying photonic qubits to stationary matter-based qubits is an essential building block for quantum communication networks. We show how such a quantum interface can be realized between the polarized nuclear spins in a singly charged quantum dot strongly coupled to a high-finesse optical cavity and a traveling-wave optical field. By adiabatically eliminating the electronic degree of freedom different effective couplings can be achieved that enable write-in, read-out, and the generation of entanglement between the nuclei and the output field of the cavity.

Q 28.2 Di 16:45 VMP 6 HS-D

Towards coupling of a single emitter to a fiber based micro cavity — •Roland Albrecht[1], Benjamin Sauer[1], Christian Deutsch[2], Jakob Reichel[2], and Christoph Becher[1] — [1]Fachrichtung 7.3, (Technische Physik), Universität des Saarlandes, Campus E2.6, 66123 Saarbrücken — [2]Laboratoire Kastler Brossel, ENS/UPMC-Paris 6/CNRS, 24 rue Lhomond, 75005 Paris, France

Coupling a single emitter to a micro cavity is a crucial step towards sucessful implementation of efficient single photon sources and of many quantum information protocols.[1] We here investigate fiber based Fabry Perot cavities which consist of a flat dielectric mirror and an optical fiber. This cavity design has several advantages: it is tunable, can be scanned transversally and is automatically fiber-coupled with very good efficiency. To achieve stable cavities, a concave impression has been produced on the fiber facet by laser machining prior to deposition of a dielectric coating. Cavities using mirrors with radii of curvature of about 50 μm, with a finesse of up to 300 and a length of a few micrometers have been realized. We use defect centers in diamond nanocrystals as single emitters. The diamond nanocrystals are deposited onto the flat mirror by spin coating. Theoretical considerations show that the chosen cavity parameters should allow for enhancement of the defect center spontaneous emission by coupling it to the microcavity due to the Purcell effect.

[1] S. Prawer and A.D. Greentree, Science 320, 1601 (2008)

Q 28.3 Di 17:00 VMP 6 HS-D

Fast Excitation and Photon Emission of a Coupled Atom-Cavity System — •Joerg Bochmann, Martin Mücke, Holger Specht, Bernhard Weber, David Moehring, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Single atoms coupled to optical cavities provide unique systems to study light-matter interaction in the quantum regime. Naturally, these systems are well suited for atom-photon entanglement and distributed quantum networks [1].

We report on the fast excitation of a single Rb atom coupled to an optical cavity using laser pulses much shorter than all relevant processes [2]. The system subsequently displays an oscillatory energy exchange between atom and cavity field leading to pronounced amplitude modulations of the emitted single photons. We further show that the cavity frequency can be used as a parameter to design the single photon shape and spectrum, e.g. in a superpostion of two tunable frequencies.

[1] T. Wilk *et al.*, Science **317**, 488 (2007)
[2] J. Bochmann *et al.*, Phys. Rev. Lett. **101**, 223601 (2008)
[3] C. DiFidio *et al.*, Phys. Rev. A **77**, 043822 (2008)

Q 28.4 Di 17:15 VMP 6 HS-D

Mode mapping in waveguided parametric downconversion — •Andreas Christ, Kaisa Laiho, Andreas Eckstein, and Christine Silberhorn — Max Planck Research Group, Günther-Scharowsky-Str. 1/Bau 24, 91058 Erlangen, Germany

The process of parametric downconversion (PDC) has been found a reliable source of entangled photon pairs for quantum cryptography and quantum information. Recent developments in the source engineering are drawing the attention from the conventional sources to waveguided setups.

One of the advantages of waveguided PDC is the discrete mode propagation of signal, idler and pump in contrast to a continuum of spatial modes in bulk crystals. Therefore, an increase in collection efficiency over several orders of magnitude is expected.

We investigate the multimode PDC in waveguided periodically poled KTP structures. Our study of the spectral and spatial structure of the twin beams reveals a profound mapping from the spatial mode propagation into the frequency distribution of the generated biphotonic states: The disjoint spectral correlations are imprinted in the spectral marginal distributions of the generated PDC states.

Our results indicate that several spatial modes can be simultaneously excited in a waveguide. The discovered modal structures have to be taken into account when designing quantum information experiments: On the one hand our findings result in the need of additional filtering to shape the PDC states. On the other hand these effects can be utilized as a multiplexed source of entangled photon pairs.

Q 28.5 Di 17:30 VMP 6 HS-D

Amplification of a Laser Beam by a Single Molecule — •Jaesuk Hwang, Martin Pototschnig, Gert Zumofen, Robert Lettow, Alois Renn, Stephan Götzinger, and Vahid Sandoghdar — Laboratory of Physical Chemistry and optETH, ETH Zurich, CH-8093 Zurich, Switzerland

In a recent work, we showed that we can strongly couple a laser beam to a single emitter, achieving more than 10% extinction in transmission [1]. We have also shown theoretically that it is possible to reflect light with 100% efficiency from a two-level system [2]. In this presentation, we report on the amplification of a laser beam by a single molecule in free space. In order to populate the upper state of the molecule, a short pump pulse excites it to the first vibrational level of the electronic excited state. This state quickly relaxes to the vibrational ground state of the electronic excited state with 10 ns lifetime. During this time and before the next pulse arrives, a weak probe laser beam interacts with the inverted molecule. We observed that a starting 7 % extinction of the probe beam is transformed into a 0.6% amplification in the presence of the pumping beam [3]. We will present a simple theoretical model that yields a very good agreement with our experimental data. [1] G. Wrigge et. al. Nature Physics 4, 60-66 (2008). [2] G. Zumofen et. al. Phys. Rev. Lett. 101, 180404 (2008). [3] J. Hwang et. al. in preparation.

Q 28.6 Di 17:45 VMP 6 HS-D

Single molecule experiments challenge the strict particle aspect of the photon — •Karl Otto Greulich — Fritz Lipmann Institute Beutenbergstr.11 D07745 Jena

In the context of the photon, the definition of the term *particle* is not as straightforward as one might believe, with consequences for the meaning of the wave- particle dualism of light. The probably strictest definition of the photon as particle is given by the *accumulation time argument*, which requires that the spatial dimensions of the photon are much smaller than the absorbing atom or molecule and that its whole energy content is concentrated in this limited volume. Otherwise the extremely short interaction time of a few femtoseconds would make it impossible that a single atom or molecule can absorb a single, freely travelling photon. Here it is shown, using data from single molecule experiments, that the accumulation time argument has, so far, not yet been satisfied and therefore, the strict particle property of the photon is, so far, not been substantiated by experiments.

Q 29: Poster I

Zeit: Dienstag 16:30–19:00 Raum: VMP 8 Foyer

Q 29.1 Di 16:30 VMP 8 Foyer

Few-body physics in an ultracold Bose-Bose mixture — •Claudia Weber[1,3], Giovanni Barontini[1], Jacopo Catani[1,2], Francesco Rabatti[1], Gregor Thalhammer[1], Francesco Minardi[1,2], and Massimo Inguscio[1,2] — [1]LENS - European Laboratory for Non-Linear Spectroscopy and Dipartimento di Fisica, Università di Firenze, Sesto Fiorentino (Firenze), Italy — [2]CNR-INFM, Sesto Fiorentino (Firenze), Italy — [3]Institut für Angewandte Physik, Universität Bonn, Bonn, Germany

We report on the creation of heterospecies bosonic molecules. Using a resonantly modulated magnetic field they are associated from an ultracold Bose-Bose mixture of ^{41}K and ^{87}Rb close to Feshbach resonances. Analyzing the data we determine the binding energy of the weakly bound molecular states depending on the Feshbach field and can explain nontrivial features as the broadening and asymmetry of the association spectrum due to the thermal distribution of the atoms. Furthermore we observe heteronuclear Efimov resonances for both series KKRb and KRbRb next to the Feshbach resonance at 38 G.

Q 29.2 Di 16:30 VMP 8 Foyer

Towards a dense and ultracold gas of polar molecules — •Marc Repp[1,2], Johannes Deiglmayr[2], Anna Grochola[2], Roland Wester[2], and Matthias Weidemüller[1,2] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg — [2]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

During the last year we investigated the formation of LiCs molecules in the rovibrational groundstate $X^1\Sigma^+, v''=0, J''=0$ [1]. Such dipolar molecules are promising candidates to explore new quantum phases, like the formation of dipolar crystals of trapped polar molecules [2]. At this poster we will present our molecular production scheme via photoassocation (PA) in a double species MOT. Currently we are upgrading our system for reaching higher molecular phase-space densities. Therefore we will precool Cesium atoms from a MOT via Raman sideband cooling and transfer them afterwards into an optical dipole trap. Gravity will be compensated by a magnetic gradient field. In a next step, we will load Lithium atoms from a MOT in the same trap and use the Cs atoms as a refrigerator. In a final step the phase-space density of the ensemble will be increased by evaporative cooling. This will be the starting point for producing a quantum-degenerate gas of polar molecules.

[1] J. Deiglmayr *et al.*, Phys. Rev. Lett. 101, 133004 (2008)
[2] G. Pupillo *et al.*, Phys. Rev. Lett. 100, 050402 (2008)

Q 29.3 Di 16:30 VMP 8 Foyer

Control and detection system for a mobile high precision atom interferometer — •Sebastian Grede, Malte Schmidt, Alexander Senger, and Achim Peters — Humboldt Universität zu Berlin, AG Optische Metrologie, Hausvogteiplatz 5-7, 10117 Berlin

Matter wave interferometry has developed into a powerful tool for precise measurements of accelerations and rotations. Because of its capability to measure accelerations, it is also a suitable tool for high precision measurements of local gravity. We present subsystems of a gravimeter (developed within the projects FINAQS and the Euro-QUASAR/IQS) based on atom interferometry and optimized for mechanical stability and mobility.

Our timing system controls the whole experimental setup, including the time critical Raman pulse sequence implementing the atom optical components of the interferometer. It is based on a PXI-Bus FPGA (Field Programmable Gate Array) card. Digital, analog and frequency output channels (provided via DDS) are all controlled by this FPGA card, resulting in low jitter between the different channels and a uniform user interface. We also present our approach for detecting the cold atoms, which is based on a differential absorption measurement using photo diodes. This cancels out the laser excess noise and mitigates the effect of the background vapour in the detection chamber. We thus aim for a quantum projection noise limited detection of atomic ensembles for atom numbers higher than 10^5. For smaller samples we would be limited by the fluctuations in the number of atoms from the background vapour in the detection beams.

Q 29.4 Di 16:30 VMP 8 Foyer

Erste Charakterisierung eines hochstabilen Uhrenlasers über eine 73 km lange Glasfaserverbindung — •Osama Terra[1], Gesine Grosche[1], Wolfgang Ertmer[3], Jan Friebe[3], Theodor Hänsch[2], Ronald Holzwarth[2], Thomas Legero[1], Burghard Lipphardt[1], Andre Pape[3], Katharina Predehl[1,2], Ernst M. Rasel[3], Matthias Riedmann[3], Uwe Sterr[1], Temmo Wübbena[3] und Harald Schnatz[1] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig — [2]Max Planck Institute for Quantum Optics, 85748 Garching — [3]Institut für Quantenoptik , Leibniz Universität Hannover, 30167 Hannover

Auf optische Resonatoren stabilisierte Laser für optische Uhren zeigen relative Kurzzeitstabilitäten im Bereich weniger 10^{-15}. Um das Frequenzrauschen dieser Uhrenlaser zu charakterisieren und zu verbessern ist in der Regel vor Ort ein zweites System mit vergleichbaren Eigenschaften erforderlich. Solche ultrastabilen Referenzlaser stehen in der PTB zur Verfügung, können aber aufgrund ihres komplexen Aufbaus bisher nicht zu einem Anwender transportiert werden. Eine 73 km lange, aktiv stabilisierte Glasfaserverbindung zwischen der PTB in Braunschweig und dem Institut für Quantenoptik (IQO) an der Universität Hannover erlaubt es, die Frequenzstabilität eines Uhrenlasers der PTB in Hannover mit einer Kurzzeitstabilität von σ_y=4x10^{-15} bei 1 s zur Verfügung zu stellen und dort für die Messung des Frequenzrauschens eines optischen Frequenznormals zu nutzen. Es wird das Glasfaserübertragungssystem vorgestellt und über die Frequenzmessung berichtet.

Q 29.5 Di 16:30 VMP 8 Foyer

Towards a quantum test of the equivalence principle with atom interferometry — Maic Zaiser, •Ullrich Velte, Christina Rode, Jonas Hartwig, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

The differential measurement of the earth's acceleration g with atom interferometric techniques using two different atomic species allows for interesting perspectives in the quest of testing the equivalence principle, a fundamental postulate within general relativity. We present a new experiment aiming for such a test, using a (quantum degenerate) mixture of Rubidium and Potassium. Besides a competitive test of the equivalence principle, the experiment also allows for systematic studies concerning the comparison of interferometry with bosonic or fermionic matter and the metrological comparison of two different gravimeters at the same place and in the same experimental environment. The basis of the experiment will be an experiment aiming at a BEC of ^{87}Rb and a quantum degenerate Fermi gas of ^{40}K by all-optical means. We will show the present status of the experiment comprising the characterization of the 2D/3D MOT as the atomic source, the implementation of optical molasses to reach very low temperatures and high initial phase space densities, and first loading studies of the optical dipole trap formed by a Thulium fiber laser with 50 W output power at 1960 nm. Besides, we will introduce our new compact diode laser system for the implementation of the light for the operation of the atomic source, as well as for the realization of the Raman transitions.

Q 29.6 Di 16:30 VMP 8 Foyer

FEM optimisation of a high-finesse reference cavity — Didier Guyomarc'h, Gaetan Hagel, Cédric Zumsteg, Caroline Champenois, Marie Houssin, and •Martina Knoop — CNRS/Université de Provence, Centre de St Jerome, Case C21, 13397 Marseille Cedex 20, France

The interrogation of the clock transition of a single trapped Ca^+ ion requires a laser at 729 nm stabilized to a couple of Hz per second with a linewidth of the same order of magnitude. These performances are achieved by locking the laser on an extremely well isolated reference cavity of very high finesse. Vertical mounting of the reference cavity can reduce its sensitivity to vibrations as described in [1]. We have designed a comparable vertical cavity with an overall length of 150 mm resulting in a FSR of 1GHz. Optimisation of the cavity design has been carried out with a Finite-Elements Method, leading to expected relative length variations below 10^{-14}. The influence of the variation of the mesh size has been studied, and the machining has been carried out in a two-step process to optimize the geometry of the presented cavity.

[1]M. Notcutt, L. Ma, J. Ye, and J. Hall, Opt. Lett 30, 1815 (2005).

Q 29.7 Di 16:30 VMP 8 Foyer

A clock laser system for a Yb optical lattice atomic clock — •U. Bressel, A. Yu. Nevsky, S. Vasilyev, I. Ernsting, and S. Schiller — Institut für Experimentalphysik, Heinrich-Heine-Universität Düsseldorf

Neutral Ytterbium is a promising candidate for a lattice optical clock [1] with a potential accuracy exceeding that of the caesium microwave clock. The $^1S_0 \rightarrow {}^3P_0$ clock transition at 578 nm is dipole forbidden and has a natural linewidth of about 10 mHz, leading to a transition Q-factor of 10^{-16}. To interrogate such a narrow transition, a laser source with a sub-Hz linewidth should be developed. We have developed a clock laser based on frequency doubling (SHG) a grating-stabilized quantum-dot laser [2] at 1156 nm using a PPLN crystal in an external enhancement cavity. With 32 mW at 1156 nm the power at 578 nm is about 3.2 mW. As an alternative, a PPLN waveguide has been used with an output of 0,190 mW at 578 nm. In order to reduce the laser linewidth, the laser is being stabilized to a vibration-insensitive ULE reference cavity. It exhibits a finesse of 330 000 (4.5 kHz linewidth) at 578 nm and zero thermal expansion at 20°C. The cavity is placed in a compact vacuum chamber with a dual-layer temperature stabilization system and mounted on active vibration isolation supports. Spectroscopy of the ^{171}Yb clock transition $^1S_0 \rightarrow {}^3P_0$ at 578 nm has been performed, yielding to an observation of the clock transition shifted 315 kHz to the expected value due to systematic effects.

[1] C. W. Hoyt et al., Phys. Rev. Lett. 95, 0303 (2005)
[2] A. Yu. Nevsky et al., Appl. Phys. B 92, 501-507, (2008)

Q 29.8 Di 16:30 VMP 8 Foyer

A tunable laser source at 5.1 μm for precision spectroscopy of a rovibrational transition of cold HD^+ ions — •U. Bressel, T. Schneider, S. Vasilyev, A. Yu. Nevsky, I. Ernsting, B. Roth, and S. Schiller — Institut für Experimentalphysik, Heinrich-Heine-Universität Düsseldorf

HD^+ is the most simple heteronuclear molecule containing just a single electron. Precise measurements of its rovibrational transition frequencies can determine QED effects in molecules, the ratio m_e/m_p [1] and improve limits of its time-dependence [2]. For high-precision vibrational spectroscopy of the $v = 0 \rightarrow v = 1$ fundamental vibrational transition a cw infrared laser tunable from 5.09 μm to 5.13 μm has been developed. It is based on difference frequency generation (DFG) between a 1064 nm Nd:YAG laser and a 1305 - 1350 nm external-cavity diode laser (ECDL). The nonlinear crystal is a periodic-poled MgO:$LiNbO_3$-crystal (PPLN), producing up to 0.6 μW at 5.115 μm. The frequency of the Nd:YAG laser is iodine stabilized. The frequency of the ECDL is stabilized via a temperature stabilized Invar cavity allowing a linewidth of about 100 kHz. The frequency of the 5 μm radiation will be determined by a simultaneous measurement of the frequency of each laser using a frequency comb.

[1] J. Koelemeij et al., Phys. Rev. Lett. 98, 173002 (2007)
[2] S. Schiller, V. Korobov, Phys. Rev. A 71, 032505 (2005)

Q 29.9 Di 16:30 VMP 8 Foyer

An optical lattice at the magic wavelength for ytterbium —

•Charbel Abou-Jaoudeh, Cristian Bruni, Florian Baumer, and Axel Görlitz — Institut für Experimentalphysik, HHU Düsseldorf, Germany

Neutral ytterbium (Yb) is an interesting candidate for the realization of an optical clock at a wavelength of 578 nm [1] using the $^1S_0 \rightarrow {}^3P_0$ transition. A promising scheme for the realization of an optical clock with Yb involves trapping of laser-cooled atoms in an optical lattice operating at the so-called "magic" wavelength at 759 nm[2].

In this poster, we report on the development of a compact source of ultracold Yb atoms for an optical lattice clock which uses only diode-based laser systems for the two laser cooling stages at 399 nm and 556 nm as well as for the optical lattice. The light for the optical lattice is generated by a tapered diode laser with an output of more than 500 mW and the lattice will be formed inside a folded standing-wave resonator which allows for the realization of a three-dimensional lattice geometry. We anticipate that this geometry will allow us to trap more than 10^5 Yb atoms in a lattice with a depth of around 100 μK.

[1] S. Porsev et al., Phys. Rev. A **69**, 021403 (2004)
[2] Z. Barber et al., Phys. Rev. Lett. **96**, 083002 (2006)

Q 29.10 Di 16:30 VMP 8 Foyer

Optische AC Kopplung - Ein neues Schema für Laser-Leistungsstabilisierungen. — •Patrick Kwee, Benno Willke und Karsten Danzmann — Max-Planck-Institut für Gravitationsphysik (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. Bislang wird die erreichte Stabilität durch Rauschquellen in der Photodiode auf ein relatives Leistungsrauschen von ca. $3.5 \times 10^{-9}/\sqrt{Hz}$ bei Fourier-Frequenzen um 10Hz begrenzt.

Die optische AC Kopplung verwendet eine Photodiode in Reflektion eines optischen Resonators, um die Empfindlichkeit der Photodiode um ca. eine Größenordnung zu erhöhen. Dadurch können die limitierenden, photodioden-internen Rauschquellen umgangen werden.

Ergebnisse einer durch Quantenrauschen limitierten Leistungsstabilisierung eines Nd:YAG Lasers bei 1064nm werden vorgestellt. Eine Analyse des theoretischen Stabilitätslimits und begrenzender Rauschkopplungen werden präsentiert.

Q 29.11 Di 16:30 VMP 8 Foyer

Diagnostic Breadboard - Ein kompaktes, automatisiertes Instrument zur Charakterisierung von Laserstrahlen. — •Patrick Kwee, Benno Willke und Karsten Danzmann — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Hannover

Für das Gelingen vieler optischer Experimente sind die Strahleigenschaften des verwendeten Lasersystems entscheidend. Ein kompaktes, automatisiertes Instrument zur Analyse vieler verschiedener Strahleigenschaften von einfrequenten Dauerstrich-Lasern wird vorgestellt.

Ein optischer Resonator ist das Kernstück dieses computergesteuerten Instruments und dient zur Messung von Frequenz- und Strahllagefluktuationen in einem Frequenzbereich von 1Hz bis 100kHz. Die Strahlqualität wird über eine kohärente Modenzerlegung mithilfe des Resonators ermittelt. Dabei können höhere Moden mit einer relativen Leistung von unter 10^{-4} aufgelöst werden. Über Photodioden kann das Leistungsrauschen von 1Hz bis 100MHz gemessen werden.

Die verwendeten Messmethoden, die Sensitivität, das Computersystem und Messergebnisse verschiedener Lasersysteme bei einer Wellenlänge von 1064nm werden präsentiert.

Q 29.12 Di 16:30 VMP 8 Foyer

Nachweis von Quecksilber in einer MOT mittels eines Zwei-Photonen-Ionisationsprozesses — •Tobias Beck, Alexander Bertz und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, Laser- und Quantenoptik, Schloßgartenstraße 7

Vorgestellt wird ein auf Channel-Electron-Multipliers und Zwei-Photonen-Ionisation basierender Detektor, der es ermöglicht, Quecksilberatome sowie -dimere in einer magnetooptischen Falle nachzuweisen. Zur Ionisation wird ein regeneratives Titan:Saphir Verstärkersystem verwendet, welches simultan fourierlimitierte ns-Pulse der Wellenlängen 789 nm sowie 761 nm emittiert. Resonatorextern wird durch effiziente Frequenzkonversion Strahlung der Wellenlängen 253,7 nm sowie 197,3 nm erzeugt. Die Quecksilberatome in der MOT werden durch die zweistufige Anregung in einen autoionisierenden Zustand gebracht, der eine besonders effiziente Ionisation ermöglicht. Die bei der Ionisation entstandenen, geladenen Teilchen werden durch Ringelektroden in die linear angeordneten CEMs fokussiert. Der aktuelle Stand der Entwicklung wird diskutiert.

Q 29.13 Di 16:30 VMP 8 Foyer

Computergestütztes Design optischer Resonatoren mittels ABCD-Matrizen und zweidimensionalem Raytracing — •Alexander Bertz und Thomas Walther — TU Darmstadt, Darmstadt, Hessen

Präsentiert wird eine grafische Entwicklungsumgebung zur Simulation von Laseresonatoren auf Grundlage des ABCD-Matrixformalismus. Die Software basiert auf der aktuellen Java-Runtime-Engine und ist somit gleichermaßen auf Unix, Windows und MacOS lauffähig. Eine leistungsfähige 3D-Engine dient zur Visualisierung der konstruierten Resonatoren, während die intuitive Benutzerführung die Echtzeitvariation aller relevanten Parameter ermöglicht. Vorgestellt wird die Programmversion 2.0, welche desweiteren über einen leistungsfähigen 2D-Raytracer verfügt.

Q 29.14 Di 16:30 VMP 8 Foyer

Aktive Regelung der Abstimmung eines ECDLs basierend auf der Polarisationsspektroskopie des Gesamtresonators — •Thorsten Führer, Walter Schäfer und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, AG Laser und Quantenoptik, Schlossgartenstr. 7, D-64289 Darmstadt

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

Es wird ein neuartiges Verfahren präsentiert, bei dem die Resonanzeigenschaften eines ECDLs in den Polarisationszustand des emittierten Laserlichts übertragen werden. Der Stokes-Parameter S_1 erfährt periodische Nulldurchgänge an den Resonanzen des ECDLs, welche die Nutzung von S_1 als Fehlersignal erlauben. Dadurch eröffnet sich die Möglichkeit, durch einen geschlossenen Regelkreis einen der Resonatoren auf den jeweils anderen zu „locken“. Beispielsweise wird der Laserdiodenstrom stets optimal an die Länge des externen Resonators angepasst. Das vorgestellte Verfahren ermöglicht große modensprungfreie Durchstimmbereiche und eine Stabilisierung des ECDL-Betriebs.

Q 29.15 Di 16:30 VMP 8 Foyer

Ein kompaktes und extrem robustes Lasersystem für Experimente mit atomaren Quantengasen — •André Wenzlawski, Max Schiemangk, Wojciech Lewoczko-Adamczyk und Achim Peters — Institut für Physik, Humboldt Universität zu Berlin

Wir präsentieren ein ultra-stabiles External-Cavity Diodenlasersystem mit integrierter Frequenzstabilisierung auf einen atomaren Übergang in Rubidium. Das innovative "Klotz-Design" mit 3-dimensional gefaltetem Strahlengang, sowie eine schnelle Regelelektronik gewährleisten eine hohe Frequenz- und Leistungsstabilität beim Betrieb unter extremen Beschleunigungsbedingungen mit den Spitzenwerten bis zu 30 g. Der Laser wird als Frequenzreferenz (Master-Laser) und als Teil eines Raman-Lasersystems zur Atominterferometrie mit einem Bose-Einstein-Kondensat (BEC) Experiment unter Schwerelosigkeit benutzt. Die miniaturisierte und mechanisch stabile BEC-Apparatur wurde im Rahmen von QUANTUS Kollaboration auf dem Weg zur Implementierung eines Quantengasexperimentes im Weltraum entwickelt und wird bei den ersten Tests im Fallturm (ZARM, Bremen) eingesetzt.

Q 29.16 Di 16:30 VMP 8 Foyer

Spectrum of the Free-Electron Laser — •Paul Preiss 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. We discuss the spectrum of FEL's operating at the border line of the quantum mechanical regime by a treatment via quantum mechanics.

Q 29.17 Di 16:30 VMP 8 Foyer

Single Mode Tunable All Solid-State UV Laser at the 282 nm Clock Transition of $^{119}Hg^+$ — •Thorsten Schmitt, Thomas A. Puppe, Andreas Nendel, Frank Lison, and Wilhelm G. Kaenders — Toptica Photonics AG, Lochhamer Schlag 19, 82166 Graefelfing / Munich, Germany

There is a growing interest in precision laser sources in the ultraviolet. Particularly demanding applications are optical frequency standards based on spectroscopy of trapped atoms or ions [1].

We present a tuneable solid-state cw laser source providing more than 30 mW at the 282 nm clock transition of $^{119}Hg^+$. An extended cavity diode laser (ECDL) at 1126 nm seeds a Yb-doped diode-pumped fiber amplifier and is then frequency-quadrupled in two successive frequency-doubling stages. The output of the second harmonic generation (SHG) shows a conversion efficiency exceeding 50 % and good longterm stability. The spectral properties of the system are defined by the master oscillator and the background added by the Yb-doped-fiber amplifier is largely suppressed. ECDLs are known to achieve the extremely narrow linewidths necessary for high-resolution laser spectroscopy [2,3]. Hence, the presented laser system provides a rugged, all solid-state laser well suited for these precision applications.

[1] J. L. Hall, Nobel Lecture (2005)
[2] H. Stoehr et al., Opt. Lett. 31, 736 (2006)
[3] J. Alnis et al., PRA 77, 053809 (2008)

Q 29.18 Di 16:30 VMP 8 Foyer

Continuous-wave single-frequency mid-IR optical parametric oscillator for spectroscopy of cold molecules — •Michael G. Hansen, Sergey V. Vasilyev, Tobias Schneider, and Stephan Schiller — Institut für Experimentalphysik, Universität Düsseldorf, Universitatsstr. 1, 40225 Düsseldorf

A continuous-wave singly-resonant optical parametric oscillator covering the $2.56 - 2.9$ μm-range for ro-vibrational spectroscopy of cold HD^+ has been developed. Planned applications are state-selective mechanical excitation using the optical dipole force [1], optical pumping and two-photon spectroscopy [2].

A PPLN-crystal with three grating-periods is used as the nonlinear material. With a 10 Watt Nd:YAG pump laser free-running output-powers of up to 2.1 Watt and a threshold of 4 Watt are achieved. Mode-hop-free oscillation is achieved by introduction of an etalon, resulting in reduced output-power of 1.5 Watt. Absorption in the crystal and in the air reduce the output-power to 0.8 Watt around 2.77 μm.

[1] Koelemeij et al., Phys. Rev. A **76**, 023413 (2007)
[2] Karr et al., J. Phys. B **38**, 853-866 (2005)

Q 29.19 Di 16:30 VMP 8 Foyer

Pound-Drever-Hall Stabilisierung einer Cavity-Leak-Out-Zelle für die höchstempfindliche Infrarot-Laseranalytik von Spurengasen — •Markus Böning, Marcus Sowa, Thomas Fritsch, Peter Hering und Manfred Mürtz — Institut für Lasermedizin, Universitätsklinikum Düsseldorf, Universitätsstr. 1, 40225 Düsseldorf

Der atemzugsaufgelöste Nachweis von Spurengasen wie z.B. Kohlenmonoxid (CO) oder Stickstoffmonoxid (NO) in geringsten Konzentrationen ist in vielen Gebieten der medizinischen Diagnostik von großem Interesse. In den vergangenen Jahren hat sich dazu die Cavity-Leak-Out Spektroskopie (CALOS) als geeignete höchstempfindliche Nachweismethode, bis in den sub-ppb Bereich, etabliert. In einer Nachweiszelle in Form eines optischen Resonators werden Spurengase mittels Absorptionsspektroskopie detektiert. Durch den Einsatz hochreflektierender Spiegel (R=99,98%) lassen sich effektive Weglängen von mehreren Kilometern erreichen. Ein durchstimmbarer CO-Laser im Wellenlängenbereich um 5μm und die Nachweiszelle werden aufeinander stabilisiert. Bisher wird dazu die bekannte 1f-Lock-In Technik verwendet. Durch den Einsatz einer neuentwickelten Pound-Drever-Hall Stabilisierung kann die Repetitionsrate zur Aufnahme der Messwerte weiter gesteigert werden. In diesem Beitrag werden die ersten Ergebnisse hinsichtlich der Optimierung der Modulationsparameter, sowie des Reglers vorgestellt.

Q 29.20 Di 16:30 VMP 8 Foyer

Laser Spectroscopy on Color Centers in Diamond Films — •David Steinmetz, Elke Neu, Christian Hepp, Michael Hauschild, and Christoph Becher — Fachrichtung 7.3 (Technische Physik), Universität des Saarlandes, 66123 Saarbrücken, Germany

Recent investigations have proven color centers in diamond to be promising candidates for applications in quantum information processing [1]. Due to their optical properties they can be regarded as "artificial atoms" and they offer access to isolated quantum systems that can be controlled at room temperature. For the nitrogen-vacancy center, a number of key experiments have been demonstrated [2,3], but its very broad emission spectrum at room temperature limits its suitability for application as "optical qubits".
We investigate color centers based on Si, W, Ta, Ni or Xe with more promising properties for single photon emitters and/or optical qubits. They can be generated either during chemical vapor deposition growth process of the diamond films or by subsequent ion implantation.
We investigate the color centers via confocal laser spectroscopy with a grating spectrometer or with a scanning Fabry-Pérot interferometer and we use a Hanbury-Brown-Twiss interferometer to study the suitability of the color centers for solid state single photon sources at room temperature.

[1] S. Prawer and A.D. Greentree, Science **320**, 1601 (2008)
[2] C. Kurtsiefer et al., Phys. Rev. Lett. **85**, 290 (2000)
[3] F. Jelezko et al., Phys. Rev. Lett. **93**, 130501 (2004)

Q 29.21 Di 16:30 VMP 8 Foyer

Spektrale Charakterisierung von Faserlasern mit resonatorinterner ultradünner Glasfaser — •D. Papencordt[1,2], B. Löhden[1], D. O'Shea[2], A. Rauschenbeutel[2], K. Sengstock[1] und V. Baev[1] — [1]Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]Abteilung QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz

Verjüngte Glasfasern mit Durchmessern vergleichbar zur Wellenlänge des geführten Lichts zeigen einen Anteil des e.m. Feldes (evaneszentes Feld) außerhalb des Lichtwellenleiters, der mit der Umgebung wechselwirken kann. Deshalb sind ultradünne Glasfasern vielversprechend für die Spektroskopie und den Nachweis von Materie, die sich in der Nähe der Faser befindet. Die Absorption von Molekülen an der Faseroberfläche im Transmissionsspektrum der verjüngten Faser ist bereits nachweisbar [1]. Hohe Empfindlichkeiten sind bei vielen Durchgängen des Lichts durch die Faser erreichbar. Dies kann z.B. durch den Einsatz der ultradünnen Glasfaser im Laserresonator erreicht werden. Wir haben einen Faserlaser aufgebaut, der einen verjüngten Faserabschnitt beinhaltet. Als aktives Material wurden Er-dotierte Fasern verwendet, die sich durch große Durchstimmbarkeit im Wellenlängenbereich von 1,52 bis 1,62 μm und breite Einzelspektren auszeichnen [2]. Wir berichten über Untersuchungen von Emissionsspektren im Faserlaser mit resonatorinterner ultradünner Glasfaser, die sich schon bei kleinen Konzentrationen von Fremdsubstanzen stark verändern.

1. F. Warken *et al.*, Opt. Exp. **15**, 11952 (2007).
2. A. Goldman *et al.*, Chem. Phys. Lett. **423**, 147 (2006).

Q 29.22 Di 16:30 VMP 8 Foyer

Highly-accurate laser wavelength meter using an atomic transition as a reference — •Anastasiya Khromova, Andrés Felipe Varón, Benedikt Scharfenberger, Christian Piltz, and Christof Wunderlich — Fachbereich Physik, Universität Siegen, Walter-Flex-Straße 3, 57068 Siegen

In order to perform accurate spectroscopic measurements or to drive atomic transitions one requires to know precisely the wavelength of the lasers. In our lab we have built a Michelson based wavelength meter [1], which uses an atomic Rb transition as a reference [2].

With our wavelength meter we are able to measure the wavelengths in the range of 350 nm - 1μm - the range of the optical components. Using Labview we are able to choose between four different wavelengths that are simultaneously coupled into the wavelength meter.

The reference laser is a frequency-stabilized diode laser at 780 nm. It is locked to the cross-over signal (linewidth 6MHz) of the $5^2S_{1/2}, F = 2 \leftrightarrow 5^2P_{3/2}, F = 2$ and $F = 3$ transition in the ^{87}Rb. The relative error on the unknown wavelength equals 10^{-8}. Counter and electronics set the limits on the precision. The details of the set up and physical principles of the used techniques will be highlighted.

[1] J. L. Hall and S. A. Lee, Appl. Phys. Lett. **29**, 367 (1976).
[2] A. Banerjee et al., Appl. Phys. Lett. **79**, 2139 (2001).

Q 29.23 Di 16:30 VMP 8 Foyer

Femtosekunden Yb:KLuW-Scheibenoszillator im solitären und positiv dispersiven Dispersionsregime — •Guido Palmer[1], Marcel Schultze[1], Andy Steinmann[1], Anna Lena Lindemann[1], Martin Siegel[1] und Uwe Morgner[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Laser Zentrum Hannover

Wir demonstrieren den ersten passiv modengekoppelten Yb:KLuW Scheibenoszillator. Im solitären Betrieb mit negativer Gesamtdispersion (Group Delay Dispersion) wird eine maximale Durchschnittsleistung von über 25 W bei einer fourier-limitierten Pulsdauer von 490 fs und einer Repetitionsrate von 34,7 MHz erreicht. Um die resonatorinternen Spitzenleistungen zu reduzieren, wurde der Laser sowohl im solitären als auch im chirped-pulse-Regime bei positiver Gesamtdispersion betrieben. Im zweiten Falle wurde eine maximale Ausgangsleistung von 9,5 W mit einem Fourierlimit der Pulse von 450 fs erzielt. Das kompakte Lasersystem verfügt über eine ausgezeichnete Strahlqualität und gute Rauscheigenschaften. Es wird die Laserperformance der beiden Dispersionregime miteinander verglichen und Skalierungslimitierungen werden aufgezeigt.

Q 29.24 Di 16:30 VMP 8 Foyer

Messung der Träger-Einhüllenden-Phase von fs-Laserpulsen in Alkali-Atomen — •Anne Harth[1,2], Mathias Hoffmann[1,2], Niels Meiser[1,2], Stefan Rausch[1,2], Thomas Binhammer[1,2] und Uwe Morgner[1,2] — [1]Institut für Quanten Optik, Leibniz Universität Hannover, Deutschland — [2]Quest: Center for Quantum Engineering and Space-Time Research, Hannover, Deutschland

Die Messung und Stabilisierung der Träger-Einhüllenden-Phase (TE-Phase) von fs-Laseroszillatoren und Verstärkersystemen ist grundsätzlich verstanden und wird erfolgreich durchgeführt. Phasenabhängige Prozesse, wie z.B. die Erzeugung hoher Harmonischer in Edelgasen im cut-off-Bereich oder die Korrelation des Impulses von Photoelektronen mit der TE-Phase eines ionisierenden Laserpulses, wurden demonstriert. Beide Methoden benötigen hohe Pulsspitzenintensitäten und beschränken somit die Messung der TE-Phase auf Verstärkersysteme.

Theoretische Arbeiten haben gezeigt, dass die Besetzungswahrscheinlichkeit gebundener Zustände von Molekülen und Atomen, die durch einen fs-Puls angeregt werden, eine TE-Phasen-Abhängigkeit schon bei Intensitäten, die direkt mit einem Laseroszillator erreicht werden können, aufweisen. Wir stellen ein Schema zur Messung der TE-Phase eines fs-Laseroszillators in Alkali-Atomen vor und diskutieren die theoretischen Ergebnisse.

Q 29.25 Di 16:30 VMP 8 Foyer

Characterization of an Ultrafast Electron Diffraction Machine — •Christian Gerbig, Cristian Sarpe–Tudoran, Matthias Wollenhaupt, and Thomas Baumert — Universität Kassel, Institut für Physik und CINSaT, D–34132 Kassel, Germany

In the recent past Ultrafast Electron Diffraction (UED) has become one of the most promising methods to directly provide insights into fundamental physical and chemical dynamics at the microscopic level and on the picosecond to subpicosecond time scale [1,2].
UED as a pump-probe technique typically consists of four stages, the first of which is photoemission of electrons from a photocathode by an ultrashort laser pulse. The second is acceleration and propagation of the electrons towards the specimen; the third is the variable delayed excitation of the specimen by a femtosecond laser pulse (pump) and subsequent diffraction of the electron bunch (probe). In the last stage the diffraction pattern is mapped onto a detector.
In this contribution we present the setup and construction of an apparatus for time-resolved UED measurements based on an amplified 25 fs Ti:Sapphire laser system. First static diffraction patterns of solid state specimens and two concepts for the electron pulse duration determination (electron-electron and electron-laser cross correlation [1]) are presented. In addition, we show improvements and a new approach related to the last three stages (see above) of our UED setup, leading to a better experimental resolution in space and time.

[1] J. R. Dwyer *et al.*, Phil. Trans. R. Soc. A 364 (2006) 741
[2] A. H. Zewail, Annu. Rev. Phys. Chem. 57 (2006) 65

Q 29.26 Di 16:30 VMP 8 Foyer

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

Femtosecond polarization pulse shaping is a tool to generate 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 as well as additional optical elements. Accurate generation of polarization-shaped pulses requires taking into account these effects and correcting the optical setup accordingly. Approaches to detect these effects based on a rotating polarizer and a spectral interference technique are presented and compared. In addition, we show effective compensation implementations making use of specifically designed transmission gratings, appropriate wave plates and the pulse shaper itself. Femtosecond laser pulses with different polarization states generated with our high-resolution polarization pulse shaper were analyzed employing the same optical scheme and Photoelectron Imaging Spectroscopy (PEIS). Results on the compensation of amplitude and phase effects are presented.

Q 29.27 Di 16:30 VMP 8 Foyer

Optical waveguide devices and electro optic modulation in ultrashort-pulse laser written lithium niobate crystals — •Stefan Ringleb[1], Katja Rademaker[1], Stefan Nolte[1], and Andreas Tünnermann[1,2] — [1]Institut für Angewandte Physik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena — [2]Fraunhofer Institut für Angewandte Optik und Feinmechanik IOF, Albert-Einstein-Straße 7, 07745 Jena

Lithium niobate ($LiNbO_3$) is a key material in integrated optics due to its large electro optic and nonlinear coefficients as well as its availability in good optical quality. Commonly, the fabrication of integrated optical devices like optical switches and modulators is done by microfabrication techniques involving lithography. In this presentation, we will describe the fabrication of three dimensional functional elements in a bulk $LiNbO_3$ crystal by using ultrashort-pulse laser writing. Here, an ultrashort laser pulse is focussed inside the bulk material, which results in a refractive index increase due to stress-induced birefringence. In this way, integrated optical devices can be fabricated in a couple of minutes and with just a few process steps. As an example, an electro optic modulator will be presented, where the waveguiding Mach-Zehnder-Interferometer structures are prepared by the technique mentioned above including the electrodes using laser ablation. Switching voltages of 23 V at a wavelength of 532 nm and modulation depths up to 11 dB are achieved.

Q 29.28 Di 16:30 VMP 8 Foyer

Ultrafast electron emission from ultrasharp metal tips — •Markus Schenk, Michael Krüger, Johannes Hoffrogge, and Peter Hommelhoff — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

For quantum optics experiments with free electrons a spatially and temporally well-controlled electron source is of high interest. We focus the output of a 7-fs laser oscillator onto a field emission tip and generate field strengths that should enable resolving the laser electric field structure in the emission current. Furthermore, the high non-linearity of the emission process in the laser electric field should lead to single electron pulses with sub-laser-cycle duration. We first aim at prooving these notions. In parallel we work towards a deterministic single electron source. The current status of the experiment is presented.

Q 29.29 Di 16:30 VMP 8 Foyer

Erzeugung Hoher Harmonischer nach Pulsverkürzung im Filament — •Emilia Schulz[1,2], Daniel Steingrube[1,2], Thomas Binhammer[1], Tobias Vockerodt[1,2], Milutin Kovacev[1,2] und Uwe Morgner[1,2,3] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]QUEST: Center for Quantum Engineering and Space-Time Research, Hannover — [3]LZH, Laser Zentrum Hannover

Zur Erzeugung einzelner Attosekundenpulse sind intensive IR-Pulse mit einer Dauer von wenigen Zyklen nötig. Wir präsentieren hier unsere ersten Ergebnisse der Erzeugung hoher Harmonischer mit Pulsen, die mit Hilfe eines Filaments komprimiert wurden. Das von uns verwendete Lasersystem erzeugt Pulse einer Dauer von 30 fs bei Energien von 1.5 mJ mit einer Repetitionsrate von 3 kHz. Nach der Filamentation kann durch Selbstphasenmodulation ein oktavbreites Spektrum erzeugt werden, das direkt mittels Selbstkompression, also ohne ergänzende Dispersions-Kompensation, sub-10-fs-Pulse liefert. Die Energie, die im Weißlichtkern des Strahlprofils, der sich zur Erzeugung kurzer Pulsdauer eignet, enthalten ist, beträgt etwa die Hälfte der Eingangsenergie. Dies System ermöglicht u.a. Untersuchungen der erzeugten Spektren der Hohen Harmonischen in Abhängigkeit von der Pulsdauer des infraroten Pulses.

Q 29.30 Di 16:30 VMP 8 Foyer

Erzeugung hochenergetischer Pulse bei 87.8 nm durch Frequenzvervielfachung energiereicher Femtosekunden-Ti:Sa-Strahlung — •Nikodem Balinski[1,2], Emilia Schulz[1,2], Daniel S. Steingrube[1,2], Heiko Kurz[1,2], Tobias Vockerodt[1,2], Uwe Morgner[1,2] und Milutin Kovacev[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]QUEST

Die Existenz leistungsstarker XUV-Strahlungsquellen ist ein vielversprechender Ausgangspunkt für die effiziente Erzeugung hochintensiver Attosekundenpulse, als auch für das Vordringen in den tiefen XUV-Bereich mittels Erzeugung hoher harmonischer Strahlung (HHG).

Systeme, welche kohärente VUV-Strahlung (< 100 nm) direkt zur Verfügung stellen würden, sind nicht verfügbar. Indiekte Quellen, z.B. über HHG, liefern nur geringe Pulsenergien.

Durch Frequenzverdreifachung (THG) der Laserstrahlung eines KrF-Systems (248.4 nm) in einem Argonjet konnten Effizienzen bis zu 1.5% erreicht werden (Appl. Phys. B **75**, 629 (2002)). Unser Ziel ist es unter Einsatz eines Femtosekunden-Ti:Sa-Lasers bei der Zentrallwellenlänge von 790 nm, eine Leistungsstarke XUV-Strahlungsquelle zu erzeugen. Das von uns verwendete System liefert Pulse mit Dauern von 100 fs bei einer Energie von 300 mJ und 10 Hz Repetitionsrsate.

Über Frequenzverdopplung und Summenfrequenzmischung in KDP-Kristallen wird die Ti:Sa-Strahlung ins VUV konvertiert (263.3 nm, bis zu 100 mJ) um anschließend über THG in einer semi-infiniten Argon-Gaszelle möglichst effizient in 87.8 nm umgewandelt zu werden.

Q 30: Poster II

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

Q 30.1 Di 16:30 VMP 9 Poster

Transport of Bogoliubov excitations in correlated disorder — Christopher Gaul, Nina Renner, and •Cord Axel Müller — Physikalisches Institut, Universität Bayreuth, Deutschland

We investigate the dynamics of an interacting BEC in presence of an external disorder potential by considering its Bogoliubov excitations. The effective disorder-averaged Bogoliubov dispersion relation is calculated via the self-energy of the impurity-scattering Hamiltonian derived recently in [1]. We find that the excitation life time is determined by elastic scattering events, whereas corrections to the speed of sound are due to virtual excitations by inelastic scattering and pair creation/annihilation processes. We explore a variety of regimes by varying the finite disorder correlation length as compared to the excitation wave-length and condensate healing length and confront our predictions with numerical simulations.

[1] Gaul and Müller, Europhys. Lett. **83**, 10006 (2008)

Q 30.2 Di 16:30 VMP 9 Poster

Emergence of mesoscopic entanglement for a Bose-Einstein condensate in a double well with time-dependent potential differences — •Bettina Gertjerenken, Stephan Arlinghaus, Niklas Teichmann, and Christoph Weiss — Institut für Physik, Carl von Ossietzky Universität, D-26111 Oldenburg, Germany

We explore the relation between mean-field chaos and multi-particle entanglement for a Bose-Einstein condensate in a periodically shaken double well [1]. The entanglement-flag used to identify mesoscopic entenglement is the quantum Fisher information.

[1] Phys. Rev. Lett. 100, 140408 (2008).

Q 30.3 Di 16:30 VMP 9 Poster

Phase fluctuations in one-dimensional quasi-condensates on an atom chip — •Thomas Betz, Robert Bücker, Christian Koller, Stephanie Manz, Wolfgang Rohringer, Aurélien Perrin, Thorsten Schumm, and Jörg Schmiedmayer — Atominstitut - Technische Universität Wien, Stadionallee 2, A-1020 Vienna, Österreich

The intrinsic elongated geometry of wire traps on an atom chip provides direct access to ultra-cold one-dimensional systems. In contrast to the three-dimensional case, one- dimensional ultra-cold Bose gases do not exhibit long-range order. The respective phase fluctuations are observed in interference experiments with split one-dimensional Bose-Einstein condensates, using radio-frequency induced double well potentials [1,2], or by directly observing density modulations in time-of-flight images [3]. Studying the spectrum of these modulations after a ballistic expansion of the atomic cloud allows to compare our system to the predictions of theory.

[1] T. Schumm et al., Nature Phys. 1, 57 (2005) [2] G.-B. Jo et al., PRL 99, 240406 (2007) [3] D. Hellweg et al., Appl. Phys. B 73 781 (2001)

Q 30.4 Di 16:30 VMP 9 Poster

Time-normally ordered correlation functions in the Wigner representation — •Bettina Berg[1], Lev I. Plimak[1], Anatoli Polkovnikov[2], Murray K. Olsen[3], Michael Fleischhauer[4], and Wolfgang P. Schleich[1] — [1]Institute of Quantum Physics, Ulm University, Germany — [2]Department of Physics, Boston University, USA — [3]ARC Centre of Excellence for Quantum-Atom Optics, University of Queensland, Australia — [4]Fachbereich Physik, Technische Universität Kaiserslautern, Germany

Applicability of the so-called truncated Wigner approximation ($-W$) [1] is extended to multitime averages of Heisenberg field operators.

We develop a path-integral approach in phase-space based on the symmetric operator ordering. This results in a new class of averages of the Heisenberg operators which we call time-symmetric. The $-W$ emerges as an approximation within this path-integral approach.

Furthermore, we show how the time-symmetric averages calculated by $-W$ can be converted to the time-normal order by relating commutators of Heisenberg operators to response of the system. For two-time commutators, this is nothing but Kubo's renowned formula for the linear response function [2]. The latter can be easily calculated numerically by introducing "quantum jumps" into phase-space trajectories [3].

[1] M. J. Werner, P. D. Drummond, J. Comput. Phys. **132**, 312 (1997). [2] R. Kubo, *Lectures in Theoretical Physics, v. 1* (Wiley, New York, 1959). [3] M.K. Olsen et al., Phys. Rev. **A62**, 023802, (2000); A. Polkovnikov, Phys. Rev. **A68**, 053604 (2003).

Q 30.5 Di 16:30 VMP 9 Poster

Atom-optics and matter wave dynamics in optical dipole potentials — •Johannes Küber, Thomas Lauber, Oliver Wille, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

In our experiment we aim to study and exploit the matter wave properties of Bose-Einstein condensates. We generate a BEC of Rb atoms by using a fiber laser at 1070nm to create a crossed dipole potential and cool evaporatively to quantum degeneracy. This approach gives us flexibility and independence of the magnetic properties of our atoms.

In our ongoing experiments, we aim to load ultra-cold atoms and BECs into optical waveguides and trapping potentials. We use miniaturized lens structures including microlens arrays, cylindrical lenses, and ring lenses illuminated by a red detuned laser. After coherent splitting and transport can be achieved it is possible to create integrated atom interferometers.

We also want to investigate the dynamics of wave packets in guiding potentials and superimposed one-dimensional geometries like optical lattices or Fabry-Perot structures. Our setup allows to implement these structures either by using standing waves or micro-lens structures.

Q 30.6 Di 16:30 VMP 9 Poster

Towards the realization of an atomic erbium quantum gas — •Jörg Drückhammer, Riad Bourouis, and Martin Weitz — Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, 53115 Bonn, Germany

The erbium atom in its $^3H_6$ electronic ground state possesses a large orbital angular momentum of $L = 5$. All so far realized quantum gases consist of atoms with an S-ground state configuration, so that in laser fields with detuning above the upper state fine structure splitting the optical dipole trapping potential is determined by the scalar electronic polarizability. In contrast, for an erbium quantum gas (with $L > 0$) the trapping potential also for far detuned dissipation-less trapping laser fields would become dependent on the internal atomic state (spin). Moreover, Raman transitions between different ground state spin pro-

jections then 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 [1]. This has prospects for novel quantum phase transitions in e.g. strongly correlated frustrated lattice configurations.
We present here experimental work aimed at laser cooling [2] and dipole trapping of atomic erbium, which should then allow for evaporative cooling towards quantum degeneracy by all-optical means. The current status of the experimental setup will be summarized.

[1]T. Salger, C. Geckeler, S. Kling und M. Weitz, PRL **99**, 190405(2007)
[2]J. J. McClelland and J.L. Hanssen, PRL **96** , 143005(2006)

Q 30.7 Di 16:30 VMP 9 Poster

Towards the observation of second sound in a strongly interacting Fermi gas — •Edmundo R. Sánchez Guajardo[1,2], Christoph Kohstall[1,2], Stefan Riedl[1,2], Leonid Sidorenkov[1], Johannes Hecker Denschlag[1], and Rudolf Grimm[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, 6020 Innsbruck, Österreich — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, 6020 Innsbruck, Österreich

Second sound is predicted to occur when two coexisting hydrodynamic fluids, one of them a superfluid, oscillate out of phase with respect to each other. In a strongly interacting Fermi gas such a system is realized close to a Feshbach resonance, where both the superfluid and the normal states are hydrodynamic. The low-lying collective modes previously studied in this Fermi gas correspond to in-phase oscillations of the two fluids. We discuss possible scenarios to excite and detect out-of-phase oscillations and thus to probe phenomena related to second sound.

Q 30.8 Di 16:30 VMP 9 Poster

Mixtures of ultracold fermionic atoms in low dimensions — •Armin Ridinger, Thomas Salez, Saptarishi Chaudhuri, Ulrich Eismann, David Wilkowski, Frédéric Chevy, and Christophe Salomon — Laboratoire Kastler Brossel, Ecole Normale Supérieure, Université Pierre et Marie-Curie-Paris 6, 24 rue Lhomond, CNRS, F-75231 Paris Cedex 05, France

We present the design of our new apparatus for creating cold mixtures of 40K and 6Li fermions with which we intend to study condensed matter physics phenomena. Our apparatus will allow us to simulate several Hamiltonians describing intereracting many-body fermionic systems in one, two and three dimensions. We report on the initial performances of our subsystems including a 2D MOT source of Potassium atoms, a Zeeman slowed Lithium beam, and a dual species magneto-optical trap. We are now working on the magnetic transport towards the science chamber where we intend to evaporate the mixture to quantum degeneracy in an optically plugged quadrupole trap. In this chamber with large optical access periodic potentials will be realized using optical lattices and a high resolution imaging system will be installed. We further report on the constuction of a solid-state laser source for Lithium in the one Watt power range suitable for laser cooling of Lithium.

Q 30.9 Di 16:30 VMP 9 Poster

Quantum Dynamics of Spin 1 Bosons in SMA — •Jannes Heinze[1], Frank Deuretzbacher[1,2], and Daniela Pfannkuche[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Germany — [2]Mathematical Physics, Lund Institute of Technology, Sweden

We investigate the dynamics of $f = 1$ spinor condensates using the fully quantum mechanical single-mode-approximation (SMA) model by Law et al. [PRL **81**, 5257], including the quadratic Zeeman effect. This model was used by Widera et al. [PRL **96**, 190405] to describe their measurements for two atoms. In this contribution, we present exact analytical results and numerical calculations for larger particle numbers N and thereby identify effects due to many-particle correlations. We discuss the behavior for different initial states and magnetic fields. For the fully stretched state where all atoms are aligned in the x-direction, we find a novel beat note phenomenon at large magnetic fields, which should be observable in experiments for small particle numbers larger than two. This beat note is a clear sign of genuine many-particle correlations. Starting from exact analytical results as well as numerical simulations of the quantum dynamics for large particle numbers, we discuss the mean field limit. The quantum dynamics are shown to converge toward the SMA mean field solution in the thermodynamic limit. That is, the many-particle correlations disappear for $N \to \infty$ and N/V constant, where V is the volume of the system. Therefore we are able to make predictions about corrections to the mean field solutions due to finite particle numbers.

Q 30.10 Di 16:30 VMP 9 Poster

Spectroscopy of BECs in Triangular Lattices — •Julian Struck, Parvis Soltan-Panahi, Georg Meineke, Christoph Becker, and Klaus Sengstock — Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Ultracold atoms in optical lattices provide unique access to controllable many-body-systems, reaching from the weakly-interacting to the strongly-correlated regime. We have realized an experimental setup for the generation of a two-dimensional lattice with a non-square symmetry through the use of a three beam lattice. By changing the polarization of the lattice beams two different lattice types can be realized: a spin-independent triangular lattice and an spin dependent hexagonal lattice.
A one dimensional standing-wave lattice perpendicular to the two-dimensional lattice can be used to realize a three-dimensional periodic confinement.
Furthermore, our experimental setup allows control over the internal degrees of freedom in the hyperfine ground manifold of ^{87}Rb. Thus we are able to study the dynamics of spinor condensates in the lattice.
Here we present the latest ideas and measurements at our experiment with special emphasize on spectroscopy methods for the detection and identification of e.g. ground state phases or number occupation on lattice sites, as well as spin dynamics on optical lattices.

Q 30.11 Di 16:30 VMP 9 Poster

Non-Abelian gauge field induced phase fluctuations in low-dimensional quantum gases — •Frank Zimmer[1], Andreas Jacob[2], Michael Merkl[1], Luis Santos[2], and Patrik Öhberg[1] — [1]SUPA, School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh, EH14 4AS, United Kingdom — [2]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, D-30167, Hannover, Germany

Phase fluctuations of ultra-cold quantum gases have been intensively investigated in recent years mainly because of their implications on applications such as matter wave interferometers, chip-based wave guides or atom laser beams. In addition their occurrence can also be used for more fundamental applications such a thermometry.

In this work we study a spinor gas subject to an optically induced non-Abelian gauge potential, and its influence on the low-energy elementary excitations. Based on this we discuss for different spatial dimensions their impact on the observable phase fluctuations.

Q 30.12 Di 16:30 VMP 9 Poster

Towards single site addressability in optical lattices — •Manuel Endres, Christof Weitenberg, Jacob Sherson, Jan Petersen, Immanuel Bloch, and Stefan Kuhr — Institut für Physik, Universität Mainz

The investigation of ultracold quantum gases in optical lattices is usually limited to global properties of the system. By contrast we are developing experimental techniques revealing the local distribution of the trapped gas. The main part of the experiment is an optical imaging system with a spatial resolution smaller than the lattice spacing of a near infrared optical lattice.

The preparation of the quantum gas begins with a 2D$^+$-MOT as a source of cold atoms. After precooling the atoms in a 3D-MOT, they are transferred to a magnetic quadrupole trap and further cooled with rf-evaporation. Making use of an optical tweezer, the cold atom cloud is transported and loaded into a 3D optical lattice in front of the ultra-high resolution imaging system.

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 qubit rotations or perturbations of the many-body system on a local scale. In general the experimental setup will open new possibilities for the investigation and manipulation of strongly correlated atomic systems for quantum simulation and quantum information processing.

Q 30.13 Di 16:30 VMP 9 Poster

Fermionic Atoms in Optical Lattices — •Victor Bezerra[1], Flavio S. Nogueira[1], and Axel Pelster[1,2] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195

Berlin, Germany — [2]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

We investigate an interacting two-component Fermi gas in an optical lattice. To this end we analyze the underlying Hubbard Hamiltonian with an additional term which breaks explicitly the U(1) symmetry. Within a strong-coupling expansion, where the hopping energy is considered to be smaller than the interaction energy, we determine the phase diagram both at zero and at finite temperature. It turns out that our theory interpolates between the Mott insulating state with an unbroken and a BCS-like state with a broken U(1) symmetry. We point out applications for future experiments and the relevance of our results for the BEC-BCS crossover in optical lattices.

Q 30.14 Di 16:30 VMP 9 Poster

Fermionic quantum gases with tunable interactions in optical lattices — •Ulrich Schneider, Lucia Hackermüller, Thorsten Best, Sebastian Will, Simon Braun, and Immanuel Bloch — Johannes Gutenberg-Universität Mainz

Mixtures of ultracold fermionic atoms in optical lattices can serve as a tool to test theoretical models of condensed matter physics, a prominent example being the Fermi-Hubbard-Hamiltonian. A Feshbach resonance can be used to control the interaction between the atoms and allows us to explore both the repulsive and the attractive side of the Hubbard model.

In the experiment we sympathetically cool ^{87}Rb and ^{40}K in an optically plugged quadrupole trap followed by an optical dipole trap and reach temperatures of 0.15 T/T_F for a ^{40}K spin mixture in F=9/2: m_F=-9/2 and m_F=-7/2. The combination of a blue-detuned optical lattice with a red-detuned dipole trap enables us to vary the trapping potential and the lattice depth independently, thereby giving us direct control over the central filling factor.

For repulsive interactions we show how the system evolves from compressible, metallic states to Mott-insulating and finally band-insulating states for increasing harmonic confinements. In the case of attractive interactions we observe a counter-intuitive increase in cloud size for strong interactions, which can be explained by a strong decrease of the entropy capacity. In addition, we present new measurements of the formation dynamics and mobility of doublons in the optical lattice.

Q 30.15 Di 16:30 VMP 9 Poster

Quantum Transport of Atoms in Fourier-Synthesized Optical Lattices — •Sebastian Kling[1], Tobias Salger[1], Luis Morales-Molina[2], Carsten Geckeler[1], Tim Hecking[1], and Martin Weitz[1] — [1]Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn, Germany — [2]Department of Physics, National University of Singapore, 2 Science Drive 3, Singapore 117542

We report on experimental results on quantum transport of Bose-Einstein condensates in periodic optical potentials of variable spatial symmetry. We have studied the band structure of the Fourier-Synthesized lattices by means of Landau-Zener transitions and Bloch oscillations. More recently, we have investigated quantum transport in driven optical potentials to yield a Hamiltonian (i.e. within the interaction time dissipation-free) quantum ratchet.
To realize such lattice potentials of variable spatial symmetry, we superimpose a conventional standing wave of $\lambda/2$ spatial periodicity with a fourth-order optical potential of $\lambda/4$ spatial periodicity. The latter is generated using the dispersive properties of multiphoton Raman transitions.

Q 30.16 Di 16:30 VMP 9 Poster

Combining a magnetic Feshbach resonance with an optical bound-to-bound transition — •Christoph Vo, Dominik Bauer, Matthias Lettner, Gerhard Rempe, and Stephan Dürr — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany

We use optical coupling between bound molecular states to control the properties of a magnetic Feshbach resonance in ^{87}Rb. For far detuned light the coupling causes an ac-Stark shift of the molecular states. This shifts the position of the magnetic Feshbach resonance which couples an incoming atomic state to the ground state of the optical transition. In this way we can shift the resonance away from 1007.4 G by $\sim$0.5 G, which is more than the width of the resonance. Application of the light can change the scattering length by an amount comparable to the background value. The light induces two-body loss with a rate coefficient of $\sim 10^{-12}$cm^3/s, which is much less than for an optical Feshbach resonance.

With the light close to resonance we observe an Autler-Townes doublet which is probed by the magnetic Feshbach resonance. We measure the two-body loss coefficient as a function of magnetic field for different optical detunings to obtain the transition frequency, the transition dipole matrix element, the excited state's magnetic moment and its lifetime.

Q 30.17 Di 16:30 VMP 9 Poster

Microwave near-field potentials for the generation of many-particle entanglement in a Bose gas — •Max Fabian Riedel, Pascal Böhi, Theodor Wolfgang Hänsch, and Philipp Treutlein — Max-Planck-Institut für Quantenoptik und LMU München

We report an experiment on the coherent manipulation of small Bose-Einstein condensates with state-selective potentials generated by on-chip microwave near-fields. We characterize the microwave near-field distribution on the μm scale and show how we use the potentials to entangle atomic spin and motional state of a BEC in a controlled and reversible way. This is the key ingredient for a quantum phase gate previously proposed in [1].

Beyond quantum information processing, our system is ideally suited to tune inter-species vs. intra-species interactions in a two-component Bose gas by controlling wave function overlap. This can be utilized to generate squeezing and many-particle entanglement in BECs [2]. We report on the progress of experiments investigating this possibility further.

[1] P. Treutlein, T. W. Hänsch, J. Reichel, A. Negretti, M. A. Cirone, and T. Calarco, Phys. Rev. A **74**, 022312 (2006)

[2] Y. Li, P. Treutlein, J. Reichel, A. Sinatra, arXiv:0807.1580 (2008)

Q 30.18 Di 16:30 VMP 9 Poster

Towards Continuous Loading of an Optical Dipole Trap with Magnetically Guided Ultra Cold Atoms — •Anoush Aghajani-Talesh, Markus Falkenau, Peter Christian, Axel Griesmaier, and Tilman Pfau — Universität Stuttgart, 5. Physikalisches Institut

Using a Cr BEC the first dipolar quantum gas was investigated recently [1]. So far, however, chromium experiments suffer from low atom numbers below 10^5 in a single BEC. To substantially improve this number, we develop a novel loading scheme for an optical dipole trap (ODT) using a magnetic guide as source of cold atoms. In this poster we present the status of our experiment: our system is capable of producing a flux of $6.3 \cdot 10^9$ guided atoms/s. To load the ODT, which is formed by a 300 W fiber laser, from this flux, a dissipative process in the ODT region is required. This can be implemented by combining a magnetic field barrier with optical pumping in the trap region. This continuous loading process was studied numerically. Our calculations show, that further reducing the transverse temperature of the guided atoms from currently 1.5 mK can appreciably enhance the ODT loading efficiency. Currently, the feasibility of transverse Doppler cooling in a compressed region in the guide is investigated experimentally.

[1] Lahaye et al., Nature **448** , 672 (2007)

Q 30.19 Di 16:30 VMP 9 Poster

Miniaturized Microwave Paul Trap for Electron Guiding — •Johannes Hoffrogge, Markus Schenk, Michael Krüger, and Peter Hommelhoff — Max-Planck-Institut für Quantenoptik, Garching bei München, Germany

We present numerical modelling results on an experiment aiming at guiding electrons in an AC quadrupole guide. In order to stably and tightly confine electrons in the transverse direction the guide has to be miniaturized and operated at microwave frequencies. Therefore, we plan to combine a microfabricated microwave guiding structure with the electrode layout of a planar two-dimensional Paul-trap on a chip substrate. With electrons emerging from a high brightness single atom tip direct injection into the transverse ground state of the guide should be feasible. This would lead to a well-defined motional quantum system with potential applications in interferometry and quantum information processing. Numerical simulations on the electrode design as well as first microwave tests of prototype structures will be presented.
We also discuss first steps towards the realization of a novel scheme to accelerate electrons with a laser field in a transparent grating structure.

Q 30.20 Di 16:30 VMP 9 Poster

A planar segmented Ion Trap with a Y-Junction — •A. Bautista-Salvador, M. Hettrich, S. A. Schulz, U. Poschinger, F. Ziesel, M. Deiss, G. Huber, R. Reichle, and F. Schmidt-Kaler — Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein Allee 11, D-89077 Ulm

We present a novel planar segmented trapping structure for single or few ions for applications in Quantum Information. The key feature of this trap is a loading zone, which is connected to a Y - junction. Thus, the ion may be shuttled in a controlled way either to the right or to the left arm by using the 58 individually addressable dc-electrodes, which was not possible with planar trapping devices so far [1,2]. We expect complex interaction sequences e.g. the interchange of two ions to be possible in our device. We discuss the geometry and fabrication of the trap electrode structure, where our method allows the inter-electrode gaps are as small as 1.2 to 4.0 μm. We report the electrical tests of the device and its operation with a single ion.

[1] S. Seidelin et. al., Phys. Rev. Lett. **96**, 253003 (2006)
[2] J. Labaziewicz et.al., Phys. Rev. Lett. **100**, 013001 (2008)

Q 30.21 Di 16:30 VMP 9 Poster

A two-colour dipole trap for neutral Caesium atoms based on ultra-thin optical fibres — •Daniel Reitz, Eugen Vetsch, Guillem Sagué, Regine Schmidt, and Arno Rauschenbeutel — Abteilung QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz

We present our experimental setup which allows us to trap more than 10^3 cold neutral Caesium atoms close to the surface of an ultra-thin optical fibre for about 50 ms. The atoms are first captured by a standard three dimensional magneto-optical-trap and then directly loaded into our two-colour dipole trap, which is created by the evanescent fields of two laser beams co-propagating through the fibre. The trap lasers at 1064 nm and 780 nm are far detuned and have a total power of about 40 mW, resulting in trapping potential of a few hundred μK. In order to detect the atoms in the trap, we measure the transmission of a weak resonant probe beam of 1 pW launched through the fibre. Each atom absorbs a few percent of this probe beam via evanescent field coupling so that the overall ensemble of atoms is optically dense for the probe. This paves the way towards the realisation of fibre-coupled atom-light-interfaces for quantum communication applications.

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

Q 30.22 Di 16:30 VMP 9 Poster

High resolution imaging of an ultracold quantum gas — •Tatjana Gericke, Peter Würtz, Andreas Koglbauer, and Herwig Ott — Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz

We describe a new 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 with the aid of ion optics and detected.

We produce a ^{87}Rb condensate in a single beam optical dipole trap formed by a focussed CO_2 laser beam. We have 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. Therefor our technique offers a versatile experimental platform for the *in situ* study of ultracold quantum gases in various trapping geometries.

Q 30.23 Di 16:30 VMP 9 Poster

Coherent motional control and interferometry of single atoms in state selective potentials — •Tan Wang, Wolfgang Alt, Jai-Min Choi, Leonid Förster, Michał Karski, Andreas Steffen, Artur Widera, and Dieter Meschede — Institut für Angewandte Physik, Uni Bonn

In our experiment we have achieved full quantum control over single Caesium atoms trapped in a 1D optical lattice, including the position along the lattice axis and the electronic and vibronic states.

We present our implementation for resolved sideband cooling relying on microwave radiation and state selective potentials. Displacing the trapping potentials for two spin states allows to effectively control the Lamb-Dicke parameter in the system and axial cooling to the vibrational ground state. Starting from the ground state, we drive coherent transitions to various vibrational states, where the Rabi-frequency depends on the displacement of the trap potentials. Further, we coherently split the wave function of single trapped atoms and delocalise it over several lattice sites using the spin dependent transport. Recombining the wave functions, we have realised a single trapped atom interferometer.

Our results point to controlled interactions of two neutral Caesium atoms.

Q 30.24 Di 16:30 VMP 9 Poster

Focusing down the beam of a deterministic single ion source to nm resolution — •Robert Fickler, W. Schnitzler, N. M. Linke, F. Schmidt-Kaler, and K. Singer — Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, D-89069 Ulm

We have realized a universal deterministic ultracold ion source on the basis of a segmented linear ion trap [1,2]. For single ion extraction we measured a mean velocity of 19.47km/s with a 1σ-spread of only 6.3m/s and a beam divergence of 600μrad. Due to the small chromatic and spherical aberration it should be possible to focus down this beam to a few nm with a simple einzel-lens [3]. In order to optimize the shape and dimension of the lens we calculated different versions with a custom-made numerical ion-ray-tracing simulation. The realized lens consists of three asymmetric layers, has an aperture of 1mm, a focal length of 10mm and is operated in the accelerating mode. Simulations for a beam with the attributes of the measured data predict a focal spot size in the nm regime and show that it is possible to achieve a spot radius of 1nm with ions cooled to the motional ground state. With our setup targeting the Heisenberg limit we have realized the perfect point source for implanting ions on demand with nm resolution, which e.g. is essential for realizing a scalable quantum computer [4].

[1] J. Meijer et al., Appl. Phys. A**83**, 321 (2006)
[2] J. Meijer et al., Appl. Phys. A**91**, 567 (2008)
[3] K. Shimizu, Jpn. J. Appl. Phys. **22**, 1623 (1983)
[4] F. Jelezko et al., Phys. Rev. Lett. **93**, 130501 (2004)

Q 30.25 Di 16:30 VMP 9 Poster

Quantum Jumps and Continuous Spin Measurement in a Strongly Coupled Atom-Cavity System — Wolfgang Alt, Tobias Kampschulte, Mkrtych Khudaverdyan, Sebastian Reick, •Alexander Thobe, Artur Widera, and Dieter Meschede — Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, 53115 Bonn, Germany

In our experiment, we study the coherent interaction between a predetermined, small number of atoms and the light field inside a high-finesse optical resonator in the strong coupling regime. To this end, we trap caesium atoms in a high-gradient magneto-optical trap and transport them into the center of the resonator mode, using an optical dipole trap [1].

By monitoring the transmission of a probe laser resonant with the cavity, we are able to measure the spin state of a single atom in 2ms without changing it. Continuous observation reveals quantum jumps between the two hyperfine states of caesium. Utilizing this non-destructive detection method, we record the interaction induced normal mode splitting of the atom-cavity system by probing the atomic state. We further demonstrate conditional dynamics of the internal states of multiple atoms, simultaneously coupled to the resonator field. Our non-destructive state detection is the first step towards a quantum non-demolition measurement of the atomic spin as is required for probabilistic atom-atom entanglement schemes.

[1] M. Khudaverdyan et al., New J. Phys. **10**, 073023 (2008).

Q 30.26 Di 16:30 VMP 9 Poster

Adaptive estimation of qudits and entanglement — •Christof Happ and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069, Germany

We discuss adaptive methods for estimating an unknown pure d-level-state (qu$d$it), of which only a limited amount of copies is available. Using information from previous measurements, the adpation steps construct measurement bases for further measurements, which improve the estimation quality more than further measurements in fixed or random directions. We present Monte-Carlo simulation results for complete reconstruction of the state (for various d) and for the entanglement (measured by concurrence) of two qubits ($d = 4$).

Q 30.27 Di 16:30 VMP 9 Poster

Quantisation of the electromagnetic field based on the Wheeler wave functional — •Daniela Denot, Lev Plimak, and Wolfgang P. Schleich — Institute of Quantum Physics, Ulm University, Ulm, Germany

We develop an approach to the quantisation of the electromagnetic field based on the concept of Wheeler's wave functional [1].

Wheeler himself introduced a wave functional for the vacuum state. A single-photon state was considered by Bialynicki-Birula [2].

Building on the work by Bialynicki-Birula we construct a full-fledged quantisation approach based on the concept of wave functionals, by introducing the coherent-state wave functionals and phase-space shift. We also consider quantum dynamics in the Wheeler representation.

[1] C. W. Misner, K. S. Thorne, and J. A. Wheeler, Gravitation, W. H. Freeman and Company, New York (1973).
[2] I. Bialynicki-Birula, Optics Communications, **179**, 5 (2000).

Q 30.28 Di 16:30 VMP 9 Poster

Nonlocal realistic theories and continuous quantum systems — •Anna Hauber und Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

Recently [1], a certain class of non-local, realistic theories (NLRT) has been formulated for two-particle systems with dichotomic observables and has been shown to be incompatible with quantum mechanics and with experimental data [2,3]. The proof uses inequalities for correlation functions, as in the original Bell case. We study how to expand the formulation to systems with continuous variables and demonstrate how such systems can violate the predictions of the NLRT. Moreover, we analyze how violations of the NLRT-inequalities are related to violations of Bell-type inequalities.

[1] A.J. Leggett, Found.Phys. **33** (2003), 1469
[2] S. Gröblacher et al., Nature **446** (2007), 871
[3] C. Branciard et al., Phys. Rev. Lett. **99** (2007), 210407

Q 30.29 Di 16:30 VMP 9 Poster

True Quantum Dephasing — •Julius Helm and Walter T. Strunz — Institut für Theoretische Physik, TU Dresden, 01062 Dresden

Doubly Stochastic channels (channels that are trace preserving and unital – i.e., mapping the identity onto itself) can be distinct into two different classes. On the one hand there are the random unitary processes, which may always be written as a convex sum of unitary transformations, also known as random external fields [1]. On the other hand, and in contrast to the classical analogue, there exist doubly stochastic channels that do not allow for this representation [2]. In the context of quantum error correction this distinction obtains some practical significance, for it was shown that errors can be fully corrected if and only if they belong to the class of random unitary channels [3].

A simple yet crucial example of doubly stochastic channels are dephasing channels, characterized by their diagonal Kraus representation (according to a fixed basis). We study the notion of random unitarity in this context. Here we are able to give physical examples of "true quantum" dephasing channels, that is, channels that do not belong to the class of random unitary channels.

[1] R. Alicki and K. Lendi, "Quantum Dynamical Semigroups and Applications", Springer (1987)
[2] L. Landau and R.F. Streater, Lin. Alg. Appl. 193, 107 (1993)
[3] M. Gregoratti and R.F. Werner, J. Mod. Opt. 50, 915 (2002)

Q 30.30 Di 16:30 VMP 9 Poster

Experimental realization of basic quantum algorithms using a 3-qubit register in diamond — •Matthias Steiner[1], Philipp Neumann[1], Johannes Beck[1], Norikazu Mizuochi[2], Florian Rempp[1], Vincent Jacques[1], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]3.Physikalisches Institut, Universität Stuttgart, D-70550 Stuttgart, Germany — [2]Graduate School of Library, Information and Media Studies, University of Tsukuba, 1-2 Kasuga, Tsukuba-City, Ibaraki 305-8550, Japan

One of the major candidates for a potential room temperature quantum processor is the NV center in diamond. Due to the possibility to control and read out single electron and nuclear spins individually spectacular experiments like the creation of multipartite entanglement [1] have been demonstrated recently. Because of the extremely long coherence times the entanglement can be used to perform simple quantum algorithms. Using the nulcear spins of single ^{13}C atoms and the electron spin of the NV-center itself as qubits we show first steps to perform algorithms similar to superdense coding and Deutsch-algorithm under ambient conditions.

[1] P. Neumann et al., *Multipartite Entanglement Among Single Spins in Diamond*, Science, **320,** 1326 (2008)

Q 30.31 Di 16:30 VMP 9 Poster

Towards a two-dimensional lattice of spins — •Christian Schneider[1], Martin Enderlein[1], Thomas Huber[1], Hector Schmitz[1,2], Axel Friedenauer[1], and Tobias Schaetz[1] — [1]Max-Planck-Institut für Quantenoptik — [2]LMU München

One of the state-of-the-art tools to investigate quantum algorithms/simulations is based on ions confined in a linear Paul trap. Recent experiments show that the bulky three-dimensional geometry of standard linear Paul traps can be translated into two-dimensional electrode setups on surfaces (but still being linear Paul traps) [1, 2]. Cryogenic conditions are shown to provide reduced heating rates allowing to further approach the surfaces [3]. A regular two-dimensional array of ions—small enough for sufficient interactions between the ions—could open a great new field of interesting experiments, e. g., the simulation of Quantum Spin Hamiltonians [4, 5], like the Bose-Hubbard model [6], or spin frustrations. Based on the above developments we aim for realizing a surface trap allowing for the confinement of a two-dimensional ion crystal (being equivalent to a lattice of spins). Our first milestone is a proof-of-concept experiment with a 2×2 array of ions at mutual distances of $20\mu m$.

[1] J. Chiaverini et al., Quant. Inf. Comp. **5**, 419, 2005
[2] S. Seidelin et al., Phys. Rev. Lett. **96**, 253003, 2006
[3] J. Labaziewicz et al., Phys. Rev. Lett. **100**, 013001, 2008
[4] D. Porras and J.I. Cirac, Phys. Rev. Lett. **92**, 207901, 2004
[5] A. Friedenauer, H. Schmitz et al., Nat. Phys. **4**, 757, 2008
[6] D. Porras and J.I. Cirac, Phys. Rev. Lett. **93**, 263602, 2004

Q 30.32 Di 16:30 VMP 9 Poster

Security evaluation of a commercial Quantum Key Distribution System — •Carlos H. Wiechers M., Christoffer Wittmann, Dominique Elser, and Gerd Leuchs — Max-Planck-Institut für die Physik des Lichts, Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, Günther-Scharowsky-Str. 1, Bau 24, 91058 Erlangen, Deutschland

Quantum Key Distribution (QKD) systems theoretically guarantee secure communication based on fundamental physical laws. First commercial products have become available during the last years. Practical implementations often deviate from their theoretical models which potentially opens security loopholes. We experimentally tested security aspects of a commercial QKD system. Here we present measurements of the mean photon number and parasitic modulations. Within the measurement error we find no discrepancy from the theoretically expected values.

Q 30.33 Di 16:30 VMP 9 Poster

Quantum Key Distribution with passive selection of decoy states — •Felix Just, Malte Avenhaus, Katiuscia Cassemiro, and Christine Silberhorn — Max-Planck-Research Group Günther-Scharowsky-Straße 1 / Bau 24 D-91058 Erlangen

Quantum Decoy protocols promise an alternative way for secure quantum key distribution (QKD) without the necessity of true single photon sources. In order to implement a decoy QKD scheme we investigate the use of a photon source based on parametric down conversion in a periodically poled KTP waveguide. Our goal is the implementation of a highly non-degenerated downconversion process. For decoy cryptography schemes it is crucial to have detailed information about the photon pair statistics of the source. For this purpose the signal photon should be in a wavelength regime where the detection efficiency is optimal. Hence, Si-APDs are used in a time multiplexing detection setup for efficient estimation of photon number statistics. Since the idler photon is intended for the key distribution via a telecommunication fiber network, the respective wavelength constitutes an obvious choice to minimize transmission losses. This in turn requires detection by an InGaAs-APD. Different grating periods on our waveguide chip provide the opportunity of tuning signal and idler wavelength for optimal detection and transmission.

Q 30.34 Di 16:30 VMP 9 Poster

Quantum Information as Complementary Classical Information — •Joseph M. Renes[1] and Jean-Christian Boileau[2] — [1]TU Darmstadt, Germany — [2]University of Toronto, Canada

Since the breakthrough by Calderbank, Shor, and Steane on the existence of quantum error-correcting codes, an oft-used notion in quantum information theory is that we can treat quantum information essentially as a strange combination of two types of classical information, pertaining to two complementary observables "amplitude" and "phase". Correcting errors afflicting either of these observables is sufficient to restore the quantum information to its original state. However, the central results of quantum information theory established recently, such as the achievable rate of quantum communication over a noisy channel, follow a different approach termed decoupling which has a natural origin in the study of quantum cryptography. We show that the decoupling-based results can be concretely established in the complementary classical information picture. By adopting an information-theoretic approach to complementarity, we are able to construct entanglement distillation protocols which straightforwardly seek to distill amplitude and phase correlations without venturing into decoupling. This gives new and intuitive proofs of both the noisy channel coding theorem and the asymptotic rates of both secret-key distillation and state merging.

Q 30.35 Di 16:30 VMP 9 Poster

Aufbau einer Heralded- Potonenquelle zur Quantum Key Distribution — •Sabine Euler, Mathias Sinther und Thomas Walther — TU Darmstadt, Institut für angewandte Physik, Schlossgartenstraße 7, 64289 Darmstadt

Die Quantenkryptographie bietet im Gegensatz zu herkömmlichen Verschlüsselungsverfahren eine abhörsichere Variante des Schlüsselaustauschs zwischen Sender (Alice) und Empfänger (Bob) einer Nachricht. Wir entwickeln eine Heralded-Photonenquelle als Alice-Modul. Ein periodisch gepolter KTP-Kristall wird bei 405nm gepumpt, durch einen Typ II Parametric Down Conversion Prozess entstehen zueinander senkrecht polarisierte Photonenpaare mit einer Wellenlänge von 810nm. Eines dieser Photonen wird nachgewiesen und dient als Vorbote, das andere wird von Alice entsprechend bekannter Quantenkryptographie-Protokolle präpariert und an Bob geschickt. Der aktuelle Stand des Projekts wird präsentiert.

Q 30.36 Di 16:30 VMP 9 Poster

Quantum Random Number Generator Using Homodyne Detection — •Christian Gabriel[1], Ruifang Dong[1], Christoffer Wittmann[1], Christoph Marquardt[1], Ulrik L. Andersen[1,2], and Gerd Leuchs[1] — [1]MPI für die Physik des Lichts, Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, Günther-Scharowsky-Strasse 1, 91058 Erlangen, Germany — [2]Department of Physics, Technical University of Denmark, Building 309, 2800 Lyngby, Denmark

True random number generators are essential for quantum key distribution systems. We investigate a quantum random number generator using homodyne detection. For this we compare measured data of anti-squeezed, squeezed and coherent beams, and analyze the randomness of the signals with various standardized test suits. In addition, we exploit the continuous variable nature of the states to extract more bits per measurement value than in usually used single photon counting methods.

Q 30.37 Di 16:30 VMP 9 Poster

Quantum Information Processing with Atoms in Arrays of Dipole Potentials — Jens Kruse, Malte Schlosser, Christian Gierl, Christoph Ewen, •Peter Schauss, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schloßgartenstr. 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. In our experiment, we use two-dimensional arrays of optical micro-potentials created by micro-fabricated lens arrays as the architecture for a scalable quantum processor. For the qubit manipulation, we apply coherent Raman coupling to the hyperfine ground states of the trapped ^{85}Rb atoms.
Due to the large lateral separation of neighbouring potential wells our high resolution detection system allows for the determination of atom numbers of separated trap sites.
We demonstrate the versatile site-selective addressability by implementing a liquid crystal display as a spatial light modulator (SLM) in front of a microlens array. By this we control the depth of each potential well separately and produce arbitrary atom distributions. Furthermore we use the SLM to pattern the intensity distribution of our laser field for qubit manipulation and demonstrate the flexible site-specific initialization and coherent manipulation of separated qubits in two-dimensional trap arrays.

Q 30.38 Di 16:30 VMP 9 Poster

Fabrication and characterization of rubidium micro cells — •Thomas Baluktsian[1], Christian Urban[1], Thomas Bublat[2], Harald Kübler[1], Jim Shaffer[3], Robert Löw[1], Harald Giessen[2], and Tilman Pfau[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart Germany — [2]4. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart Germany — [3]The Homer L. Dodge Department of Physics and Astronomy, The University of Oklahoma, Norman, OK, 73019

Small glass cells filled with rubidium vapor are promising candidates for QIP based on a blockade mechanism between Rydberg atoms. In order to realize e.g. single photon sources based on vapor cells, cell dimensions in the order of the length scale of the Rydberg-Rydberg interaction ($\approx 5\ \mu m$) are required.
We present a method how to fabricate spectroscopy micro cells filled with rubidium vapor. In these cells the rubidium vapor is either confined to a 2D (quantum well) or a 1D (quantum wire) geometry. We performed measurements with a confocal microscope on structures ranging from 10 to 100 μm. Two photon excitation (5S → 6D) provides a fluorescence signal that was spectrally analyzed. Wall induced spin changing processes could be identified.

Q 30.39 Di 16:30 VMP 9 Poster

Entanglement distribution between a trapped atom and two photons — •Stephan Ritter, Bernhard Weber, Holger P. Specht, Tobias Müller, Jörg Bochmann, Martin Mücke, David L. Moehring, and Gerhard Rempe — Max-Planck-Institut fü Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

While atoms make an excellent qubit for the storage of quantum states, photons are naturally well suited for the distribution of quantum information. Therefore efficient atom-photon interfaces are an important prerequisite for distributed quantum computing networks.

Here, we report on the implementation of a deterministic entanglement protocol. In a first step, entanglement between a single atom trapped within a high-finesse optical cavity and an emitted photon is created. Subsequently, the atomic quantum state is mapped onto a second photon, allowing for photon-photon entanglement. The entanglement has been verified using both a Bell inequality measurement and full quantum-state tomography [1].

Trapping of the atom within the cavity mode and repeated cooling stages result in an increase in the number of atom-photon entanglement events per atom by a factor of 10^5 compared to previous experiments [2]. In addition, the presence of exactly one atom in the cavity can be detected with greater than 99 % fidelity.

[1] B. Weber *et al.*, arXiv:0811.3612 (2008).
[2] T. Wilk *et al.*, Science **317**, 488 (2007).

Q 30.40 Di 16:30 VMP 9 Poster

Generation of Greenberger-Horne-Zeilinger (GHZ), W, and-cluster states using bimodal cavities — •Denis Gonta[1], Thomas Radtke[2], and Stephan Fritzsche[3] — [1]Max–Planck–Institut für Kernphysik, Postfach103980, D–69029 Heidelberg — [2]Institut für Physik, Universität Kassel,Heinrich-Plett-Str. 40, D-34132 Kassel — [3]Physikalisches Institut der UniversitätHeidelberg, Philosophenweg 12, D-69120 Heidelberg

In the framework of microwave cavity QED, we propose several schemes to engineer the entangled N-partite GHZ and W states [1] as well as the two-dimensional 2×N and 3×N cluster states. These states are produced between a chain of two-level Rydberg atoms in a deterministic way by using the bimodal cavities within the resonant atom-cavity interaction regime. In contrast to standard (single-mode) cavity schemes, such *bimodal* cavities possess two independent modes of the light field. In addition, we suggest some theoretical schemes to reveal the non-classical correlations of the entangled three- and four-partite GHZ and W states in order to ensure that no statistical (i.e. uncorrelated) mixtures of states have been produced. An extension of the scheme to produce two dimensional cluster states of arbitrary size is also possible.

[1] D. Gonta, S. Fritzsche, and T. Radtke, Phys. Rev. A **77**, 062312 (2008).

Q 30.41 Di 16:30 VMP 9 Poster

Kontrollierte Transporte in mikrostrukturierten Ionenfallen — •Frank Ziesel, Ulrich Poschinger, Gerhard Huber, Stephan Schulz, Amado Bautista, Markus Deiss, Kilian Singer und Ferdinand Schmidt-Kaler — Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, D-89069 Ulm

Mikrostrukturierte Paulfallen besitzen eine Vielzahl von separat ansteuerbaren Elektroden und erlauben damit einen frei definierbaren axialen Einschluss von einzelnen Ionen oder Ionenkristallen. Durch die zeitliche Änderung der Kontrollspannungen können Ionen transportiert und Ionenkristalle getrennt werden. Wir untersuchen die Eigenschaften von Mikrofallen in dreidimensionaler [1] und planarer Geometrie [2] in numerischen Simulationen, um den Einschluss von Ionen und deren Transport zu optimieren und vergleichen diese Ergebnisse mit Experimenten in einer 3D und einer 2D Mikro-Ionenfalle. Dort konnten wir die Eigenschaften des Fallenpotentials über den gesamten Transportweg spektroskopisch untersuchen. Die numerischen Simulationen stimmen mit den Messungen bis auf weniger als 2% überein. Von besonderem Interesse sind hierbei Kreuzungen in einer Ionenfalle, ebenso wie Übergänge in geometische Strukturen mit Abmessungen von wenigen μm.

[1] S. Schulz et al., New J. Phys. **10**, 045007 (2008)
[2] R. Reichle et al., Fortschr. Phys. **54**, 666 (2006)

Q 30.42 Di 16:30 VMP 9 Poster

Hocheffiziente cw-Biphotonen-Strahlquellen für die Quantenspektroskopie — •Michael Seefeldt, Andreas Jechow, Axel Heuer und Ralf Menzel — Institut für Physik und Astronomie, Universität Potsdam, Karl-Liebknecht-Straße 24/25, D-14476 Potsdam.

Paare von verschränkten Photonen, sogenannte Biphotonen, zeichnen sich durch nichtklassische Eigenschaften aus. Sie bilden damit die Basis für eine Vielzahl von Experimenten der Quantenoptik. Für die vorgestellten Untersuchungen wurden Biphotonen mit Hilfe der *parametric down-conversion* (PDC) in verschiedenen periodisch gepolten $LiNbO_3$-Kristallen (PPLN) generiert.

Mit der ersten, sehr kompakten Strahlquelle konnten mittels eines frequenzverdoppelten Halbleiterlasers (Anregungswellenlänge 488 nm) in einem PPLN-Wellenleiter Biphotonen in einem räumlichen Mode erzeugt werden. Der maximale Photonenfluss beträgt bei einer Anregungsleistung von 15 mW über 10^{11} Photonenpaare pro Sekunde. Dies entspricht einer Effizienz von $8 \cdot 10^{-6}$. Die Wellenlänge dieser Biphotonenquelle ist in einem Bereich um 976 nm durchstimmbar.

Bei der zweiten Strahlquelle wurde das Anregungslicht eines Ar^+-Lasers (488 nm) in einen Bulk-PPLN eingestrahlt. Es ließen sich $1{,}7{\cdot}10^{11}$ Photonenpaare pro Sekunde mit einer Wellenlänge von 976 nm und einer spektralen Bandbreite von 25 nm nachweisen. Bei einer maximalen Pumpleistung von 100 mW ergibt dies eine Konversions-Effizienz von ca. 10^{-6}.

Es wurden jeweils die spektralen Verläufe, Photonenflüsse sowie Korrelationseigenschaften des erzeugten PDC-Lichts gemessen.

Q 30.43 Di 16:30 VMP 9 Poster

Photon counting with fiber-coupled superconducting single photon detectors — •Gesine Steudle[1], Sander Dorenbos[2], Ingmar Müller[1], Valery Zwiller[2], and Oliver Benson[1] — [1]Humboldt-Universität zu Berlin, AG Nano-Optik, Germany — [2]TU Delft, Kavli Institute of Nanoscience, Netherlands

One of the main challenges of fiber-based single photon devices is the efficient and feasible detection of single photons at telecommunication wavelengths. Especially for quantum communication and quantum cryptography this point is crucial. A promising approach is the use of superconducting single photon detectors. In our case these detectors consist of a small NbN wire which is arranged in a meander. Wires are 5 nm thick and 100 nm wide and the meander area covers $10\mu m \cdot 10\mu m$. To provide optimal coupling to the experimental setup a single mode optical fiber is glued directly on the detector chip. Presently, we archieve system efficiencies of 10% (in the visible). Single photon detection was shown measuring the intensity correlation function of a single photon source. The main advantages of this type of detectors are high count rates of the order of 1 GHz, a time resolution below 100 ps, a low dark cout rate, and reasonable quantum efficiencies in the IR. Furthermore, the fixed fiber coupling provides easy handling of the detector unit.

Q 30.44 Di 16:30 VMP 9 Poster

Phase modulation of single photons — •Eden Figueroa, Jörg Bochmann, David Moehring, Martin Mücke, Christian Nölleke, Stephan Ritter, Holger Specht, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Garching

Recently, photonic sources with the capability to tailor the bandwidth of single photons have been developed. Using either DCLZ schemes in atomic ensembles or atoms trapped in QED cavities the production of long photons (as compared to the detection time) has been achieved. The production of photons with these characteristics enables the high frequency modulation of the photon shape, opening interesting avenues for research [1]. In this work we extend these ideas, by studying the effect of phase modulation in the interference of two photons produced by atoms trapped in a QED cavity. One single photon is sent through a fiber electro-optical modulator, and the result of the applied phase change is studied via its interference with a second un-modulated reference photon. If no modulation is introduced, a Hong-Ou-Mandel behavior is expected. Interestingly, if a phase change is applied within the photon envelope, the coalescence behavior of the interference can be altered. This scheme can be applied in the context of quantum key distribution as proposed by Inoue et al. [2], and might compare favorably to the latter, since intrinsically it does not require phase stability.

[1] P. Kolchin, et al. Phys. Rev. Lett. 101, 103601 (2008)
[2] K. Inoue et al. Phys. Rev. Lett. 89, 037902 (2002)

Q 30.45 Di 16:30 VMP 9 Poster

Generation of Narrow-Band Polarization-Entangled Photon Pairs for Atomic Quantum Memories — •Xiao-Hui Bao[1,2], Yong Qian[1], Jian Yang[1], Han Zhang[1], Zeng-Bing Chen[1], Tao Yang[1,2], and Jian-Wei Pan[1,2] — [1]Hefei National Laboratory for Physical Sciences at Microscale and Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China — [2]Physikalisches Institut der Universitaet Heidelberg, Philosophenweg 12, Heidelberg 69120, Germany

We report an experimental realization of a narrow-band polarization-entangled photon source with a linewidth of 9.6 MHz through cavity-enhanced spontaneous parametric down-conversion. This linewidth is comparable to the typical linewidth of atomic ensemble based quantum memories. Single-mode output is realized by setting a reasonable cavity length difference between different polarizations, using of temperature controlled etalons and actively stabilizing the cavity. The entangled property is characterized with quantum state tomography, giving a fidelity of 94% between our state and a maximally entangled state. The coherence length is directly measured to be 32 m through two-photon interference.

Q 30.46 Di 16:30 VMP 9 Poster

Shaped Single Photons from a Coupled Atom-Cavity System — •David Moehring, Jörg Bochmann, Martin Mücke, Bernhard Weber, Holger Specht, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

We report on the fast excitation and subsequent single photon emission of a single atom trapped and coupled to a high-finesse optical cavity [1]. In contrast to the simple exponential decay governing free-space emission, the coupled atom-cavity system evolves with a coherent oscillatory energy exchange between the atom and the cavity. We record the shape of the emitted single photons and investigate the dependence on detuning of the cavity with respect to the atomic resonance. The observed oscillatory behavior is in excellent agreement with theory and illustrates the fundamentals of cavity quantum electrodynamics at the single particle level. Our technique opens up new perspectives for shaping single-photon wave packets as well as new possibilities for quantum networking experiments.

[1] J. Bochmann et al., Phys. Rev. Lett. 101, 223601 (2008).

Q 30.47 Di 16:30 VMP 9 Poster

Towards Nanoemitters Coupled to Surface Plasmons in Metal Nanostructures — •Thomas Aichele[1], Oliver Benson[1], Nils Nüsse[2], and Bernd Löchel[2] — [1]Humboldt-Universität zu Berlin, Inst. Physik, Nanooptik, Berlin, Germany — [2]Helmholtz-Zentrum Berlin f. Materialien und Energie, Anwenderzentrum f. Mikrotechnik, Berlin, Germany

We discuss and present initial experimental results towards the implementation of individual quantum emitters into surface plasmon (SP) waveguide structures. The SP waveguides are made of metal nanostructures on a dielectric surface using electron beam lithography and lift-off. Nanowire quantum dots and diamond nanocrystals are considered as individual quantum emittes. These systems can be translated across the substrate surface using scanning probe microscopy. They are thus precisely positioned on a nanometer scale relative to the metal nanostructures. In this way, a highly compact single-photon device, integrated in on-chip quantum optics experiments can be realized.

Q 30.48 Di 16:30 VMP 9 Poster

Quantum interference and entanglement in flux qubits — •Keyu Xia, Mihai Macovei, Jörg Evers, and Christoph H. Keitel — MPI für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Superconducting qubits, and in particular flux qubits, are promising candidates for a number of applications in quantum information science. In this work, we discuss different aspects of quantum interference and entanglement in flux qubits.

First, we propose a robust coherent control scheme for the creation of Bell states of two coupled flux qubits via a dynamic control of the qubit transition frequency near their optimal point [1]. Using this technique, an arbitrary superposition of different Bell states composed of the collective ground and excited states can be achieved. The preparation is robust against imperfections in the driving fields.

Secondly, we discuss ground state cooling of a nanomechanical resonator. Our approach is to make use of quantum interference via coupling it to a flux qubit. This flux qubit is modeled as a $\Lambda-$type three-level system, enabling the use of electromagnetically induced transparency to implement the ground state cooling. We find ground state occupations of more than 90% in the steady state. Interestingly, compared to sideband cooling of the resonator, a contribution proportional to the initial phonon number of the nanomechanical resonator is suppressed by a factor of the detuning.

[1] K. Xia, M. Macovei, J. Evers, and C. H. Keitel, arXiv:0810.2453

Q 30.49 Di 16:30 VMP 9 Poster

The Riemann ζ-Function in Phase Space — •Cornelia Feiler, Rüdiger Mack, and Wolfgang P. Schleich — Institute for Quantum Physics, Ulm University

The Riemann hypothesis, a conjecture about the distribution of the so called non-trivial zeros of the Riemann ζ-function, is at the very heart of number theory. The distribution of these zeros 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 propose a new physical approach to the Riemann ζ-function. We consider the states of an harmonic oscillator with a logarithmic coupling to an external field. With an appropriate projection we obtain the values $\zeta(s)$ for $\Re s > 1$. With the help of an entangled system, similar to the Jaynes-Cummings-Model [3], we managed to reach into the critical strip, where the non-trivial zeros of the ζ-function are expected to be.

[1] E. C. Titchmarsh. *The Theory of the Riemann Zeta-Function.* Oxford, Charlendon Press, 1967.
[2] Wolfgang P. Schleich. *Quantum Optics in Phase Space.* Wiley-VCH Verlag, Berlin, 2001.

Q 30.50 Di 16:30 VMP 9 Poster

Raman spectroscopy of a single ion coupled to a high-finesse optical cavity — •Andreas Stute[1,2], Helena G. Barros[1,2], Tracy Northup[1], Carlos Russo[1], Piet O. Schmidt[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, A-6020 Innsbruck — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, A-6020 Innsbruck

We describe an ion-based cavity-QED system consisting of a single trapped $^{40}Ca^{+}$ ion coupled to the mode of a high-finesse optical resonator. Intra-cavity photons are generated in a vacuum-stimulated Raman process between two atomic states driven by a laser and the cavity vacuum field. We observe Raman spectra for different excitation polarizations and find quantitative agreement with theoretical simulations. We can resolve motional sidebands in the Raman spectrum due to the residual motion of the Doppler-cooled ion, which also leads to ion delocalization with respect to the standing wave of the catvity mode. The detection of the photons leaving the cavity through one of the mirrors in a Hanbury Brown and Twiss setup allows the measurement of light intensity and its correlations $g^{(2)}(\tau)$. For a pulsed excitation the $g^{(2)}(\tau)$ reveals the signature of a single photon source, whereas for continuous excitation we can tune the photon statistics from sub-Poissonian to super-Poissonian statistics. This system offers prospects for cavity-assisted resolved-sideband ground-state cooling and coherent manipulation of ions and photons.

Q 30.51 Di 16:30 VMP 9 Poster

Development of a cold atom cavity quantum electrodynamics experiment using tunable bottle microresonators — •Danny O'Shea, Alexander Rettenmaier, and Arno Rauschenbeutel — Abteilung QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz

We recently developed a novel type of whispering gallery mode resonator that confines light by a mechanism similar to the confinement of electrons or ions in a magnetic bottle. Our "bottle resonators"confine light in mode volumes measuring as small as 1000-1500 μm^3 and can store light for up to $\sim$ 160 ns. This corresponds to a quality factor of 3.6×10^8 at caesium or rubidium wavelengths. Calculations indicate an atom-field coupling rate deep within the so-called strong coupling regime. In contrast to other monolithic structures, such as photonic crystals and microtori, our bottle resonators can be tuned to any desired atomic transition, making them much more amenable to quantum optics experiments. We set up an apparatus to deliver cold rubidium atoms to the location of the bottle resonator 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.

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

Q 30.52 Di 16:30 VMP 9 Poster

Role of entanglement in open system dynamics — •Ansgar Pernice and Walter Strunz — Institut für Theoretische Physik, TU Dresden

When two previously independent quantum systems interact, the total state will almost always become entangled. We expect this to be true also for "open" quantum systems that interact weakly with their "heat baths": system and environment become entangled. Nevertheless, it is interesting to note that the usual description of (Markovian) open quantum system dynamics in quantum optics, solid state or chemical physics rests on an assumption of separability of the total state. Moreover, most instances of decoherence – despite the usual parlance that it results from entanglement – may perfectly be understood without entanglement. In this project we want to investigate in more detail the role of system-environment entanglement in quantum optical and solid state devices, where the heat bath is provided by either light or phonon modes. The influence of temperature and the nature of the presumably oberserved entanglement (bound or free) will be of particular interest.

Q 30.53 Di 16:30 VMP 9 Poster

Collisional-induced emergence of a pointer basis — •Marc Busse and Klaus Hornberger — Arnold Sommerfeld Center for Theoretical Physics, Ludwigs-Maximilians-Universität München

The influence of environmental degrees of freedom on a quantum system typically leads to a super-selection of a specific set of robust system states, called pointer states. Most characteristically, any superposition of these states gets rapidly mixed, while the only stable states are the pointer states themselves.

By using a specific unravelling of the master equation of collisional decoherence [1], we study the emergence and dynamics of pointer states in the motion of a quantum test particle in a gas environment. We demonstrate that the complete set of pointer states is obtained by the solitonic solutions of the nonlinear equation corresponding to the deterministic part of the orthogonal unravelling [2]. They move according to the corresponding classical equations of motion. In contrast to linear coupling models, the pointer basis turns out to be non-Gaussian, with a width determined by both the mean free path and the thermal de-Broglie wavelength of the gas environment. By analyzing the jump statistics of the orthogonal unravelling we further derive the statistical weights of the pointer states in the decohered ensemble, which are found to be given by their overlap with the initial state.

[1] K. Hornberger et. al., Phys. Rev. A 70, 053608 (2004).
[2] L. Diosi, Phys. Lett. 114A, 451 (1986).

Q 30.54 Di 16:30 VMP 9 Poster

Experimental demonstration of spin squeezing on the clock transition — •Patrick Windpassinger, Daniel Oblak, Ulrich Hoff, Jürgen Appel, Niels Kjaergaard, and Eugene S. Polzik — QUANTOP, Niels Bohr Institute, Copenhagen, Denmark

The so-called projection noise of an ensemble of uncorrelated atoms is a current limitation to the precision of atomic clocks. In recent experiments on dipole trapped ensembles of Cs atoms in an equal superposition of the clock states we have observed the quantum projection noise by interrogations using off-resonant probe laser light. Since the dispersive light-atom interaction has a quantum nondemolition measurement character we can use the information gained when applying a probe pulse of light to predict the outcome of a subsequent measurement beyond the standard quantum limit. Hence a reduction or "squeezing" of the population difference is encountered. Since a two-level quantum system is equivalent to a spin 1/2 particle this is referred to a pseudo-spin squeezing. The observation of squeezing implies that the particles in the ensemble are non-classically correlated (entangled). When taking into account decoherence resulting from spontaneously scattered probe photons our experiments show about 3 dB of spectroscopically relevant squeezing (noise reduction).

[1] D. Oblak et al., Phys. Rev. A 71, 043807 (2005)
[2] P. Windpassinger et al, Phys. Rev. Lett. 100, 103601 (2008)
[3] J. Appel et al., arXiv:0810.3545 (2008)

Q 30.55 Di 16:30 VMP 9 Poster

Asymptotic dynamics of random unitary channels — •Jaroslav Novotny[1,2], Gernot Alber[2], and Igor Jex[1] — [1]Department of Physics, FJFI CVUT, Prague, Czech Republic — [2]Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Darmstadt, Germany

We investigate random unitary channels and their asymptotic dynamics under repeated application. It is demonstrated that, despite the fact that random unitary channels are typically not normal, their asymptotic dynamics are determined completely by their eigenspaces associated with eigenvalues of unit modulus. We also investigate first implications of this general result for the asymptotic dynamics of quantum networks consisting of arbitrary numbers of qubits which are coupled by randomly applied controlled-not operations.

Q 30.56 Di 16:30 VMP 9 Poster

Transmission properties of microresonators coupling to multi-level atoms — •Sandra I. Schmid and Jörg Evers — MPI für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Microresonators offer the possibility to achieve strong coupling between atoms and light fields. For example, in [1,2] strong coupling between a toroidal microresonator and a two-level atom was achieved. The light is fed into the resonator via a tapered glass fiber. Internal reflections form pairs of counterpropagating whispering gallery modes inside the resonator. Atoms can be coupled to these circulating fields via the evanescent field component leaking out of the resonator. Such couplings have an influence on the photon flux that leaves the resonator.

Here, we investigate a system where a three-level atom couples to a microresonator. Each of the atomic transitions couples to one pair of modes within the resonator. In this setup, the position dependence and the polarizations of the light fields have to be considered. We are interested in the impact of the atom on the output photon flux. Our observables are photon intensity and spectrum as well as correlations among different photon modes.

[1] B. Dayan et al., Science 319, 1062 (2008)
[2] T. Aoki et al., Nature 443, 671 (2006)

Q 30.57 Di 16:30 VMP 9 Poster

Towards efficient single photon-atom coupling in free space — •Andrea Golla, Robert Maiwald, Simon Heugel, A. S. Villar, Klaus Mantel, Norbert Lindlein, Markus Sondermann, and Gerd Leuchs — Institut für Optik, Information und Photonik (IOIP), Universität Erlangen-Nürnberg, Staudtstr. 7/B2, 91058 Erlangen

Efficient coupling between light and matter is desirable for quantum information applications as well as for fundamental research. Here we report about the progress of our experiment that aims at efficient excitation of a single ion by a single photon in free space. We discuss several important aspects of the experiment which include: the development and testing of an optically highly accessible ion trap, the choice of the ionic species, the generation of the optimum dipolar radiation pattern by use of a parabolic mirror as well as the correction of the interferometrically measured aberrations of a parabolic mirror.

Q 30.58 Di 16:30 VMP 9 Poster

Spatial high-precision measurements in quantum optical systems — •Qurrat- ul-Ain and Jörg Evers — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Accurate measurement of the position of a quantum particle or of distances between quantum particles are a subject of long-standing interest in quantum mechanics. A particular class of schemes to measure interparticle distance on a scale short as compared to the involved light wavelengths is based on dipole-dipole interactions between the particles [1,2]. This interaction affects the optical properties and this can be detected in the optical far field.

Here, we present a scheme for the measurement of the distance between two nearby identical atoms via the collective resonance fluorescence. We are in particular interested in a realistic description requiring as little prior knowledge about the system as possible. In contrast to previous work, we consider four-level atoms with complete Zeeman manifolds. Thus, we take into account the usual dipole-dipole couplings that couple the parallel dipole moments as well as the so far mostly neglected couplings between orthogonal dipole moments in the two atoms [3]. A consequence of including these orthogonal dipole-dipole couplings is that those atomic levels may also be populated which are not driven by laser fields.

[1] C. Hettich et al., Nature 298, 385 (2002).
[2] Jun-Tao Chang, Jörg Evers, Marlan O. Scully, and M. S. Zubairy, Phys. Rev. A 73, 031803(R) (2006).
[3] G. S. Agarwal and A. K. Patnaik, Phys. Rev. A 63, 043805 (2001).

Q 30.59 Di 16:30 VMP 9 Poster

Multiphoton absorption in BTO crystals — •Andrew Matusevich and Vladislav Matusevich — Institute of Applied Optics, Friedrich-Schiller-University, Max-Wien-Platz 1, 07743 Jena, Germany

We present experimental and theoretical investigations of the multiphoton absorption in photorefractive BTO crystals. A model for impurity centers characterized by different lifetimes is proposed to explain the dynamics of the photo-induced absorption. Cw-radiation as well as ns- and ps- pulses at 355nm, 532nm are used to investigate non-linear photoinduced absorption processes and show their bistable behaviour. We suppose that the multiphoton absorption in photorefractive crystals can be used for detection of ultra short pulses.

Q 30.60 Di 16:30 VMP 9 Poster

Fabrication and characterization of photonic structures on ultrathin optical fibers — •Christian Wuttke[1], Angelika Sehrbrock[2], Stephan Irsen[2], and Arno Rauschenbeutel[1] — [1]Abteilung QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz — [2]Forschungszentrum caesar, Labor für Elektronenmikroskopie und Analytik, Ludwig-Erhard-Allee 2, 53175 Bonn

We present experimental results on the fabrication and characterization of photonic structures on ultrathin optical fibers. They are realized from standard optical fibers which are flame heated while simultaneously pulling to produce a waist with a diameter of 500 nm. The photonic structure is then carved out of the ultrathin part of the fiber using focused ion beam milling (FIB). The optical properties are spectrally characterized by transmission and reflection measurements. Our current focus lies on the improvement of the periodicity and the reflectivity of the photonic structures and their use for realizing ultra-low mode-volume optical microresonators.

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

Q 30.61 Di 16:30 VMP 9 Poster

Fabrication and utilization of fiber-based Fabry-Perot resonators in ultra-thin fiber applications — •Andreas Jöckel, Christian Wuttke, and Arno Rauschenbeutel — Abteilung QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz

We present experimental results on the fabrication and utilization of fiber-based Fabry-Perot resonators. The Fabry-Perot fiber resonators are realized by applying dielectric mirrors in the form of so-called transfer coatings to the end facets of standard optical fibers. With these resonators we observe finesses up to 130 in agreement with the mirror reflectivity of about 98%. An ultra-thin fiber part can be integrated into these resonators by flame heating and elongating the fiber yielding waist diameters down to 500 nm and finesses of 50. These resonators can be used to precisely characterize the loss of the tapered section as well as to enhance the sensitivity of spectroscopic techniques which rely on the ultra-thin fiber's evanescent field. In addition, it is possible to create pure higher order beams by using a multi-mode fiber resonator as a transversal mode filter. These higher order beams are useful in various applications including a new type of atom trap based on ultra-thin fibers [1].

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

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

Q 30.62 Di 16:30 VMP 9 Poster

Optimierung eines nichtlinearen optischen Schleifenspiegels zur Amplitudenregeneration — •Tobias Röthlingshöfer[1], Klaus Sponsel[1], Christian Stephan[1], Georgy Onishchukov[1,3], Bernhard Schmauss[2,3] und Gerd Leuchs[1,3] — [1]Max-Planck-Institut für die Physik des Lichts, Institut für Optik, Information und

Photonik, Universität Erlangen-Nürnberg — [2]Optische Hochfrequenztechnik und Photonik, Universität Erlangen-Nürnberg — [3]Erlangen Graduate School in Advanced Optical Technologies (SAOT)

Phasenkodierte Modulationsformate werden in der optischen Datenübertragung zunehmend eingesetzt. Durch nichtlineare Effekte in Übertragungsfasern, wie Selbstphasenmodulation, wird jedoch Amplitudenrauschen in nichtlineares Phasenrauschen umgewandelt und beeinträchtigt so besonders phasenkodierte Signale.

Mit Hilfe eines modifizierten Faser-Sagnac Interferometer, z.B. eines dispersionsunbalancierten Schleifenspiegels, ist die Amplituden-Regeneration von phasenkodierten optischen Datenformaten, wie z.B. differentielle Phasenumtastung möglich. Somit wird die Entstehung nichtlinearen Phasenrauschens bei der Signalausbreitung in Übertragungsfasern unterdrückt, ohne dass die Phasenkodierung der Daten zerstört wird. Mittels numerischer Simulationen wurden verschieden modifizierte Sagnac Interferometer hinsichtlich ihrer Regenerationscharakteristik untersucht und miteinander verglichen.

Q 30.63 Di 16:30 VMP 9 Poster

Observation of double-charge vortex solitons in hexagonal photonic lattices — •Dennis Göries[1], Bernd Terhalle[1], Patrick Rose[1], Tobias Richter[2], Tristram J. Alexander[3], Anton S. Desyatnikov[3], Wieslaw Krolikowski[3], Friedemann Kaiser[2], Yuri S. Kivshar[3], and Cornelia Denz[1] — [1]Institut für Angewandte Physik, Westfälische Wilhelms-Universität Münster, Germany — [2]Institut für Angewandte Physik, Technische Universität Darmstadt, Germany — [3]Nonlinear Physics Center and Laser Physics Center, Research School of Physical Sciences and Engineering, Australian National University, Canberra, ACT 0200, Australia

Wave propagation in periodic nonlinear structures is associated with many exciting novel opportunities of controlling light for future applications in all-optical information processing. A well known example is the existence of discrete self-localized states, e. g. discrete solitons or more complex discrete vortex solitons carrying phase dislocations and transverse energy flows. In this work, we present the experimental observation of stable double-charge ringshaped vortex solitons generated in optically-induced photorefractive photonic lattices, and corroborate our results by numerical simulations using the full anisotropic photorefractive model. We demonstrate that the stability is determined by intersite power exchange, and show that for a focusing nonlinearity single-charge vortices are unstable whereas double-charge vortices are stable . The results are subsequently extended to the case of a defocusing nonlinearity and reveal that in this case the single charge vortex is stable whereas the double-charge vortex is unstable.

Q 30.64 Di 16:30 VMP 9 Poster

Optimizing the excitation of plasmonic waveguide modes by a nanoantenna — •Jing Wen and Peschel Ulf — MPI für die Physik des Lichts, Erlangen, Germany

Plasmonic waveguides can be regarded as key elements of a future optical integration on a sub-wavelength scale. Hence, their coupling to the macroscopic world namely their excitation remains a challenging task. Here we propose to use nanoantennas to achieve that goal. We performed numerical simulations of the excitation of a plasmonic gap waveguide by a dipole antenna, which is attached to it. The coupling efficiency is strongly influenced by the properties of both the antenna and the plasmonic waveguide. For an optimized configuration the coupling efficiency of the antenna-based excitation can be more than 100 times larger than that without antenna. Surprisingly this optimization can to some extend be performed by using arguments from classical microwave theory as e.g. impedance matching.

Q 30.65 Di 16:30 VMP 9 Poster

Characterisation of single nano-structures with highly focused beams — •Sabine Dobmann, Peter Banzer, Ulf Peschel, and Gerd Leuchs — MPI für die Physik des Lichts, IOIP FAU Erlangen

The optical investigation of sub-wavelength nano-structures becomes more and more important since those will form the building blocks of new optical materials. Those so-called metamaterials gain their rather counter-intuitive properties mainly from the excitation of electric and magnetic resonances in the individual nano-structures which form this 'artifical matter'. For the investigation of these resonances we use highly focused polarisation tailored light which provides a non-homogeneous polarisation distribution at a sub-wavelength scale. Pure longitudinal electric or magnetic field components are formed on-axis, depending on the chosen incoming polarisation structure (radial or azimuthal), while transverse electric and magnetic field components persist off-axis. By placing sub-wavelength nano-structures in the beam different coupling scenarios can be achieved. By choosing beams with the respective polarization pattern structures can be selectively exposed either to pure electric or magnetic fields. To characterize the excited resonances of the nano-structures, we measure the forward- and back-scattered intensities and check for the polarisation distribution of the transmitted or reflected far-fields.

Q 31: Laseranwendungen: Optische Messtechnik

Zeit: Mittwoch 14:00–16:00 Raum: Audi-A

Q 31.1 Mi 14:00 Audi-A

Quasi-monolithisches Interferometer zur Untersuchung der Nichtreziprozität einer Glasfaser für Weltraumanwendungen — •Roland Fleddermann, Frank Steier, Christian Diekmann, Gerhard Heinzel und Karsten Danzmann — Albert-Einstein-Institut Hannover, Max-Planck-Institut für Gravitationsphysik und Leibniz Universität Hannover, Callinstr. 38, 30167 Hannover

Die Laser Interferometer Space Antenna (LISA) Mission von ESA und NASA zur Detektion von Gravitationswellen im Frequenzbereich zwischen 0,1 mHz und 1 Hz benötigt Glasfasern zum Austausch von Licht zwischen den beiden optischen Bänken auf jedem der drei Satelliten.

Bei dieser Anwendung kann reziprokes Phasenrauschen subtrahiert werden, nichtreziprokes Phasenrauschen würde die Messgenauigkeit jedoch limitieren. Daher messen wir das fundamentale nichtreziproke Rauschen einer polarisationserhaltenden single-mode Glasfaser, um zu verifizieren, dass diese Rauschquelle die Phasenmessungen bei LISA mit einer Genauigkeit von $1\,\mathrm{pm}/\sqrt{\mathrm{Hz}}$ ($\approx 10\,\mu\mathrm{rad}/\sqrt{\mathrm{Hz}}$ bei 1064 nm) nicht zerstört. Hierzu wurde ein quasi-monolithisches Interferometer, das in seiner Funktionsweise dem Anwendungsfall bei LISA entspricht, auf einer Zerodur© Platte mit einem thermischen Ausdehnungskoeffizienten unter $0,1 \cdot 10^{-6}$/K aufgebaut und charakterisiert.

Mit diesem Aufbau wurde ein Rauschen zwischen $40\,\mu\mathrm{rad}/\sqrt{\mathrm{Hz}}$ und $400\,\mu\mathrm{rad}/\sqrt{\mathrm{Hz}}$ für Frequenzen zwischen 1 mHz und 1 Hz erreicht, welches nicht durch die Faser limitiert ist.

Wir geben eine Übersicht über erste Ergebnisse und über Untersuchungen der externen Einflüsse auf das beobachtete Rauschen.

Q 31.2 Mi 14:15 Audi-A

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

In the current concepts for the LISA payload architecture an Optical Readout (ORO) is necessary to detect relative motion between the inertial reference (i.e. the proof mass) and the optical bench aboard on each spacecraft. In collaboration with the Humboldt University Berlin and the HTWG Konstanz, a prototype ORO has been realized over the past years, which meanwhile is close to achieving the required picometer-sensitivity in translation and nanorad-sensitivity in attitude metrology. The polarizing heterodyne interferometer is characterized by a highly symmetric setup and employs differential wavefront sensing for determination of the proof mass tilt in 2 degrees of freedom. We will discuss the experimental setup and its latest performance, as well as its application to first verification of critical LISA subsystems. For example, the tilt mechanism of the so-called In-Field Pointing and the mirror surface flatness in the pm-range. Our current activities further include novel developments for other critical parts of the optical metrology chain, namely the laser source and the phasemeter, where the respective approach and first results will be presented.

Q 31.3 Mi 14:30 Audi-A

Ein optisches Dilatometer zur hochpräzisen CTE-Wert Be-

stimmung — •Steffen Waimer[1,4], Martin Gohlke[1,2], Dennis Weise[1], Thilo Schuldt[2,3], Ulrich Johann[1], Achim Peters[2] und Claus Braxmaier[3] — [1]EADS Astrium GmbH — [2]Humboldt-Universität zu Berlin — [3]HTWG Konstanz — [4]HS Esslingen

Im Rahmen der LISA Missionsstudie wurde von der EADS Astrium GmbH in Zusammenarbeit mit Humboldt Universität zu Berlin und der HTWG Konstanz ein hochpräzises heterodynes Interferometer entwickelt, dessen Rauschlevel im Pikometerbereich für Translationsmessungen bzw. Nanoradbereich für Winkelmessungen liegen. Das Interferometer stellt die Grundlage für ein hochgenaues Dilatometer dar, mit dem der lineare thermische Ausdehnungskoeffizient (engl. coefficient of thermal expansion – CTE) verschiedenster Materialien getestet werden kann. Zur Zeit werden CTE-Werte unterschiedlicher kohlestofffaserverstärkter Verbundwerkstoffe (engl. carbon fiber reinforced plastic – CFRP) im Hinblick auf die LISA Mission vermessen. Im Vortrag werden die laufenden Aktivitäten vorgestellt und die Ergebnisse der aktuellen Messungen präsentiert.

Q 31.4 Mi 14:45 Audi-A

Abstandsstabilisierung optischer Tische für das AEI 10 m-Prototyp-Interferometer — •Oliver Kranz[1], Alessandro Bertolini[1], Michael Born[1], Jens Breyer[1], Yanbei Chen[2], Katrin Dahl[1], Stefan Gossler[1], Fumiko Kawazoe[1], Gerrit Kühn[1], Harald Lück[1], Kasem Mossavi[1], Henning Ryll[1], Kentaro Somiya[2], Kenneth A. Strain[1], Bob Taylor[1], Benno Willke[1], Alexander Wanner[1] und Karsten Danzmann[1] — [1]Max-Planck-Institut für Gravitationphysik (Albert-Einstein-Institut), Institut für Gravitationsphysik, Leibniz Universität Hannover, Callinstr. 38, D-30167 Hannover — [2]California Institute of Technology, Pasadena, CA 91125

Um die Empfindlichkeit von Gravitationswellendetektoren der 3-ten Generation zu verbessern, werden am AEI Hannover relevante Techniken in einem 10 m-Prototyp-Interferometer erprobt. Dieses wird in seiner Messgenauigkeit hauptsächlich durch quantenmechanische Rauscheffekte limitiert sein. Dafür ist es notwendig, den Prototypen von Seismik zu isolieren, sowie thermisches Driften zwischen den optischen Komponenten zu minimieren. Dazu werden aufgehängte optische Tische mittels heterodyn Mach-Zehnder-Interferometrie verbunden. Ein Arm eines solchen Interferometers ist Referenz-, der andere Messarm. Letzterer vermisst den Abstand zu einem 10 m entfernten Tisch. Nach Überlagerung und Detektion der beiden Strahlen werden mit einem Phasenmeter deren Phasendifferenzen bestimmt. Diese sind ein Maß für die Relativbewegungen der Tische zueinander, welche über Aktuatoren an den Tischen kompensiert werden. Ziel ist, eine relative Stabilität zwischen den Tischen von 100 pm/$\sqrt{\text{Hz}}$ bei 10 mHz zu erreichen.

Q 31.5 Mi 15:00 Audi-A

Frequenzstabilisierung auf Grundlage zweier Interferometer mit Weglängenunterschied — •Christian Diekmann, Antonio Garcia Marin, Benjamin Sheard, Felipe Guzman Cervantes, Frank Steier, Iouri Bykov, Joachim Kullmann, Gerhard Heinzel und Karsten Danzmann — Albert-Einstein-Institut, Hannover, Deutschland

Der weltraumgestützte Gravitationswellendetektor LISA muss die Abstände zwischen seinen drei Satelliten auf 12 pm/$\sqrt{\text{Hz}}$ im Frequenzbereich zwischen 1 mHz und 1 Hz messen. Da die Längen der drei Arme von ungefähr 5 Millionen km nicht genau übereinstimmen ist eine Frequenzstabilität der Laser von 10^{-4} Hz/$\sqrt{\text{Hz}}$ in diesem Frequenzbereich erforderlich.

Die notwendige Frequenzstabilität wird in drei Schritten erreicht. Dazu werden im ersten Schritt alle sechs Laser jeweils für sich mittels einer Resonator-, Jod- oder Frequenzstabilisierung auf Grundlage zweier Interferometer mit Armlängenunterschied auf unter 100 Hz/$\sqrt{\text{Hz}}$ vorstabilisiert.

Eine Frequenzstabilisierung auf Grundlage von zwei Interferometern mit Armlängenunterschied wurde bereits für das LISA Technology Package (LTP) demonstriert. Dabei wurde eine Frequenzstabilität von 2 kHz/$\sqrt{\text{Hz}}$ bei 1 Hz erreicht. Dieses Prinzip der Frequenzstabilisierung soll für den Einsatz bei LISA untersucht werden.

Q 31.6 Mi 15:15 Audi-A

Absorptionsmessung in Flüstergalerieresonatoren* — •Tobias Beckmann, Judith R. Schweysg, Sergej Hermann, Daniel Haertle und Karsten Buse — Physikalisches Institut, Universität Bonn, Wegelerstr. 8, 53115 Bonn

Flüstergalerieresonatoren sind Scheiben, an deren Rand Licht durch Totalreflexion geführt wird. Bei hinreichender Oberflächenqualität ist die Güte der Resonatoren nur von der Absorption im Material abhängig.

Mit mechanischen Methoden werden Resonatoren hoher Güte hergestellt, mit deren Hilfe geringe Absorption auch in kleinen Probenvolumina gemessen werden kann. Das Herstellungsverfahren ist nicht materialspezifisch: Es liefert sowohl bei Polymethylmethacrylat (PMMA, Plexiglas) als auch bei Lithiumniobatkristallen hervorragende Ergebnisse.

Resonatoren aus PMMA erreichen bei 635 nm Wellenlänge Güten bis zu 4×10^7; das ist ein neuer Rekord in Polymeren. Damit können Absorptionskoeffizienten bis hinunter zu 0,3 m^{-1} gemessen werden – in weniger als 1 cm^3 Material. Bei 1550 nm absorbiert PMMA stärker, und die Absorptionsmessungen in Resonatoren zeigen gute Übereinstimmung mit herkömmlichen Messungen. In einem transparenteren Material wie Lithiumniobat zeigen wir, dass selbst eine Absorption von nur 0,1 m^{-1} messbar ist.

*Wir danken der Deutschen Forschungsgemeinschaft (FOR 557), der Deutschen Telekom AG und der Deutschen Telekom Stiftung für die finanzielle Unterstützung.

Q 31.7 Mi 15:30 Audi-A

Flüstergaleriemoden in Lithiumniobatkristallen — •Sergej Hermann, Tobias Beckmann, Daniel Haertle und Karsten Buse — Physikalisches Institut, Universität Bonn, Wegelerstr. 8, 53115 Bonn

Zum einen zeigen wir ein einfaches Verfahren zur Herstellung von Flüstergalerie-Resonatoren aus Lithiumniobatkristallen. In diesen runden und monolithischen Resonatoren wird das Licht durch Totalreflexion geleitet, und es können extrem hohe Resonator-Güten von 10^8 erreicht werden.

Zum anderen werden Anwendungen dieser Resonatoren in der nichtlinearen Optik untersucht. Die notwendige Phasenanpassung wird in Lithiumniobatkristallen durch periodisches Polen erreicht. Das gewöhnliche Streifenmuster der Domänen (PPLN) reicht in makroskopischen Flüstergalerie-Resonatoren aus, um nichtlineare Prozesse zu demonstrieren. Andere, an die runde Geometrie des Resonators angepasste Polungsstrukturen, sind aber nach Berechnungen eine Größenordnung effizienter. Durch Optimieren dieser Polungsstrukturen lassen sich auch die Vorzugsrichtungen der Domänenwände einhalten, die durch die Kristallstrukur von Lithiumniobat vorgegeben ist. Wir untersuchen die nichtlinear-optische Effizienz verschiedener Polungsmuster, unter Einbezug der Ungenauigkeiten, die in der Herstellung entstehen können.

*Wir danken der Deutschen Forschungsgemeinschaft (FOR 557) und der Deutschen Telekom AG für die finanzielle Unterstützung.

Q 31.8 Mi 15:45 Audi-A

Sensitive method for measurement of weak nonresonant third-order optical nonlinearities — •Anatoly Sherman, Erik Benkler, and Harald Telle — Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany

A sensitive method for measurement of weak nonresonant third-order optical nonlinearities (n_2) in waveguides is demonstrated. Its value is referenced to the nonlinearity of a thin bulk sample with well-known optical properties. The contribution of this bulk sample to the total nonlinear signal is switched on and off by scanning it across the focal plane of the waveguide output without changing the beam geometry. Thus, the measurement becomes independent of mode field parameters and laser parameters like pulse length, shape, chirp and peak power.

The experimental scheme combines nearly degenerate four-wave mixing of short pulses at 1.5 μm (duration $\approx$ 100 fs) with heterodyne detection for ultra-high sensitivity. As a first experimental demonstration of this method, we measure the nonresonant nonlinearity of a 21 mm short strand of air-filled hollow-core photonic crystal fiber. The measured value which is more than 1000 times smaller than in standard optical fiber (SMF-28) is in good agreement with theoretical calculations. Possible limitations e. g. due to noise contributions and parasitic nonlinear effects in the photodetector will be discussed.

As a universal method, the presented scheme also allows the measurement of third-order optical nonlinearities of highly asymmetric waveguides or bulk samples as well.

Q 32: Materiewellenoptik

Zeit: Mittwoch 14:00–15:15 Raum: Audi-B

Q 32.1 Mi 14:00 Audi-B

Berry phase in atom optics — •Polina V. Mironova, Maxim A. Efremov, and Wolfgang P. Schleich — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

The Berry phase is determined only by the parameter space topology and hence cannot be disturbed significantly by noise. It can be used to construct robust quantum gates. We suggest a scheme to observe the Berry phase using the atomic external degrees of freedom. We consider two consecutive interactions of an atom with a near-resonant standing light waves. An atom is scattered by a standing wave, which is formed by two red-detuned traveling light waves, with wave vectors $\mathbf{k}_1$ and $\mathbf{k}_2$, $|\mathbf{k}_1| = |\mathbf{k}_2| = k$, $\measuredangle(\mathbf{k}_1, \mathbf{k}_2) = 2\alpha$. Afterwards, the atom is scattered by a second standing wave, which is formed by two blue-detuned traveling light waves, with wave vectors $\mathbf{k'}_{1,2} \updownarrows \mathbf{k}_{1,2}$. We assume that both interactions turn-on and turn-off adiabatically. Within the rotating wave approximation and the adiabatic approximation on the atomic center-of-mass motion we obtain that the dynamical phase is cancelled out and the final state of the atom differs from the initial state of the atom only by twice the familiar Berry phase, which depends on the atomic external degrees of freedom. Therefore, the scattering picture is determined by the atomic center-of-mass position.

Q 32.2 Mi 14:15 Audi-B

BEC and guided atom-optics in dipole potentials — •Oliver Wille, Johannes Küber, Thomas Lauber, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

In our ATOMICS (ATom Optics with MICro Structures) experiment, we achieved BEC by loading Rb-atoms directly from a magneto-optical trap into a crossed dipole trap created by a 1070nm fiber laser and evaporatively cool to quantum degeneracy by lowering the power of the two trapping beams. The fully optical setup has the advantage of being independent of the magnetic properties of the atoms and allows to impose arbitrary magnetic fields.

We want to study the coherence properties of a BEC in dipole potentials created by microfabricated optical elements illuminated with a red detuned laser field. Micro-optical elements are available in various shapes including micro lens arrays, cylindrical lens arrays and ring shaped lenses. With these micro lenses it is possible to build waveguides, beam splitters or toroidal trapping potentials. With coherent transport and splitting of a wave packet it is possible to create integrated atom interferometers and even more complex configurations.

As a second line of experiments, we plan to investigate the dynamics of matter waves in different 1D potential geometries including spatially limited optical lattices and Fabry-Perot like structures.

Q 32.3 Mi 14:30 Audi-B

Focussing a Helium atom beam by reflection from a concave surface — •Christian Schewe, Bum Suk Zhao, Gerard Meijer, and Wieland Schöllkopf — Fritz-Haber-Institut, Berlin

Results of 1-dimensional focussing of a Helium-atom beam reflected from a concave, cylindrical surface are presented. The atomic beam is created by a supersonic expansion and collimated by a skimmer and two slits, variable in size (5-20 μm). For grazing incident angles of a few milliradian the beam is coherently reflected by quantum reflection [1]. Beam profiles at the focus are measured by cutting off the intensity by scanning a knife edge with a piezo (analogy to waist measurement by a razor blade in laser optics). The width of the focus is limited by the source size, by spherical aberration and by diffraction effects. We tune the deBroglie-wavelength by changing the temperature of the atom beam source to see how diffraction influences the focus' width and shape. The smallest focus achieved so far is 1.0±0.1 μm.

[1] Zhao et al., Phys. Rev. A, 78 010902(R), (2008).

Q 32.4 Mi 14:45 Audi-B

Atom Interferometry using Large Momentum Transfer Beam Splitters — •Sven Herrmann, Sheng-wey Chiow, Holger Müller, and Steven Chu — Physics Department, 382 Via Pueblo Mall, Varian 226, Stanford, CA 94305, USA

Light-pulse atom interferometers have been used for precision measurements e.g. of the fine-structure constant α, the local gravitational acceleration g, the Sagnac effect, or Newton's gravitational constant. A way to increase the sensitivity of these measurements is to increase the splitting between the interferometer arms by using large-momentum transfer (LMT) beam splitters. Here, we present two realizations of such LMT beam splitters and their application in simultaneous conjugate Ramsey Borde interferometers in an atomic Cs-fountain, aiming to measure the photon recoil and thus the fine structure constant.
First, we have used multi-photon Bragg diffraction of atomic wave packets at an optical lattice as a beam splitter. Up to $30\hbar k$ can be transferred in a single diffraction. Second, we have embedded such beam splitters between de- and accelerating sections of Bloch oscillations. With both beam splitters we demonstrate interferometry with a splitting of up to $24\hbar k$. Such beam splitters combined from Bragg diffraction and Bloch oscillations should ultimately allow to significantly increase the momentum splitting by increasing the number of Bloch oscillations. This opens the door to much improved precision measurements using atom interferometry.

Q 32.5 Mi 15:00 Audi-B

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

GAIN (Gravimetric Atom Interferometer) is a new design for 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 would 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 will open up the possibility for a number of interesting applications.

We present first results of the operational interferometer setup and discuss the next steps necessary to achieve full accuracy. These will involve a thorough examination of the systematic effects, which are outlined briefly.

Q 33: Quantengase: Bosonen

Zeit: Mittwoch 14:00–16:00 Raum: VMP 6 HS-A

Preisträgervortrag Q 33.1 Mi 14:00 VMP 6 HS-A

Von der Laserschwelle zum Quantenphasenübergang - und zurück — •Robert R. F. Graham — Fachbereich Physik, Universität Duisburg/Essen — Träger der Max-Planck-Medaille

Vortrag zur Verleihung der Max-Planck Medaille 2009

Seit Planck, Bose und Einstein wird Licht verstanden als ein Quantengas mit thermodynamischen Eigenschaften wie Energie und Entropie, und im thermodynamischen Gleichgewicht auch mit Temperatur und Druck. Nach Erfindung des Lasers lernten wir dann zu verstehen, dass noch eine weitere Quantenphase von Licht auftreten kann als Bose-Einstein Kondensat eines Gases von Photonen fester Frequenz. Die Quantenfluktuationen der Spontanemission treiben den Übergang zu diesem Zustand an der Laserschwelle, thermische Fluktuationen spielen dagegen keine signifikante Rolle. Es ist somit ein Quantenphasenübergang, doch kein solcher zwischen thermodynamischen Gleichgewichten, sondern zwischen getriebenen Fließgleichgewichten. Die neuen Fragen, die dies aufwirft, haben mich seitdem immer wieder beschäftigt. Einige davon werden im Vortrag thematisiert.

Mit der Realisierung von Bose-Einstein Kondensaten in Atomfallen im letzten Jahrzehnt hat sich nun ein Kreis geschlossen. Im Vordergrund stand diesmal zunächst Einsteins wohlbekannter Quantenphasenübergang. Doch ebenso wie beim Licht gibt es auch hier die andere, in diesem Kontext neue Seite des Phaenomens, die des Atomlasers. Sicherlich wird seine weitere Entwicklung in verschiedenen stationären und dynamischen Zuständen experimentell, aber auch theoretisch ein interessantes Thema für die nähere Zukunft bleiben.

Gruppenbericht Q 33.2 Mi 14:30 VMP 6 HS-A

Free expansion of a Bose-Einstein condensate in microgravity — •Wojciech Lewoczko-Adamczyk[1], Achim Peters[1], Tim van Zoest[2], Ernst Rasel[2], Wolfgang Ertmer[2], Anika Vogel[3], Kai Bongs[3], Klaus Sengstock[3], Endre Kajari[4], Reinhold Walser[4], Wolfgang Schleich[4], Thorben Könemann[5], Klaus Lämmerzahl[5], and Hansjörg Dittus[5] — [1]Institut für Physik, Humboldt Universität zu Berlin — [2]Institut für Quantenoptik, Leibniz-Universität Hannover — [3]Institut für Laserphysik, Universität Hamburg — [4]Institut für Quantenphysik, Universität Ulm — [5]ZARM, Universität Bremen

We report on the current status of the free fall Bose-Einstein condensate (BEC) experiment at the ZARM drop tower in Bremen. After the realization of the first BEC in microgravity, the dynamics of the condensate in the shallow, decompressed trap and during the free expansion were studied comprehensively. With the resulting knowledge and understanding of the relevant processes, a free expansion time up to one second has already been achieved. This unprecedented time of free evolution leads to new possibilities for the study of BEC-coherence. It can also be applied to enhance the sensitivity of inertial quantum sensors based on ultra-cold matter waves. Our compact and portable BEC-apparatus will be presented in detail. Special emphasis will be put on its robustness and reliability, which opens new routes to quantum optics experiments also on other microgravity platforms, like ballistic rockets or the International Space Station. This work was realized within the QUANTUS collaboration.

Q 33.3 Mi 15:00 VMP 6 HS-A

Towards a BEC of Strontium — •Simon Stellmer[1,2], Rudolf Grimm[1,2], and Florian Schreck[1] — [1]Institut für Quantenoptik und Quanteninformation, 6020 Innsbruck, Austria — [2]Institut für Experimentalphysik, Universität Innsbruck, 6020 Innsbruck, Austria

Atomic Strontium shows some remarkable atomic properties related to its electronic configuration as an alkaline earth metal. Very long-lived metastable states, narrow intercombination lines, and zero magnetic moment for the bosonic isotopes offer unique possibilities for optical clocks, employment of optical Feshbach resonances, quantum computation and quantum simulation. While the cooling of true alkaline earth atoms into quantum degeneracy has not been achieved so far, a new approach is taken by the Innsbruck group.

In this talk, we will sketch the cooling strategy used, report on the current status of the experiment, and illustrate some possible future applications.

Q 33.4 Mi 15:15 VMP 6 HS-A

Casimir energy of a BEC: from moderate interactions to the ideal gas — •Jürgen Schiefele and Carsten Henkel — Universität Potsdam, Institut für Physik und Astronomie, Karl-Liebknecht-Str. 24/25, 14 476 Potsdam, Germany

A pair of parallel conducting plates separated by vacuum imposes boundary conditions on the electromagnetic vacuum fluctuations. This causes a change in the (infinite) vacuum energy density, and leads to an attractive interaction between the two plates. The resulting force on the plates is known as the Casimir force.

When a weakly interacting dilute Bose-Einstein condensate (BEC) is confined between parallel plates, there is an analogous effect caused by the quantum fluctuations (Bogoliubov modes) on top of the ground state of the BEC. We derive a renormalized expression for the zero temperature Casimir energy of a BEC confined to a parallel plate geometry with periodic boundary conditions. Our expression is formally equivalent to the free energy of a bosonic field at finite temperature, with a nontrivial density of modes that we compute analytically. As a function of the interaction strength, it smoothly describes the transition from the weakly interacting Bogoliubov regime (phononic Casimir effect) to the non-interacting ideal BEC (no Casimir effect).

J. Schiefele and C. Henkel, J. Phys A (2009) in press.

Q 33.5 Mi 15:30 VMP 6 HS-A

Creation and detection of a mesoscopic gas in a non-local quantum superposition — •Christoph Weiss[1] and Yvan Castin[2] — [1]Institut für Physik, Universität Oldenburg — [2]Laboratoire Kastler Brossel, École Normale Supérieure, Paris

We investigate the scattering of a quantum matter wave soliton on a barrier in a one dimensional geometry and we show that it can lead to mesoscopic Schrödinger cat states, where the atomic gas is in a coherent superposition of being in the half-space to the left of the barrier and being in the half-space to the right of the barrier. We propose an interferometric method to reveal the coherent nature of this superposition and we discuss in details the experimental feasibility.

[1] Phys. Rev. Lett, in press; arXiv:0806.3395v1

Q 33.6 Mi 15:45 VMP 6 HS-A

Multi-resonant amplification in a trapped spinor condensate — •Gebremedhn Gebreyesus, Philipp Hyllus, and Luis Santos — Institut für Theor. Physik, Appelstr. 2, Leibniz Universität Hannover

We study theoretically spin changing collisions in a spinor condensate prepared initially in the $m_F = 0$ state. Due to the interplay between quadratic Zeeman effect, spin-changing collisions, and trap energy, the spin transfer into $m_F = \pm 1$ presents an intriguing dependence on the applied magnetic field. In particular, we show that the spin-transfer velocity reflects the instability of the corresponding Bogoliubov modes. Contrary to the case of an homogeneous gas, the spin transfer velocity is characterized by the appearance of marked resonances as a function of the applied magnetic field. We comment on the relevance of these results for recent experiments performed in Berkeley and in Hannover.

Q 34: Quanteninformation: Konzepte IV

Zeit: Mittwoch 14:00–15:45 Raum: VMP 6 HS-D

Q 34.1 Mi 14:00 VMP 6 HS-D

Classification of qubit entanglement: $SL(2)$ versus $SU(2)$ invariance — •Andreas Osterloh — Institut für theoretische Physik, Leibniz Universität Hannover, Appelstrasse 2, 30167 Hannover.

The role of $SU(2)$ invariants for the classification of multiparty entanglement is discussed and exemplified for the Kempe invariant I_5 of pure three-qubit states. It is found to being an independent invariant only in presence of both W-type entanglement and threetangle. In this case, constant I_5 admits for a wide range of both threetangle and concurrences. Furthermore, the present analysis indicates that an $SL^{\otimes 3}$ orbit of states with equal tangles but continuously varying I_5 must exist. This means that I_5 provides no information on the entanglement in the system in addition to that contained in the tangles (concurrences and threetangle) themselves. Together with the numerical evidence that I_5 is an entanglement monotone this implies that $SU(2)$ invariance or the monotone property are too weak requirements for the characterization and quantification of entanglement for systems of three qubits, and that $SL(2,\mathbb{C})$ invariance is required. This conclusion can be extended to general multipartite systems (including higher local dimension) because the entanglement classes of three-qubit systems appear as subclasses.

Q 34.2 Mi 14:15 VMP 6 HS-D

Entanglement and permutational symmetry — •Géza Tóth[1,2,3] and Otfried Gühne[4,5] — [1]Física Teórica, Universidad del País Vasco, Apdo. 644, E-48080 Bilbao — [2]Ikerbasque-Basque Foundation for Science, E-48011 Bilbao — [3]Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, H-1525 Budapest — [4]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, A-6020 Innsbruck — [5]Institut für Theoretische Physik, Universität Innsbruck, A-6020 Innsbruck

We study entanglement and separability for permutationally symmetric quantum states. We show that for bipartite symmetric systems the most relevant entanglement criteria coincide. However, we provide a method to generate examples of bound entangled states in symmetric systems, for the bipartite and the multipartite case. These states shed some new light on the nature of bound entanglement.

Q 34.3 Mi 14:30 VMP 6 HS-D

Entanglement properties of Werner-like three-qubit states — •Christopher Eltschka and Jens Siewert — Institut für theoretische Physik, Universität Regensburg, D-93040 Regensburg, Germany

We analyse the entanglement properties of the Werner-like three-qubit states of the form $\rho(p) = p|\mathrm{GHZ}\rangle\langle\mathrm{GHZ}| + (1-p)\rho_{\mathrm{mixed}}$, where $|\mathrm{GHZ}\rangle = (|000\rangle + |111\rangle)/\sqrt{2}$ is the three-qubit GHZ state, and ρ_{mixed} is the completely mixed three-qubit state. Using geometrical considerations in the space of density matrices, we estimate the maximal value of p for which the three-tangle vanishes, i.e. the maximal p for which $\rho(p)$ describes a W-class state. We give an optimal decomposition for that state, and from that try to derive an optimal GHZ\W witness.

Q 34.4 Mi 14:45 VMP 6 HS-D

Non-local structure, adjoint orbits, and efficient implementations of unitary transformations in three-qubit systems — •Robert Zeier — Department Chemie, Technische Universität München, Lichtenbergstrasse 4, 85747 Garching, Germany

We analyze the non-local structure of unitary transformations in three-qubit systems. Computing integral cohomology groups we gain insight into the algebraic structure of cosets with respect to local operations. We employ this information in our analysis of adjoint orbits. We discuss applications to efficient implementations of unitary transformations.

Q 34.5 Mi 15:00 VMP 6 HS-D

Characterizing entanglement with geometric entanglement witnesses — •Philipp Krammer — Fakultät für Physik, Universität Wien, A-1090 Vienna, Austria — Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, D-40225 Düsseldorf, Germany

A challenge in quantum information theory is the detection of entangled states on a finite dimensional Hilbert space. Useful tools for this purpose are entanglement witnesses; they provide a geometrically intuitive method to detect entanglement.

We show how to detect entangled, bound entangled, and separable bipartite quantum states of arbitrary dimension and mixedness using geometric entanglement witnesses. These witnesses are constructed using properties of the Hilbert-Schmidt geometry and can be shifted along parameterized lines. The involved conditions are simplified using Bloch decompositions of operators and states. As an example we determine the three different types of states for a family of two-qutrit states that is part of the "magic simplex", i.e. the set of Bell-state mixtures of arbitrary dimension.

Q 34.6 Mi 15:15 VMP 6 HS-D

On polynomial invariants of multipartite qubit systems — •Andreas Osterloh[1] and Dragomir Ž. Djokovic[2] — [1]Institut für theoretische Physik, Leibniz Universität Hannover, Appelstrasse 2, 30167 Hannover, Germany. — [2]Department of Pure Mathematics, University of Waterloo, Waterloo, Ontario, N2L 3G1, Canada.

It is a recent observation that entanglement classification for qubits is closely related to local $SL(2,\mathbb{C})$-invariants including the invariance under qubit permutations, which has been termed SL^* invariance. In order to single out the SL^* invariants, we analyze the $SL(2,\mathbb{C})$-invariants of four resp. five qubits and decompose them into irreducible modules for the symmetric group S_4 resp. S_5 of qubit permutations. A classifying set of measures of genuine multipartite entanglement is given by the ideal of the algebra of SL^*-invariants vanishing on arbitrary product states. We find that low degree homogeneous components of this ideal can be constructed in full by using the approach using local invariant operators. Our analysis highlights an intimate connection between this latter procedure and the standard methods to create invariants, such as the Ω-process. As the degrees of invariants increase, the comb based method proves to be particularly efficient.

Q 34.7 Mi 15:30 VMP 6 HS-D

Dynamical Control of Entanglement — •Felix Platzer, Florian Mintert, and Andreas Buchleitner — Albert-Ludwigs-Universität Freiburg, Germany

We study the possibility to control entanglement dynamics with the help of coherent driving. Based on algebraic approximations to multipartite generalizations of the concurrence C [1,2], we analytically find local control Hamiltonians that maximize time derivatives of C. With this approach we investigate optimal ways of preparing highly entangled multi-partite states for various types of interactions, both in closed systems and in the presence of dissipation and decoherence.

[1] F. Mintert and A. Buchleitner, Phys. Rev. Lett. **98**, 140505 (2007)
[2] L. Aolita, A. Buchleitner and F. Mintert, Phys. Rev. A **78**, 022308 (2008)

Q 35: Quanteneffekte: QED / Interferenz und Korrelationen I

Zeit: Mittwoch 14:00–16:00 Raum: VMP 6 HS-E

Q 35.1 Mi 14:00 VMP 6 HS-E

Eddy currents and the thermal Casimir effect — •Francesco Intravaia and Carsten Henkel — Universität Potsdam, Institut für Physik und Astronomie, Karl-Liebknecht-Str. 24/25, 14476 Potsdam, Germany

We study the contribution of eddy currents to the Casimir effect between two thick metallic plates. Using the Drude model for the optical response of the metal, we identify a class of diffusive modes that live in the bulk of the two plates and are electromagnetically coupled across the vacuum gap. Recently, it was pointed out that eddy currents give an important contribution to the heat transfer between two metallic surfaces [1]. It also turns out that the contribution of these modes is responsible for the difficulties in calculating the thermal correction for the Casimir force [2]. Even the applicability of the Nernst heat theorem (third law of thermodynamics) must reviewed: in fact the subspace spanned by the eddy currents can generate a highly degenerate ground state for a temperature-dependent dissipation rate. Features of the eddy spectrum also suggest that these modes may not be in equilibrium for an experiment with a finite characteristic duration. We propose to evaluate an adiabatic pressure in order to take into account this phenomenon.

[1]P.-O. Chapuis, S. Volz, C. Henkel, K. Joulain, and J.-J. Greffet, Phys. Rev. B 77, 035431 (2008).
[2] K. A. Milton, J. Phys. A 37 (2004) R209; G. L. Klimchitskaya and V. M. Mostepanenko, Contemp. Phys. 47 (2006) 13

Q 35.2 Mi 14:15 VMP 6 HS-E

Thermal Casimir and Casimir-Polder interaction with superconductors and metals — •Harald Haakh, Francesco Intravaia, and Carsten Henkel — Universität Potsdam, Institut für Physik und Astronomie, Karl-Liebknecht-Str. 24/25, 14476 Potsdam, Germany

We study the Casimir interactions with superconducting surfaces, with emphasis on finite temperature corrections. This is motivated by current controversies around the interaction between dissipative plates [1]. For the atom-surface interaction, we analyze the magnetic dipole contribution whose resonance frequencies are unusually small relative to the temperature. We use thermal response theory and characterize the superconductor by common optical models. The atom-metal interaction (free) energy allows to recover previous results [2] and is for $T > 0$ strongly suppressed at large distances. The atom-superconductor entropy jumps at T_c, illustrating the "participation"of the atom in the phase transition. The similarities between the two Casimir interactions suggest that the thermal Casimir controversy for metals could be checked by precision measurements of the atom-surface interaction, e.g., using differences between isotopes that differ only in their magnetic properties.

[1] K. A. Milton, J. Phys. A 37 (2004) R209; G. L. Klimchitskaya and V. M. Mostepanenko, Contemp. Phys. 47 (2006) 131
[2] C. Henkel, B. Power, and F. Sols, J. Phys.: Conf. Ser. 19 (2005) 34

Q 35.3 Mi 14:30 VMP 6 HS-E

Photoemission of a Single-Electron Wave-Packet in a Strong Laser Field — •Carsten Müller[1], Justin Peatross[2], Karen Z. Hatsagortsyan[1], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Department of Physics and Astronomy, Brigham Young University, USA

The radiation emitted by a single-electron wave packet in an intense laser field is considered. A relation between the quantum mechanical formulation and its classical counterpart is established via the electron's Wigner function. We show that the partial emissions from different momentum components of the wave packet do not interfere when the driving field is a plane wave. In a focused laser beam, however, quantum interference in the scattered radiation in principle is possible. We outline an experimental setup dedicated to put these conclusions to the test.

[1] J. Peatross, C. Müller, K. Z. Hatsagortsyan, and C. H. Keitel, Phys. Rev. Lett. 100, 153601 (2008)
[2] C. Müller, J. Peatross, K. Z. Hatsagortsyan, and C. H. Keitel, in preparation

Q 35.4 Mi 14:45 VMP 6 HS-E

Cavity QED with Cold Ion Coulomb Crystals — •Magnus Albert, Joan Marler, Aurelien Dantan, Peter Herskind, and Michael Drewsen — QUANTOP, Department of Physics and Astronomy, University of Aarhus, DK-8000 Aarhus C, Denmark

Clouds of cold ions are an interesting alternative system to a single atom/ion for studying CQED effects. When trapped and cooled below a critical temperature, these ions form a spatially ordered state, referred to as an ion Coulomb crystal. In our setup, we trap and cool $^{40}Ca^{+}$ ions in sufficient number to access the so-called strong collective coupling regime, where the collective coupling, $g\sqrt{N}$, exceeds both the dipole decay rate, γ, and the cavity decay rate, κ, without using an extremely high finesse cavity[1]. We will present the first signals of collective strong coupling, in this system - most dramatically manifested via the vacuum Rabi splitting. Finally, we measure the temporal coherence of collective Zeeman sub-states in the $3d^3D_{3/2}$-level by induced Lamor precession. The measured coherence times are of the order of the best reported values for single ions in equivalent magnetic field sensitive states[2]. Our results make the system a promissing candidate for the realisation of various quantum information devices, including quantum repeaters and quantum memories.

[1] P. Herskind, A. Dantan, M.B. Langkilde-Lausen, A. Mortensen, J. L. Sørensen and M. Drewsen, Appl. Phys. B **93**, 373 (2008)
[2] P. Herskind, A. Dantan, J. Marler, M. Albert and M. Drewsen, *Realisation of Collective Strong Coupling with Ion Coulomb Crystals in an Optical Cavity*, submitted

Q 35.5 Mi 15:00 VMP 6 HS-E

Two-photon gateway in one-atom cavity quantum electrodynamics — •Alexander Kubanek, Alexei Ourjoumtsev, Ingrid Schuster, Markus Koch, Pepijn Pinkse, Karim Murr, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Single atoms absorb and emit light from a resonant laser beam photon by photon. However, an atom strongly coupled to light inside a high-finesse optical cavity forms a new system with an anharmonic energy structure. This anharmonicity allows the selective excitation of a two-photon resonance [1], where the system absorbs and emits pairs of photons. In a photon correlation experiment [2] we demonstrate how the system transforms an incoming random stream of laser photons into a correlated beam of output photons, thereby acting as a two-photon gateway. The Poissonian distributed light changes into super-Poissonian, bunched light. This effect opens up the possibility to control the interaction of two photons by means of one atom.

[1] I.Schuster et al., Nature Phys. 4, 382 (2008)
[2] A.Kubanek et al., Phys. Rev. Lett. 101, 203602 (2008)

Q 35.6 Mi 15:15 VMP 6 HS-E

Momentum-space interferometry with trapped ultracold atoms — •Andreas Ruschhaupt[1], Adolfo del Campo[2], and J. Gonzalo Muga[3] — [1]Institut für Mathematische Physik, TU Braunschweig, Mendelssohnstrasse 3, 38106 Braunschweig — [2]Institute for Mathematical Sciences, Imperial College London, SW7 2PE, UK — [3]Departamento de Quimica-Fisica, Universidad del Pais Vasco, Apartado 644, 48080 Bilbao, Spain

Quantum interferometers are generally set so that phase differences between paths in coordinate space combine constructive or destructively. Indeed, the interfering paths can also meet in momentum space leading to momentum-space fringes. We propose and analyze a method to produce interference in momentum space by phase-imprinting part of a trapped atomic cloud with a detuned laser. For one-particle wave functions analytical expressions are found for the fringe width and shift versus the phase imprinted. The effects of unsharpness or displacement of the phase jump are also studied, as well as many-body effects to determine the potential applicability of momentum-space interferometry.

Reference: arXiv:0810.1720

Q 35.7 Mi 15:30 VMP 6 HS-E

Pump-probe spectroscopy of two-atom entanglement in ultracold gases — •Christiane P. Koch[1] and Ronnie Kosloff[2] — [1]Freie Universität Berlin, Institut für Theoretische Physik, Arnimallee 14, 14195 Berlin — [2]Hebrew University, Dept. of Physical Chemistry, Jerusalem 91904, Israel

Two atoms in an ultracold gas are entangled at short inter-atomic distances due to threshold effects where the potential energy of their interaction dominates the kinetic energy. The entanglement manifests itself in a distinct nodal structure of the pair density at short range. We suggest pump-probe spectroscopy to study this entanglement: A suitably chosen, short laser pulse excites part of the atomic pair density to an electronically excited state. This depletes the ground state pair density in a range of distances, creating a 'hole'. The dynamics of this non-stationary wave packet can be monitored by a time-delayed probe pulse. We find different 'hole' dynamics for coherent and incoherent initial states, corresponding, respectively, to a BEC and an ultracold thermal ensemble.

Q 35.8 Mi 15:45 VMP 6 HS-E

Coherent control of nuclear forward scattering — •Adriana Pálffy, Jörg Evers, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Resonant excitation is the key ingredient to applications in many areas of physics. To some extent, the different areas are unified by common ideas to coherently control the dynamics as it is well known from atomic systems. In nuclear physics, monochromatized synchrotron radiation and upcoming high-frequency laser sources allow for coherent photo-excitation. Such an excitation in a nuclear ensemble is of excitonic nature, leading to coherent nuclear reemission in the forward direction. 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.

Here, we study more advanced coherent control schemes based on the experimental setup of [1]. We show that the accelerated nuclear forward scattering allows for the generation of two correlated coherent decay pulses out of one excitation, providing single-photon entanglement in the keV regime. Furthermore, the possibility to selectively populate excited nuclear states or metastable states by controlling branching ratios of coherently-driven transitions is addressed.

[1] Y. V. Shvyd'ko *et al.*, Phys. Rev. Lett. 77, 3232 (1995)

Q 36: Laseranwendungen

Zeit: Mittwoch 16:30–18:30 Raum: Audi-A

Q 36.1 Mi 16:30 Audi-A

Ein Brillouin-LIDAR zur Messung von Temperaturprofilen des Ozeans: Erste Tiefenaufgelöste Messungen — •Alexandru Popescu, Kai Schorstein und Thomas Walther — Institut für Angewandte Physik, AG Laser und Quantenoptik, Technische Universität Darmstadt, Schlossgartenstr. 7, D-64289 Darmstadt

Unumstritten ist der immense Einfluss der Weltmeere auf das Klima. Die Kenntnis des Wärmegehaltes liefert einen wichtigen Indikator für weitere Parameter wie den Nährstoff-, Sauerstoff- und CO_2-Gehalt. Eine Fernerkundungsmethode zur kostengünstigen Bestimmung des maritimen Temperaturprofils würde wertvolle Daten für bestehende Modelle und Prognosen in vielen Bereichen der Ozeanographie liefern. Durch neue Entwicklungen in der Laser- und Detektortechnologie rückt die Vermessung der Brillouin-Streuung als Temperaturindikator in greifbare Nähe. Eine große Herausforderung besteht in der exakten Bestimmung der Temperatur abhängigen Frequenzverschiebung der Brillouin-Streuung, die für eine Wassertemperatur von 0°C-40°C zwischen 7-8 GHz liegt. Für ein Flugzeug gestütztes LIDAR-System eignen sich Faserverstärker basierende Laserquellen und **E**xcited **S**tate **F**araday **A**nomalous **D**ispersion **O**ptical **F**ilter (ESFADOF) als schmalbandige, statische Kantenfilter. In diesem Beitrag werden neue Erkenntnisse der Strahlquelle und des Detektors hin zu einem praktikablen System, sowie erste tiefenaufgelößte Messungen im Labor präsentiert.

Q 36.2 Mi 16:45 Audi-A

Korrektur der thermischen Linse im Gravitationswellendetektor GEO600 — •Holger Wittel, Jerome Degallaix, Hartmut Grote, Harald Lück, Mirko Boris Prijateli und Karsten Danzmann — Albert-Einstein-Institut Hannover, Max-Planck-Institut für Gravitationsphysik und Universität Hannover

Der Gravitationswellendetektor GEO600 ist ein großes Michelson-Interferometer, es soll die von Albert Einstein vorhergesagten Gravitationswellen direkt nachweisen. Um diesen winzigen Effekt messen zu können sind sehr hohe Lichtleistungen nötig. Deshalb werden nach dem geplanten Upgrade von GEO600 kontinuierlich mehrere 10kW Laserleistung den Strahlteiler passieren. Obwohl er mit 0,25 ppm pro cm eine extrem geringe Absorption für Quarzglas aufweist, ist die entstehende thermische Linse ein großes Problem, sie verringert die Empfindlichkeit oder macht den Betrieb des Detektors gar unmöglich. Deshalb wird ein 'thermal compensation system' notwendig, mit dem die thermische Linse durch gezieltes Aufheizen des Strahlteilers korrigiert wird, dies kann mit einem CO2-Laser oder einer thermischen Strahlungsquelle erfolgen.

Q 36.3 Mi 17:00 Audi-A

Eignung eines Quantenkaskadenlasers für die Cavity Leak-Out Spektroskopie — •Kathrin Heinrich, Thomas Fritsch, Peter Hering und Manfred Mürtz — Institut für Lasermedizin, Universitätsklinikum Düsseldorf, Universitätsstr. 1, 40215 Düsseldorf

Die Cavity Leak-Out Spektroskopie ist eine Weiterentwicklung der Absorptionsspektroskopie. Durch den Einsatz eines Resonators hoher Güte werden effektive Absorptionsstrecken von bis zu 10 km erreicht, womit Absorptionskoeffizienten von α=10^{-11} cm^{-1} nachgewiesen werden können. Die für die medizinische Diagnostik relevanten Spurengase, wie z.B. CO oder NO, weisen im mittleren Infrarotbereich ein charakteristisches Absorptionsspektrum auf. Aus diesem Grund eignen sich Laserquellen in diesem Spektralbereich besonders gut für den Nachweis von Spurengasen aus dem menschlichen Atem oder anderen gasförmigen Proben. Die erreichbaren Nachweisgrenzen liegen im ppt-Bereich. Quantenkaskadenlaser finden unter anderem aufgrund ihres guten Abstimmbereichs, ihrer kompakten Bauweise und der Möglichkeit des Betriebs bei Raumtemperatur Anwendung als mögliche Laserquelle für die lasergestützte Absorptionsspektroskopie. Vorgestellt werden die Eignung eines Quantenkaskadenlasers (λ=5,33 μm) für den Einsatz in der Cavity Leak-Out Spektroskopie und erste Ergebnisse.

Q 36.4 Mi 17:15 Audi-A

Ein Festkörperlsersystem für spektroskopische Voruntersuchungen für Resonanzionisations Laserionenquellen — •Christoph Mattolat, Fabio Schwellnus, Sebastian Raeder, Sebastian Rothe, Tina Gottwald und Klaus Wendt — Johannes Gutenberg-Universität, Mainz

Die resonante Laserionisation ist seit Ihrer ersten Demonstration vor 20 Jahren inzwischen zur Ionisationsmethode der Wahl an ISOL-Einrichtungen avanciert. Durch die schrittweise resonante Anregung und anschließende Ionisation mit Laserlicht kann elementselektiv ein radioaktiver Ionenstrahl erzeugt werden. Die Lasersysteme der ISOL-Einrichungen der heutigen Generation bestehen aus weit abstimmbaren, wartungsfreien Titan:Saphir-Lasern. Für eine effiziente Ionisation ist die Kenntnis der starken Übergangslinien in dem interessanten Element Voraussetzung. Diese Übergangslinien finden sich teils in der Literatur, aber insbesondere der für die besonders effiziente Ionisation notwendige letzte resonante Schritt in einen autoionisierenden Zustand ist für eine Vielzahl von Elementen nicht bekannt. Für das hier vorgestellte Spektroskopiesystem wurde das vorhandene Lasersystem um einen um annähernd 300 nm kontinuierlich abstimmbaren Titan:Saphir-Laser erweitert und eine kompakte Atomstrahlquelle mit Massenfilter aufgebaut. Die benötigten Anregungsschemata können an dem System in kürzester Zeit entwickelt und getestet werden. Das System und erste Spektroskopische Untersuchungen werden vorgestellt.

Q 36.5 Mi 17:30 Audi-A

Nachweis und Untersuchung molekularer Prozesse mittels ultradünner Glasfasern — •Ariane Stiebeiner, Olga Rehband, Ruth Garcia-Fernandez und Arno Rauschenbeutel — Abteilung QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz

In ultradünnen Glasfasern mit einem Durchmesser unterhalb der Wellenlänge des geführten Lichts liegt ein signifikanter Teil der Leistung in Form eines starken evaneszenten Feldes vor. Dadurch kann Materie an der Faseroberfläche mit der geführten Lichtmode gekoppelt werden. Wir haben gezeigt, dass durch Messung der modifizierten Fasertransmission eine hochempfindliche spektroskopische Untersuchung von adsorbierten Molekülen auf der Oberfläche von ultradünnen Glasfasern möglich ist [1]. Die Empfindlichkeit ist um Größenordnungen höher als bei konventionellen Methoden mit freipropagierende Laserstrahlen.

Wir zeigen gleichzeitige Messungen der Absorption und Fluoreszenz dünner Schichten organischer Moleküle an Raumluft. Diese erlauben uns den Nachweis sehr geringer Oberflächenbedeckungen sowie eine zeitliche Auflösung der Ablagerung der Moleküle auf der Faseroberfläche. Darüber hinaus beobachten wir Fluoreszenzsignale bei Wellenlängen unterhalb der Anregungswellenlänge. Diese Anti-Stokes-Fluoreszenz lässt sich in unserem Fall mit der Thermalisierung der inneren Freiheitsgrade der Moleküle mit der Faseroberfläche erklären.
Gefördert von der Volkswagenstiftung, der ESF und der EC.

[1] F. Warken et al., Opt. Express 15, 11952-11958 (2007)

Q 36.6 Mi 17:45 Audi-A

Full spatial range characterization of transverse forces in optical tweezers — •Karl Probst, Márton Gelléri, and Carsten Fallnich — Institut für Angewandte Physik, WWU Münster, Corrensstraße 2-4, 48149 Münster

While the trapping forces applied by optical tweezers systems can in principle be calculated rigorously using Mie theory, in practice this possibility is limited by knowledge about the incident light distribution. A drawback of commonly applied methods employing Boltzmann statistics to characterize optical tweezers is that the displacement of particles relative to the trap center must never cross the position of maximum force or the particles are dropped from the trap.

We present a new scheme for the characterization of a single beam gradient trap that allows characterization of the radial trapping force up to several trap diameters. For this we set a trap in circular motion with a speed relative to the surrounding medium chosen so a particle is dropped from the trap with a low but finite probability and retrapped on the next cycle of the trap's motion.

A mathematical formulation describing the position, distribution width and amplitude of the particle count density in this experiment is supplied for the case of periodic sampling. First experimental results show that this method can be successfully applied for characterization of the transverse trapping force of a single beam gradient trap with a good reproduction of predictions made by rigorous theory.

Q 36.7 Mi 18:00 Audi-A

Non-linear Compton scattering of laser pulses with strong temporal and spatial variations off relativistic electrons — •Daniel Seipt, Thorger Sünert, and Burkhard Kämpfer — Forschungszentrum Dresden-Rossendorf, PF 510119, 01314 Dresden, Germany

Scattering experiments with high-intensity lasers and multi-MeV electron beams are gathering great interest as new light sources. Such experiments, especially with ultrashort laser pulses are prepared at Forschungszentrum Dresden-Rossendorf using the superconducting linac ELBE as brilliant source of monoenergetic electrons with energies of $10 - 40$ MeV. We present simulations of the scattering spectra focusing on the effects of temporal and spatial variations of intensity in short optical laser pulses (Laser strength parameter significantly above 1) and the resulting shift of the non-linear Compton edge as well as higher and very high harmonic radiation.

Q 36.8 Mi 18:15 Audi-A

On the interaction of highly focused beams with metallic edges or the knife-edge method in the nano-world — •Marchenko Pavel, Sergejus Orlovas, Susanne Quabis, Ulf Peschel, and Gerd Leuchs — MPI für die Physik des Lichts, Erlangen, Deutschland

The so-called "knifeedge" method is frequently used to determine the intensity distribution of laser beams. Metal edges of various orientations are moved across the spot and the transmitted power is measured with a photo diode. Finally the intensity distribution is reconstructed by analyzing the slope of the photocurrent. But if beams are focused down to the nanoscale the modification of the electric field by the metal edge cannot longer be ignored and simple evaluation schemes fail. Understanding the mechanisms of the interaction between the edges and the fields becomes essential to evaluate the measurement.

In our experiment we investigate this effect with nanometer resolution. Linearly and radially polarized beams at 633 and 780 nm are focused by a high numerical aperture objective onto a sample. The sample is a p-i-n photodiode covered with thin (<200nm) patterned films made of Au, Zn/Au, Cr and Ge. We move the spot over the edges of the respective structures and for each one record the photocurrent as a function of the position.

The measurements reveal material dependent shifts of the electric field distribution where the direction of the polarization vector and the conductivity of the respective structures play an important role.

Q 37: Ultrakalte Atome: Manipulation und Detektion / Rydbergatome (mit A)

Zeit: Mittwoch 16:30–18:45 Raum: Audi-B

Q 37.1 Mi 16:30 Audi-B

Effects of Non-Abelian Gauge Potentials — •Andreas Jacob[1], Luis Santos[1], Michael Merkl[2], Frank Zimmer[2], and Patrik Öhberg[2] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover — [2]SUPA, School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh, United Kingdom

Artificial electromagnetism may be created for neutral atoms, e.g. by rotating the gas. Other forms of inducing artificial electromagnetism are possible, including ways of generating non-Abelian vector potentials. In this talk, we will first discuss simple laser setups that allow the creation of non-Abelian gauge potentials for atoms with a tripod level scheme. We will comment on specific experimental implementations in e.g. ^{4}He* and ^{87}Rb. In particular we will discuss a simple laser arrangement that generates a non-Abelian vector potential proportional to the Pauli matrices. This gauge potential induces a quasi-relativistic physics for cold gases similar to that in graphene, including the possibility of observation of metamaterial phenomena as Veselago lensing. We shall discuss in particular the effects of this gauge potential in the linear and nonlinear atom optics of condensates, including the possibility of creating regions of negative mass in the dispersion relation which allow for bright solitons in the presence of repulsive interactions.

Q 37.2 Mi 16:45 Audi-B

State-selective microwave near-field potentials on atom chips — •Pascal Böhi[1,2], Max F. Riedel[1,2], Theodor W. Hänsch[1,2], and Philipp Treutlein[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München

The spectacular experiments with ultracold neutral atoms are intimately connected with the availability of sophisticated techniques for coherent control of internal and motional degrees of freedom of the atoms. For quantum information processing and quantum simulations, for example, tailored potentials are required which control atomic dynamics, but at the same time, control of internal degrees of freedom is needed. Potentials which are in principle arbitrarily configurable can be realized in static magnetic near-field traps on microfabricated 'atom chips'. However, state-selectivity is limited in these potentials.

In this talk we show how we use on-chip microwave near-fields to generate versatile state-selective potentials varying on a μm scale and use these potentials for the state-selective coherent manipulation of Bose-Einstein condensates. We entangle atomic spin and motional state in a controlled and reversible way, as required for a quantum phase gate previously proposed [1]. Our system also constitutes a trapped-atom interferometer with internal-state labeling and is furthermore useful for experiments on squeezing and many-particle entanglement in Bose-Einstein condensates [2].

[1] P. Treutlein et al., Phys. Rev. A 74, 022312 (2006)
[2] Y. Li et al., arXiv:0807.1580 (2008)

Q 37.3 Mi 17:00 Audi-B

Light Sheet Fluorescence Imaging of Cold Atoms — •Robert Bücker[1], Aurélien Perrin[1], Stephanie Manz[1], Thomas Betz[1], Christian Koller[1], Wolfgang Rohringer[1], Martin Göbel[1], Jörg Rottmann[2], Thorsten Schumm[1], and Jörg Schmiedmayer[1] — [1]Atominstitut der Österreichischen Universitäten, TU Wien, Stadionallee 2, A-1020 Vienna, Austria — [2]Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, D-69120 Heidelberg, Germany

Fluorescence imaging with illumination by a light sheet is commonly used in optical microscopy of biological specimen. We transfer this approach to detection of ultracold Bosonic gases in an atom chip experiment. During time of flight, the expanding cloud pierces a thin horizontal sheet of near-resonant light. Scattered photons are collected by an imaging objective and detected by an electron-multiplying CCD. This scheme allows for extremely low background and high sensitivity unattainable with conventional methods. By autocorrelation analysis we confirm the efficient detection of single atoms within dilute clouds at a spatial resolution on the order of 10 μm, limited by stochastic motion of the atoms during interaction time. Time-of-flight imaging on a single-atom level paves the way for studying second-order correlations in the various regimes of low-dimensional degenerate Bose gases feasible in our experiment.

Q 37.4 Mi 17:15 Audi-B

Quantum resolution limits for imaging Bose gases — •Antonio Negretti[1,2], Carsten Henkel[3], and Klaus Molmer[2] — [1]Institut für Quanteninformationsverarbeitung, Universität Ulm, Albert-Einstein-Allee 11, D-89081 Ulm, Germany — [2]Lundbeck Foundation Theoretical Center for Quantum System Research Department of Physics and Astronomy, University of Aarhus, DK-8000 Aarhus C, Denmark — [3]Universität Potsdam, Institut für Physik und Astronomie, Karl-Liebknecht-Str. 24/25, D-14476 Potsdam, Germany

We present an analysis of the resolution limits for observables contained in the density profiles for an ultracold Bose gas of atoms. Within the Bogoliubov approximation we compute the density-density correlations by including both quantum and thermal fluctuations. These correlations provide a tool to construct the (approximate) joint counting statistics of atoms in an array of pixels covering the gas. As an example of the general theory, we derive the position uncertainty of a dark soliton in a quasi one dimensional Bose gas. The smallest uncertainty scales with the atomic background density, n, as $n^{-3/4}$, beating the classical shot noise limit. Intriguingly, the sensitivity is slightly improved when quantum fluctuations are included.

Q 37.5 Mi 17:30 Audi-B

Image formation in scanning electron microscopy of ultracold quantum gases — •Peter Würtz, Tatjana Gericke, Andreas Koglbauer, and Herwig Ott — Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz

We review the image formation and reconstruction of our recently developed scanning electron microscope for ultracold atoms. In our experimental setup, a focussed electron beam with a FWHM of 100 nm ionizes atoms, which are subsequentl y accelerated towards an ion detector. Obtaining images from the time resolved signal of ion detection events involves several post-processing methods to account for effects disturbing the imaging process. For applications with optical la ttices, drifts and fluctuations of the lattice potential have to be determined and compensated for. We discuss differen t imaging modes and interaction mechanisnms and show that the microscope is a very versatile tool for the detection and manipulation of ultracold atoms.

Q 37.6 Mi 17:45 Audi-B

Coherent excitation of ultra-long-range Rydberg molecules — •Björn Butscher[1], Vera Bendkowsky[1], Johannes Nipper[1], Jonathan Balewski[1], James Shaffer[1,2], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Deutschland — [2]Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, USA

At ultralow temperatures - in so-called frozen Rydberg gases - the scattering of the Rydberg electron and a nearby polarizable ground state atom can generate an attractive potential due to the negative scattering length which is able to bind the ground state atom to the

Rydberg atom at a well localized position within the Rydberg electron wave function. The resulting giant molecules can have an internuclear separation of several thousand Bohr radii, which places them among the largest known molecules to date.

Here we present spectroscopic data on the observation of vibrational ground and first excited state of Rubidium dimers Rb(5S)-Rb(nS). We apply a Born-Oppenheimer model to explain the measured binding energies for principal quantum numbers n between 34 and 40 and extract the s-wave scattering length for electron-Rb(5S) scattering in the relevant low energy regime $E_{\rm kin} < 100\,\text{meV}$. We also determine the lifetimes and the polarizabilities of these molecules [arXiv:0809.2961].

Additionally, we report on the observation of trimer states, where two ground state atoms are bound by a Rydberg atom.

Q 37.7 Mi 18:00 Audi-B

Controlling the pair distribution in an ultracold Rydberg gas — •Christoph S. Hofmann, Thomas Amthor, Christian Giese, Hanna Schempp, Brett DePaola, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg

We show that the pair distribution in an ultracold Rydberg gas can be influenced by means of red or blue detuned Rydberg excitations. To demonstrate this the ionization of the Rydberg gas is used as a sensitive probe [1,2]: For attractive interaction potentials, atoms excited to Rydberg states on the red-detuned wing of the resonance are observed to ionize first, since more atom pairs are prepared at small interatomic distances and hence experience strong attractive forces. This excitation scheme is extended by using Autler-Townes-splittings of up to 150 MHz in order to exploit a wider frequency range for the pair distribution control. This allows to address pairs with a 1.6 times smaller pair distance, yielding an increase of the interaction strength by more than one order of magnitude. A Monte Carlo model for the description of such a system is presented and agrees well with experimental observations. The Autler-Townes-splitting moreover allows for rapid frequency chirps across a resonance without actually tuning any of the excitation laser frequencies.

[1] T. Amthor et al., Phys. Rev. Lett. 98, 023004 (2007)
[2] T. Amthor et al., Phys. Rev. A 76, 054702 (2007)

Q 37.8 Mi 18:15 Audi-B

Autler-Townes Splitting in an inverted three-level system using Rydberg gases — •Hanna Schempp, Christian Giese, Sebastian Saliba, Thomas Amthor, Christoph S. Hofmann, Brett DePaola, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg

We investigate coherent excitation phenomena in ultracold Rydberg gases. In a three level Rydberg system Autler-Townes (AT) splitting can be seen by coupling the lower transition and probing the excitation to a Rydberg state [1,2]. The long lifetimes of Rydberg atoms permit us to investigate AT splitting in an inverted Rydberg system, i.e. starting with all atoms in the Rydberg state and stimulating them down to the intermediate state which is split by a strong laser field coupling the intermediate and the ground state. We show the first experimental results and discuss the features of our system.

[1] B. K. Teo et al., Phys. Rev. A 68, 053407 (2003)
[2] J. Deiglmayr et al., Opt. Comm. 264, 293 (2006)

Q 37.9 Mi 18:30 Audi-B

Exciton transport in ordered and disordered samples of cold Rydberg atoms — Torsten Scholak, •Thomas Wellens, and Andreas Buchleitner — Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

We study coherent dipolar energy transfer between resonant levels of Rydberg atoms. We determine the transport properties by examining the spectral structure and the associated eigenfunctions. To highlight the impact of disorder on the Rydberg exciton transport, we introduce a disorder parameter allowing us to switch continuously from an ordered to a completely disordered sample of atoms. Special attention is dedicated to the transition from diffusive to non-diffusive transport, as well as to the metamorphosis of the nearest-neighbor level spacing distribution from Wigner to Poisson.

Q 38: Quantengase: Gemische

Zeit: Mittwoch 16:30–18:00 Raum: VMP 6 HS-A

Q 38.1 Mi 16:30 VMP 6 HS-A

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

Mixtures of ultracold Bosons and Fermions in optical lattices are promising candidates for the investigation of intriguing complex quantum phases, some of which go beyond the scope of conventional condensed-matter systems. The key control parameter for the mixture, which is the strength of interspecies interaction, can conveniently be tuned in the experiment by means of an interspecies Feshbach resonance, combined with rapid hyperfine transitions in and out of the resonant collision channel.

The observation of the collapse and revival dynamics of a macroscopic bosonic matter wave field, and its modification by a fermionic admixture, provides copious information about the Bose-Fermi mixture. We extract how the interspecies interaction affects the occupation number statistics in the system. Moreover, we demonstrate the importance of orbital effects beyond the usual single-band picture, leading to a renormalization of the Hubbard parameters. A detailed understanding of these effects will be an important prerequisite for the preparation of complex many body quantum states in Bose-Fermi mixtures.

Q 38.2 Mi 16:45 VMP 6 HS-A

Self-Trapping of Bosons and Fermions in Optical Lattices — •Dirk-Sören Lühmann[1], Kai Bongs[2,3], Klaus Sengstock[2], and Daniela Pfannkuche[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Germany — [2]Institut für Laser-Physik, Universität Hamburg, Germany — [3]MUARC, University of Birmingham, UK

Degenerate mixtures of bosonic and fermionic atoms in three-dimensional lattices offer new insight into strongly correlated many-body physics. Already for the single-band Hubbard model, the interplay between interaction and tunneling is reflected in a complex phase diagram. Experimentally, the presence of fermions leads primarily to a reduction of the bosonic superfluidity for attractive interspecies interaction [1-3], which is apparently not covered by ridgid single-band physics. We theoretically investigate [4] the enhanced localization of bosonic atoms allowing for orbital changes and find a self-trapping of the bosons. The fermionic orbitals are substantially squeezed, which results in a strong deformation of the effective potential for bosons. We introduce a renormalized Bose-Hubbard model to predict the critical lattice depth using effective bosonic tunneling and on-site interaction. The results, in general, demonstrate the important role of orbital renormalization and are in good agreement with the recent experiment in Ref. [3], where Feshbach resonances are used to tune the boson-fermion interaction.

[1] K. Günter et al., PRL 96, 180402 (2006). [2] S. Ospelkaus et al., PRL 96, 180403 (2006). [3] Th. Best et al., PRL (in press), arXiv:0807.4504. [4] D.-S. Lühmann et al., PRL 101, 050402 (2008).

Q 38.3 Mi 17:00 VMP 6 HS-A

Nonlinear corrections to the BFHM induced by higher Bloch band — •Alexander Mering and Michael Fleischhauer — Fachbereich Physik, Technische Universität Kaiserslautern, Germany

Experiments with ultracold atoms in deep lattices are mostly described theoretically by means of single band Hubbard-type Hamiltonians. For increasing interactions it is however necessary to take into account higher band effects. We present analytic calculations of the higher band corrections both of the hopping amplitudes J and the interaction amplitudes U and V for intra- and interspecies interaction in the Bose-Fermi-Hubbard Hamiltonian and derive nonlinear corrections to the hopping amplitudes mediated by the inter-species interaction. We adiabatically eliminate the higher bands by means of a second order perturbation theory using the exact solution of the dynamics in all higher bands. From these corrections the shift of the Mott insulator to superfluid transition caused by the coupling to the higher bands can be determined as a function of the filling and the interspecies scattering strength. Further simplification can be obtained by using harmonic oscillator approximation for the wannier functions yielding purely analytic results for the amplitudes J, U and V.

Q 38.4 Mi 17:15 VMP 6 HS-A

Interaction dependent adiabatic heating of Bose-Fermi mixtures in optical lattices — •Marcus Cramer — Imperial College London, UK

In recent experiments with Bose-Fermi mixtures in optical lattices a decrease in bosonic coherence as compared to the purely bosonic case has been observed [1-3]. This effect has been attributed to adiabatic heating [4] and to a renormalization of interaction and tunneling amplitudes [5]. Here, we investigate in detail the role of the inter-species interaction in the adiabatic heating process and determine the final temperature of the mixture in the lattice. Within a Hartree-Fock-Bogoliuobov mean-field approach, we are able to treat the full three dimensional situation including the (anisotropic) harmonic confinement. We find remarkable qualitative agreement between the obtained increase in temperature and the recently observed decrease of coherence as a function of the Bose-Fermi interaction [3], suggesting that temperature effects could be one of the main causes for the loss of coherence.

[1] S. Ospelkaus *et al.*, Phys. Rev. Lett. **96**, 180403 (2006).
[2] K. Günter *et al.*, Phys. Rev. Lett. **96**, 180402 (2006).
[3] Th. Best *et al.*, arXiv:0807.4504.
[4] M. Cramer *et al.*, Phys. Rev. Lett. **100**, 140409 (2008).
[5] D.-S. Lühmann *et al.*, Phys. Rev. Lett. **101**, 050402 (2008).

Q 38.5 Mi 17:30 VMP 6 HS-A

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

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

Q 38.6 Mi 17:45 VMP 6 HS-A

Strongly interacting Lithium Rubidium mixtures — •Carsten Marzok, Benjamin Deh, Reinhard Maier, Alexander Schilke, Philippe W. Courteille und Claus Zimmermann — Physikalisches Institut, Universität Tübingen, 72076 Tübingen

Ultracold atomic gases are a versatile instrument allowing to study the rich field of many body physics with unprecedented control. In this context, the Li-Rb system can provide particular insights owing to the large mass ratio. Additionaly, both Fermi-Bose mixtures (^{6}Li-^{87}Rb) and Bose-Bose mixtures (^{7}Li-^{87}Rb) can be realized in the same apparatus, further enlarging the range of possible experiments. Up to now, experiments in the strongly interacting regime with these isotopes were hampered by an imprecise knowledge of the heteronuclear scattering parameters particularly with respect to Feshbach resonances. In a series of experiments we now have located two such resonances in the Fermi-Bose-mixture and five in the Bose-Bose mixture. Based on these observations, groups in Berlin (Saenz) and Hannover (Tiemann) have determined the potential curves such that the scattering properties are now well described. We present our experimental observations of the Feshbach resonances and our progress towards the study of the strongly interacting mixtures by means of Bragg spectroscopy.

Q 39: Quanteninformation: Konzepte V

Zeit: Mittwoch 16:30–18:00 Raum: VMP 6 HS-D

Q 39.1 Mi 16:30 VMP 6 HS-D

Evolution of entanglement entropy in disordered quantum spin chains after a local quench — •Zoltán Zimborás and Heiko Rieger — Institut für Theoretische Physik, Universität des Saarlandes, Saarbrücken, Germany

It is by now rather well-known how the entanglement entropy of a segment of spins in a homogeneous chain evolves after a global or local quench,i.e., after an instantaneous (global or local) change of parameters in the Hamiltonian. In this talk we report on results about the evolution of entanglement entropy in disordered spin chains after a local quench. We will present both analytical and numerical results, which show that there is a noticable difference between the homogeneous and disordered cases.

Q 39.2 Mi 16:45 VMP 6 HS-D

Entanglement entropy in quantum spin chains with finite range interaction — •Zoltan Kadar[1] and Zoltan Zimboras[2] — [1]ISI Foundation, Torino, Italy — [2]Universität des Saarlandes, Saarbrücken, Germany

Translation invariant spin chains with finite range interaction are of great interest, because they both model magnetic properties of solids and their pure states are sufficiently simple to study entanglement. The von Neumann entropy of the bipartite case has been computed for a large class of models with reflection invariant spectrum and their behaviour at the critical points were analysed in the literature. We relax the symmetry property of the interaction and provide results in the general case motivated by several concrete models currently under study.

Q 39.3 Mi 17:00 VMP 6 HS-D

Critical exponents of quantum critical models by means of a QuMERA channel — •Simone Montangero — Institut für Quanteninformationsverarbeitung Albert-Einstein-Allee 11 D-89069 Ulm Deutschland

We discuss an iterative method for the optimization of a tensor network based on the Multiscale Entanglement Renormalization Ansatz (MERA) which is suited for quantum critical systems in the thermodynamic limit. We test this technique to compute the critical exponents of the Ising and XXZ model where we can compare the method with the exact values. The agreement is typically of the order of few % already for moderate dimensions of the tensor indices.

Q 39.4 Mi 17:15 VMP 6 HS-D

Coupling strength estimation for spin chains despite restricted access — •Daniel Burgarth[1], Koji Maruyama[2], and Franco Nori[2] — [1]Imperial College, London, England — [2]RIKEN, Wako-Shi, Japan

Quantum control requires full knowledge of the system many-body Hamiltonian. In many cases this information is not directly available due to restricted access to the system. Here, we show how all coupling strengths in a spin chain can be indirectly estimated by measuring *one spin at the end of the chain.* The Hamiltonian we study is given by $H = \sum_n c_n \vec{\sigma}_n \cdot \vec{\sigma}_{n+1}$ where the c_n are arbitrary nearest-neighbor coupling strengths to be estimated. We also discuss the efficiency of the estimation and give a numerical example.

Q 39.5 Mi 17:30 VMP 6 HS-D

Unifying all classical spin models in a Lattice Gauge Theory — •Gemma De las Cuevas[1,2], Wolfgang Duer[1,2], Hans J. Briegel[1,2], and Miguel Angel Martin-Delgado[3] — [1]Institut für Theoretische Physik, Universität Innsbruck, Technikerstraße 25, A-6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaften, Innsbruck, Austria — [3]Departamento de Física Teórica I, Universidad Complutense, 28040. Madrid, Spain

We show that the partition function of all classical spin models, including all discrete Standard Statistical Models and all abelian discrete Lattice Gauge Theories (LGTs), can be expressed as a special instance of the partition function of the 4D $\mathbb{Z}_2$ LGT. In this way, all classical spin models with apparently very different features are unified in a single complete model, and a physical relation between all models is established. As applications of this result, we present a new method to do mean field theory for abelian discrete LGTs with $d \geq 4$, and we show that the computation of the partition function of the 4D $\mathbb{Z}_2$ LGT is a computationally hard (#P-hard) problem. We also extend our results to abelian continuous models, where we show the approximate completeness of the 4D $\mathbb{Z}_2$ LGT. All results are proven using quantum information techniques.

Q 39.6 Mi 17:45 VMP 6 HS-D

A Unified View on Controllability of Spin Chains — •Uwe Sander, Andreas Spörl, and Thomas Schulte-Herbrüggen — Technische Universität München, Department Chemie, Lichtenbergstr. 4, 85747 Garching

Lie theory provides a powerful tool for addressing controllability of quantum systems such as spin-chains with nearest-neighbour Ising or Heisenberg interactions. In a unified picture, we describe the family of fully controllable spin chains as well as chains whose controllability is restricted by symmetry. Even in these restricted cases Lie-algebraic tools allow one to assess whether special tasks like transferring qubit-packages from one end to the other are feasible. The results can be generalised to arbitrary spin topologies.

Q 40: Quanteneffekte: Interferenz und Korrelationen II

Zeit: Mittwoch 16:30–18:00 Raum: VMP 6 HS-E

Q 40.1 Mi 16:30 VMP 6 HS-E

Eine Quanten-Irrfahrt in der Paulfalle — •Hector Schmitz[1,2], Robert Matjeschk[1], Christian Schneider[1], Jan Glückert[1], Axel Friedenauer[1] und Tobias Schaetz[1] — [1]MPI für Quantenoptik, Garching — [2]LMU München, Garching

Die Quantenmechanik ist reich an Phänomenen, die der Alltagserfahrung widersprechen. Dazu gehört die so genannte Quanten-Irrfahrt, (engl.: *quantum random walk*), die Abweichungen von den Vorhersagen klassischer Modelle zeigt und Potential für effiziente Quantenalgorithmen bereit hält.

Im Experiment stellen wir mit Hilfe eines einzelnen gefangenen $^{25}Mg^{+}$-Ions die asymmetrische Irrfahrt entlang einer eindimensionalen Linie vor. Zwei elektronische Hyperfein-Zustände des Ions kodieren die zwei Seiten einer Quanten-Münze (Qubit); ihr „Wurf“ wird durch einen RF-Puls realisiert, der eine Superposition der Zustände $|\mathrm{Kopf}\rangle$ und $|\mathrm{Zahl}\rangle$ erzeugt. Eine zustandsabhängige Dipolkraft verschiebt das Ion, dessen Bewegung im harmonischen Potential der Paulfalle als kohärentes Wellenpaket beschrieben werden kann, im Phasenraum gleichzeitig nach links *und* rechts. Wir beobachten im dritten Schritt in Übereinstimmung mit dem theoretischen Modell die Signatur, die nur durch Interferenzeffekte erklärbar ist, da das Ion alle möglichen Pfade gleichzeitig beschreitet.

Weiterhin untersuchen wir die Umstände, die sich durch das Lamb-Dicke-Regime ergeben und zeigen einen Weg auf, die Methode auf eine größere Zahl von Schritten zu erweitern.

Q 40.2 Mi 16:45 VMP 6 HS-E

A semiclassical approach for the fidelity decay of δ-kicked atoms — •Martina Abb[1,2], Italo Guarneri[3], and Sandro Wimberger[1,2] — [1]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 19, D-69120 Heidelberg — [2]Heidelberg Graduate School of Fundamental Physics, Albert-Ueberle-Str. 3-5, D-69120 Heidelberg — [3]Center for Nonlinear and Complex Systems, Universita degli Studi dell'Insubria, Via Valleggio 11, I-22100 Como

Fidelity, the overlap of two wavefunctions with slightly different time evolutions, constitutes a sensitive measure to changes in the parameters of a given quantum system. Recently, an experiment performed at Harvard [1] confirmed the predictions (such as saturation of fidelity for long times) made for δ-kicked atoms at exact quantum resonance conditions [2]. This group also explored their immediate vicinity, which can be theoretically described by a near-integrable system [3]. We expand the region of parameters theoretically treated so far by numerical quantum calculations and offer a semiclassical ansatz to explain the observed fidelity decay close to quantum resonance. Moreover, we predict the occurence of experimentally accessible revivals of fidelity.

[1] S. Wu, A. Tonyushkin, and M. G. Prentiss, Preprint arXiv:0801.0475v3.
[2] S. Wimberger and A. Buchleitner, J. Phys. B: At. Mol. Opt. Phys. **39**, L145-L151 (2006).
[3] S. Wimberger, I. Guarneri, and S. Fishman, Nonlinearity **16**, 1381-1420 (2002)

Q 40.3 Mi 17:00 VMP 6 HS-E

Electromagnetically induced absorption as a consequence of quantum interference — •Hsiang-Shun Chou[1,2] and Jörg Evers[1] — [1]MPI für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Institute of Optoelectronic Sciences, National Taiwan Ocean University, Keelung, Taiwan 202

Electromagnetically induced absorption (EIA) is a quantum optical effect that leads to a substantial enhancement of the absorption rate of a probe field by the presence of a coupling field. EIA has been observed in a number of different systems, such as degenerate two-level systems [1,2,3]. The signature for EIA is an additional resonance with subnatural width observed in the spectra. So far, density matrix calculations including spontaneous coherence transfer have been suggested for a description of EIA. However, for certain cases of upper state and lower state angular momentum, it was reported that the EIA spectrum can not be explained by spontaneous coherence transfer [2]. In this paper, we propose an alternative simple physical picture which helps us gain deeper insight into EIA. We show that a constructive interference, which leads to EIA, arises naturally in the dressed state basis. This treatment illustrates the essential ingredients of EIA for all cases in a clear and simple way.

[1] A. M. Akulshin et al., Phys. Rev. A 57, 2996 (1998).
[2] S.-K. Kim et al., Phys. Rev. A 68, 063813 (2003).
[3] K. Dahl et al., Opt. Lett. 33, 983 (2008).

Q 40.4 Mi 17:15 VMP 6 HS-E

Intensity-field correlation of single-atom resonance fluorescence — •Sebastian Gerber[1], Lukas Slodicka[1], Daniel Rotter[1], Jürgen Eschner[2], Howard Carmichael[3], and Rainer Blatt[1] — [1]Experimentalphysik Innsbruck, Technikerstrasse 25, 6020 Innsbruck — [2]ICFO-Institut de Ciències Fotòniques, 08860 Castelldefels (Barcelona), Spain — [3]Department of Physics, University of Auckland, Auckland, New Zealand

We report measurements of an intensity-field correlation function of the resonance fluorescence of a single trapped Ba+ ion.

An Ba+ ion is loaded into a linear Paul trap and is continuously laser-cooled. Detection of a photon prepares the atom in its ground state and we observe its evolution under interaction with a laser field of well defined phase. We record the regression of the resonance fluorescence source field. This provides a direct measurement of the field of the radiating dipole of a single atom and exhibits a strong non-classical behavior. In the setup an interference measurement is conditioned on a fluorescence photon detection. Thus, the recorded third-order correlation function demonstrates an aspect of wave-particle duality at the single-atom, single-photon level.

Q 40.5 Mi 17:30 VMP 6 HS-E

Spontaneous photon transfer by coupling a two-mode light field to an atomic reservoir — •Gor Nikoghosyan and Michael Fleischhauer — Fachbereich Physik, Technische Universität 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 have large variety of applications; e.g. creation of new quantum states, transfer of photons of optical frequency to microwave domain and vice versa.

Q 40.6 Mi 17:45 VMP 6 HS-E

Investigation of spatial correlation of biphotons using a blazed grating — •Dirk Puhlmann and Martin Ostermeyer —

Institut of Physics and Astronomy, University of Potsdam, Potsdam, Germany

Correlations between photons can be exploited for resolution improvements in different methods of quantum imaging. Since Fock-states of N-photons of wavelength λ propagate through phase shifts N-times faster as coherent states they can appear as if they had a de Broglie wavelength of λ/N. This can be observed e.g. in diffraction experiments of biphotons at conventional gratings.

Using a blazed grating, different number states could be separated or sorted on the one hand. On the other hand evaluation of the diffraction pattern by the one-photon and two-photon rate allows for an analysis of the spatial correlation between correlated photons. An experimental demonstration of these ideas tested for a biphoton beam will be presented. A comparison to calculated diffraction patterns is carried out. Fraunhofer diffraction patterns for two-photon and one-photon detection were calculated and analyzed using a Fourier-optical approach [1].

[1] Shimizu, R., Edamatsu, K. & Itoh, *Phys. Rev. A* **74**, 013801-10(2006).

Q 41: Quantengase: Dipolare Gase

Zeit: Donnerstag 10:30–12:30 Raum: Audi-A

Q 41.1 Do 10:30 Audi-A

Effects of Bending modes on the quantum statistics of self-assembled chains of polar molecules — •Jörg Duhme, Michael Klawunn, and Luis Santos — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, D-30167, Hannover, Germany

Under certain circumstances quantum gases caught in harmonical traps can form layers. Dipolar gases are needed for a long-range interaction between different layers. In dilute gases this anisotropic interaction causes the formation of chains (filaments) of dipolar molecules [1]. We studied the effect of the bending modes of these filaments on the quantum statistics of the whole system made of several layers. Furthermore we investigated the effect of the bending modes on the critical temperature of the system to form a BEC of chains. The bending modes have important consequences for the critical temperature as well as for the quantum statistics of the whole system.

[1] D.W. Wang, M. Lukin, E. Demler, Phys. Rev. Lett. 97, 180413 (2006)

Q 41.2 Do 10:45 Audi-A

Roton instability in dipolar Bose-Einstein condensates in an 1D optical lattice — •Michael Klawunn and Luis Santos — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstr. 2,D-30167 Hannover, Germany

The non-local nonlinearity introduced by Dipole-Dipole interaction plays a crucial role in the physics of dipolar Bose-Einstein condensates. In a sufficiently strong one-dimensional periodic potential we have a stack of strongly confined pancake condensates, which shows under certain conditions a roton minimum in the dispersion law of collective excitations. We have analyzed these roton-instabilities for the cases of transversal excitations of a straight vortex-line created in the direction of the optical lattice [1,2] or homogeneous in-plane excitations in all layers.

[1] M. Klawunn, R. Nath, P. Pedri, L. Santos, Phys. Rev. Lett. 100, 240403 (2008); [2] M. Klawunn, L. Santos, submitted to New J. Phys.

Q 41.3 Do 11:00 Audi-A

Faraday Instability in 2D dipolar Bose-Einstein Condensates — •Rejish Nath Gopinathan Rejani and Luis Santos — Institute of Theoretical Physics, Leibniz University of Hannover

We discuss the Faraday instability (Faraday Patterns) in two dimensional dipolar homogeneous BECs. Faraday instability in BEC is induced by temporally periodically modulating the non-linearities in the system, e.g. the s-wave scattering length, (using Feshbach resonances), the dipole-dipole interaction(by modulating the external field) or the external confinement. The Faraday patterns are significantly modified in the presence of a roton in the Bogoliubov spectrum. This effect can be employed to reveal easily the appearance of a rotonized spectrum in dipolar BECs, in the on-going experiments.

Q 41.4 Do 11:15 Audi-A

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

Rotating Bose-Einstein condensates with contact interactions and electromagnetically induced attractive $1/r$ atomic interactions are studied. As a special feature the $1/r$ interactions allow for the case of self-trapping. Variational calculations are carried out both for self-trapping and for the case of an external trapping potential within the limits of Gross-Pitaevskii theory. In addition the Bogoliubov equations of the system are solved numerically to analyse the stability of the localised vortices.

Q 41.5 Do 11:30 Audi-A

Macroscopic excitations and quantum tunnelling of Bose-Einstein condensates with long-range interactions — Torsten Schwidder, •Holger Cartarius, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Macroscopic excitations and quantum tunnelling are discussed for Bose-Einstein condensates with both an attractive $1/r$ and a dipolar interaction. A time-dependent variational approach to the nonlinear Gross-Pitaevskii equation leads to classical Hamiltonians in canonical form which are quantized by diagonalization in a complete Sturmian-type basis set and using the method of complex dilatation. The real and imaginary parts of the resonance energies provide the macroscopic quantum excitations and decay rates of the condensate, respectively. The results are compared with excitations obtained by a harmonic approximation to the potential and tunnelling rates derived using the “bounce trajectory.” Significant differences between the semiclassical and exact quantum results are observed in particular for the decay rates.

Q 41.6 Do 11:45 Audi-A

Two-dimensional solitons in dipolar Bose-Einstein condensates — •Patrick Köberle, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

One of the key features of dipolar Bose-Einstein condensates is their instability with respect to collapse. It has been shown in [1] how this instability is affected by the shape of an external (3D) trap. However, according to [2], it is possible to create stable condensates which are only trapped in one direction perpendicular to the polarization axis. Using a numerical simulation we demonstrate how these two-dimensional solitons can be created in experiment, in particular in ^{52}Cr condensates.

[1] T. Koch *et al.*, Nature Physics **4**, 218 (2008)
[2] I. Tikhonenkov, B. A. Malomed, and A. Vardi, Phys. Rev. Lett. **100**, 090406 (2008)

Q 41.7 Do 12:00 Audi-A

Decay rates of attractive Bose-Einstein condensates with long-range interaction — •Axel Keller, Torsten Schwidder, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

The ground state of a trapped Bose-Einstein condensate with attractive interaction is known to be metastable in a certain range of (negative) scattering lengths. We study the decay of this state for condensates with long-range dipolar and electromagnetically induced $1/r$ interaction. The decay rates due to thermal excitation and macroscopic quantum tunnelling are calculated using different methods, including transition state theory, and compared to the rate of atom loss by two-body and three-body inelastic collisions.

Q 41.8 Do 12:15 Audi-A

Classical and semiclassical dynamics of dipolar Bose-Einstein condensates — •Torsten Schwidder, Jörg Main, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik,

Universität Stuttgart, 70550 Stuttgart

Using a time-dependent Gaussian ansatz we convert the Gross-Pitaevskii equation for dipolar Bose-Einstein condensates into a two-dimensional nonintegrable Hamiltonian system. This opens the possibility to apply the powerful methods known from classical nonlinear dynamics to the motion of the condensate. We find periodic orbits of the classical system, describing periodic oscillations of the condensate, surrounded by quasi-periodic and chaotic trajectories. The stability of the periodic orbits is investigated in dependence of the physical parameters of the condensate and the existence of bifurcations is demonstrated.

Furthermore, we address the topic of macroscopic quantum tunnelling, which means a tunnelling from the metastable ground state of the condensate into collapse, in a semiclassical approach. The "bounce trajectory" is used to calculate the corresponding decay rates.

Q 42: Quanteninformation: Atome und Ionen II

Zeit: Donnerstag 10:30–12:30 Raum: Audi-B

Q 42.1 Do 10:30 Audi-B

Ion traps with enhanced optical and physical access — •Robert Maiwald[1], Dietrich Leibfried[2], Joe Britton[2], J.C. Bergquist[2], Gerd Leuchs[1], and D.J. Wineland[2] — [1]Institut für Optik, Information und Photonik (IOIP), Universität Erlangen-Nürnberg, Staudtstr. 7/B2, 91058 Erlangen, Germany — [2]National Institute of Standards and Technology (NIST), Boulder, CO 80305, USA

Small, controllable and highly accessible quantum systems that are well isolated from their environment can serve as a probe at the single quantum level to study a multitude of effects, including fundamental processes of nature. We present a novel radio-frequency ion trap geometry that provides largely unrestricted optical access of up to 96% of 4π in one of the experimentally tested traps. We discuss fabrication of these traps, their characterization by use of single laser cooled ions and potential applications of similar trap structures in quantum optics and electric and magnetic field sensing.

Q 42.2 Do 10:45 Audi-B

Sub microsecond, highly efficient ionisation detection of single ^{87}Rb atoms — •Florian Henkel[1], Michael Krug[1], Norbert Ortegel[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

Fast and efficient state detection of qubits stored in single atoms represents an integral part regarding future implementations of quantum computation with neutral atoms [1].

In order to realise such a readout, single neutral ^{87}Rb atoms are ionised out of the background gas in a two-photon process ($\lambda_1 = 780$ nm, $\lambda_2 = 473$ nm). The charged ionisation fragments (e^- and $^{87}Rb^+$) are accelerated into two channel electron multipliers. Observing both fragments we are able to detect single ^{87}Rb atoms with an absolute efficiency of $\sim$93.7 % within 460 ns after ionisation being considerably faster than conventional fluorecence detection schemes.

This technique is a promising approach as an atomic readout unit for a final, loophole-free test of Bells inequality [2]. In principle, this detection should also be applicable to atomic arrays [3] or atoms in optical lattices [4].

[1] D. P. DiVincenzo, Fortschritte der Physik 48, 771-784 (2000)
[2] J. Volz et al., Phys. Rev. Lett. 96, (2006)
[3] Y. Miroshnychenko et al., Nature 442, 151 (2006)
[4] I. Bloch, Nature 453, 1016-1022 (2008)

Q 42.3 Do 11:00 Audi-B

Manipulation und Kontrolle von Ionen in einer mikrostrukturierten Paulfalle — •Ulrich Poschinger, Gerhard Huber, Frank Ziesel, Markus Deiss, Max Hettrich, Kilian Singer und Ferdinand Schmidt-Kaler — Institut für Quanteninformationsverarbeitung, Universität Ulm

Wir präsentieren experimentelle Ergebnisse zu essentiellen Teilschritten der Realisierung eines skalierbaren Quantencomputers basierend auf einer mikrostrukturierten, segmentierten Ionenfalle[1]. Eine Änderung der Fallenkontrollspannungen erlaubt die Steuerung der Ionen-Position und dessen Einschluss in segmentierten Mikrofalle. Über Laserpulse auf dem $^{40}Ca^+$ $S_{1/2} - D_{5/2}$ Quadrupolübergang und dem Ramanübergang zwischen beiden Zeemanniveaus $S_{1/2}$ Zustands kühlen wir ein Ion nahe an den quantenmechanischen Grundzustand und realisieren ein Qubit. In Kombination dieser kohärenter Zustandsmanipulation durch Laserpulse und einer schnellen Ansteuerung von Fallen-Kontrollelektroden können wir Qubits an jeden Ort der Falle bewegen und dort die Fallenfrequenz bestimmen. Zukünftige Schritte im Sinne der Skalierbarkeit beeinhalten das Kühlen, Manipulieren und Auslesen von Zwei-Ionen Kristallen.

[1] S. Schulz, U. Poschinger, F. Ziesel and F. Schmidt-Kaler, NJP 10, 045007(2008)

Q 42.4 Do 11:15 Audi-B

Ionentransport in einer mikrostrukturierten segmentierten Y-Oberflächenfalle — •S. A. Schulz, A. Bautista-Salvador, F. Ziesel, M. Hettrich und F. Schmidt-Kaler — Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, 89069 Ulm

Experimentelle Quanteninformationsverarbeitung mit mikrostrukturierten Ionenfallen beschränkt sich bisher auf die Verwendung nur weniger Qubits - ein skalierbarer Ansatz zur Kontrolle vieler Qubits stellt die Unterteilung mikrostrukturierter Ionenfallen in verschiedene Speicher- und Prozessorbereiche dar. Die Adressierbarkeit einzelner Qubits ist fundamental für die Realisierung von räumlich verteilter Verschränkung auf der Basis des Transports einzelner Qubits. Eine Vielzahl von segmentierten Kontrollelektroden erlaubt die Untersuchung komplexer Quantenalgorithmen mittels Verschiebeoperationen vieler Qubits.

Wir stellen ein Design, numerische Simulationen und die Entwicklung einer planaren linearen Paulfalle auf der Basis einer Y-Geometrie vor. Drei voneinander unabhängige lineare Fallenbereiche sind über eine Kreuzung miteinander verbunden. Lineare Verschiebeoperationen können über 58 individuell ansteuerbare Kontrollelektroden durchgeführt werden. Dabei werden Frequenzen der axialen Bewegung im Bereich einiger MHz erwartet. Es werden numerische Simulationen für Ionentransporte mit konstanter Axialfrequenz diskutiert. Der stabile Transport einzelner Ionen über die Kreuzung unter Berücksichtigung der Axialfrequenz zeigt die Skalierbarkeit der vorgestellten Ionenfalle.

Q 42.5 Do 11:30 Audi-B

Simulating the Quantum Magnet Reloaded — •Christian Schneider[1], Hector Schmitz[1,2], Martin Enderlein[1], Thomas Huber[1], Axel Friedenauer[1], and Tobias Schaetz[1] — [1]Max-Planck-Institut für Quantenoptik — [2]LMU München

The simulation of the dynamics of quantum mechanical systems on a classical computer is a hard task, because the requirements of computational power increase exponentially with (linearly) increasing number of quantum mechanical constituents. One possibility to cope with that problem is a quantum simulator. In 2008 our group successfully demonstrated in a proof-of-concept experiment all building blocks for the simulation of Quantum Spin Hamiltonians with trapped Mg ions [1] based on a proposal by Porras and Cirac [2]. The simulation of an adiabatic evolution of two spins from paramagnetic ($|\rightarrow\rightarrow\rangle$) to ferromagnetic order ($|\uparrow\uparrow\rangle$ or $|\downarrow\downarrow\rangle$) of the Quantum Ising Hamiltonian was performed with a fidelity exceeding 98%. Recently we achieved the initialization of up to five ions in the motional ground state in the radial degrees of freedom and a phase gate [3] with two ions with a fidelity exceeding 90%. We will present our results, talk about our future plans of one- and two-dimensional simulations of Quantum Spin Hamiltonians [2, 4] and discuss the challange of scalability.

[1] A. Friedenauer, H. Schmitz et al., Nat. Phys. **4**, 757, 2008
[2] D. Porras and J.I. Cirac, Phys. Rev. Lett. **92**, 207901, 2004
[3] D. Leibfried et al., Nature **422**, 412, 2003
[4] T. Schaetz et al., J. Mod. Opt. **54**, 2317, 2007

Q 42.6 Do 11:45 Audi-B

Scalable Architecture for Quantum Information Processing

with Atoms — •Jens Kruse, Malte Schlosser, Christoph Ewen, Peter Schauss, Christian Gierl, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schloßgartenstr. 7, 64289 Darmstadt

Quantum information processing with neutral atoms represents an important experimental approach complementing systems based on trapped ions. By using ultra-cold atoms in two-dimensional dipole trap arrays, one can realize highly controllable and scalable systems 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. Due to the large lateral separation of neighboring potential wells, each trap is individually addressable. For flexible architectures, we implement a liquid crystal display in front of a microlens array as a pixel-addressable intensity modulator. By this we are able to control each potential well separately and produce arbitrary trap configurations. We demonstrate the flexible site-specific initialization and coherent manipulation of separated small ensembles of ^{85}Rb atoms in two-dimensional trap arrays by applying coherent Raman coupling between hyperfine ground states, representing the qubit states.

Advanced schemes for scalable atom observation allow us to detect single atoms in two-dimensional sets of dipole traps with high efficiency and reliability.

Q 42.7 Do 12:00 Audi-B

Optimized two-dimensional microtrap arrays for quantum simulation with trapped ions — •Roman Schmied[1], J. Ignacio Cirac[1], Janus H. Wesenberg[2], and Dietrich Leibfried[3] — [1]MPI für Quantenoptik, Garching, Germany — [2]Department of Materials, University of Oxford, England — [3]National Institute of Standards and Technology, Boulder, U.S.A.

Trapped ions are a promising system for building quantum simulators. For a given simulation problem, it is advantageous if we can individually trap the ions in a well-defined spatial arrangement with specified trap curvatures. We introduce an efficient method for constructing arbitrary two-dimensional (single- and multi-layered) arrays of electric microtraps by calculating and optimizing the shapes of the necessary electrodes. Our method allows for large-scale periodic microtrap designs with maximal trapping depths for a given simulation unit cell. In addition to the general method, we present several examples, including a quantum simulator for the Kitaev toric code [1].

[1] A. Kitaev, Ann. Phys. 321 (2006) 2

Q 42.8 Do 12:15 Audi-B

Perspectives of simulating spin-Boson systems with trapped ions — •Martin Enderlein[1], Hector Schmitz[2], Christian Schneider[1], Thomas Huber[1], and Tobias Schaetz[1] — [1]Max-Planck-Institut für Quantenoptik — [2]LMU München

Under certain conditions, the Hamiltonian describing the electronic structure as well as the Coulomb interaction of trapped ions resembles the spin-Boson Hamiltonian which, e.g., describes quantum dissipation in solid-state physics. We aim for a quantum simulation where the spin is represented by two laser-coupled electronic levels of one ion and the phonons in a crystalline chain of ions play the role of the Bosonic bath [1]. Since trapped atomic ions provide a very clean system with a wide range of tunable parameters, this might also allow the experimental access to the strong coupling regime of the spin-Boson model (SBM), inaccessable in typical solid-state systems.

In this presentation we would like to discuss interesting features of the SBM and the perspectives of simulating them in our setup [2]. Since we recently achieved the initialisation of five ions in the radial motional ground state, we hope to observe behaviour characteristic for the SBM in a feasibility study.

[1] D. Porras *et al.*, Physical Review A **78**, 010101 (2008)
[2] A. Friedenauer *et al.*, Nature Physics **4**, 757 (2008)

Q 43: Ultrakurze Pulse: Anwendungen I

Zeit: Donnerstag 10:30–12:30 Raum: VMP 6 HS-A

Preisträgervortrag Q 43.1 Do 10:30 VMP 6 HS-A

Neuer Kurzpulslaser für die Materialbearbeitung — •Christoph Gerhard — LINOS Photonics, Göttingen — Träger des Georg-Simon-Ohm-Preises

In dieser Präsentation soll eine neuartige Laserquelle zur Mikromaterialbearbeitung vorgestellt werden. Hierbei handelt es sich um einen diodengepumpten Festkörperlaser mit mehrfach gefaltetem Resonator. Durch die Kombination zweier Techniken zur passiven Modenkopplung sowie den Einsatz eines akustooptischen Modulators gelang die Realisierung einer stabilen, modengekoppelten Kurzpulslaserquelle im Pikosekundenbereich mit einstellbarer Wiederholrate. Hierbei wurde erstmals der passiv modengekoppelte Betrieb des laseraktiven Mediums Nd:GdVO4 bei geringer Wiederholrate erreicht. Die Laserquelle wurde anschließend um einen optischen Verstärker erweitert, welcher eine Verstärkung um den Faktor 30 ermöglicht. Weiterhin wurden Materialbearbeitungsversuche an verschiedenen Werkstoffen wie beispielsweise Aluminium und Glas durchgeführt. Weiterführende Arbeiten mit dieser Laserquelle haben zudem die Erzeugung von Superkontinua zum Gegenstand.

Q 43.2 Do 11:00 VMP 6 HS-A

Fs- Lentotomie: Änderung der Akkommodationsamplitude durch das Bearbeiten von transparentem Linsengewebe in vitro mit fs- Laserpulsen — •Heike Hoffmann — Laser Zentrum Hannover, 30419 Hannover, Deutschland

Das aktuelle Forschungsgebiet befasst sich mit dem Ziel, die Altersweitsichtigkeit zu behandeln. Das Behandlungskonzept, basierend auf der Theorie des Akkommodationsprozesses nach Helmholtz, wird fs-Lentotomie genannt. Hierbei werden mit Hilfe von Femtosekunden- Laserpulsen Mikroschnitte innerhalb transparentem Linsengewebes platziert, um feine Gleitebenen zu erzeugen, die zur Steigerung der Flexibilität des sich im Alter verhärtenden Gewebes beitragen sollen. Ziel hierbei ist es, die Beeinflussung des Akkommodationsprozesses durch die Laserbehandlung in vitro, zu messen und zu beurteilen. Zur Implementierung der Gleitebenen sowohl im Inneren von humanen Spenderlinsen als auch in Schweinelinsen wird ein 100 kHz- fs- Lasersystem (Wellenlänge 1040 nm, Pulsrate 306 fs, Pulsenergie 1.3-1.6 *J) verwendet. Mechanische und geometrische Änderungen des Gewebes während der fs- Lentotomie- Behandlung sollen analysiert werden. Mit Hilfe der experimentellen Ergebnisse und theoretischen Modellrechnungen kann gezeigt werden, dass die Auswirkungen der Gleitebenen innerhalb des Linsengewebes nach dem Laservorgang einen Anstieg der Akkommodationsamplitude hervorrufen.

Q 43.3 Do 11:15 VMP 6 HS-A

Korrektur der Aberrationen in Augen mittels adaptiver Optik zur Reduktion der Schwellenergie von Femtosekundenlaserpulsen in der Therapie der traktiven Netzhautablösung — •Anja Hansen und Holger Lubatschowski — Laser Zentrum Hannover, Hollerithallee 8, 30419 Hannover, Deutschland

Stark fokussierte Femtosekundenlaserpulse erzeugen einen optischen Durchbruch im Fokusvolumen und damit eine Materialtrennung durch die resultierende Kavitationsblase im optisch transparenten Glaskörper des Auges (Photodisruption). Dabei wird ein Teil der Pulsenergie in einem nichtlinearen Prozess lokal im Fokus absorbiert, wobei die Schwellenergie für einen optischen Durchbruch von der Größe des Fokusvolumens abhängt. Bei einer Applikation von Femtosekundenlaserpulsen im hinteren Abschnitt des Glaskörpers wird der Fokus durch die Aberrationen der vorderen Komponenten des Auges, wie Hornhaut und Linse, verzerrt, so dass eine erhöhte Schwellenergie für einen optischen Durchbruch erforderlich ist und sich das Risiko einer parasitären Schädigung der Retina aufgrund der erhöhten Energie vergrößert. Hier wird gezeigt, dass durch den Einsatz einer adaptiven Optik die Aberrationen des Auges ausgeglichen werden können und ein definierter Fokus im hinteren Augenabschnitt erzeugt werden kann. Dies eröffnet die Möglichkeit einer nichtinvasiven Therapie der traktiven Netzhautablösung mit Femtosekundenlaserpulsen. Dabei kann eine erneute Anhaftung der Netzhaut ermöglicht werden, indem die Zugkräfte der epiretinalen Gewebsmembranen auf die Netzhaut abgebaut werden. Dazu werden diese Membranen durch Photodisruption durchtrennt.

Q 43.4 Do 11:30 VMP 6 HS-A

Kavitationsblasendynamik beim laserinduzierten optischen

Durchbruch durch ultrakurze Laserpulse — •Nadine Tinne, Valeria Nuzzo, Silvia Schumacher, Tammo Ripken und Holger Lubatschowski — Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover

Ultrakurze Laserpulse zur dreidimensionalen Bearbeitung von transparenten Materialien finden in der Materialwissenschaft, besonders aber in der Medizin und Biophotonik innerhalb der letzten Jahre immer häufiger Anwendung. Ziel ist es dabei, die Bearbeitungs- bzw. im medizinischen Bereich die Behandlungsdauern erheblich zu verkürzen. Die Entwicklung bewegt sich deshalb in die Richtung, für diese Prozesse Laser zu verwenden, die bei einer hohen Repetitionsrate zugleich über hohe Pulsenergien verfügen. Während der Schneideffekt, den Einzelpulse als Folge eines optischen Durchbruchs und einer daraus resultierenden Kavitation in biologischem Gewebe hervorrufen, gut verstanden ist, ist die Wechselwirkung zeitlich und räumlich dicht aufeinander folgender Pulse weitestgehend unbekannt.

Der dabei stattfindende Wechselwirkungsprozess kann mit Hilfe von Kurzzeitphotographie experimentell sichtbar gemacht werden und ermöglicht somit eine Untersuchung der Abhängigkeit von Pulswiederholrate und Spotabstand nachfolgender Pulse. Die gegenseitige Beeinflussung räumlich und zeitlich benachbarter Kavitationsblasen in Abhängigkeit von Pulsenergie und Pulsabstand wird im Modellmedium Wasser untersucht, um eine Optimierung der Parameter für eine verkürzte Behandlungsdauer zu finden.

Q 43.5 Do 11:45 VMP 6 HS-A

Double waveguide couplers produced by adaptive femtosecond writing — •Matthias Pospiech[1], Moritz Emons[1], Andy Steinmann[1], Guido Palmer[1], Uwe Morgner[1,2], Roberto Osellame[3], Nicola Bellini[3], and Giulio Cerullo[3] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland — [2]Laserzentrum Hannover e.V. — [3]Istituto di Fotonica e Nanotecnologie - CNR, Dipartimento di Fisica - Politecnico di Milano

We report on a novel method to create waveguide coupler devices in fused silica by combining the technique of adaptive beam shaping with femtosecond laser writing. The method is based on a programmable phase modulator and a dynamic variation of the phase-pattern during the writing process. The major advantage is the possibility to create complex devices in a single sweep by simultaneously writing two or more waveguides with changing separation. The guiding properties and the coupling behavior between the waveguides are investigated.

Q 43.6 Do 12:00 VMP 6 HS-A

Von Polystyrolkugeln zu photonischen Komponenten für die Telekommunikation — •Thorsten Schweizer[1], Roman Kiyan[1], Rainer Kling[1], Wendel Wohlleben[2], Alvaro Blanco[3] und Cefe López[3] — [1]Laser Zentrum Hannover e.V., Hannover — [2]BASF, Ludwigshafen — [3]Instituto de Ciencia de Materiales de Madrid, Madrid

Winzige Kugeln aus Polystyrol bilden nicht nur die Grundlage für eine Vielzahl chemischer Produkte, sondern können auch als Basis für die Herstellung neuer photonischer Komponenten dienen. Aus einer Dispersion mit 1-Mikrometer großen Polystyrolkugel lässt sich durch Selbstorganisation ein kolloidaler Kristall mit einer Opal-Struktur herstellen. Dieser Kristall dient als Vorlage, um durch Infiltration mit einem hochbrechenden Material wie Silizium und nachfolgendem Entfernen der Polystyrolkugel einen sogenannten "photonischen Kristall" mit inverser Opal-Struktur zu erhalten. Ein solcher inverser Opal aus Silizium weist ähnlich der elektronischen Bandlücke in Halbleitermaterialien eine "photonische Bandlücke" auf, d.h. Licht mit Wellenlängen innerhalb dieser Bandlücke kann sich nicht im Kristall ausbreiten.

Vor der Inversion des Kristalls werden mit einem fs-Laser mittels Zwei-Photonen-Polymerisation eines infiltrierten Polymers gezielt Fehlstellen in den Kristall eingebaut, die lokal die Bandlücke schließen und damit als Wellenleiter für Licht mit Wellenlängen innerhalb der photonischen Bandlücke dienen können.

In diesem Vortrag stellen wir die Arbeit des EU-Projektes "NewTon" bezüglich der Herstellung neuer optischer Komponenten aus photonischen Kristallen für die Telekommunikation vor.

Q 43.7 Do 12:15 VMP 6 HS-A

Spatio - temporal coherence of free electron laser pulses in the soft x-ray regime — •Sebastian Roling[1], Rolf Mitzner[1,2], Björn Siemer[1], Tino Noll[2], Kai Tiedtke[2], Wolfgang Eberhardt[2], and Helmut Zacharias[1] — [1]Physikalisches Institut, Westfälische Wilhelms-Universität, 48149 Münster — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH

The mutual coherence properties of soft x-ray free electron laser pulses at FLASH are measured at 23.9 nm by interfering two time-delayed partial beams directly on a CCD camera. These two pulses are generated in a beam splitter and delay unit (autocorrelator) where both pulses are derived from the same optical source by wavefront beam splitting at a sharp mirror edge. The device operates at photon energies from hν = 30 to 200 eV. A delay is possible with sub femtosecond precision. At zero delay a visibility of (0.63 ± 0.04) is measured. The delay of one partial beam reveals a coherence time of about 6 fs at 23.9 nm. The visibility further displays a non-monotonic decay, which can be rationalized by the presence of a multiple pulse structure. From the interferences also the spatial coherence of the FEL pulses can be assessed. The pulses show a fairly uniform coherence over a large part of the beam profile with very similar time coherence properties. Only at the very edges of the profile a significant reduction of the coherence can be noticed.

Q 44: Ultrakalte Atome, Ionen und BEC II (mit A)

Zeit: Donnerstag 10:30–12:15 Raum: VMP 6 HS-C

Das Programm der Sitzung ist unter A 24 zu finden.

Q 45: Laserentwicklung: Nichtlineare Effekte

Zeit: Donnerstag 10:30–12:30 Raum: VMP 6 HS-D

Q 45.1 Do 10:30 VMP 6 HS-D

Nichtlineare Verluste in einfach-resonanten optisch parametrischen Oszillatoren* — •Ingo Breunig, Rosita Sowade, Jens Kiessling und Karsten Buse — Physikalisches Institut, Universität Bonn, Wegelerstr. 8, 53115 Bonn, Deutschland

Wir präsentieren ein Modell, welches die Oszillation einfach-resonanter optisch parametrischer Oszillatoren (OPO) beschreibt. In diesen Systemen werden aus einem Pumpfeld das Idler- und das Signalfeld erzeugt, wobei letzteres resonant überhöht wird. Bringt man nichtlinear von dieser Signalintensität abhängige Verluste in den Resonator ein, so wird ein bistabiles Verhalten vorhergesagt. Solche Bistabilitäten der Idlerleistung in Abhängigkeit von der kohärenten Pumpleistung haben wir in einem Dauerstrich-OPO beobachtet, in den zusätzlich ein sättigbarer Absorber eingesetzt wurde. Die Breite der Hysterese hängt hierbei davon ab, wie viel inkohärente Leistung diesem Absorber zugeführt wird.

*Wir danken der Deutschen Forschungsgemeinschaft (FOR 557) und der Deutschen Telekom AG für die finanzielle Unterstützung.

Q 45.2 Do 10:45 VMP 6 HS-D

Einfluss der Pumpschwelle auf die einmodige Ausgangsleistung einfach-resonanter optisch parametrischer Oszillatoren* — •Rosita Sowade, Ingo Breunig, Jens Kiessling und Karsten Buse — Physikalisches Institut, Universität Bonn, Wegelerstr. 8, 53115 Bonn, Deutschland

In einem einfach-resonanten optisch parametrischen Oszillator (OPO) entstehen aus einem Pumpfeld ein Idler- und ein Signalfeld, wobei letzteres resonant überhöht wird. Ein Modell sagt für solche Systeme vorher, dass es bei gegebener Pumpleistung eine optimale Pumpschwelle gibt, um die höchste Ausgangsleistung mit einmodiger Idlerwelle zu erzielen. Daher müssen die Resonatorverluste und die parametrische Verstärkung angepasst werden. Insbesondere zeigen wir, dass deswegen - entgegen der Intuition - kürzere nichtlineare Kristalle zu höheren eimodigen Ausgangsleistungen führen können. In unserem Aufbau liefert ein 2,5 cm langer Lithiumniobatkristall 1,5 W monochromatische Idlerleistung im Vergleich zu 0,5 W, die mit einem 5 cm langen Kristall im gleichen Resonator erreicht werden. Zusätzlich konnten durch einen Auskoppelspiegel 3 W bei 3,2 μm und 7 W bei 1,5 μm mit dem OPO erzeugt werden.

*Wir danken der Deutschen Forschungsgemeinschaft (FOR 557) und der Deutschen Telekom AG für die finanzielle Unterstützung.

Q 45.3 Do 11:00 VMP 6 HS-D

532-nm-pumped cw singly resonant optical parametric oscillator based on MgO:PPLN — •Sebastian Zaske[1], Dong-Hoon Lee[2], and Christoph Becher[1] — [1]Fachrichtung 7.3 (Technische Physik), Universität des Saarlandes, Campus E2.6, 66123 Saarbrücken — [2]Division of Physical Metrology, Korea Research Institute of Standards and Science (KRISS), 1 Doryong-Dong, Yuseong-Gu, Daejeon 305-340, Republic of Korea

In recent years the development of green-pumped, cw singly resonant optical parametric oscillators (cw SROs) based on undoped periodically poled $LiNbO_3$ (PPLN) has been impeded by the effects of photorefractive damage and green-induced infrared absorption (GRIIRA). It has been demonstrated that both effects can be eliminated or at least significantly reduced by MgO doping. Our results show that MgO-doped PPLN can be considered an appropriate nonlinear material for green-pumped cw SROs at moderate pump powers: we report on a cw SRO based on MgO:PPLN and pumped at 532 nm by a single-mode DPSS laser. At a pump power of 2 W, it generates more than 300 mW of single frequency idler output power at 1416 nm. To prove the tunability, spectral purity and narrow linewidth of our device we performed Doppler-free saturation spectroscopy of the Cs D_2 line at the signal wavelength of 852 nm. Furthermore we achieved frequency stabilization of the SRO's signal frequency to one of the hyperfine components of the Cs D_2 transition.

Q 45.4 Do 11:15 VMP 6 HS-D

Lyman-α Erzeugung durch Vier-Wellen-Mischen unter Ausnutzung einer Zweiphotonenresonanz in Quecksilber — •Daniel Kolbe, Martin Scheid, Frank Markert und Jochen Walz — Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz

Kontinuierliche kohärente Lyman-α Strahlung bei 121,56 nm ist wichtig zur Kühlung von magnetisch gefangenem Antiwasserstoff. Diese Wellenlänge im Vakuum-Ultravioletten kann durch Vier-Wellen-Mischen 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-alpha Leistung, steigern. Im Speziellen wird die Summenfrequenz zweier Laser genau auf eine Zweiphotonenresonanz abgestimmt. Die Phasenanpassung wird dabei mit Hilfe der Temperatur des Quecksilberdampfes eingestellt. Erste Ergebnisse der Lyman-α Produktion werden vorgestellt und die mögliche Ausnutzung einer Einphotonenresonanz diskutiert.

Q 45.5 Do 11:30 VMP 6 HS-D

Aufbau eines miniaturisierten Heatpipe-Ofens zum Vier-Wellen-Mischen im Drei-Farben-Resonator — •Volker Neises, Tobias Weber, Daniel Kolbe, Frank Markert, Martin Scheid, Andreas Müllers, Ruth Steinborn und Jochen Walz — Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz.

Kontinuierliche kohärente Lyman-α-Strahlung im Vakuum-Ultraviolett kann durch Vier-Wellen-Mischen in Quecksilberdampf erzeugt werden. Diese soll zukünftig zur Kühlung von Antiwasserstoff in einer Magnetfalle dienen. Um die Konversion zu verstärken, sollen die Fundamentalstrahlen in einem Drei-Farben-Resonator überhöht werden. Ein miniaturisierter Heatpipe-Ofen, welcher im Resonator platziert werden kann und auf dessen geometrische und optische Anforderungen abgestimmt ist, ist hierbei ein entscheidender Bestandteil. Das Heatpipe-Prinzip soll das Einstellen stabiler Dampfdrücke zur Phasenanpassung beim nichtlinearen optischen Vier-Wellen-Mischprozess ermöglichen. Dabei ist es wichtig die Fenster des Heatpipe-Ofens hitzebeständig und quecksilberresistent abzudichten. Im Vortrag werden Aufbau sowie erste experimentelle Ergebnisse vorgestellt.

Q 45.6 Do 11:45 VMP 6 HS-D

Drei-Farben-Überhöhungsresonator zur Erzeugung von kontinuierlicher, kohärenter Strahlung im VUV — •Tobias Weber, Volker Neises, Martin Scheid, Daniel Kolbe, Frank Markert, Andreas Müllers, Ruth Steinborn, and Jochen Walz — Institut fürPhysik, Johannes Gutenberg-Universität Mainz, 55099 Mainz.

Durch Vier-Wellen-Mischen in Quecksilberdampf kann kontinuierliche, kohärente Strahlung bei 121,567 nm erzeugt werden. Diese Lyman-α-Strahlung soll künftig verwendet werden, um Antiwasserstoff in einer Magnetfalle für die höchstauflösende Laserspektroskopie zu kühlen. Die Ausgangsleistung der Lyman-α-Quelle ist proportional zum Produkt der Eingangsleistungen der drei Fundamentalstrahlen. Durch gleichzeitige Überhöhung dieser Eingangsleistungen in einem Doppel-Z-Resonator soll die Konversion um mehrere Größenordnungen verstärkt werden. Es wurde ein Aufbau mit Prismen gewählt, die die im fokussierten Arm überlagerten Strahlen im kollimierten Arm aufspalten. Dies ermöglicht die separate Stabilisierung der drei Strahlen, sowie die unabhängige Justage der Foki aufeinander. Der benötigte Quecksilberdampf befindet sich in einer miniaturisierten Zelle im Fokus des Resonators. Erste experimentelle Ergebnisse werden vorgestellt.

Q 45.7 Do 12:00 VMP 6 HS-D

Effizienter weit abstimmbarer Pikosekunden-OPG in LBO — •Tobias Traub, Felix Rübel und Johannes L'huillier — Technische Universität Kaiserslautern, Fachbereich Physik, Erwin-Schrödinger-Straße 46, 67663 Kaiserslautern

Weit durchstimmbare Pikosekunden-Laserimpulse im IR sind von Bedeutung für vielzählige Anwendungen in Wissenschaft und Technik, wie zum Beispiel die zeitaufgelöste Spektroskopie oder Diagnostik.

Ein interessantes Konzept zur Erzeugung dieser Laserimpulse ist ein grün gepumpter optisch parametrischen Generator (OPG). Im Gegensatz zu einem Ti:Saphir Laser emittiert ein grün gepumpter OPG auch im mittleren Infrarot bis 2700 nm. Wir berichten über solch einen effizienten grün gepumpten OPG aus Lithiumtriborat (LBO) mit einem weiten Durchstimmbereich von 660 nm bis 2700 nm. Die Durchstimmung der Signal- und Idlerwellenlänge erfolgt über nichtkritische Temperaturphasenanpassung im Bereich von 100 bis 150 °C. Die Pumpimpulsenergie von 10 μJ erzeugt bei idealer Boyd-Kleinman-Fokussierung eine Leistungsdichte von 50 GW/cm^2. Die totale Konversionseffizienz lag über 50 % für Signalwellenlängen von 790 nm bis 1064 nm und Idlerwellenlängen von 1064 nm bis 1630 nm.

Darauf aufbauend wurde ein OPG mit injection seeding untersucht. Durch injection seeding konnte die volle Halbwertsbreite von 40 nm auf 0,2 nm bei gleichbleibend hoher Konversionseffizienz reduziert werden. Das Zeit-Bandbreite-Produkt konnte dadurch um einen Faktor 200 auf das dreifache des Fourierlimits gesenkt werden.

Q 45.8 Do 12:15 VMP 6 HS-D

Ultradünne Cr:YAG-Schichten für Güteschaltung — •Friedjof Tellkamp, Bilge Ileri, Teoman Gün, Klaus Petermann und Günter Huber — Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Es wurden einkristalline, undotierte 100-YAG-Substrate mittels Pulsed Laser Deposition (PLD) mit einer Dünnschicht aus Cr,Mg:YAG versehen. Die Dotierungen betrugen jeweils 10% Chrom und 10% Magnesium zur Ladungskompensation für 4-wertiges Chrom. Durch eine in-situ Messung mit Reflective High Energy Electron Diffraction (RHEED) konnte Layer-by-Layer Wachstum beobachtet werden. Die hergestellten Schichten haben eine Dicke von etwa 3 μm bis 5 μm. Die Schichten wurden in einem diodengepumpten Nd:YAG-Laser bei 1,06 μm auf ihre Eigenschaften als passiver Güteschalter hin untersucht. Das System hat eine Wiederholrate von etwa 200 kHz mit Pulsenergien von etwa 0,4 μJ. Die Pulsbreiten betragen ca. 300 ns. Die Schichten wurden im Resonator mit einem sättigbaren Cr:YAG-Volumenkristall verglichen. Dieser zeigte deutlich kleinere Pulsbreiten und Wiederholraten. Hier soll eine numerische Simulation Aufschluss über Verluste und Dynamik der Sättigung in beiden Systemen geben.

Q 46: Quanteneffekte: Lichtstreuung und Ausbreitung

Zeit: Donnerstag 10:30–12:15 Raum: VMP 6 HS-E

Q 46.1 Do 10:30 VMP 6 HS-E

Negative refraction in atomic two-component media — •Bastian Jungnitsch[1,2] and Jörg Evers[2] — [1]Institut für Quantenoptik und Quanteninformation, Technikerstraße 21a, 6020 Innsbruck, Austria — [2]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

We discuss the feasibility of negative refraction at optical wavelengths and low absorption in gases consisting of two species of atoms. In such a setup, one species contributes the electric response, and the other one the magnetic response, respectively.

To obtain a negative refractive index, both responses must be large. We therefore optimize the typically small magnetic susceptibility in different systems. Specifically, we investigate a mechanism in closed-loop systems that enhances the magnetic response by a scattering of the electric probe field component into the magnetic probe transition. In addition to a parametric enhancement by a factor of α^{-1} [1], where α is the fine structure constant, we find a strong non-parametric enhancement of the response [2].

Based on these findings, we calculate the refractive index for several combinations of two realistic level schemes. Since we consider active media, potential instabilities of the probe field are also addressed. As the main result, we obtain high negative refractive indices at vanishing absorption for several candidate systems.

[1] J. B. Pendry, Science 306, 1353 (2004).
[2] B. Jungnitsch and J. Evers, Phys. Rev. A 78, 043817 (2008)

Q 46.2 Do 10:45 VMP 6 HS-E

Sub-wavelength position measurements with running wave driving fields — •Jörg Evers[1] and Sajid Qamar[1,2] — [1]MPI für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Centre for Quantum Physics, COMSATS Institute of Information Technology, Islamabad, Pakistan

Spatial precision measurements are of interest both for a number of important applications and from a fundamental point of view. Applications arise, e.g., in life sciences, and more basic questions are related, e.g., to the uncertainty principle. A wide class of proposals for position measurements with sub-wavelength precision based on quantum optical ideas makes use of standing wave light fields. The standing wave acts as a ruler for the position measurement, and at the same time forms a spatial intensity pattern that can encode position information via a intensity-dependent dynamics of the atom.

Here, we discuss a setup for sub-wavelength position measuremerents of quantum particles which in contrast to previous work operates with running-wave laser fields. The position is encoded in the phase of the applied fields rather than in the spatially modulated intensity of a standing wave. This is achieved by deliberately breaking the phase matching condition usually assumed in related setups. Due to the running fields, cases where the atom remains undetected since it is close to a node of the standing wave field are avoided. Reversing the directions of the driving laser fields allows to switch between different magnification levels.

Q 46.3 Do 11:00 VMP 6 HS-E

Effective magnetic fields for stationary Dark-State Polaritons — •Johannes Otterbach[1], Razmik Unanyan[1], Julius Ruseckas[2], Gediminas Juzeliunas[2], and Michael Fleischhauer[1] — [1]Fachbereich Physik, Technische Universität Kaiserslautern, Germany — [2]Inst. of Theoretical Physics and Astronomy of Vilnius University, 01108 Vilnius, Lithuania

Recently there is a growing interest in creating effective magnetic fields for neutral particles to study many-body phenomena in the absence of Coulomb interactions. Here we propose a mechanism to create effective magnetic fields for light-matter quasi particles, so-called dark-state polaritons (DSP). These particles arise in the coherent Raman interaction of a weak probe field with an ensemble of Λ-type atoms driven by a strong classical control field. Upon misaligning these beams an effective magnetic field is created. Albeit the achievable magnetic field per particle is not higher than in cold atom gases, DSP have a number of advantages. By using counter propagating control beams stationary DSPs are created. At large pulse lengths these particles behave as bosonic Schrödinger particles with a variable mass which can be controlled externally. Thus their effective temperature can easily be controlled and be made very small. Finally a confinement to lower dimensions is readily done by wave-guide or resonator techniques. These effective fields can be used to study a variety of single- and many-particle effects as e.g. Lorentz forces for neutral particles, anyonic statistics, vortex lattices and the bosonic analogue of the fractional quantum Hall effect (FQHE).

Q 46.4 Do 11:15 VMP 6 HS-E

Dynamical control of pulse propagation in electromagnetically induced transparency — •Martin Kiffner[1,2] and Tarak Nath Dey[2,3] — [1]Physik-Department, Technische Universität München, D-85748 Garching, Germany — [2]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [3]Indian Institute of Technology, Guwahati, Guwahati- 781 039, Assam, India

The phenomenon of electromagnetically induced transparency (EIT) gives rise to counterintuitive effects like the slowing and stopping of light and is of great importance, e.g., for the fields of quantum information theory and nonlinear optics [1].

In contrast to the generic EIT setup, we consider a phase modulated control field and demonstrate that this alteration gives rise to periodic changes of the transparency window in frequency space. This feature enables the propagation of probe pulses with disjoint frequency spectra at different times, and thus enhances the potential of EIT media for the purpose of signal processing. For the explanation of our results, we put forward the concept of time-dependent susceptibilites that yields qualitative as well as quantitative agreement with the numerical integration of Maxwell-Bloch equations. Our theoretical model also applies to other systems.

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

Q 46.5 Do 11:30 VMP 6 HS-E

Coherent Spin Manipulation in Diamond — •Eric Kessler, Géza Giedke, and Juan Ignacio Cirac — Max-Planck-Institut für Quantenoptik, Garching, Germany

Diamond, as a pure and clean material, seems to be an attractive playground for solid state quantum computation. For instance, the carbon nuclear spins display extremely long decoherence times even at room temperature due to their weak mutual interaction. On the other hand however, single nuclear spins are hardly addressable individually.

This drawback can be overcome by the use of intentionally implanted defects like the NV (Nitrogen-Vacancy) Center. Those impurities bring physical richness into the system and open the possibility of coherent manipulation of the nuclear spin system, as they both interact strongly with nuclear spins and are easily accessible via optical and microwave fields.

We present a method to simulate different classes of Hamiltonians in the nuclear Hilbert space using fast microwave and laser pulses resonant to the NV Center's transitions.

Q 46.6 Do 11:45 VMP 6 HS-E

New approach to multiple scattering of intense laser light by cold atoms — •Tobias Geiger[1,2], Thomas Wellens[1], Vyacheslav Shatokhin[2], and Andreas Buchleitner[1] — [1]Institute of Physics, University of Freiburg, Hermann-Herder- Str. 13, 79104 Freiburg, Germany — [2]Stepanov Institute of Physics, National Academy of Sciences, Nezavisimosti Avenue 68, 220072 Minsk, Belarus

We present two different methods to calculate the spectrum of laser light multiply scattered between cold atoms. The first approach uses the well-known master equation for the time evolution of the reduced atomic density matrix. Due to the exponentially large Hilbert space, this approach is limited to calculations with only a small number of atoms. Therefore, we would like to present a second approach, based on the solutions of the Bloch equations for each individual atom, which are linked to each other in a self-consistent way. We will prove the equivalence between both approaches for the case of two distant atoms, and discuss the possibility of spectral calculations for a disordered sample of many atoms.

Q 46.7 Do 12:00 VMP 6 HS-E

Four-wave mixing enhanced white-light cavity — •Jörg Evers and Robert Fleischhaker — MPI für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

In an optical cavity, the bandwidth of supported frequencies and the intensity buildup are inversely proportional. Thus, higher buildup is only possible at the cost of a reduced available frequency range, and this limits possible applications such as in gravitational wave detection. To overcome this limitation, the concept of a white-light cavity was developed, in which the bandwidth of the cavity is enhanced via a medium with negative dispersion inside the cavity. The negative dispersion leads to a frequency-dependent phase compensation that effectively renders a wider range of frequencies resonant with the cavity [1].

Here, we discuss a white-light cavity medium based on four-level atoms in double-Λ configuration. This configuration is known to exhibit resonantly enhanced four-wave mixing [2], such that the spatiotemporal dynamics inside the medium becomes relevant. We perform a full simulation of the propagation of all fields, and find that the probe field dispersion is in addition changed by a coherent field which is generated within the medium via four-wave mixing. Counter-intuitively, this in-medium dynamics leads to a further enhancement of the cavity bandwidth [3].

[1] A. Wicht et al., Opt. Commun. 134, 431 (1997)
[2] M. Jain et al., Phys. Rev. Lett. 77, 4326 (1996)
[3] R. Fleischhaker and J. Evers, Phys Rev. A 78, 051802(R) (2008)

Q 47: Quantengase: Gitter und Tunneln I

Zeit: Donnerstag 14:00–16:00 Raum: Audi-A

Q 47.1 Do 14:00 Audi-A

Controlling a magnetic Feshbach resonance with laser light — •Matthias Lettner, Dominik M. Bauer, Christoph Vo, Gerhard Rempe, and Stephan Dürr — Max Planck-Institut für Quantenoptik, Hans Kopfermann Str.1, 85748 Garching

The capability to tune the strength of the elastic inter particle interaction is crucial for many experiments with ultracold gases. Magnetic Feshbach resonances are a tool widely used for this purpose, but future experiments would benefit from additional flexibility such as spatial modulation of the interaction strength on short length scales. Optical Feshbach resonances offer this possibility in principle, but suffer from fast particle loss due to light-induced inelastic collisions. Here we show that light near-resonant with a molecular bound-to-bound transition can be used to shift the magnetic field at which a magnetic Feshbach resonance occurs. This makes it possible to tune the interaction strength with laser light and at the same time induce considerably less loss than an optical Feshbach resonance would do. For small detuning from the bound-to-bound transition we observe a splitting of the Feshbach resonance similar to an Autler-Townes doublet.

Q 47.2 Do 14:15 Audi-A

Collisional properties of metastable neon in different internal states — •Jan Schütz, Jonas Keller, Matthias Euler, Norbert Herschbach, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

We measured the scattering lengths of laser-cooled neon atoms in the metastable state $^3P_2$ for the bosonic isotopes ^{20}Ne and ^{22}Ne and the suppression of two-body losses due to spin-polarization. After implementing a dipole trap, we determined the two-body loss coefficients of both isotopes in the second metastable state $^3P_0$. In all cases the good-to-bad ratios are found to be too low for efficient evaporative cooling without modification of the collisional properties.

We currently investigate the possibility to coherently control collisional interactions by preparing the atoms in superposition states of different magnetic sublevels of the $^3P_2$ state. We are therefore implementing a STIRAP scheme between the $^3P_0$ and $^3P_2$ states. We report on the status of the experiment.

Q 47.3 Do 14:30 Audi-A

The non-Abelian Ring: Interferometer & Josephson Effects — •Michael Merkl[1], Frank E. Zimmer[1], Patrik Ohberg[1], and Gediminas Juzeliunas[2] — [1]Heriot-Watt University, EH14 4AS Edinburgh, UK — [2]Vilnus University, 01108 Vilnius, Lithuania

In this work we consider optically induced non-trivial gauge potentials for the external motion of cold atoms. In the electromagnetically induced transparency (EIT) regime this can be achieved if the system stays in certain eigenstates, so called dark states. The resulting vector potential can be non-Abelian for a set of two degenerated dark states [1]. Non-Abelian vector potentials gives us a tool to investigate connections to very different areas of physics in the framework of cold atoms. The spacial shape of the trap and restriction to one dimension is the key technique used with non-Abelian potentials to observe a wide range of phenomenona [2]. In the present talk, we consider a non-Abelian ring in detail. Herby two limits are of interest. A interferometer set up, where small wave packets move in both directions, and the completely filled ring. The dynamics in the latter leads naturally to an exact description by Josephson equations which show non-trivial oscillations in the time and spacial domain.

[1] J. Ruseckas, G.Juzeliūnas, P Öhberg and M. Fleischhauer, PRL 95, 010404 (2005)
[2] M. Merkl, F.E. Zimmer, G. Juzeliūnas and P. Öhberg, EPL 83, 54002 (2008)

Q 47.4 Do 14:45 Audi-A

Probing Atom-Wall interactions by Quantum Reflection of Bose-Einstein Condensates — •Naceur Gaaloul for the Quantus Team, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik, Gottfried Wilhelm Leibniz Universität, Welfengarten 1 D -30167, Hannover, Germany

Recently a free expansion of a 10000 Rb-atom condensate was achieved for extremely long times (1s). The Bose-Einstein condensate is first prepared and trapped magnetically in the vicinity of an atom chip. The release of the atomic ensemble is performed when the experiment is dropped down in the ZARM tower facility in Bremen. Thus a free expansion is obtained during the free fall and could be used to observe quantum refection of the BEC on the chip surface. Several experiments of quantum reflection were done in the last years, but our model predicts high reflectivity due to the very slow incident velocities (less than 1 mm/s) of the cold atoms in the Quantus experiment. The dilute character of the cloud after 1s of expansion should also minimize the effect of mean-field interactions and lead to a good agreement with the quantum reflection theory. In addition, we interpret theoretically the expected interference fringes between reflected and incoming atoms to obtain a highly accurate measurement of the shift caused by the atom-surface interactions. Thus we could probe the attractive Casimir-Polder potential over an extended spatial range only reached thanks to the coherence of the source and the use of interferometric measurements.

The QUANTUS project is a collaboration of the U Hamburg, U Ulm, HU Berlin, MPQ Munich, ZARM at U Bremen, and the LU Hanover. It is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50 WM 0346.

Q 47.5 Do 15:00 Audi-A

Stability of Bloch oscillations in certain interacting BECs — •Christopher Gaul[1], Cord Axel Müller[1], Rodrigo de Lima[2], Elena Díaz García[2], and Francisco Dominguez-Adame[2] — [1]Physikalisches Institut, Universität Bayreuth, Deutschland — [2]Universidad Complutense de Madrid, España

We consider Bloch oscillations of a BEC in an optical lattice, using a tight binding model in the mean-field regime. Single-particle Bloch oscillations are very sensitive to any dephasing effect like on-site disorder or particle-particle interaction. Here we investigate the influence of a time-dependent repulsive interaction with zero time-average. In this driven system, we identify two distinct mechanisms for the collapse of Bloch oscillations: One mechanism acts directly on the width of the wave packet, resulting in an immediate decay of the oscillation. The other mechanism is more subtle and consists in an instability to perturbations on a short length scale compared to the width of the wave packet. Here it takes a long time for the perturbations to grow, which suddenly destroy the Bloch oscillation.

Q 47.6 Do 15:15 Audi-A

Solitonic eigenstates of the chaotic Bose-Hubbard Hamiltonian — •Tobias Zech[1], Hannah Venzl[1], Bartłomiej Oleś[2], Moritz Hiller[1], Florian Mintert[1], and Andreas Buchleitner[1] — [1]Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany — [2]Marian Smoluchowski Institute of Physics and Mark Kac Complex Systems Research Center, Jagiellonian University, Reymonta 4, 30-059 Kraków, Poland

The Bose-Hubbard Hamiltonian, that describes bosons in an optical lattice, exhibits quantum chaos [1] for comparable values of on-site and tunneling energies. We analyze the parametric level evolution as a function of an additional tilt of the lattice. Within the chaotic bulk of the spectrum we identify levels showing regular behavior, termed "solitonic eigenstates". Similar patterns are known in classical mechanics, where a mixed phase space contains regular islands that are embedded in the chaotic sea. We present a characterization of the solitonic states and construct systematically distinct manifolds of them.

[1] A. Buchleitner, A.R. Kolovsky, Phys. Rev. Lett. **91**, 253002 (2003)

Q 47.7 Do 15:30 Audi-A

Particle number squeezing in a two-well system — •Cédric Bodet and Thomas Gasenzer — Institut für Theoretishe Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg

The dynamical evolution of a Bose-Einstein condensate trapped in a one-dimensional lattice potential is investigated theoretically in the framework of the Bose-Hubbard model. The emphasis is set on the development of non-classical correlations and squeezing under circumstances where the system is strongly interacting and the evolution can no longer be described by classical statistical dynamics. We approach this problem by numerically solving the Schrödinger equation for this model and comparing those results to classical simulations. We study in detail particle number fluctuations, on-site and between sites, in order to investigate the conditions for producing squeezed states in experimentally realistic configurations, for example by raising a lattice potential inside a condensate.

Q 47.8 Do 15:45 Audi-A

Resonance solutions of the nonlinear Schrödinger equation in an open double-well potential — Kevin Rapedius and •Hans Jürgen Korsch — FB Physik, TU Kaiserslautern, 67663 Kaiserslautern, Germany

The resonance states and the decay dynamics of the nonlinear Schrödinger (or Gross-Pitaevskii) equation are studied for a simple, however flexible model system, the double delta-shell potential. This model allows analytical solutions and provides insight into the influence of the nonlinearity on the decay dynamics. The bifurcation scenario of the resonance states is discussed, as well as their dynamical stability properties. A discrete approximation using a biorthogonal basis is suggested which allows an accurate description even for only two basis states in terms of a nonlinear, nonhermitian matrix problem.

Journal reference: K. Rapedius, H. J. Korsch, "Resonance solutions of the nonlinear Schrödinger equation in an open double-well potential", Journal of Physics B, in press

Q 48: Quanteninformation: Quantenkommunikation I

Zeit: Donnerstag 14:00–16:00 Raum: Audi-B

Q 48.1 Do 14:00 Audi-B

Robustness of an optimal d-dimensional teleportation protocol — •Bruno Gouvêa Taketani[1], Fernando de Melo[2], Andreas Buchleitner[2], and Ruynet Lima de Matos Filho[1] — [1]Instituto de Física, Universidade Federal do Rio de Janeiro, Caixa Postal 68528, RJ 21941-972, Brazil — [2]Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

Quantum information tasks have as a main resource maximally entangled pure states. However, in real world applications, decoherence and impurities lead to the creation of mixed, non-maximally entangled quantum states. Protocols have been created to allow for the optimal usage of the non-local structure of such mixed states, but require complete knowledge of the noisy channel.

We consider here the robustness of the optimal teleportation protocol based on Bell measurements [1], for a $d \otimes d$ bipartite system. In this protocol, Alice performs Bell measurements on her set of particles. Bob, who knows the quantum channel state and the result of Alice's measurement, can decide which unitary operations to apply to his system, in order to maximize the protocol's fidelity. We analyze the robustness of this protocol when the channel is not completely known.

[1] S. Albeverio, S. M. Fei, and W. L. Yang, Phys. Rev. A **66**, 012301 (2002).

Q 48.2 Do 14:15 Audi-B

Fiber-based QKD system with Heterodyne Detection of Coherent States — •Christoffer Wittmann[1], Josef Fürst[1], Carlos Wiechers[1,2], Dominique Elser[1], Denis Sych[1], and Gerd Leuchs[1] — [1]Max-Planck-Institut für die Physik des Lichts , Günther-Scharowsky-Str. 1 / Bau 24, 91058 Erlangen, Germany — [2]Instituto de Física de la Universidad de Guanajuato

We present a fibre-based continuous-variable quantum key distribution system. It uses weak optical coherent states at the telecommunication wavelength (1550nm) as a quantum signal. The signal and a local oscillator are sent through an optical fiber using a time and polarization multiplexing technique. The system is automated such that the polarisation drift in the channel is compensated. In the receiver, a heterodyne detector measures conjugate quadratures of the signal [1] without any prior knowledge about the signal phase. We reconstruct the Q-function of the transmitted signal for the channel lengths 3m, 20km and 40km. The estimated excess noise originating from the channel transmission is about 1% percent. The channel attenuation allows for an estimated secret key of about 0.001 bit per pulse for a fibre channel of 20km length.

[1] S. Lorenz, N. Korolkova, and G. Leuchs, Appl. Phys. B: Lasers Opt. 79, 273 (2004).

Q 48.3 Do 14:30 Audi-B

Daylight free space quantum cryptography — •Harald Krauss[1], Martin Fürst[1,3], Sebastian Schreiner[1], Henning Weier[1,3], Markus Rau[1], and Harald Weinfurter[1,2] — [1]Department für Physik der LMU München, Schellingstr. 4/III, 80799 München — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching — [3]quTools GmbH, Königinstr. 11a, 80539 München

The BB84 quantum key distribution (QKD) scheme allows provably secure communication. We report on our free space implementation of the BB84 protocol linking two Siemens buildings downtown Vienna in the framework of a QKD network demonstration (SECOQC). The setup uses polarization encoded attenuated laser pulses in combination with decoy states to ensure secret key generation over a distance of 80 m. For the first time continuous and fast daylight operation could be achieved. Employing an active automatic position tracking system and improved filtering methods, key distribution rendered possible even during bad weather conditions. Our system is fully remotely controllable and integrates into SECOQC's network which provides the interface for secure communication in common network applications. The experiments prove daylight free space QKD to be feasible. High secure keyrates of already 20 kbit/s were achieved on a 24/7 basis, while the setup still stays both robust and simple, allowing for everyday applications.

Q 48.4 Do 14:45 Audi-B

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

We demonstrate for the first time the feasibility of free space quantum key distribution with continuous variables under real atmospheric conditions [1]. More specifically, we transmit weak coherent polarization states over a 100m free space channel on the roof of our institute's building. In our scheme, signal and local oscillator are combined in a single spatial mode auto-compensating atmospheric fluctuations and resulting in excellent interference. Furthermore, the local oscillator acts as a spatial and a spectral filter thus allowing for unrestrained daylight operation.

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

Q 48.5 Do 15:00 Audi-B

Towards long-distance atom-photon and atom-atom entanglement — •Michael Krug[1], Florian Henkel[1], Norbert Ortegel[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

Entanglement between single neutral atoms separated by several hundred meters is an essential step towards future applications in long-distance quantum communication like the quantum repeater and a first loophole-free test of Bell's inequality [1]. Atom-photon entanglement is the key element to realize both goals. By swapping the entanglement from two non-interacting entangled atom-photon pairs via a photonic Bell-state measurement onto the two atoms a pair of entangled atoms at large distances can be prepared.

Here we present progress towards long-distance atom-atom entanglement. We have established a robust photonic fiber-communication channel of 300 m length, which allowed us to reliably distribute atom-photon entanglement [2]. Towards two entangled ^{87}Rb atoms we present recent progress in the setup of our second mobile single-atom trap. First atom-photon correlation measurements are discussed.

[1] W. Rosenfeld et al., *Towards a loophole-free test of Bells inequality with entangled pairs of neutral atoms*, accepted for publication in *Advanced Science Letters* (2009)

[2] W. Rosenfeld et al., *Long-Distance Atom-Photon Entanglement*, arXiv:0808.3538v1

Q 48.6 Do 15:15 Audi-B

Towards two photon interference using NV color centers in diamond — •Florian Kaiser, Vincent Jacques, Helmut Rathgen, Fedor Jelezko, and Jörg Wrachtrup — 3. Physikalisches Institut in Stuttgart

The NV color center in diamond is of special interest for quantum information science because it exhibits a paramagnetic ground state, that spin can be optically polarized and read out with long coherence times [1,2]. To perform quantum operations by using such solid state spin qubits, multipartite entanglement among single spins is required. One strategy to entangle two distant qubits requires the emission of Fourier-transform limited single photons from each NV center. By performing a two photon interference experiment, it would then be possible to create conditional entanglement between the spin qubits without any direct interactions between them [3]. However counting rates are yet not sufficient to use such a protocol. To increase the photon collection efficiency, different Solid Immersion Lens techniques are investigated. We demonstrate a five times enhancement of the setup collection efficiency, which might be sufficient to perform two photon interference between two independent NV centers.

[1] F. Jelezko et al., Phys. Rev. Lett. 92, 076401 (2004).

[2] T. Gaebel et al., Nat. Phys. 2, 408 (2006).

[3] D. L. Moehring et al., Nature 449, 68 (2007).

Q 48.7 Do 15:30 Audi-B

Quantum Memory with Optically Trapped Atoms — •Thorsten Strassel[1], Valentin Hagel[1], Chih-Sung Chuu[1], Bo Zhao[1], Yu-Ao Chen[1], Markus Koch[1], Shuai Chen[1], Zhen-Sheng Yuan[1,2], Jörg Schmiedmayer[3], and Jian-Wei Pan[1,2] — [1]Physikalisches Institut, Heidelberg, Germany — [2]Hefei National Laboratory for Physical Sciences at Microscale, Department of Modern Physics, Department of Modern Physics, University of Science and Technology of China, Hefei, China — [3]Atominstitut der Österreichischen Universitäten, TU-Wien, Vienna, Austria

A quantum memory is a key element for long distance quantum communication and in the conversion of probabilistic single photon sources into deterministic ones. We report the experimental demonstration of a quantum memory of an increased lifetime for DLCZ-type protocols with ultra-cold atoms for single photon states in a far red-detuned optical dipole trap (FORT). The generation of the collective atomic state is heralded by the detection of a Raman scattered photon and accompanied by storage in the ensemble of atoms. The optical dipole trap provides confinement for the atoms during the quantum storage while retaining the atomic coherence. By addressing first-order magnetic field insensitive atomic states the dephasing of the atomic coherence caused by stray fields is suppressed. We probe the quantum storage by cross-correlation of the photon pair arising from the Raman scattering and the retrieval of the atomic state stored in the memory. Non-classical correlations are observed for storage times up to 60 microseconds. In addition we provide an outlook on future experiments.

Q 48.8 Do 15:45 Audi-B

Optical Implementations of Discrete- and Continuous-Variable Quantum Error Correcting Codes — •Ricardo Wickert and Peter van Loock — OQI Group, Max-Planck Research Group, Institute of Optics, Information and Photonics, University of Erlangen-Nuernberg

Reliability is of paramountal importance in both Quantum Computation, ensuring the accuracy of calculations, and in Quantum Communication, protecting the transmitted state from losses along the channel. As in the classical case, Quantum Error Correction (QEC) relies on redundancy[1]. However, Quantum Mechanics imposes fundamental limits which affect information processing directly; one example is the so-called 'No-Cloning' theorem[2], which forbids the creation of perfect copies of a given state. In this context, we propose theoretical implementations for different quantum error correcting codes (QECC). Particular cases considering the encoding of discrete variables[3] (ie, $\alpha|0>+\beta|1>$) as well as continuous variables[4] (utilizing the quadratures of the electric field) are discussed, based on a linear optics toolbox with beam splitters, phase shifters and conditional photon or homodyne detection.

References:

[1] P. W. Shor, Phys. Rev. A 52, R2493 (1995)

[2] W. K. Wootters and W. H. Zurek, Nature 299, 802 (1982)

[3] P. Kok et al, Rev. Mod. Phys 79, 135 (2007)

[4] S. L. Braunstein and P. van Loock, Rev. Mod. Phys. 77, 513 (2005)

Q 49: Ultrakurze Pulse: Anwendungen II

Zeit: Donnerstag 14:00–16:00 Raum: VMP 6 HS-A

Q 49.1 Do 14:00 VMP 6 HS-A

Measurement and Optimization of Isolated Attosecond Pulse Contrast for Optical Streaking in Molecules — •Thomas Pfeifer[1,2], Mark J. Abel[1], Phillip M. Nagel[1], Willem Boutu[1], M. Justine Bell[1], Daniel M. Neumark[1], and Stephen R. Leone[1] — [1]University of California, Berkeley & Lawrence Berkeley National Lab, USA — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Deuschland

A fast and efficient method to measure the contrast of an isolated attosecond pulse, defined as the ratio between the energy in the main pulse and the energy in the satellite pulses in the neighboring half-cycles, is presented. The method is based on scanning the carrier-envelope phase (CEP) of a few-cycle high-harmonic driver pulse and measuring the photoelectron spectra produced by the combined action of the attosecond pulses and strong-field visible laser pulse in a second interaction region as a function of the CEP but at constant time delay. The data can then be used to immediately determine the contrast as a function of CEP and thus to find the particular CEP value that produces the maximal contrast, which is of major importance for attosecond experiments. We used the optimized isolated attosecond pulses for performing cycle-resolved optical streak-field measurements in molecules (SF_6, N_2).

Q 49.2 Do 14:15 VMP 6 HS-A

Attosecond control of electron dynamics in a multi-electron molecule — •Philipp von den Hoff[1], Irina Znakovskaya[2], Matthias Kling[2], and Regina de Vivie-Riedle[1] — [1]Ludwig-Maximilians-Universität, München, Deutschland — [2]Max-Planck Institut für Quanten Optik, Garching, Deutschland

Laser pulses with stable electric field waveforms have opened up the opportunity to achieve coherent control on attosecond timescales. Waveform controlled few-cycle pulses have only recently been used to control electron localization in the dissociative ionization of the prototype molecules D_2 and HD. After initial ionization, these systems contain a single electron. The steering of this electron originates from a light-induced coherent superposition of two electronic states. The CEP controls the directional emission of charged and uncharged fragments upon the break-up of the molecule. The theoretical description of coupled electron and nuclear dynamics in multi-electron molecules is a challenge and its appropriate treatment the aim of state-of-the-art research. We present theoretical results on the direct strong-field control of electronic motion in the multi-electron system CO^+. The experimentally observed high degree of CEP control over the directional emission of C^+ and O^+ fragments from the dissociative ionization of CO can be explained as an interplay between the asymmetry in the ionization step and the laser induced asymmetry during the dissociation. Our theoretical treatment is in good qualitative and quantitative agreement with the experimental observation.

Q 49.3 Do 14:30 VMP 6 HS-A

Relativistic monoenergetic electron acceleration with 8fs laser pulses — •Alexander Buck[1], Karl Schmid[1,2], Laszlo Veisz[1], Christopher Sears[1], Daniel Herrmann[1], Raphael Tautz[1], Franz Tavella[3], Ulrich Schramm[4], Michael Geissler[5], Jürgen Meyer-ter-Vehn[1], Dietrich Habs[2], and Ferenc Krausz[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Department für Physik der LMU München, Am Coulombwall 1, 85748 Garching, Germany — [3]Deutsches Elektronensynchrotron DESY/HASYLAB, Notkestrasse 85, 22607 Hamburg, Germany — [4]Forschungszentrum Dresden-Rossendorf e.V., Bautzner Landstraße 128, 01328 Dresden, Germany — [5]Queen's University Belfast, Belfast BT7 1NN (UK)

We present new experimental results from our relativistic laser-plasma-based electron accelerator that is able to directly access the so-called bubble regime. For these experiments we use our novel ultra broadband non-collinear optical parametric chirped pulse amplifier (OPCPA) that delivers 8fs pulses with multi-TW peak power on target at 10Hz repetition rate. The pulses are shorter than half the plasma period at typical electron plasma densities used for the acceleration experiments. This allows us to directly access the bubble regime without relying on self-modulation of the laser pulse in the plasma and produce clean, monoenergetic electron spectra in the 10 to 100 MeV range. A parameter study of the acceleration process will be presented.

Q 49.4 Do 14:45 VMP 6 HS-A

Mehrfarbige XUV Interferometrie mit hohen Harmonischen — •Dirk Hemmers und Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf

In diesem Beitrag wird ein neuartiges Interferometer vorgestellt, das im XUV Spektralbereich arbeitet. Das Interferometer besteht aus einer Kombination einer Doppellochblende mit einem Transmissionsgitter. Im Fall einer aus diskreten Spektrallinien bestehenden Lichtquelle können Interferogramme mehrerer Spektralfarben gleichzeitig aufgenommen werden. Es werden Experimente vorgestellt, in denen hohe Harmonische eines Titan-Saphir Lasers als Lichtquelle für das Interferometer benutzt werden. Dabei wird das Interferometer zunächst eingesetzt, um die Kohärenzlänge der einzelnen Harmonischen zu bestimmen. Weiterhin werden gleichzeitig Brechungsindex und Transmission einer dünnen Berylliumfolie interferometrisch im Spektralbereich zwischen 17 und 25 nm vermessen.

Q 49.5 Do 15:00 VMP 6 HS-A

First Demonstration of High Harmonic Generation (HHG) in a Hollow-Core Photonic Crystal Fiber — •T. Südmeyer[1], O. H. Heckl[1], C. R. E. Baer[1], C. Kränkel[1], S. V. Marchese[1], F. Schapper[1], M. Holler[1], U. Keller[1], J. S. Robinson[2], J. W. G. Tisch[2], F. Couny[3], P. Light[3], F. Benabid[3], and P. St. J. Russell[4] — [1]Department of Physics, Institute of Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland — [2]Quantum Optics and Laser Science (QOLS), Blackett Laboratory, Imperial College London, London SW7 2BW, UK — [3]Department of Physics, University of Bath, Bath BA2 7AY, UK — [4]Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg, D-91058 Erlangen, Germany

We present for the first time the generation of high harmonic radiation in a hollow-core photonic crystal fiber (HC-PCF). The threshold energy for HHG in xenon was shown to be as low as 440 nJ using a Ti:sapphire amplifier operating at a repetition rate of 1 kHz with a pulse duration of 30 fs. We observed harmonics from the 7th to the 13th order, located in the wavelength range of 50-130 nm. Similar laser pulse energies are today well achievable by diode pumped solid-state lasers operating at multi MHz repetition rates. The increase in repetition rate by more than a factor of thousand compared to typical Ti:sapphire amplifier systems has great potential for substantially increasing the available average photon flux in the VUV and XUV spectral region. Furthermore, it is expected that the efficiency can be significantly enhanced by guiding and improved phase-matching using optimized dispersion engineering in PCFs.

Q 49.6 Do 15:15 VMP 6 HS-A

Ultrakurzpulsfaserlasersysteme zur Erzeugung höherer Harmonischer (HHG) - Anforderungen an Lasersysteme — •Manuel Krebs[1], Steffen Hädrich[1], Jan Rothhardt[1], Damian N. Schimpf[1], Jens Limpert[1] und Andreas Tünnermann[1,2] — [1]Friedrich-Schiller-Universität Jena, Institut für Angewandte Physik, Albert-Einstein-Str. 15, 07745 Jena, Germany — [2]Fraunhofer-Institut für Angewandte Optik und Feinmechanik, Albert-Einstein-Str. 7, 07745 Jena, Germany

Die Verfügbarkeit zeitlich und räumlich kohärenter Ultraviolettstrahlung ermöglicht eine große Zahl von Anwendungen wie die Abbildung kleinster Strukturen oder die Herstellung ultrakurzer Pulse im Attosekundenbereich. Zur Erzeugung kommt vielfach High Harmonic Generation zum Einsatz.

Eine interessante Option zur Erzeugung von UV-Strahlung bei hohen Repetitionsraten bieten faserbasierte Chirped-Pulse-Amplifier (FCPA), die im Bereich von 100kHz arbeiten und Durchschnittsleistungen von weit über 100W bei ~800fs Pulsdauer ermöglichen. Hohe Repetitionsraten und größere Pulsdauern verursachen jedoch störende Ionisationseffekte im Medium. Die Verkürzung der Pulsdauern der anregenden Laser und die Kontrolle der Ionisierung des Mediums stellen die aktuellen Herausforderungen bei der Weiterentwicklung der HHG dar und werden im Vortrag analysiert. So zeigen Techniken wie Hollow Core Compression und parametrische Verstärkung aussichtsreiche Ansätze zur weiteren Verkürzung der Pulsdauern von FCPA-Systemen bei gleichzeitiger Erhöhung der Pulsspitzenleistung.

Q 49.7 Do 15:30 VMP 6 HS-A

Quasimonoenergetische Elektronenbeschleunigung mit einem 100-TW-Lasersystem im Universitätslabor — •Thomas Königstein, Bernhard Hidding, Ralph Jung, Ariane Pipahl, Jens Osterholz, Monika Toncian, Toma Toncian, Oswald Willi und Georg Pretzler — Institut für Laser- und Plasmaphysik, Heinrich-Heine Universität Düsseldorf

Mit dem kürzlich in Düsseldorf installierten 100-TW-Ultrakurzpulslasersystem werden bis zu 23 fs kurze Laserpulse bei Energien von bis zu 3 Joule erzeugt. Unter Verwendung von einfachen Gas-Jet Targets wurden auf besonders einfache Weise stark relativistische Elektronenpulse generiert, indem die Laserpulse in in die Gas-Jets fokussiert wurden. Der Laserpuls setzt Elektronen frei und erzeugt über eine Plasmawelle im Gas-Jet elektrische Beschleunigungsfelder bis zu einigen GV/m. Die entstehenden, scharf kollimierten Elektronenpulse können Energien bis zu einigen 100 MeV haben. Die Pulsdauern dieser Elektronenpulse sind noch geringer als die der generierenden Laserpulse und können bis zu nur einigen Femtosekunden betragen. Es können quasimonoenergetische Elektronenpulse sowie Doppel-Elektronenpulse und andere Arten von Energiespektren erzeugt werden. Diese Ergebnisse eröffnen die Möglichkeit zu einer Vielzahl von Anwendungen auf Universitätslabor-Skala, die bislang nur in einigen großen Forschungseinrichtungen denkbar waren.

Q 49.8 Do 15:45 VMP 6 HS-A

Femtosecond thin disk lasers with >10 μJ pulse energy for high field physics at multi-megahertz repetition rates — •T. Südmeyer[1], S.V. Marchese[1], C.R.E. Baer[1], S. Hashimoto[1], M. Golling[1], G. Gingras[2], B. Witzel[2], and U. Keller[1] — [1]Department of Physics, Institute of Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland — [2]Centre d'optique, photonique et laser, Université Laval, Pav. d'optique-photonique Québec G1V 0A6, Canada

Ultrafast laser oscillators have become ubiquitous in science and technology. For many years, however, their pulse energy has been limited to the nanojoule regime. Applications requiring more intense pulses relied on complex amplifier systems, which typically operate at low pulse repetition rates in the kilohertz regime. Recently, femtosecond thin-disk lasers exceeded pulse energies above the 10 μJ level, such that some of these experiments can now be driven at multi-megahertz repetition rates, which opens promising new avenues for many applications. We confirm the advantages of high field science at multi-megahertz repetition rate by photoelectron imaging spectroscopy measurements in argon and xenon and discuss further pulse energy scaling of femtosecond thin disk lasers.

Q 50: Ultrakalte Atome, Ionen und BEC III (mit A)

Zeit: Donnerstag 14:00–16:00 Raum: VMP 6 HS-C

Das Programm der Sitzung ist unter A 27 zu finden.

Q 51: Quantengase: Gitter und Tunneln II

Zeit: Donnerstag 16:30–18:30 Raum: Audi-A

Q 51.1 Do 16:30 Audi-A

Dissipation induced coherence and stochastic resonance of an open two-mode Bose-Einstein condensate — •Dirk Witthaut[1], Friederike Trimborn[2], and Sandro Wimberger[3] — [1]QUANTOP, Niels Bohr Institute, University of Copenhagen, DK-2100 Copenhagen, Denmark — [2]Institut für mathematische Physik, TU Braunschweig, D-38106 Braunschweig, Germany — [3]Institut für theoretische Physik, Universität Heidelberg, D-69120, Heidelberg, Germany

We discuss the dynamics of a Bose-Einstein condensate in a double-well trap subject to phase noise and particle loss. The phase coherence of a weakly-interacting condensate as well as the response to an external driving show a pronounced stochastic resonance effect: Both quantities become maximal for a finite value of the dissipation rate matching the intrinsic time scales of the system. Even stronger effects are observed when dissipation acts in concurrence with strong inter-particle interactions, restoring the purity of the condensate almost completely and increasing the phase coherence significantly.

Q 51.2 Do 16:45 Audi-A

Controlling the Landau-Zener decay in a Bose-Einstein condensate realization of the Wannier-Stark problem — •Ghazal Tayebirad[1,2], Alessandro Zenesini[3], Hans Lignier[3], Donatella Ciampini[3], Jagoda Radogostowicz[3], Oliver Morsch[3], Ennio Arimondo[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]Dipartimento di Fisica, Università degli Studi di Pisa, Largo Pontecorvo 3, 56127 Pisa, Italy

A comprehensive study of the tunneling dynamics of a Bose-Einstein condensate (BEC) in a tilted periodic potential is presented. This system enjoys a continuing popularity in many experimental groups [1]. In excellent agreement with experiments, our theoretical calculations, based on a mean-field theory for a many-particle condensate, explain the temporal behavior of the Landau-Zener (LZ) tunneling. While for a typical initial state of a BEC being strongly localized in momentum space, we observe a step-like structure in the survival probability as a function of time (resembling periodic Bloch oscillations), these structures are gradually washed out by increasing either the initial width in momentum space or the atom-atom interactions, together with other observed time-dependent structures in the profile of the survival probability, this clarifies to what extend we can expect deviation from a purely exponential decay in the studied LZ tunneling process.

[1] T. Schulte *et al.*, Phys. Rev. A, **77**, 023610 (2008); C. Sias *et al.*, Phys. Rev. Lett. **98**, 120403 (2007)

Q 51.3 Do 17:00 Audi-A

Effective model for the inter-band coupling in a many-body Wannier-Stark system — •Patrick Plötz[1,2] 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

Interacting bosons in a one-dimensional optical lattice are studied in the presence of an additional and tunable tilting force in the strongly-correlated many-particle regime. We use a two-band Bose-Hubbard description of this many-body Wannier-Stark problem for a realization with ultracold atoms. We find resonances in the quantum dynamics of the interband-coupling, connect our results to single-particle Wannier-Stark theory, and analyse the effect of the many-body interaction using an effective model. Our model captures the essentials of the original system. It predicts, for instance, collapses and revivals in the occupation of the two lowest bands, which are indeed found numerically in the full many-body system.

Q 51.4 Do 17:15 Audi-A

Ac-driven Atomic Quantum Motors — •Alexey Ponomarev, Sergey Denisov, and Peter Hänggi — Institute of Physics, University of Augsburg, Universitätstr. 1, D-86159 Augsburg

We consider ac-driven quantum motors consisting of two different, interacting ultracold atoms placed into a ring-shaped optical lattice which is submerged in a pulsating magnetic field. While the first atom carries a current, the second one serves as a quantum starter. For zero-momentum localized initial conditions, the amplitude of the generated dc-current saturates to the same non-zero value, independently on the initial phase lag of an external ac-field. This behavior distinctly differs from that predicted for dissipationless single-particle systems [1]. Also work against a load realized by an external biased potential has been investigated.

[1] S. Denisov, L. Morales-Molina, S. Flach, and P. Hänggi, Phys. Rev. A **75**, 063424 (2007).

Q 51.5 Do 17:30 Audi-A

Directed Transport of Ultracold 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, D-53859 Bonn

Ratchets are considered as a tool, which generate a directed motion of particles in the absence of any gradients or net forces. The ratchet effect can be realized for instance in a fluctuating environment as a physical mechanism of microbiological motion. In order to observe a directed transport of atoms, one has to break the space-time symmetry of the system [1]. Here we report on the realization of a quantum ratchet in the absence of dissipative processes (Hamiltonian regime) within the interaction time.

We load a ^{87}Rb Bose-Einstein condensate into a sawtooth-like asymmetric optical lattice potential, which is realized by superimposing an optical standing wave with $\lambda/2$ spatial periodicity with a fourth-order potential with $\lambda/4$ spatial periodicity, where λ denotes the wavelength of the used laser [2]. Besides the spatial, also the temporal symmetry of the system is broken by modulation of the lattice potential depth. We experimentally observe directed transport of atoms arising from Hamiltonian ratchet transport in the quantum regime.

[1] S. Denisov et al., Phys. Rev. A **75**, 063424 (2007)
[2] G. Ritt et al., Phys. Rev. A **74**, 063622 (2006)

Q 51.6 Do 17:45 Audi-A

Theoretical Investigation of a Hamiltonian Quantum Ratchet — •Tim Hecking[1], Luis Morales-Molina[2], Tobias Salger[1], Carsten Geckeler[1], Sebastian Kling[1], and Martin Weitz[1] — [1]Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn, Germany — [2]Department of Physics, National University of Singapore, 2 Science Drive 3, Singapore 117542

We study the dynamics of a Bose-Einstein condensate in a quantum ratchet, that consists of a biharmonic, amplitude modulated potential in the absence of dissipation (Hamiltonian regime) [1]. The system considered here exhibits negligible atom-atom interaction, therefore the results can be obtained by numerical integration of the linear Schrödinger equation. Of particular interest is the dependence of the atomic mean momentum on critical parameters, such as the modulation period and the symmetry properties of the system. By comparison of our theoretical model with the results of an experimentally realized quantum ratchet [2], good agreement is achieved.

[1] S. Denisov et al., Phys. Rev. A **75**, 063424 (2007)
[2] T. Salger et al., to be published

Q 51.7 Do 18:00 Audi-A

Wavepacket dynamics in energy space of a chaotic trimeric Bose-Hubbard system — •Moritz Hiller[1], Tsampikos Kottos[2,3], and Theo Geisel[3] — [1]Fakultät für Physik, Albert-Ludwigs-Universität Freiburg, Germany — [2]Department of Phsyics, Wesleyan University, Middletown CT, USA — [3]Max-Planck-Insitut für Dynamik und Selbstorganisation, Göttingen, Germany

We study the energy redistribution of interacting bosons in a ring-shaped quantum trimer as the coupling strength between neighboring sites of the corresponding Bose-Hubbard Hamiltonian undergoes a sudden change δk. In the framework of (ultra-)cold atoms on optical lattices this perturbation corresponds to a modulation of the trapping potential. Our analysis is based on a three-fold approach combining linear response theory calculations as well as semiclassical and random matrix theory considerations. The δk-borders of applicability of each of these methods are identifed by direct comparison with the exact quantum mechanical results. We find that while the variance of the evolving quantum distribution shows a remarkable quantum-classical correspondence (QCC) for all δk-values, other moments exhibit this QCC only in the non-perturbative δk-regime.

Q 51.8 Do 18:15 Audi-A

Scattering Properties of Bose-Hubbard Hamiltonians with two and three sites — •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, Bunsentraße 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 and a central site that is coupled to a Bose-Hubbard system consisting of two or three wells (dimer/trimer). For the case of the dimer, we find that the resonance widths undergo a sequence of bifurcations resulting from the complexity of the underlying classical phase space structure. In the case of the trimer, we focus on the parameter regime corresponding to classically chaotic motion. We analyze the statistical properties of the scattering matrix and compare our results to the predictions of random matrix theory for chaotic scattering.

Q 52: Quanteninformation: Quantenkommunikation II

Zeit: Donnerstag 16:30–19:00 Raum: Audi-B

Q 52.1 Do 16:30 Audi-B

Towards device independent security in quantum cryptography — •Torsten Franz and Reinhard Werner — Institut für Mathematische Physik, TU Braunschweig

Quantum cryptography enables two parties to perform private communication. Crucial for the security are the assumptions, which have to be made about the practical implementation of the theoretical protocol. In the device independent scenario one tries to consider only as few assumptions as possible, while still guaranteeing security even against the most general, i.e. coherent, attacks. We will present results on the problem in a black-box scenario.

Q 52.2 Do 16:45 Audi-B

Sicherheitsanalyse eines quantenkryptographischen Protokolls von Barrett, Hardy & Kent — •Rainer Plaga — Bundesamt für Sicherheit in der Informationstechnik, 53175 Bonn

Barrett, Hardy and Kent haben ein quantenkryptographisches Protokoll vorgeschlagen, dessen Sicherheit bewiesen werden kann, ohne die Annahme zu machen, dass die Gesetze des Quantenphysik absolut korrekt sind (Phys. Rev. Lett. 95 (2005), 010503). Benötigt wird auschliesslich die Annahme dass keine überlichtschnellen Signal ausgetauscht werden können. Ich analysiere die Rolle einer weiteren Zusatzanahme, die von den Autoren explizit gemacht wird. Ein Angriff der die spezielle Relativitättheorie respektiert und ohne diese Zusatzanahme erfolgreich ist, wird vorgestellt.

Q 52.3 Do 17:00 Audi-B

Quantum control of noisy channels — •Raffaele Romano and Peter van Loock — OQI Group, Max-Planck Research Group, Institute of Optics, Information and Photonics, University of Erlangen-Nuernberg

Title: Quantum control of noisy channels
Abstarct: We present a formalism that paves the way to the application of control theoretical tools to the analysis of noisy channels [1]. The control parameters are given by the resources available to sender and receiver, that is local operations and classical communication (LOCC), and entanglement shared among the two parties through their local ancillas. By using the Choi-Jamiolkowski isomorphism between completely positive maps and (non-normalized) states [2], we show how a noisy channel is manipulated by these controls, and provide some preliminary results based on this formalism. In particular, we prove that standard Quantum Teleportation is the only deterministic scheme that can perfectly correct an arbitrary noisy channel relying on a single use of the channel (that is, with one-way communication) [3]. Moreover, we discuss a hybrid protocol based on both Quantum Teleportation and Quantum Error Correction to faithfully transmit quantum states through specific noisy channels.

References:
[1] R. Romano, P. van Loock, arXiv:0811.3014
[2] A. Jamiolkowski, Rep. Math. Phys. 3, 275 (1972)
[3] R. Romano, P. van Loock, in preparation

Q 52.4 Do 17:15 Audi-B

On superdense coding with noisy channels — •zahra shadman, hermann kampermann, and dagmar bruss — Heinrich-Heine-Universität, Institut für Theoretische Physik III, Düsseldorf, Deutschland

We study the capacity of a superdense coding protocol in the case of a noisy channel. We consider the case where the channel acts on Alice's side, and the one where it acts both on Alice's and Bob's side. In the latter case, the noise can be correlated or uncorrelated. We study various noise models and various bipartite input states, and derive the optimal capacity.

Q 52.5 Do 17:30 Audi-B

Quantum error correction for hybrid quantum repeater — •Nadja Bernardes and Peter van Loock — OQI Group, Max Planck Research Group, Institute of Optics, Information and Photonics, University Erlangen-Nuremberg, Germany

We discuss quantum error correction (QEC) protocols for quantum repeaters based upon atomic qubit-entanglement distribution through optical coherent-state communication (hybrid quantum repeater). The effect of photon losses on a coherent-state qubit is a decrease of the coherent-state amplitude and a random phase flip error; the latter effect leads to the distribution of imperfect entanglement between neighboring repeater stations, when the light field is sent through the lossy communication channel and subsequently measured for conditional two-qubit entangled-state preparation. The conceptually simplest approach is then to perform entanglement distillation and swapping on the level of the qubit states in order to enhance the fidelity and increase the distance of the distributed entangled states. However, this approach requires complicated local quantum logic. Here we consider alternative ways to suppress the effect of photon losses for entanglement distribution. In particular, QEC codes can be applied to the optical mode that mediates the interaction between the qubits. An example for a possible QEC scheme is similar to the well-known 3-qubit phase flip code. We describe a scheme in which this code is employed for entanglement distribution and compare its performance with the canonical schemes based upon entanglement distillation.

Q 52.6 Do 17:45 Audi-B

Communicating at the quantum speed limit using optimal control — •Michael Murphy[1], Tommaso Caneva[3], Simone Montangero[1], Vittorio Giovanetti[2], Tommaso Calarco[1], Rosario Fazio[2,3], and Guiseppe Santoro[3] — [1]Institut für Quanteninformationsverarbeitung, Universität Ulm, Albert-Einstein-Allee 11, D-89069 Ulm, Germany — [2]NEST-CNR-INFM & Scuola Normale Superiore, P.zza dei Cavalieri 7,56126 Pisa, Italy — [3]International School for Advanced Studies (SISSA), Via Beirut 2-4, I-34014 Trieste, Italy

Optimal control theory is a promising candidate for a drastic improvement of the performance of quantum information tasks. We explore its ultimate limit in the case of a one-dimensional chain of coupled spin-1/2 particles, and demonstrate that it coincides with the ultimate speed limit allowed by quantum evolution (the quantum speed limit), such that optimal control reaches the best performance allowed by the laws of quantum mechanics.

Q 52.7 Do 18:00 Audi-B

Optimizing Gaussian communication for hybrid quantum repeater — •Ludmila Praxmeyer and Peter van Loock — OQI Group, Max Planck Research Group, Institute of Optics, Information and Photonics, University Erlangen-Nuremberg

For long distance quantum communication, distribution of entanglement over large distances, overcoming effects of noise and decoherence, is needed. Various quantum repeater schemes [1] were proposed to provide a theoretical solution to this problem. We shall present an optimized version of the hybrid quantum repeater [2,3], based on Gaussian optical-state communication and Gaussian, homodyne-based, conditional entangled state preparation. We show that use of squeezed light significantly increases the fidelity of states obtained while probability of success is aintained. We also show that hybrid entanglement swapping [4] between squeezed states of light and atoms in the cavity makes scheme [2] more practical compared to the case when entanglement swapping is performed solely on the level of the atoms.

References:
[1] H.-J. Briegel *et al.*, Phys. Rev. Lett. **81**, 5932 (1998),
[2] P. van Loock *et al.*, Phys. Rev. Lett. **96**, 240501 (2006),
[3] T. D. Ladd *et al.*, New J. Phys. **8**, 164 (2006),
[4] P. van Loock *et al.*, Phys. Rev. A **78**, 062319 (2008).

Q 52.8 Do 18:15 Audi-B

Quantum key distribution based on general finite-dimensional systems — •Kedar S. Ranade and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt

It is well-known that qubit-based quantum key distribution protocols can be generalised to protocols based on higher dimensional information carriers (so-called qudits). We prove security bounds for qudit-based prepare-and-measure protocols, which may use both one-way and two-way error correction, by generic means of evaluating such bounds through associated entanglement-based protocols.

Q 52.9 Do 18:30 Audi-B

Continuous-variable quantum key distribution with qudits — •Ulrich Seyfarth and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Darmstadt

A generalisation of the continuous-variable protocol investigated by Grosshans and Grangier [1] is proposed. Secret key rates are evaluated for cases in which an eavesdropper can extract information by beam-splitting attacks. These rates are calculated for direct and reverse reconciliation over the channel transmittivity. Optimisations of this protocol are discussed.

[1] F. Grosshans and P. Grangier, Phys. Rev. Lett. 88,57902 (2002).

Q 52.10 Do 18:45 Audi-B

Quantum key distribution using phase-shift keying — •Denis Sych and Gerd Leuchs — Max-Planck-Institut für die Physik des Lichts, IOIP, Universität Erlangen-Nürnberg, Günther-Scharowsky-Str. 1, Bau 24, 91058 Erlangen, Deutschland

We report on the detailed analysis of a new protocol for continuous variable quantum key distribution using phase-shift keying. The novelty of the protocol is a multi letter alphabet consisting of coherent states of light with a fixed amplitude and variable phase. Information is encoded in the phase of a coherent state which can be chosen from a regular discrete set consisting, however, of an arbitrary number of letters from two to infinity. Thus our protocol can be regarded as a smooth transition between the protocols based on discrete and continuous modulation of coherent states.

We evaluate the security of the protocol against the beam-splitting and intercept-and-resend attacks. For error correction we consider the direct and reverse reconciliation schemes, both idealized and realistic. We investigate how imperfections of the realistic error correction schemes affect the key rate. As a result we show that the secret key generation rate of the proposed protocol can be of an order higher than that of the binary phase encoding. The optimal parameters (number of letters, amplitude of the signal, and postselection thresholds) are explicitly presented.

Q 53: Ultrakurze Pulse: Anwendungen III

Zeit: Donnerstag 16:30–17:45 Raum: VMP 6 HS-A

Q 53.1 Do 16:30 VMP 6 HS-A

Concepts of phase, amplitude, and polarization shaping — •Fabian Weise, Stefan M. Weber, Mateusz Plewicki, Ludger Wöste, and Albrecht Lindinger — Institut für Experimentalphysik, Freie Universität Berlin, Arnimalle 14, 14195 Berlin

Femtosecond pulse shaping is a very powerful technique and was successfully applied to a variety of different systems - especially in the field of coherent control. Extending the common parameters phase and amplitude by including the parameter polarization became an emerging topic in the past few years. Since physical systems are mostly three dimensional, adding the polarization increases significantly the controllability.

Initially, we will discuss different concepts of femtosecond polarization shaping and their experimental implementation. We present new setups for pulse shaping which enable us to simultaneously and independently modulate the parameter phase, amplitude, and polarization. We demonstrate the capabilities of these setups using systematic scans of the relevant pulse parameters and parametric example pulses.

Furthermore, we present the implementation in a feedback loop optimization of multi photon ionization of NaK in a molecular beam. The resulting pulse increases the ionization yield compared to a pulse without polarization modulation. The pulse form reveals the ionization dynamics including the orientation of the transition dipole moment of the participating electronic states.

Q 53.2 Do 16:45 VMP 6 HS-A

Controlling spectral hole intensities via self-phase modulation using tailored fs laser pulses — •Jens Köhler, Tillmann Kalas, Cristian Sarpe-Tudoran, Matthias Wollenhaupt, and Thomas Baumert — Universität Kassel, Institut für Physik und Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), Heinrich-Plett-Str. 40, D-34132 Kassel, Germany

In previous experiments [1] we have removed a small interval of frequency components from the broad spectrum of an ultrashort laser pulse in order to study the refilling of the resulting spectral hole via self-phase modulation (SPM) as a function of the laser intensity. Recently, making use of femtosecond pulse shaping techniques we extended our studies by taking into account additional parameters like the magnitude of amplitude modulation and the spectral phase in the corresponding spectral range. By using the spectral phase as single control parameter holes with adjustable depth as well as an intensity overshoot in a narrow spectral band are observed. The optimization of the spectral hole generation and refilling process is discussed. Results on controlling the spectral hole intensities employing spectrally phase and/or amplitude modulated femtosecond laser pulses are presented. In addition, we suggest possible applications of these effects in the field of label-free nonlinear microscopy, such as the use as a new contrast mechanism for the investigation of transparent samples.

[1] A. Präkelt *et al.*: Appl. Phys. Lett. **87**(12), 121113 (2005)

Q 53.3 Do 17:00 VMP 6 HS-A

Pulse characterization in the UV down to 263 nm by autocorrelation measurement using diamond photodiodes — •Fabian Kleimeier[1], Thorben Haarlammert[1], Jean-Francois Hochedez[2], Ali BenMoussa[2], Udo Schühle[3], and Helmut Zacharias[1] — [1]Physikalisches Institut, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany — [2]Royal Observatory of Belgium, Ringlaan 3, 1180 Brussels, Belgium — [3]Max-Planck-Institut für Sonnensystemforschung, Max-Planck-Str. 2, 37191 Katlenburg-Lindau, Germany

Interferometric second-order autocorrelation is a common way to characterise ultra-short pulses. Until recently this method was limited to wavelengths greater than 400 nm due to the lack of nonlinear materials or photodiodes with a sufficiently large bandgap. Solar-blind diamond pin-photodiodes developed within the LYRA project for the space mission PROBA-II have a bandgap of 5.5 eV, corresponding to a wavelength of about 225 nm, which permits two-photon absorption of light at wavelength longer than about 230 nm without significant background by a linear response. Using these diodes we were able to record fringe-resolved second-order autocorrelations of the second and third harmonic of a Ti:sapphire laser. The phase can be reconstructed by optimization algorithms using schemes like PICASO (femtosecond pulse retrieval by Phase and Intensity from Correlation And Spectrum Only).

Q 53.4 Do 17:15 VMP 6 HS-A

Self-referencing of optical frequency combs — •C. Grebing, S. Koke, and G. Steinmeyer — Max Born Institute, Berlin, Germany

Stabilization of the carrier-envelope phase (CEP) drift of femtosecond oscillators has found widespread application in frequency metrology and high-field nonlinear optics. To date, stabilization of laser oscillators exclusively relies on phase coherent locking of the measured carrier-envelope frequency f_{CE} to a reference [1]. Such locking always requires feedback into the laser, which, however, causes detrimental side effects on other laser parameter and requires complex locking electronics. Additionally, using the traditional stabilization sheme it is impossible to produce a pulse train with constant CEP ($f_{CE} = 0$), which would greatly simplify the set-up of CEP stable amplified systems. We propose and demonstrate a novel technique that allows for intrinsic stabilization of an optical frequency comb to zero offset. Our scheme does neither require any sophisticated servo electronics nor any feedback to the laser. It relies on splitting the output beam of a femtosecond oscillator by means of an acousto-optic frequency shifter (AOFS), with the zero-order signal being fed into an f-to-$2f$ interferometer. This interferometer serves to measure the f_{CE}, which is electronically filtered out and directly fed into the piezoelectric transducer of the AOFS. Doing so, the AOFS output in the first diffraction order experiences a shift by exactly f_{CE}, i.e., it is shifted to a constant CEP. Our method is readily applicable to any type of mode-locked laser, with the measurability of f_{CE} being the only prerequisite.

[1] A. Poppe, et al., Appl. Phys. B **72**, 373 (2001).

Q 53.5 Do 17:30 VMP 6 HS-A

Chromatic dispersion spectrometer for joint spectral measurements — Malte Avenhaus, •Andreas Eckstein, Peter Mosley, and Christine Silberhorn — Max-Planck-Institut for the Science of Light, Erlangen

We introduce a simple yet powerful method to measure the joint spectral intensitiy of ultrashort bi-photon states, applicable to a broad wavelength range. To this end we utilize the chromatic dispersion of an optical fiber as well as time-resolved single photon detection. The wavelength working range of our spectrometer is limited by photon detector sensitivity only. We achieve high resolution with moderate measurement times in the telecom wavelength regime and demonstrate resulting spectra from a KTP-based parametric downconversion source.

Q 54: Ultrakalte Atome, Ionen und BEC IV (mit A)

Zeit: Donnerstag 16:30–18:00 Raum: VMP 6 HS-C

Das Programm der Sitzung ist unter A 31 zu finden.

Q 55: Poster III

Zeit: Donnerstag 16:30–19:00 Raum: VMP 8 Foyer

Q 55.1 Do 16:30 VMP 8 Foyer

Multi Ion Optical Clocks — •Tanja Mehlstäubler — QUEST at PTB, Bundesallee 100, 38116 Braunschweig

The recently established excellence cluster QUEST (Quantum Engineering and Space Time Research) addresses the questions of quantum sensors and tests of fundamental theories. With time and frequency being the most accurate measurable physical quantities today, optical clocks will allow us to search for deviations in the predictions of Einsteins general relativity, test modern unifying theories and develop new sensors for gravity and navigation. In this context, relative frequency inaccuracies as low as 10^{-18} are targeted.

Optical ion clocks have the potential to resolve time and frequency with such ultra-high precision, but would require integration times of many days to weeks, posing even limits on the systematic evaluation at such high levels of accuracy. The QUEST junior research group at PTB is addressing this problem with a new ansatz, that is aiming at the design and test of new ion trap geometries that can accommodate many (10-100) ions. Today, the most promising clock candidates in terms of sensitivity to environment and systematic effects are atoms with transitions between $^1S_0$ and $^3P_0$ states. Due to the lack of higher electronic moments in these states, such as quadrupole moments, utilizing trap geometries with many ions is feasible.

We will present our new project towards multi-ion clocks, discuss recent results from traps used in quantum computation with trapped ions and strategies to control micromotion and heating rates down to the 10^{-18} regime.

Q 55.2 Do 16:30 VMP 8 Foyer

Tunable Frequency References for LISA – Laboratory Reference Systems — •Klaus Döringshoff, Katharina Möhle, Evgeny V. Kovalchuk, and Achim Peters — Humboldt Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Hausvogteiplatz 5-7, 10117 Berlin

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

We maintain a cross-linked reference system including molecular references based on methane and iodine as well as several fixed cavities made from fused silica and ULE. With regard to the LISA requirements, we put a special emphasis on the long-term stability of our references in the frequency range between 0.1 mHz and 1 Hz.

We report on comparative measurements of the frequency stability of our different references. A special focus will be on the performance of a new ULE reference cavity, which as an unusual feature exhibits a turning point of the thermal expansion curve above room temperature.

Q 55.3 Do 16:30 VMP 8 Foyer

Tunable Frequency References for LISA – Piezo-Tuned Cavities — •Katharina Möhle, Klaus Döringshoff, 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, which should be achieved in three steps, including prestabilization to a Fabry-Perot cavity. The requirements for this prestabilization are a frequency stability of $30\,\mathrm{Hz}/\sqrt{\mathrm{Hz}}$ from 1 mHz

to 1 Hz, as well as a tunability of ± 15 MHz, in order to accommodate slow Doppler-shifts caused by yearly variation of the triangular satellite configuration. In addition there should be the capability to tune the frequency by more than one free spectral range from time to time.

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. In this case one has to evaluate 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. We present first results for the frequency stability obtained with different piezoelectric materials and discuss alternative approaches.

Q 55.4 Do 16:30 VMP 8 Foyer

Lasersysteme für hochauflösende Sagnac-Interferometrie mit kalten Atomen — •Peter Berg, Gunnar Tackmann, Christian Schubert, Michael Gilowski, Thijs Wendrich, Wolfgang Ertmer und Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover

Am Institut für Quantenoptik wird ein Atominterferometer zur hochauflösenden Messung von Rotationen, basierend auf Raman-Wechselwirkungen, realisiert. Diese Anwendung stellt hohe Anforderungen an die Eigenschaften des für die kohärente Manipulation der Atome benötigten Lasers, insbesondere an die Intensität und die Linienbreite. Ausgehend von der geforderten interferometrischen Sensitivität leiten wir die Ansprüche für die Lasersysteme ab und beschreiben die technologische Umsetzung. Um die angestrebte Messgenauigkeit des Interferometers von 10^{-9} rad/(s$\sqrt{Hz}$) bezüglich Rotationen zu erreichen, sollen künftig eine nutzbare optische Ausgangsleistung von 1 W pro Raman-Laser und eine Linienbreite von 100 kHz unter Zuhilfenahme einer Phasenstabilisierung der beiden Raman-Laser aufeinander (Phase-Lock-Loop) erzielt werden. Zur Verwirklichung dieser Ziele werden bei 780 nm laufende interferenz-stabilisierte Diodenlaser mit erweitertem Resonator und nachgeschaltetem Trapezverstärker verwendet. Diese Arbeit wird unterstützt von DFG SFB407, QUEST und FINAQS.

Q 55.5 Do 16:30 VMP 8 Foyer

Entwicklung eines schmalbandigen Lasersystems zur Spektroskopie des Uhrenübergangs in neutralem Quecksilber — •Christian Junge, Patrick Villwock und Thomas Walther — Technische Universität Darmstadt, Institut für Angewandte Physik, Laser- und Quantenoptik, Schlossgartenstraße 7, 64289 Darmstadt

Eine Optical Lattice Clock, basierend auf neutralen Quecksilberatomen in einem optischen Gitter, ist ein vielversprechender Ansatz für die nächste Generation von Atomuhren. Der $^1S_0$-$^3P_0$ Uhrenübergang von Quecksilber liegt bei einer Wellenlänge von 265,6 nm und hat eine natürliche Linienbreite von unter 1 Hz und stellt damit hohe Anforderungen an das zur Spektroskopie verwendete Lasersystem. Unser Ansatz ist die Entwicklung eines sehr stabilen External Cavity Diode Lasers (ECDL) bei 1062,4 nm, dessen Ausgangsleistung mit einem Yb-dotierten Faserverstärker erhöht wird. Anschließend soll mittels zweifacher Frequenzkonversion die benötigte Wellenlänge von 265,6 nm generiert werden. Es wird der aktuelle Stand des Projektes vorgestellt.

Q 55.6 Do 16:30 VMP 8 Foyer

Metrologie für Einzelphotonenquellen und -detektoren — •Waldemar Schmunk, Silke Peters, Helmuth Hofer und Stefan Kück — Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Fachbereich Optische Technologien

Der Einsatz von Einzelphotonenquellen und Detektoren mit wohldefinierten Eigenschaften gewinnt im Bereich der Quantenoptik und der Quantenkryptographie zunehmend an Bedeutung. Dabei ist es notwendig, eine metrologische Vergleichbarkeit der unterschiedlichen Quellen (z.B. Spektrum, Photonenstatistik, Emissionsrate) und Detektoren zu schaffen (z.B. Quanteneffizienz, spektrales Verhalten). Ziel ist es letztlich, allgemeine Standards für Quellen und Detektoren zu erhalten.

In einem ersten Schritt werden N/V-Zentren, die durch Ausbildung von Fehlstellen im Diamantgitter entstehen als Einzelphotonenquellen verwendet. Diese werden optisch bei 532 nm angeregt und ihre Fluoreszenz im nahen infraroten Spektralbereich mittels konfokaler Mikroskopie detektiert. Dies gewährleistet, dass innerhalb des Anregungsvolumens nur ein einziges Zentrum erfasst wird. Zur Charakterisierung dient ein Hanbury-Brown-Twiss Aufbau mit zwei Si-Avalanche-Photodioden und einem Koinzidenzzähler. Aus der gemessenen Koinzidenzverteilung wird die Korrelationsfunktion zweiter Ordnung bestimmt, die ein Maß für die Güte der Einzelphotonenquelle darstellt. Mittels solcher Einzelphotonenquellen können nun Detektoren bezüglich ihrer Quanteneffizienz untereinander kalibriert werden. Das Messunsicherheitsbudget für eine solche Kalibrierung wird ebenfalls vorgestellt und diskutiert.

Q 55.7 Do 16:30 VMP 8 Foyer

Delbrück scattering in combined Coulomb and laser fields and vacuum polarization effects in a plasma — •Ben King, Antonino Di Piazza, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Delbrück scattering is the scattering of a high-energy photon by the Coulomb field of a nucleus. It is one of the few effects of quantum vacuum polarization that has been measured experimentally. We study here how the presence of a strong laser field modifies the cross-section of Delbrück scattering and find a relevant enhancement at small scattering angles [1]. In addition, the total cross section is (logarithmically) enhanced with respect to that of pure Delbrück scattering. Finally, based on our previous paper [2], we present preliminary considerations on vacuum polarization effects induced by a strong laser field in a plasma at finite temperature [3].

[1] A. Di Piazza and A. I. Milstein, Phys. Rev. A **77**, 042102 (2008).
[2] A. Di Piazza, K. Z. Hatsagortsyan, and C. H. Keitel, Phys. Plasmas **14**, 032102 (2007).
[3] B. King, A. Di Piazza, and C. H. Keitel, in preparation.

Q 55.8 Do 16:30 VMP 8 Foyer

Radiative effects in the motion of a laser driven classical electron and Compton scattering in ultra-short laser pulses — •Felix Mackenroth, Antonino Di Piazza, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The Landau-Lifshitz equation describes the classical motion of a charged particle in an external electromagnetic field by taking into account the effect on the particle motion of the field radiated by the charge itself (radiation reaction). We present here the exact analytical solution of this equation when the external field is a plane wave of arbitrary form and polarization [1]. We can determine in this way the physical parameter characterizing the so-called "radiation dominated regime" when the radiation reaction force is comparable with the Lorentz force. The above considerations are classical. We also study the quantum scattering of an electron by an ultra-short strong laser field (multiphoton Compton scattering) [2]. We point out the qualitative and quantitative differences with the usually considered case of an infinite monochromatic laser wave.

[1] A. Di Piazza, Lett. Math. Phys. **83**, 305 (2008).
[2] F. Mackenroth, A. Di Piazza, and C. H. Keitel, in preparation.

Q 55.9 Do 16:30 VMP 8 Foyer

Experimental implementation of a quantum random walk on a single-trapped-ion — •Robert Matjeschk, Hector Schmitz, Christian Schneider, Jan Glueckert, Axel Friedenauer, Martin Enderlein, Thomas Huber, and Tobias Schaetz — MPI für Quantenoptik, Hans-Kopfermann Str. 1, 85748 Garching

Ions, confined in a Paul trap and under influence of controlled laser fields provide one of the best controllable quantum mechanical systems up to date in which elements of quantum theory and quantum information theory can be realized and analyzed. In the framework of this work we realized a quantum random walk (QRW) with a single trapped ion. The difference of a QRW to a classical random walk is, that not a certain path is realized with a certain probability, but that all possible paths are realized at the same time – this leads to interference effects. We implemented the QRW in one motional degree of freedom of the ion. The steps of the QRW were fulfilled by applying a state-dependent optical dipole force. We used state-of-the-art techniques for preparation (cooling to the motional ground state), manipulation and detection of the state of the ion and extended them to specialized methods for the implementation of the QRW. By theoretical investigations of the QRW in the special system of a trapped ion and numerical analysis we developed a model that is suitable for the description of the QRW and that serves as a basis for further investigations.

Q 55.10 Do 16:30 VMP 8 Foyer

Quantum random walk with linear optics — •Andreas Schreiber, Katiuscia Cassemiro, and Christine Silberhorn — Günther-Scharowsky-Str. 1, Bau 24 , D-91058 Erlangen

In a classical random walk the probability distribution for the walker's position is a Gaussian, which variance equals to the number of steps ($\sigma^2 = n$). Contrariwise, the quantum counterpart shows a quadratically faster spread, due to quantum interference.

We implement a discrete time quantum random walk (QRW) in one dimension. Photons traveling through an optical fiber network undergo a conditional time translation, which depends on the polarization state selected by a coin. The experiment is realized with intense light field, but it can straightforwardly be extended to the single photon level.

As the classical random walk has many applications in classical computation, the QRW is a potential tool to speed up the realization of algorithms in a quantum computer.

Q 55.11 Do 16:30 VMP 8 Foyer

Generation of Total Angular Momentum Eigenstates in Remote Qubits — •Andreas Maser[1], Uwe Schilling[1], Thierry Bastin[2], Enrique Solano[3], Christoph Thiel[1], and Joachim von Zanthier[1] — [1]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, Erlangen, Germany — [2]Institut de Physique Nucléaire, Atomique et de Spectroscopie, Université de Liège au Sart Tilman, Liège, Belgium — [3]Departamento de Química-Física, Universidad del País Vasco - Euskal Herriko Unibertsitatea, Bilbao, Spain

We propose a scheme enabling the universal coupling of angular momentum of N remote noninteracting spin-1/2 particles (qubits) using linear optical tools only. Hereby, an arbitrary number of particles can be entangled in their two-level long-lived ground states via the use of suitably designed projective measurements. In reference to the algorithm describing the coupling of angular momentum of individual spin-1/2 particles, our method couples successively remote qubit states to a multi-qubit compound system. Thereby, it offers access to the entire coupled basis of an N-qubit compound system of dimension 2^N, i.e., to the 2^N symmetric and nonsymmetric total angular momentum eigenstates [1].

[1] A. Maser *et al.*, quant-ph/0812.0959 (2008).

Q 55.12 Do 16:30 VMP 8 Foyer

Dynamic Entanglement of Atomic Motion — •Mark Rodenberger and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany

We analyze continuous bipartite entanglement of motional atomic degrees of freedom. The model consists of two atoms scattered on a quantized electric field one after the other, i.e. they never directly interact. A certain velocity regime allows for a complete analytical treatment of the corresponding dynamics. The resulting density operator is examined by means of various entanglement criteria and measures. In particular, we are interested in the scaling of entanglement with classical parameters like the initial momentum.

Q 55.13 Do 16:30 VMP 8 Foyer

Stabilisierung chiraler Moleküle durch Stöße — •Johannes Trost und Klaus Hornberger — Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians-Universität, München

Bei komplexeren chiralen Molekülen wird die Superposition von links- und rechts-händigen Enantiomeren - obwohl energetisch am günstigsten - nicht beobachtet (Hunds Paradoxon). Als Erklärung bietet sich Dekohärenz durch Streuprozesse mit Molekülen des Umgebungsgases an. Anhand eines einfachen chiralen Moleküls (Dideuteriumdisulfid, D_2S_2) entwickelten wir ein Modell, das dispersive Wechselwirkungen mit einfachen Hintergrundgasen realistisch und konsistent beschreibt. Numerische Berechnungen ergeben eine überraschend hohe Dekohärenzrate durch Stöße bei niedrigen Temperaturen. Eine Born'sche Näherung zeigt, dass der Effekt kaum von der Temperatur des Umgebungsgases abhängt. Durch Variation der Stoßrate ließe sich im Experiment der Effekt nachweisen. [1]

[1] J. Trost and K. Hornberger, arXiv:0811.2140

Q 55.14 Do 16:30 VMP 8 Foyer

Photonic properties of bichromatic Optical Lattices — •Stefan Rist[1], Patrizia Vignolo[2], and Giovanna Morigi[1] — [1]Departament de Fisica, Universitat Autonoma de Barcelona — [2]Institut Non-Linéaire de Nice, Université de Nice-Sophia Antipolis

We study theoretically the photonic spectrum of a bichromatic optical lattice, in the regime in which the atoms are well localized in the lattice sites and their dipolar transitions couple weakly to the probe light. The photonic spectrum is characterized as a function of the interparticle distance D inside the primitive Wigner-Seitz cell. Depending on D and on the atomic species composing the Wigner-Seitz cell, two or more photonic bandgaps can be found. We then determine the dynamics, when the atoms couple to the standing-wave mode of a Fabry-Perot cavity, and study the cavity transmission spectrum in the strong coupling regime.

Q 55.15 Do 16:30 VMP 8 Foyer

Chiral and non-chiral negative refraction with low absorption via magneto-electric cross-couplings — •Jürgen Kästel[1], Michael Fleischhauer[1], Susanne F. Yelin[2,3], and Ronald L. Walsworth[2,4] — [1]Fachbereich Physik, Technische Universität Kaiserslautern, Germany — [2]ITAMP, Cambridge, MA, USA — [3]UConn, Storrs, CT, USA — [4]Harvard University, Cambridge, MA, USA

Negative refraction of light advanced to one of the most active areas in photonics research in recent years. As the generation of a negative index of refraction in metamaterials is well understood the strong absorption present in such media remains to be the main obstacle to applications. We propose a novel approach that uses effects similar to EIT leading to resonantly enhanced magneto-electric cross-coupling which leads to negative refraction with simultaneously strong suppression of absorption. The refractive index can be fine-tuned and impedance matched by means of external laser fields. We analyze the orientation and polarization dependence of the refractive index and discuss the prospects of attaining an isotropic and/or polarization independent, i.e., non-chiral refraction.

Q 55.16 Do 16:30 VMP 8 Foyer

Untersuchung von Schwefelkohlenstoff mittels Quantenbeatspektroskopie — •Daniel Depenheuer, Jörg Kohl-Landgraf und Thomas Walther — TU Darmstadt, Institut für angewandte Physik, Laser und Quantenoptik, Schlossgartenstr. 7, 64289 Darmstadt

Präsentiert wird ein Projekt, bei dem die Eigenschaften des 10V Bandes von Schwefelkohlenstoff mittels Quantenbeatspektroskopie untersucht werden sollen. Hierzu wurde ein Lasersystem aufgebaut, das fourierlimitierte ns-Laserpulse bei 323.8nm erzeugen kann, um Energieniveaus von Schwefelkohlenstoff kohärent anzuregen. Der Schwefelkohlenstoff wird in einem hypersonic Jet in einer Vakuumkammer spektroskopiert. Mittels gepulster elektrischer und magnetischer Felder lassen sich die Energieniveaus des Schwefelkohlenstoffs aufspalten und die Quantenbeats manipulieren.

Q 55.17 Do 16:30 VMP 8 Foyer

Towards quantum optical experiments with ions in the solid state — •Lutz Petersen, Michael Jobst, Stephan Götzinger, and Vahid Sandoghdar — Laboratory of Physical Chemistry and optETH, ETH Zurich, CH-8093 Zurich, Switzerland

A number of quantum optical phenomena, such as qubit population transfer or EIT, can be investigated in the solid state using rare-earth ions. Although embedded in a solid-state matrix, these emitters can exhibit exquisitely narrow radiative linewidths on the order of kilohertz and inhomogeneous broadenings smaller than one gigahertz. Ultralong dephasing times have been measured at temperatures below 10 K, merely limited by the spontaneous emission lifetime.

Our investigations focus on two transitions of praseodymium doped into an yttrium-orthosilicate crystal (YSO): the well-studied $^3H_4-^1D_2$ transition at 606 nm and the $^3H_4-^3P_0$ transition at 488 nm. We use a micro-photoluminescence setup to investigate these ions at cryogenic temperatures. We are currently constructing a tunable laser source with sub-kilohertz linewidth for high-resolution spectroscopy. Future experiments involving such a narrow-band excitation source will be discussed.

Q 55.18 Do 16:30 VMP 8 Foyer

Delocalization of atoms in a disorder potential due to spontaneous emission — •Boris Nowak[1,2], Peter Schlagheck[1], Jami Kinnunen[2,3], and Murray J. Holland[2] — [1]Institut für Theoretische Physik, Universität Regensburg — [2]JILA, University of Colorado at Boulder — [3]Department of Engineering Physics, Helsinki University of Technology

Recently two groups have reported on the observation of Anderson localization of Bose-Einstein condensates in a one dimensional disorder potential [1,2]. This effect is caused by the coherent wave nature of atoms and is therefore significantly altered by a dissipative process such as spontaneous emission. We report on our studies of a near resonantly driven two level atom subject to an external disorder potential. To this end we numerically compute the master equation evolution for the reduced density matrix by employing the Monte Carlo wavefunction method [3]. We particularly focus on the influence of spontaneous emission onto the time dependent expansion process of the atomic wave packet in a disorder potential.

[1] J. Roati et al., Nature **453** (2008)
[2] J. Billy et al., Nature **453** (2008)
[3] R. Dum et al., Phys. Rev. A **45** (1992)

Q 55.19 Do 16:30 VMP 8 Foyer

Frequenzvervierfachung eines Faserverstärkers bei 1014,8nm — •Joachim Rest, Patrick Villwock, Mathias Sinther und Thomas Walther — TU Darmstadt, Institut für angewandte Physik, Schlossgartenstraße 15, 64289 Darmstadt

Das Kühlen und Fangen von Quecksilberatomen in einer Magneto-optischen-Falle ermöglicht eine Vielzahl von Anwendungen. Unter anderem die Untersuchung der fermionischen Isotope im Bezug auf einen neuen Zeitstandard. Ziel unserer Arbeit ist es ein alternatives Lasersystem aufzubauen mit dem eine Magneto-optische-Falle mit Quecksilberatomen realisiert werden kann. Dieses Lasersystem basiert auf einem bereits realisiertem Ytterbium-dotierten Faserverstärker bei 1014,8nm, der eine teilweise Depolarisation aufweist. Die nötige Wellenlänge von 253,7nm für das Doppler-Kühlen soll dann durch zweifache externe Frequenzverdopplung realisiert werden. Es wird der aktuelle Stand vorgestellt.

Q 55.20 Do 16:30 VMP 8 Foyer

Ein flexibler ns-Titan:Saphir Laser als nahezu universelle Lichtquelle — •Jörg Kohl-Landgraf, Daniel Depenheuer und Thomas Walther — TU Darmstadt, Institut für angewandte Physik, Laser und Quantenoptik, Schlossgartenstr. 7, 64289 Darmstadt

Wir stellen einen ns-Titan:Saphir Laser vor, der durch nichtlineare Frequenzkonversion das Spektrum von UV-C bis in den mittleren IR Bereich hinein abdecken kann. Durch Injection-seeding wird ein schmalbandiger Betrieb in der Nähe des Fourierlimits erreicht. Vorgestellt wird die Charakteristik des Lasers sowohl in der Nähe des Verstärkungsmaximums von Titan:Saphir, als auch am Rande des Verstärkungsprofils. Die nichtlinearen Frequenzkonversionsprozesse sind aufgrund der hohen spektralen Leistungsdichte des Lasers sehr effizient. Durch die sehr stabile Buildup Zeit des Lasers sind neben der Erzeugung höherer Harmonischer auch die Erzeugung von Summen- und Differenzfrequenzen zwischen dem Titan:Saphir Puls und dem Pumppuls möglich.

Q 55.21 Do 16:30 VMP 8 Foyer

Numerical model of a pulsed loop-oscillator with gain grating — •Robert Elsner 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. 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 might be applicable for frequency stabilization. Thus the scheme has the potential for spectrally stable 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. 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 55.22 Do 16:30 VMP 8 Foyer

Herstellung und Charakterisierung von Kanalwellenleitern in Nd:YAG mittels fs-Laserpulsen — •Jörg Siebenmorgen, Thomas Calmano, Klaus Petermann und Günter Huber — Universität Hamburg, Institut für Laser-Physik, Luruper Chaussee 149, 22761 Hamburg

Mit Laserpulsen einer Pulsdauer von 140 fs wurden Zerstörspuren in Nd-dotierten und undotierten YAG-Kristallen geschrieben. Aufgrund von spannungsinduzierter Doppelbrechung konnte Wellenleitung in verschiedenen Kanälen in der Umgebung von Einzelspuren und im Zentrum von Doppelspuren beobachtet werden.

Die geringsten Wellenleiterverluste von 1,4 dB/cm bei einer Wellenlänge von 1063 nm traten bei Wellenleiterkanälen zwischen Doppelspuren mit einem Abstand von 25 μm auf.

Die Fluoreszenzcharakteristik wurde ortsaufgelöst untersucht und Konfokal-Mikroskopiebilder aufgenommen. Zusätzlich wurde die Fluoreszenzlebensdauer am Ort der Wellenleiter bestimmt. Bei diesen Untersuchungen zeigte sich kein Unterschied zwischen den wellenleitenden Bereichen und dem nicht modifizierten Material.

Um den zugrunde liegenden Wellenleitungsmechanismus genauer zu untersuchen, wurden die Proben in H_3PO_4 bei einer Temperatur von 50°C geätzt. Dabei zeigte sich ein hochselektiver Abtrag des modifizierten Materials mit Ätzraten von bis zu 5 μm/h.

Q 55.23 Do 16:30 VMP 8 Foyer

Ein Diodenlaser System bei 369 nm — •Peter Kaufmann, Nuala Timoney, Thomas Collath, Michael Johanning und Christof Wunderlich — Fachbereich Physik, Universität Siegen, 57072 Siegen, Deutschland

Laserlicht der Wellenlänge 369 nm kann zur Anregung des Dipolübergangs $^2S_{1/2} \leftrightarrow {}^2P_{1/2}$ im Ytterbium$^+$ Ion verwendet werden. Dieser optische Übergang wird sowohl zur Laserkühlung als auch zum Zustandsnachweis bei Experimenten mit in Paulfallen gespeicherten Yb^+-Ionen benutzt.

Wir erzeugen frequenzstabilisiertes Laserlicht der gewünschten Wellenlänge mit der optischen Leistung $P = 3$ mW unter Verwendung einer auf -5 Grad Celsius gekühlten, kommerziell erhältlichen Laserdiode in Littrowkonfiguration bei gleichzeitiger Stabilisierung auf einen konfokalen optischen Resonator.

Der experimentelle Aufbau wird vorgestellt und hinsichtlich Temperaturabhängigkeit der Wellenlänge, optischer Leistung und Frequenzstabilität durch den direkten Vergleich mit einem frequenzverdoppelten Ti:Sa Lasersystem charakterisiert. Die Eignung des Systems zur Manipulation von Yb^+-Ionen wird durch die Messung der Fluoreszenz eines in einer Paulfalle gespeicherten $^{172}Yb^+$-Ions demonstriert.

Q 55.24 Do 16:30 VMP 8 Foyer

Laserentwicklung zur Erzeugung von Bose Einstein Kondensaten unter Schwerelosigkeit — •Anika Vogel[1], Nadine Meyer[2], Julian Hofmann[1], Alexandra Dwenger[1], Kai Bongs[1] und Klaus Sengstock[2] — [1]Institut fuer Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]School of Physics and Astronomy, University of Birmingham, Edgbaston, B152TT, UK

Untersuchungen an Bose-Einstein Kondensaten in Schwerelosigkeit eroeffnen neue Moeglichkeiten hinsichtlich kleinerer Temperaturen und Dichten. Die wesentlich verlaengerte Beobachtungszeit ermöglicht sensitivste Atominterferometrische Messungen.

Im Rahmen einer deutschlandweiten Kollaboration entwickelten wir ein Lasersystem zum erfolgreichen Einsatz unter den extremen Bedingungen am Fallturm in Bremen als Pilotprojekt für zukünftige Weltraummissionen.

Auf diesem Poster sollen die neuesten Weiterentwicklungen hinsichtlich weiterer, wesentlich verbesserter Temperatur- und mechanischer Stabilität der Lasersysteme präsentiert werden.

Das Projekt wird finanziert von dem Deutschen Zentrum für Luft- und Raumfahrt DLR unter der Fördernummer DLR 50 WM 0346.

Q 55.25 Do 16:30 VMP 8 Foyer

Steuerung der Polarisation eines Faserlasers — •Ortwin Helmig, Klaus Sengstock und Valeri Baev — Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Faserlaser als kohärente Strahlungsquellen gewinnen in der Technik immer mehr an Bedeutung. Sie bieten neben hohen Leistungen auch gute Strahlqualitäten. Eine bestehende Einschränkung ist, daß die Polarisation dieser Laser nur bei der Verwendung von speziellen polarisationserhaltenden Fasern klar definiert sein kann. Wir demonstrieren neue Konzepte zur Polarisationssteuerung, die auch bei Verwendung von zylindersymmetrischen aktiven Glasfasern anwendbar sind. Diese Konzepte stützen sich auf die Reduzierung bzw. Erhöhung der Resonatorverluste für eine bestimmte Polarisation. Eine Reduzierung der Resonatorverluste für eine Polarisation erzielt man mit einem polarisationsanbhängigen Hilfsresonator, der an den bestehenden Faserlaser angekoppelt wird. Erhöhung der Resonatorverluste für eine Polarisation kann des weiteren durch eine spezielle Strukturierung der Faserendfläche erreicht werden. Beide Methoden wurden für einen Pr,Yb:ZBLAN upconversion Faserlaser bei 635 nm bzw. 492 nm erfolgreich eingesetzt. So konnte mit einer zylindersymmetrischen Faser ein Polarisationsgrad des Laserlichts von mehr als 100:1 erzielt werden.

Q 55.26 Do 16:30 VMP 8 Foyer

Transverse modes in few-mode fiber amplifiers — •Niklas

Andermahr[1,2], Martin Schäferling[2], Christian Vorholt[2], and Carsten Fallnich[2] — [1]Laserzentrum Hannover, Hollerithallee 8, 30419 Hannover, Germany — [2]Institut für Angewandte Physik - WWU Münster, Corrensstraße 2, 48149 Münster, Germany

Large mode area fibers are used for high-power fiber amplifiers, as they accomplish to reduce the power density within the core. However, a larger core diameter in general allows the propagation of higher-order transverse modes.

We model the propagation of transverse modes by solving the Fresnel wave equation [1]. Thereby the electrical field is calculated, which allows to visualize the intensity distribution within the fiber. Moreover, the modal powers and the modal polarization states are derived from the electrical field. As the gain saturates locally, the transverse modes can interact with each other. A polarization dependent mode amplification is found that is in good agreement with recent experimental results [2].

[1] N. Andermahr and C. Fallnich, Opt. Express **16** (24), 20039 (2008)
[2] N. Andermahr and C. Fallnich, Opt. Express **16** (12), 8679 (2008)

Q 55.27 Do 16:30 VMP 8 Foyer

Lasersystem zur Erzeugung der 'Magic Wavelength' von Hg — •Rudolf Mitsch, Patrick Villwock und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, Laser- und Quantenoptik, Schloßgartenstraße 7, 64289 Darmstadt

Neutrales Quecksilber besitzt ein hohes Potential für einen neuen Zeitstandard basierend auf einem optischen Gitter. Das benötigte optische Gitter liegt bei der magischen Wellenlänge, die den Abstand der Energieniveaus des zu spektroskopierenden Uhrenübergangs in 1. Ordnung nicht ändert. Für Quecksilber wird die magische Wellenlänge durch Rechnungen zwischen 340-360nm vorhergesagt. Präsentiert werden Arbeiten zu einem Lasersystem in diesem Wellenlängenbereich.

Q 55.28 Do 16:30 VMP 8 Foyer

Numerische Modellierung periodischer und aperiodischer Strukturen zur Quasiphasenanpassung — •Felix Rübel, Heiner Hartogh und Johannes A. L'huillier — Technische Universität Kaiserslautern, Fachbereich Physik, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern, Deutschland

Frequenzkonversion in periodisch gepolten ferroelektrischen Kristallen zur Quasiphasenanpassung (QPM) ist von besonderer Bedeutung für viele Anwendungen. QPM-Materialien bieten gegenüber Phasenanpassung mit Doppelbrechung den Vorteil, dass das größte nichtlineare Tensorelement genutzt werden kann. Des weiteren wird die Wellenlänge der konvertierten Strahlung nur von der Periodizität der Polungsstruktur bestimmt. Es ist daher möglich mehrere Konversionprozesse in einem Kristall mit entsprechend angepassten Polungsperioden zu integrieren. Gleichzeitig ermöglichen aperiodische Strukturen die Eigenschaften von quasiphasenangepassten Prozessen zu beeinflussen und zu optimieren sowie die simultanen Erzeugung mehrerer Prozesse in einem Gitter. In diesem Beitrag werden verschiedene periodische und aperiodische QPM-Strukturen systematisch theoretisch untersucht. Hierzu werden für vorgegebene Gitter die gekoppelten Amplitudengleichungen für die Summenfrequenzerzeugung numerisch gelöst. Es werden gechirpte Gitter zur Erhöhung der spektralen Akzeptanzbreite sowie zur simultanen QPM mehrerer Prozesse diskutiert sowie der Einfluss von Gitterfehlern auf den Konversionsprozess systematisch untersucht.

Q 55.29 Do 16:30 VMP 8 Foyer

Emissionsdynamik von vielmodigen Festkörperlasern. Theorie und Anwendungen — •Oliver Back, Klaus Sengstock und Valeri Baev — Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Vielmodige Festkörperlaser zeigen eine sehr komplexe Emissionsdynamik. Sie wird zum einen durch die Lebensdauer des oberen Laserniveaus, die Resonatorverluste und der Anzahl der Polarisations- und Longitudinalmoden, zum anderen durch die partielle Entkopplung und durch die nichtlineare Kopplung der Moden bestimmt. Der Grund für die Modenentkopplung liegt in der Sättigung der Inversion durch die stehenden Lichtwellen eines Vielmodenlasers, die zu räumlicher Inhomogenität der Verstärkung in longitudinaler sowie in azimutaler Richtung führt. Nichtlineare Kopplung kann z.B. durch die Frequenzverdoppelung im Laserresonator verursacht werden. Der Grad der Kopplung, bzw. Entkopplung bestimmt maßgeblich die Emissionsdynamik und beschränkt damit die möglichen praktischen Anwendungen von vielmodigen Festkörperlasern. Das entwickelte Modell hat es uns erlaubt, die Emissionsdynamik von verschiedenen vielmodigen Festkörperlasern ausführlich zu beschreiben und gezielt zu steuern um die Laser für bestimmte Anwendungen zu optimieren. Unter anderem wurden Möglichkeiten gezeigt, das Emissionsrauschen eines Vielmodenlasers mit und ohne Frequenzverdoppelung im Laserresonator zu reduzieren [1], sowie die Empfindlichkeit von Absorptionsmessungen im Resonator eines Vielmodenlasers zu erhöhen.

1. R. Hartke et al., Appl. Phys. Lett. 92, 101107 (2008).

Q 55.30 Do 16:30 VMP 8 Foyer

Modellierung der Emissionsdynamik von vielmodigen Faserlasern — •Dmitrij Kondratjew[1,2], Oliver Back[1], Klaus Sengstock[1] und Valeri Baev[1] — [1]Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]Lebedev Institut, Leninskij pr. 53, 119991 Moskau Russland

Die meisten Faserlaser sind vielmodig und ihre praktische Anwendung erfordert Kenntnis und Berücksichtigung der Emissionsdynamik einzelner Moden. Wir berichten über die Entwicklung eines theoretischen Modells, das die Emissionsleistung einzelner Lasermoden theoretisch beschreibt. Ausgangspunkt des Modells ist das Ratengleichungssystem für einen vielmodigen Laser, das die Unterscheidung der Moden sowohl durch ihre Frequenzen als auch durch ihren Polarisationszustand zulässt. Dieses Modell berücksichtigt Quantenrauschen, räumliche Inhomogenität der Verstärkung, sowie nichtlineare Prozesse, die aufgrund hoher spektraler Leistungsdichte, die durch extrem geringe Querschnitte der Fasern bedingt ist, eine wesentliche Rolle spielen. Stimulierte Brillouin-Streuung führt zur Umverteilung der Leistung einzelner Moden und begrenzt dadurch die Empfindlichkeit des Emissionsspektrums bezüglich schmalbandiger resonatorinterner Absorption. Das entwickelte Modell ermöglicht die Optimierung der Laserparameter zwecks Erhöhung der Empfindlichkeit von Absorptionsmessungen im Resonator verschiedener Faserlaser.

Q 55.31 Do 16:30 VMP 8 Foyer

Spektroskopie vom Verbrennungsprozessen im Resonator eines Er^{3+}-dotierten Faserlasers — •Benjamin Löden[1], Svetlana Kuznetsova[1], Anatoly Goldmann[2], Sergej Cheskis[2], Klaus Sengstock[1] und 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

Verbrennungsprozesse spielen in einer Vielzahl von technischen Anwendungen eine wichtige Rolle. Ein Verständnis der Prozesse in Flammen ermöglicht es, diese bezüglich der Effizienz und der Vermeidung von schädlichen Nebenprodukten zu optimieren. Er^{3+}-dotierte Faserlaser bieten die Möglichkeit, in-situ mit hoher Empfindlichkeit im Laserresonator verschiedene Moleküle in einer Flamme zu vermessen [1]. Diese breitbandigen Faserlaser können mittels einer asphärischen Linse und Variation der Faserlänge im Spektralbereich von 1,52 bis 1,62 μm durchgestimmt werden. Mit ihnen wurden Absorptionsspektren von C_3H_8-, C_2H_2- und CH_4-Niederdruckflammen, teilweise unter Beigabe von H_2S oder NH_3, als Funktion des Abstands zum Brenner und der Konzentration aller Komponenten mit hoher Empfindlichkeit im Laserresonator gemessen. Aus den Spektren konnten mehrere Moleküle in der Flamme, unter anderem HCN, CO, CO_2, H_2O und C_2H_2, identifiziert und ihre Konzentrationen gemessen werden. Die dargestellte Methode ist daher zur Analyse, Überwachung und Optimierung von Verbrennungsprozessen geeignet.

1. A. Goldman *et al.*, Chem. Phys. Lett. 423, 147 (2006)

Q 55.32 Do 16:30 VMP 8 Foyer

From Absorption to Transparency without Switching Dispersion — •Katrin Dahl, Luca Spani Molella, Rolf-Hermann Rinkleff, and Karsten Danzmann — Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Institute for Gravitational Physics, Leibniz Universität Hannover, Callinstr. 38, D-30167 Hannover

With a probe laser beam and coupling laser beam of counter-rotating circular polarizations, the absorption and dispersion in a degenerate two-level system was studied.

For counter-rotatingly polarized laser beams we measured coupling laser absorption spectra as a function of the coupling laser power, below and above the saturation power of the atomic cesium sample. In the case of a probe laser power below saturation for all coupling laser powers, "absorption within transparency" was registered exclusively. By contrast, above saturation a switch from "absorption within transparency" to "transparency within transparency" was detected when the coupling laser power was larger than the constant probe laser power. Interestingly, the corresponding dispersion spectra of the coupling laser remained positive. In other words, opposed to the absorption spectra no switch was observed.

The work was made possible through the financial support of the Collaborative Research Centre SFB407 of the German Research Foundation (Deutsche Forschungsgemeinschaft).

Q 55.33 Do 16:30 VMP 8 Foyer

Implementation of Atom Trap Trace Analysis for ^{39}Ar — •Joachim Welte[1], Florian Ritterbusch[1], Isabelle Steinke[1], Anna Wonneberger[2], Markus Oberthaler[1], and Werner Aeschbach-Hertig[2] — [1]Kirchhoff Inst. f. Physics, University of Heidelberg, Heidelberg/ Germany — [2]Inst. of Environmental Physics, University of Heidelberg, Heidelberg/ Germany

Dating water samples with ^{39}Ar ($T_{1/2}$ = 269a) is currently restricted by the limits of "traditional" Low Level Counting, namely the large samples necessary and the long measurement time. We try to overcome these limitations by Atom Trap Trace Analysis for this isotope and thus bridging the "dating gap" of 100 - 1000 years of water sample age. An ATTA table-top apparatus would find applications in many different fields due to its small size and "low" cost.

We report on several first steps that have been undertaken, e.g. from the environmental physics side of the project water degassing and gas separation and from the atom-optical side measurement of hyperfine structure of ^{39}Ar, single atom detection and design of an atomic beam including source and collimation.

Q 55.34 Do 16:30 VMP 8 Foyer

Silizium als Testmassenmaterial für zukünftige Gravitationswellendetektoren — •Jessica Dück, Sebastian Steinlechner, Nico Lastzka, Karsten Danzmann und Roman Schnabel — Max-Planck-Institut für Gravitationsphysik (AEI) und Institut für Gravitationsphysik, Leibniz Universität Hannover

Um die Existenz von Gravitationswellen direkt nachzuweisen, befindet sich derzeit die erste Generation erdgebundener Gravitationswellendetektoren (GWD) in der Messphase.
Diese Detektoren haben ihre Designempfindlichkeit erreicht und zeigen eine minimale spektrale Rauschdichte von lediglich $3 \cdot 10^{-23}/\sqrt{Hz}$. Dabei stellt das thermische Rauschen einen limitierenden Faktor da.
Um das Thermische Rauschen der folgenden Generation GWD zu reduzieren, wird ein Betrieb bei kryogenen Temperaturen erforderlich. Fused Silica, welches bisher als Testmassenmaterial verwendet wurde, entspricht bei tiefen Temperaturen jedoch nicht den mechanischen Anforderungen.
Kristallines Silizium hingegen besitzt insbesondere bei tiefen Temperaturen eine hohe mechanische Güte. Die inakzeptabel hohe Absorption bei 1064 nm kann durch einen Umstieg auf die Telekommunikationswellenlänge von 1550 nm vermieden werden. Bei dieser Wellenlänge wird ein Absorptionskoeffizient von unter $10^{-8}/cm$ vermutet zu dessen Vermessung wir Techniken vorstellen.
Eine Bestimmung des Absorptionskoeffizienten stellt somit eine wichtige Grundlage zur Verwendung von Silizium als Testmassenmaterial in zukünftigen kryogenen GWD dar.

Q 55.35 Do 16:30 VMP 8 Foyer

Laser ranging and data communication in space-based applications — •Juan Jose Esteban Delgado, Johannes Eichholz, Antonio Garcia Marin, Ioury Bykov, Joachim Kullmann, Gerhard Heinzel, and Karsten Danzmann — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) and Universität Hannover. Callinstrasse 38 30167 Hannover, Deutschland

Ranging measurements and data communication in the radio band have been extensively used in space-based applications, for example in GNSS or GRACE. The increasing demand in high-bandwidth communication and precision ranging will make optical systems ideal for these applications. Experiments in Apollo missions have long ago demonstrated precision ranging measurement and the inter-spacecraft laser link between the NFIRE and the TerraSAR-X recently showed the viability of high-speed optical communication. Our investigations are focused on laser ranging and data communication for the Laser Interferometer Space Antenna (LISA) mission. We present the LISA baseline design and the progress of our experimental demonstration in laboratory.

Q 55.36 Do 16:30 VMP 8 Foyer

Temporal pulse characterization of a multi-TW three-cycle optical parametric chirped pulse amplifier — •Raphael Tautz[1], Laszlo Veisz[1], Daniel Herrmann[1], Karl Schmid[1,2], and Ferenc Krausz[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Ludwig-Maximilians-Universistät, München, Germany

We report on our home-built diagnostic tools, which are specially designed and optimized to characterize our ultra-intense three-cycle light pulses with duration of 8 fs, generated by an optical parametric chirped pulse amplifier (OPCPA). An all-reflective single-shot second order intensity autocorrelator has been designed and realized, which is suitable to perform a real-time observation of pulse-duration and -shape with a repetition rate of 10 Hz. Hereby a temporal resolution of 200 as and an observation window of 560 fs have been achieved. Besides it is extendable to a single-shot second harmonic generation frequency resolved optical gating (SHG FROG) device within few minutes. Its high accuracy and repetition rate provide excellent feedback for optimizing the pulse-duration using an accousto-optical modulator. Furthermore the high dynamic range of the already existing third order intensity correlator for contrast measurements has been improved. The measureable pulse intensity contrast spans over more than 10 orders of magnitude within +- 300 ps. This allows a more accurate investigation of the contrast of our OPCPA system, uncovering the contribution from superfluorescence and seed contrast. Altogether these devices allow a fast and reliable characterization of our multi-TW three-cycle pulses.

Q 55.37 Do 16:30 VMP 8 Foyer

Grenzen der Pulsdauer in solitären Festkörperlasern — •Fabian Lücking[1], Marcel Schultze[1], Guido Palmer[1] und Uwe Morgner[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Laserzentrum Hannover e.V.

Dem Flächentheorem zufolge ist die Pulsdauer in solitär betriebenen Oszillatoren mit Hilfe der resonatorinternen Dispersion beliebig skalierbar und lediglich durch die Verstärkungsbandbreite des Lasermediums limitiert. Die tatsächlich erreichbaren Pulsdauern liegen jedoch deutlich darüber. Es zeigt sich, dass ein gewisses Mindestmaß an Dispersion nötig ist, um stabile Modenkopplung zu realisieren. Diese minimal notwendige Dispersion skaliert mit der Pulsenergie und erzwingt somit längere Pulse bei langen Resonatoren.

Um diese Grenzen des Flächentheorems zu untersuchen, wurde ein diodengepumpter Yb:KYW Oszillator aufgebaut, der insgesamt fünf stabile Resonatorvarianten mit Repetitionsraten zwischen 16 und 165 MHz ermöglicht. Dabei wurde in jeder Konfiguration die resonatorinterne Dispersion variiert, um jeweils kürzeste stabile Einzelpulse zu erreichen.

Ergänzend zu den experimentellen Ergebnissen wurden numerische Simulationen basierend auf dem Split-Step-Fourier-Verfahren durchgeführt. Diese geben Aufschluss über die Ursachen der Pulsinstabilität und zeigen mögliche Wege zu weiterer Pulsverkürzung auf.

Q 55.38 Do 16:30 VMP 8 Foyer

Interplay between absorption, dispersion and refraction in high-order harmonic generation — •Hatem Dachraoui[1], Thierry Auguste[2], Andreas Helmstedt[1], Peter Bartz[1], Martin Michelswirth[1], Norbert Mueller[1], Walter Pfeiffer[1], Pascal Salieres[2], and Ulrich Heinzmann[1] — [1]Fakultät für Physik, Universität Bielefeld, Universitätsstr. 25 33615 Bielefeld, Germany — [2]CEA-Saclay, IRAMIS, Service des Photons Atomes et Molaecules, F-91191 Gif-sur-Yvette, France

The high-order harmonic generation efficiency in Neon gas cell at high pumping energy is experimentally and theoretically examined. The dependence of the cutoff and of the plateau harmonics efficiency on gas pressure, interaction length and Laser intensity provides information about the interplay between the different terms entering the phase-matching relation. In particular, the dispersion because of free electrons and atoms and the re-absorption of the harmonics by the medium are relevant. Both simulations and experiments show that the interaction length and gas pressure may be used to control the cutoff harmonics.

Q 55.39 Do 16:30 VMP 8 Foyer

Combining fs pulse tailoring and self-phase modulation for nonlinear microscopy. — •Tillmann Kalas, Jens Köhler, Cristian Sarpe-Tudoran, Matthias Wollenhaupt, and Thomas Baumert — Universität Kassel, Institut für Physik und CINSaT, Heinrich-Plett-Str. 40, D-34132 Kassel, Germany

Nonlinear label-free microscopy is a powerful tool for the investigation of physical and biological samples with high spatial resolution. Often intrinsic Second- or Third-Harmonic Generation (SHG,THG) as well as Coherent Anti-Stokes Raman Scattering (CARS) is used as contrast mechanism.

We make use of femtosecond pulse shaping in combination with self-phase modulation (SPM) in order to generate the nonlinear signals [1,2]. Extending our previous studies [1], femtosecond laser pulses, amplitude and phase modulated in a narrow spectral interval, are focused into a waterjet serving as transparent sample. SPM leads to a redistribution of the power spectral density. Detailed observation of the intensity in the above mentioned spectral band holds the possibility to distinguish between different materials and their concentrations in a sample. Currently the impact of different pulse shapes on the SPM modified power spectral density is studied. In particular spectral phase dependencies to optimize possible contrast mechanisms are under investigation and results are presented.

[1] A. Präkelt *et al.*: Appl. Phys. Lett. **87**(12), 121113 (2005)
[2] M. C. Fischer *et al.*: Opt. Lett. **30**(12), 1551(2005)

Q 55.40 Do 16:30 VMP 8 Foyer

Simultaneous production of multiple waveguides for photonic devices by femtosecond laser writing — •Moritz Emons[1], Matthias Pospiech[1], Andy Steinmann[1], Guido Palmer[1], Uwe Morgner[1,2], Roberto Osellame[3], Nicola Bellini[3], and Giulio Cerullo[3] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland — [2]Laserzentrum Hannover e.V. — [3]Istituto di Fotonica e Nanotecnologie - CNR, Dipartimento di Fisica - Politecnico di Milano

We describe the application of beam shaping for the creation of multiple foci and their use in femtosecond laser writing. This technique is capable of producing waveguide based photonic devices in a single sweep by simultaneously writing. We give an introduction into the beam shaping algorithm and show results of sample devices (e.g. couplers) with their guiding properties and their specific functional properties.

Q 55.41 Do 16:30 VMP 8 Foyer

Femtosekunden Feld-Synthesizer — •Stefan Rausch[1,3], Thomas Binhammer[2], Anne Harth[1,3] und Uwe Morgner[1,3] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]VENTEON Laser Technologies GmbH, Garbsen — [3]QUEST - Centre for Quantum Engineering and Space-Time Research, Hannover

Ein Femtosekunden Feld-Synthesizer ermöglicht es, die elektrische Feldamplitude von Femtosekunden-Pulsen auf Zeitskalen unterhalb ihrer optischen Schwingungsperiode von 2,7 fs bei 800 nm zu kontrollieren. Der hier präsentierte Feld-Synthesizer basiert auf einer einzigartigen Kombination von oktav-breitem Titan:Saphir-Laser-Oszillator mit computergesteuertem, prismenbasiertem LCD-Pulsformer und einer SPIDER-Puls-Charakterisierung. Mit diesem System ist es möglich, die spektrale Phase und Amplitude von ultrakurzen Laserpulsen mit einer Dauer von weniger als 5 Femtosekunden unabhängig voneinander zu beeinflussen. Wird der genutzte Master-Oszillator zusätzlich auf seine Träger-Einhüllenden-Phase stabilisiert, welche die Position der elektrischen Feld-Oszillation unterhalb der Einhüllenden charakterisiert, können sämtliche Parameter, die den ultrakurzen Feldverlauf beschreiben, kontrolliert werden. Es ist nun z.B. möglich, Pulse mit einer Dauer von nur 3,6 Femtosekunden zu erzeugen - die kürzesten Pulse, die bisher direkt aus einem Femtosekunden-Oszillator erzeugt wurden. Es können aber auch maßgeschneiderte Pulse mit gewünschter spektraler oder zeitlicher Form generiert werden. Die so synthetisierten Feldverläufe finden ihre Anwendung im Bereich der kohärenten Kontrolle und der Spektroskopie von Feld-sensitiven Prozessen.

Q 55.42 Do 16:30 VMP 8 Foyer

Dynamics of free electron plasma produced by shaped femtosecond laser pulses in water — •Cristian Sarpe-Tudoran, Matthias Wollenhaupt, Alexander Horn, Lars Englert, Jens Köhler, and Thomas Baumert — Universität Kassel, Institut für Physik und CINSaT, Heinrich-Plett-Str. 40, D-34132 Kassel, Germany

The generation of high density free electron plasma is the first step in the laser induced optical breakdown process; a better knowledge of the plasma dynamics [1] can contribute to increase the precision of the ablation process and to reduce the collateral damage. Recently we have shown that tailored ultrashort laser pulses are suitable for robust manipulation of optical breakdown in the case of high bandgap solid dielectrics [2, 3]. In this contribution we report our studies to investigate the free electron plasma evolution produced by shaped femtosecond laser pulses in a thin water jet. By using a spectral interferometric technique the early times dynamics is observed with a high temporal resolution and the dependence of the free electron density on laser intensity and temporal pulse shapes is accurately obtained.

[1] C. Sarpe-Tudoran et al. Appl. Phy. Lett. 88, 2161109 (2006)
[2] L. Englert et al. Opt. Express 15, 17855 (2007)
[3] L. Englert et al. Appl Phys A 92, 749 (2008)

Q 55.43 Do 16:30 VMP 8 Foyer

Phase-matching of high-order harmonic generation in a semi-infinite gas cell geometry — •Daniel Sebastian Steingrube[1,2], Tobias Vockerodt[1,2], Uwe Morgner[1,2], and Milutin Kovacev[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, D-30167 Hannover, Germany — [2]QUEST, Centre for Quantum Engineering and Space-Time Research

We study high-order harmonic generation (HHG) by rare gases and their mixture in a semi-infinite gas cell geometry. Our experiment confirms recent results by Takahashi et. al. [PRL **99**, 053904 (2007)] of enhanced HHG in gas mixtures. The harmonics from Xenon atoms enhance the observed yield from Helium atoms by about two orders of magnitude.

The emphasis of our studies places on short focal lengths. The enhancement effect and the phase matching conditions are investigated in detail at different focusing. A systematic study on the experimental phase matching conditions is performed which includes mixing ratios and the focusing position dependence. Using the experimental parameter maps optimal conditions for the enhancement process are found.

Our study of the enhancement effect extends towards experimental conditions suited for low-energy pump pulses at high repetition rates. Especially, the enhancement effect at short focal lengths promises to lead to a joint frontier of precision spectroscopy and ultrafast science.

Q 55.44 Do 16:30 VMP 8 Foyer

Hohenharmonischen-Erzeugung an einer Nanopartikelquelle — •Heiko Kurz[1,2], Daniel Steingrube[1,2], Detlev Ristau[3], Uwe Morgner[1,2,3] und Milutin Kovacev[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]QUEST — [3]Laserzentrum Hannover e.V.

Die Erzeugung laserinduzierter Plasmen findet Anwendung in der Quantenoptik bei der Erzeugung Hoher Harmonischer Strahlung (HHG), sowie bei der Erzeugung weicher Röntgenstrahlung. Während Hohe Harmonische Strahlung aktuelles Forschungsgebiet in der Attosekundenpulserzeugung ist, wird inkohärente weiche Röntgenstrahlung in der Halbleiterlithographie eingesetzt.

Dieser Beitrag stellt ein innovatives Konzept für die HHG mittels einer Nanonpartikelquelle vor. In unserem Experiment wird eine Quelle zur Erzeugung eines Nanopartikel-Targets im Hochvakuum erstellt. Dabei lassen sich die Nanopartikel-Parameter im Target gezielt manipulieren. Die Partikelgröße, deren Konzentration sowie die Stoffklasse sind hier von besonderem Interesse. Nahezu alle festen Stoffe des Periodensystems lassen sich mit diesem flexiblen Targetkonzept untersuchen. Es werden Änderungen im Hohen Harmonischen Spektrum und in deren Konversionseffizienz in Abhängigkeit der Nanopartikel-Parameter studiert. Dies ermöglicht eine genauere Überprüfung der Ein-Elektronen-Näherung, sowie der bei Mehrelektronen-Wechselwirkungen beobachteten Skalierungsgesetze. Erste experimentelle Messungen und Ergebnisse an Metall-Nanopartikeln werden vorgestellt.

Q 55.45 Do 16:30 VMP 8 Foyer

Single-cycle gap soliton in a subwavelengthstructure — •Xiao-Tao Xie and Mihai Macovei — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Few-cycle pulse propagation has attracted considerable attention recently with the discovery of many interesting phenomena such as self-induced transparency or formation of few- and single-cycle solitons [1]. Here we demonstrate that a single-cycle optical pulse can be generated when a pulse possessing few optical cycles penetrates through resonant two-level dense media with a subwavelength structure. The single-cycle gap soliton phenomenon in the full Maxwell-Bloch equations without the slowly varying envelope and rotating wave approximations is observed. Our study shows that the subwavelength structure can support the formation of a single-cycle gap soliton even in the case when the structure period breaks the Bragg condition, suggesting a way towards shortening high-intensity laser fields to few- and even to single-cycle pulse durations.

[1] V. P. Kalosha and J. Herrmann, Phys. Rev. Lett. **83**, 544 (1999).

Q 55.46 Do 16:30 VMP 8 Foyer

Hybridlinsen aus asphärisch-refraktiven und diffraktiven Flächen als Ersatz der Kittglieder eines Linsen-Umkehrsystems — •Manuela Tesmar[1], Christian Sinn[1], Volker Tautz[1] und Andrea Koch[2] — [1]Carl Zeiss Sports Optics GmbH, Wetzlar — [2]HAWK, Fakultät N, Göttingen

Der Beitrag stellt eine Hybridlinse mit einer refraktiven und einer diffraktiven optischen Fläche vor. Mit derartigen Hybridlinsen lassen sich gewöhnliche Kittglieder optischer Systeme ersetzen, die aus zwei sphärischen Einzellinsen unterschiedlichen Materials bestehen und deren Aufgabe die Korrektion der sphärischen und chromatischen Aberration ist. Die refraktive Fläche stellt dabei eine Asphäre dar, deren Oberfläche so gestaltet ist, dass die Schnittpunkte sowohl achsferner als auch achsnaher Strahlen möglichst zusammenfallen und so die sphärische Aberration korrigieren. Die diffraktive Fläche in Form eines rotationssymmetrischen Gitters korrigiert chromatische Aberrationen, wobei sie von ihrer im Vorzeichen umgekehrten Dispersion im Vergleich zu der von refraktiven Flächen profitiert. Im Blick auf Anwendungen im Zoom-Umkehrsystem wird die spektral sehr unterschiedliche Beugungseffizienz näher beleuchtet. Darüber hinaus sollen die technologischen Möglichkeiten zum Präzisionsblankpressen der vorgestellten Hybridlinsen erläutert werden.

Q 55.47 Do 16:30 VMP 8 Foyer

Photonic applications and experimental results on ultra-high Q bottle microresonators — •Andreas Vogler, Michael Pöllinger, Danny O'Shea, and Arno Rauschenbeutel — Abteilung QUANTUM, Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz

We have developed a novel type of whispering gallery microresonator that confines light by a mechanism similar to the confinement of charged particles in a magnetic bottle. The monolithic resonator, shaped like a highly prolate ellipsoid, is directly structured on a standard optical glass-fiber. Unlike other whispering gallery mode resonators, e.g. microspheres, the light is not just confined in a narrow ring close to the surface in the equatorial plane but allows a more complex mode structure. The bottle resonator concept yields ultra-high intrinsic quality factors $Q \approx 3.6 \cdot 10^8$ in combination with an unique tunability, which stems from it's Fabry-Perot-like mode structure along the fiber-axis.

We present experimental results on coupling of bottle modes among each other in one as well as in two macroscopically separated bottle resonators. Furthermore, we examine the coupling of bottle modes with the modes of a single mode fiber ring resonator. Finally, we present first results towards the use of bottle microresonators as all-optical fiber-based four-port devices for ultralow-power photonics applications like, e.g., all-optical switching.

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

Q 55.48 Do 16:30 VMP 8 Foyer

Concentration and enhancement of dipole radiation by nanospheres — •Sarina Wunderlich[1,2], Oleksandr Zhuromskyy[1], and Ulf Peschel[1] — [1]MPI für die Physik des Lichts, Erlangen — [2]Erlangen Graduate School in Advanced Optical Technologies (SAOT)

Resonantly excited atoms and molecules emit dipolar radiation thus forming the smallest light sources. Many applications as e.g. sensing or imaging would benefit from an enhancement of these fields.

Here we demonstrate by numerical simulations that nanospheres can fulfil that purpose. We present simulations of surface modes and field distributions, which are excited by a single dipole attached to a sphere of metallic or dielectric material with a thin metallic layer. Surface plasmons are excited at the metal to air interface and show resonant behaviour if the circumference of the sphere is an integer multiple of the plasmon wavelength. The plasmon propagation constant can be tuned by varying the permittivity of the material or the thickness of the metallic layer. In a resonance, the field distribution is highly symmetric and allows for sub-wavelength resolution imaging of the position of one or more dipoles at the surface.

Q 55.49 Do 16:30 VMP 8 Foyer

High order transverse modes in a Fabry-Perot cavity - Beyond the paraxial approximation — •Markus Koch, Martin Zeppenfeld, Borys Hagemann, Michael Motsch, Pepijn Pinkse, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Many interesting effects have been observed, when atoms or molecules are coupled to the modes of an optical cavity. Among them cavity cooling has attracted a lot of attention over the last years, since it promises to cool atoms or molecules without the need for a closed cycling transition. For best cooling a cavity with as many as possible degenerate transversal modes is needed.

We have performed high-precision measurements on the spectrum of the transverse modes of a high-finesse Fabry-Perot cavity. We find that the degeneracy of high Laguerre-Gaussian modes, predicted by the paraxial approximations, is lifted. Taking into account corrections beyond the paraxial approximation, we can quantitatively describe the splitting. We also observe two distinct sets of modes which indicates a coupling between the orbital and the spin angular momentum of light within the cavity.

Apart from the theoretical appeal, these new insights into the mode spectrum of a high-finesse cavity will be important for the design of non-spherical cavity mirrors to recover the mode degeneracy.

Q 55.50 Do 16:30 VMP 8 Foyer

Negative refraction and nanoscale coupling in plasmonic waveguide arrays — •Arian Kriesch[1,2] and Ulf Peschel[1] — [1]MPI für die Physik des Lichts, Erlangen, Germany — [2]Erlangen Graduate School in Advanced Optical Technologies (SAOT)

Recently it was demonstrated that highly birefringent materials can show negative refraction. An array of metallic stripes can serve as such kind of metamaterial, but it also forms a system of coupled plasmonic waveguides thus transferring the concept of optical discreteness to the nano-world.

Here we report results of a finite elements simulation of the propagation of electromagnetic waves in planar arrays of plasmonic nanowaveguides made from gold or silver on substrates of silicon or silica. We have optimized this configuration to obtain strong coupling between the waveguides, but also minimum losses. We intend to realize this structure and to analyze it by scanning near field optical microscopy (SNOM) as well as by cathodoluminescence (CL) imaging. The experimental examination of the predicted coupling effects promises new insights into the processes of discrete diffraction and negative refraction on previously unmatched small scales. A further goal is to achieve the formation of discrete spatial solitons in such a nanoarray.

Q 56: Poster IV

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

Q 56.1 Do 16:30 VMP 9 Poster

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

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

Q 56.2 Do 16:30 VMP 9 Poster

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

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

Q 56.3 Do 16:30 VMP 9 Poster

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

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

[1] A.Eckardt, arXiv:0811.2353
[2] N.Teichmann, D.Hinrichs, M.Holthaus, A.Eckardt, arXiv:0810.0643

Q 56.4 Do 16:30 VMP 9 Poster

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

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

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

Q 56.5 Do 16:30 VMP 9 Poster

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

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

Q 56.6 Do 16:30 VMP 9 Poster

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

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

Q 56.7 Do 16:30 VMP 9 Poster

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

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

Q 56.8 Do 16:30 VMP 9 Poster

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

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

Q 56.9 Do 16:30 VMP 9 Poster

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

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

Q 56.10 Do 16:30 VMP 9 Poster

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

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

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

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

Q 56.11 Do 16:30 VMP 9 Poster

Spinor Condensates: Spin Dynamics and Magnetism in Trian-

gular Lattices — •Parvis Soltan-Panahi, Julian Struck, Georg Meineke, Christoph Becker, and Klaus Sengstock — Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

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

Q 56.12 Do 16:30 VMP 9 Poster

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

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

Q 56.13 Do 16:30 VMP 9 Poster

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

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

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

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

Q 56.14 Do 16:30 VMP 9 Poster

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

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

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

Q 56.15 Do 16:30 VMP 9 Poster

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

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

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

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

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

Q 56.16 Do 16:30 VMP 9 Poster

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

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

[1] I. Bloch, J. Dalibard, W. Zwerger, Rev. Mod. Phys. 80, 885 (2008)
[2] N. Nygaard, R. Piil, K. Mølmer, Phys. Rev. A 78, 023617 (2008)
[3] M. Grupp, R. Walser, W. Schleich, A. Muramatsu and M. Weitz, J. Phys. B: At. Mol. Opt. Phys. 40 (2007) 2703-2718

Q 56.17 Do 16:30 VMP 9 Poster

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

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

Q 56.18 Do 16:30 VMP 9 Poster

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

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

Q 56.19 Do 16:30 VMP 9 Poster

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

Bose Einstein Condensates (BEC) opened the way for realization of atomic ensembles with Heisenberg limited uncertainty. In microgravity extremely dilute samples of BEC can be obtained and observed after a free evolution on timescales of seconds. Applications range from atom optics to matter wave interferometry. This has led us to realize a BEC of 10000 87Rb atoms in microgravity. The experimental results (to be published) establish the fact, that in a microgravity environment ultra-large condensates (˜1.5 mm) after a free evolution of 1 second can be observed. In particular, microgravity provides mass independent confining potential which is very important for the research on a mixture of quantum gases. We aim to realize a new setup for multi-species experiments, which can be used in catapult mode doubling the time for microgravity to 9 seconds. The experiment is planned to use 87Rb and 40K as degenerate Bose and Fermi gases respectively and can be used to carry out experiments on interferometry, Bose-Fermi mixtures and tests of the weak equivalence principle in quantum domain. Up to date progress and future prospects of this ambitious and technically challenging project will be presented. The Quantus project is a collaboration of MPQ Munich, U Bremen, U Ulm, U Hamburg, HU Berlin, and LU Hanover supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50 WM 0346.

Q 56.20 Do 16:30 VMP 9 Poster

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

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

The QUANTUS project is a collaboration of the U Hamburg, U Ulm, HU Berlin, MPQ Munich, ZARM at U Bremen, and the LU Hanover. It is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50 WM 0346.

Q 56.21 Do 16:30 VMP 9 Poster

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

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

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

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

Q 56.22 Do 16:30 VMP 9 Poster

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

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

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

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

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

Q 56.23 Do 16:30 VMP 9 Poster

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

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

Q 56.24 Do 16:30 VMP 9 Poster

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

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

Q 56.25 Do 16:30 VMP 9 Poster

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

Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany

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

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

Q 56.26 Do 16:30 VMP 9 Poster

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

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

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

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

Q 56.27 Do 16:30 VMP 9 Poster

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

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

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

Q 56.28 Do 16:30 VMP 9 Poster

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

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

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

Q 56.29 Do 16:30 VMP 9 Poster

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

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

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

Q 56.30 Do 16:30 VMP 9 Poster

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

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

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[2] D. Porras, J. I. Cirac, Phys. Rev. **9**3, 263602 (2004).
[3] X.-L. Deng, D. Porras, J. I. Cirac, Phys. Rev. A **7**2, 063407 (2005).

Q 56.31 Do 16:30 VMP 9 Poster

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

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

Q 56.32 Do 16:30 VMP 9 Poster

Bose-Einstein Condensation of stationary light and relativistic dynamics: Klein tunneling and *Zitterbewegung* — •Razmik Unanyan, Johannes Otterbach, and Michael Fleischhauer —

Fachbereich Physik, Technische Universität Kaiserslautern, D-67663 Kaiserslautern

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

Q 56.33 Do 16:30 VMP 9 Poster

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

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

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

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

Q 56.34 Do 16:30 VMP 9 Poster

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

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

Q 56.35 Do 16:30 VMP 9 Poster

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

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

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

Q 56.36 Do 16:30 VMP 9 Poster

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

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

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

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

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

Q 56.37 Do 16:30 VMP 9 Poster

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

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

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

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

Q 56.38 Do 16:30 VMP 9 Poster

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

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

Q 56.39 Do 16:30 VMP 9 Poster

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

We describe a framework for the design of optimal electromagnetic pulses to implement given operations on N-level quantum systems. The techniques are demonstrated in a variety of concrete examples:

(i) the optical manipulation of Pr dopant ions in a $YrSO_4$ crystal, (ii) the preparation of cluster states on coupled spin systems - where both analytical solutions in an idealised case and numerical solutions for an experimental ion trap system are obtained, and (iii) the implementation of quantum computing gates in a superconducting cavity grid architecture.

Q 56.40 Do 16:30 VMP 9 Poster

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

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

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

Q 56.41 Do 16:30 VMP 9 Poster

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

We investigate free space quantum key distribution using continuous variables under real atmospheric conditions. More specifically, we transmit weak coherent polarization states over a 100m free space channel on the roof of our institute's building [1]. The use of a retro-reflector enables us to place Alice's and Bob's station on the same optical table. In our scheme, signal and local oscillator are combined in a single spatial mode auto-compensating atmospheric fluctuations and resulting in excellent interference. Furthermore, the local oscillator acts as a spatial and a spectral filter thus allowing for unrestrained daylight operation. We present investigations of the atmospheric channel with respect to excess noise, spatial beam jitter and transmission statistics. Furthermore we report on the first steps of the implementation of a point-to-point link.
[1] D. Elser et al., arXiv:0811.4756 [quant-ph] (2008).

Q 56.42 Do 16:30 VMP 9 Poster

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

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

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

Q 56.43 Do 16:30 VMP 9 Poster

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

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

Q 56.44 Do 16:30 VMP 9 Poster

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

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

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

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

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

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

Q 56.45 Do 16:30 VMP 9 Poster

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

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

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

Q 56.46 Do 16:30 VMP 9 Poster

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

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

Q 56.47 Do 16:30 VMP 9 Poster

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

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

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

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

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

Q 56.48 Do 16:30 VMP 9 Poster

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

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

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

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

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

Q 56.49 Do 16:30 VMP 9 Poster

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

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

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

Q 56.50 Do 16:30 VMP 9 Poster

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

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

Q 56.51 Do 16:30 VMP 9 Poster

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

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

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

Q 57: Photonik I

Zeit: Freitag 10:30–12:30 Raum: Audi-A

Q 57.1 Fr 10:30 Audi-A

Visualization of the Gödel Universe — •Michael Buser[1], Endre Kajari[1], Wolfgang P. Schleich[1], Frank Grave[2], Günter Wunner[2], and Hanns Ruder[3] — [1]Universität Ulm — [2]Universität Stuttgart — [3]Universität Tübingen

The Gödel universe is an intriguing solution of the Einstein's field equation and was found by Kurt Gödel in 1949. It is the first cosmological solution of a universe which includes closed time-like worldlines on which an observer can travel back in time. In our talk we address the issue how an observer located in such a universe would perceive his surrounding visually. This is particularly interesting since the Gödel universe provides a couple of compelling optical effects such as the existence of an optical horizon. Since the light propagation, which determines the visual appearance of objects to an observer, is intrinsically tied to the curvature of the underlying spacetime, the visualization we present in our talk also gives an deeper insight into the structure of the Gödel universe.

Q 57.2 Fr 10:45 Audi-A

Detection and Spectroscopy of Preselected Single Nanoparticles Soft-Landed on Optical Fibre Tapers — •Alexander Kuhlicke, Markus Gregor, and Oliver Benson — Humboldt-Universität zu Berlin, Institut für Physik, AG Nano-Optik, Hausvogteiplatz 5-7, 10117 Berlin

Due to their evanescent field, tapered optical fibres offer the opportunity for efficient sensing and probing of nano-sized particles on or near their surface. We developed a method to place single dye-doped polystyrene beads on tapered fibres with the help of a linear Paul-trap and to detect them by the change of the fibre transmission as well as through their fluorescence collected by the fibre.
Our segmented trap geometry allows for high degree of spatial control of the particles inside the trap. It is possible to confine several particles at once, move them within the trap and separate a single particle from the others. The fluorescence spectrum of such a preselected particle can be taken before it is placed on the fibre taper.
This method of controllably storing several and manipulating single particles permits to repeat a landing experiment several times without the necessity to reload the trap and also avoids deposition of unwanted particles on the taper.
We present recent results concerning the detection of single nanoparticles placed on a tapered optical fibre and give an outlook on possible applications of such a system.

Q 57.3 Fr 11:00 Audi-A

Integrated photonic devices in organic media for optical networks — •Christian Stark, Jens Adams, Jonas Gortner, and Susanna Orlic — Optical Technologies Lab, Technische Universität Berlin

Integrated photonic devices represent an essential part of modern network technology. Photosensitive organic materials provide a powerful and flexible solution to build these devices. Compact de/multiplexers for WDM can be created by combining waveguides with holographic grating filters. We compare different approaches to writing waveguides for operation in the single mode regime. Methods to maximize the field overlap within the fiber are investigated in order to minimize coupling losses. Increasing integration of network systems demands continuous shrinking of individual devices. Thus we look for possibilities of decreasing bending losses. Waveguides with different geometries and refractive index profiles are analyzed in terms of field distribution, coupling and bending losses. Holographic WDM filters are created by transferring an interference patterns created by two laser beams into a periodic index modulation of a photopolymer bulky sample. We show filter characteristics of holographic gratings and discuss their applicability in WDM networks.

Q 57.4 Fr 11:15 Audi-A

Amplitude and Phase Dynamics in Silicon Compatible Waveguides with Highest Kerr-Nonlinearities — •Nicole Lindenmann[1], Thomas Vallaitis[1], René Bonk[1], Christian Koos[2], Wolfgang Freude[1], and Juerg Leuthold[1] — [1]Institute for Photonics and Quantum Electronics , University of Karlsruhe, 76131 Karlsruhe, Germany — [2]Carl Zeiss AG, Corporate Research and Technologies, 73447 Oberkochen, Germany

Hybrid integration of silicon waveguides with nonlinear organic materials is a way to enhance nonlinear optical properties of silicon-on-insulator nanophotonic devices. Highly nonlinear slot waveguides have been fabricated using deep-UV lithography, standard CMOS processing, and organic molecular beam deposition of a small molecule with a high third-order optical polarizability. The waveguides feature ultrafast Kerr-nonlinearities with nonlinear parameters of 104000 1/[W km] and without measurable impairment by two photon induced free carriers. Amplitude and phase dynamics of these waveguides have been characterized using a heterodyne pump-probe technique.

Q 57.5 Fr 11:30 Audi-A

Superkontinuumserzeugung in einem Glasfaser-Ringresonator — •Sebastian Knitter, Michael Böhm, Felix Bremerkamp und Fedor Mitschke — Institut für Physik, Universität Rostock, Universitätsplatz 3, 18055 Rostock

Verschiedenste Anwendungen erfordern spektral breitbandige und raumkohärente Lichtquellen. Superkontinuumsquellen [1], in denen das Spektrum von ultrakurzen Pulsen in Glasfasern unter Einwirkung nichtlinearer Effekte verbreitert wird, erfüllen diese Anforderungen. Im Gegensatz zur etablierten „single-pass“-Methode [2] ist in unserem System die (mikrostrukturierte) Glasfaser in einem passiven Ringresonator eingebaut und wird von einem modengekoppelten Nd:YAG-Laser synchron gepumpt.

Durch die Rückkopplung erfolgt die spektrale Verbreiterung besonders wirkungsvoll. Wir konnten mit Pumppulsen einer Dauer von 15 ps und einer Spitzenleistung von 500 W ein Spektrum erzeugen, das sich über 160 THz erstreckt. Bei Verstimmung der Ringlänge bezüglich der Wiederholfrequenz des Pumplasers entstehen THz-Frequenzkämme.

In numerischen Simulationen und Laborexperimenten wurde untersucht, wie sich die besonderen Dispersionseigenschaften der Glasfaser auf die Erzeugung des Superkontinuums auswirken. Die in der Numerik identifizierten Prozesse beschreiben die Lage der dominanten Strukturen im experimentellen Spektrum gut.

[1] J. Dudley et al., Rev. Mod. Phys. **78**, 1135 (2006)
[2] J. Ranka et al., Opt. Lett. **25**, 25 (2000)

Q 57.6 Fr 11:45 Audi-A

Nonlinear optics and interferometric sensing with subwavelength-diameter optical fibres — •Dimitri Pritzkau, Ulrich Wiedemann, Konstantin Karapetyan, Wolfgang Alt, and Dieter Meschede — nstitut für Angewandte Physik, Wegelerstr. 8, 53115 Bonn

We report on the progress of our project aimed on investigation of subwavelength-diameter optical fibres application for non-linear optics as well as molecule detection and manipulation. A subwavelength-diameter fibre is manufactured from a commercial optical fibre by flame- heating and stretching in a specially built fibre pulling machine. We are using fibres with the waist of about 500 nm diameter and several millimeters length. Due to the subwavelength diameter, more than half of the electromagnetic field of the guided light propagates outside the fibre, in the evanescent wave. For the investigation of non-linear effects, a Ti:Sa laser tunable between 850 and 1020 nm and operating in both mode-locked and CW modes is used.

Previous experiments have demonstrated the possibility of third-harmonic generation using the non-linearity of the silica fibre itself. However, efficiency of just 10^{-6} has been obtained so far. Our goal is to achieve highly efficient third-harmonic generation by interaction of the evanescent field with dense caesium vapour. A different application of interest is the dispersive detection of surface-adsorbed molecules using a dual-mode in-fibre Mach-Zehnder interferometer.

The current status of our research as well as the analysis of self-phase modulation recently observed in our lab will be presented.

Q 57.7 Fr 12:00 Audi-A

Optimization of microcavities in diamond-based photonic crystals — •Janine Riedrich-Möller, Elke Neu, and Christoph Becher — Fachrichtung 7.3 (Technische Physik), Universität des Saarlandes, Campus E 2.6, 66123 Saarbrücken

In recent years color centers in diamond have attracted significant interest as isolated, photostable single photon emitters. For many future

applications of color centers, e.g. quantum networks or probabilistic quantum computers [1], it is essential to couple these single emitters to a cavity mode of high Q-factor and small modal volume. Microcavities in diamond-based photonic crystal slabs offer the possibility for efficient coupling and large enhancement of the spontaneous emission (Purcell effect). Using Fourier- and real space analysis (FDTD), we optimize the structure according to the principles of "gentle confinement"[2]: By gentle variation of the field envelope vertically radiated power can be suppressed and the Q-factor can be improved significantly up to $Q \approx 320000$ at a modal volume of $V = 0.35(\lambda/n)^3$. In practice, the Q-factor is primarily limited by absorption of the dielectric material. We investigate the influence of material absorption and discuss possible techniques to fabricate photonic crystal structures in thin nanocrystalline diamond films.

[1] S. Prawer and A. D. Greentree, Science **320**, 1601 (2008)
[2] Y. Akahane, T. Asano, B.-S. Song and S. Noda, Nature **425**, 944 (2003)

Q 57.8 Fr 12:15 Audi-A

A fully tunable ultra-high Q whispering-gallery-mode microresonator – experimental results and use for ultralow-power photonics applications. — •Michael Pöllinger, Danny O'Shea, and Arno Rauschenbeutel — Abteilung QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz

We present experimental results on a fully tunable whispering-gallery-mode microresonator. Our so-called "bottle microresonator" confines light by a mechanism similar to the confinement of electrons or ions in a magnetic bottle. In contrast to microspheres and microtori, where the light is typically guided in a narrow ring along the equator of the structure, the prolate shape of the bottle microresonator gives rise to an advantageous mode structure, containing equidistantly spaced axial modes similar to a Fabry-Pérot microcavity. The frequency spacing of these modes only depends on the curvature of the resonator profile and thus allows tuning the resonator to an arbitrary frequency. This is not possible for other WGM geometries due to their large mode spacing. Moreover, the resonator yields an ultra-high intrinsic quality factor of 3.6×10^8 and a mode volume around 1300 μm^3. These values in conjunction with the tunability reveal the enormous potential of our bottle microresonator for cavity quantum electrodynamics applications and nonlinear optics. As an example, we present first results towards the use of the resonator as an all-optical-fibre-based four-port device for ultralow-power photonics applications like, e.g., all-optical switching.

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

Q 58: Quanteninformation: Atome und Ionen III

Zeit: Freitag 10:30–12:00 Raum: VMP 6 HS-A

Q 58.1 Fr 10:30 VMP 6 HS-A

a millisecond quantum memory for scalable quantum networks — •bo zhao[1], yuao chen[1,2], xiaohun bao[1,2], thorsten strassel[1], chihsung chuu[1], xianmin jin[2], jörg schmiedmayer[3], zhensheng yuan[1,2], shuai chen[1], and jianwei 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 — [3]Atominstitut derösterreichischen Universitäten, TU-Wien, A-1020 Vienna Austria

Scalable quantum information processing critically depends on the capability of storage of a quantum state. Although atomic memories for classical lights and continuous variables have been demonstrated with milliseconds storage time, there is no equal advance in the development of quantum memory for single excitations, where only around 10 μs storage time was achieved. Here we report our experimental investigations on extending the storage time of quantum memory for single excitations. We isolate and identify distinct mechanisms for the decoherence of spin wave in atomic ensemble quantum memories. By exploiting the magnetic field insensitive state, "clock state", and generating a long-wavelength spin wave to suppress the dephasing, we succeed in extending the storage time of the quantum memory to 1 ms. Our result represents a substantial progress towards long-distance quantum communication and enables a realistic avenue for large scale quantum information processing.

Q 58.2 Fr 10:45 VMP 6 HS-A

Detection and engineering of spatial entanglement with ultracold bosons — John Goold[1], Libby Heany[2], •Thomas Busch[1], and Vlatko Vedral[2,3] — [1]Physics Department, University College Cork, Cork, Ireland — [2]Centre for Quantum Technologies, National University of Singapore, Singapore — [3]School of Physics and Astronomy, University of Leeds, Leeds, LS2 9JT, UK

Natural entanglement between spatial modes is known to exist in samples of cold atomic gases as a consequence of spatial coherence. To detect this kind of entanglement an interferometric scheme can be used, which at the same time also quantification of any bi-modal or multi-modal setup.

We will outline the interferometric scheme and show that it can straightforwardly be applied to interacting Bose gases of fixed particle number and even finite temperatures. Furthermore we will show that spatial entanglement can be described using the off-diagonal elements of a systems reduced single-particle density matrix.

When applying the scheme to the problem of an interacting, harmonically trapped boson pair in one dimension, we show that while entanglement rapidly decrease with temperature, one can always find modes for which a finite amount can be found. At zero temperature a significant amount of entanglement can be found for all interaction strengths and we will demonstrate how by changing the interaction parameter the distribution of entanglement between different spatial modes can be modified.

Q 58.3 Fr 11:00 VMP 6 HS-A

Test der Quanten-Jarzynski-Gleichung mit kalten Ionen in einer segmentierten Paul-Falle — •Gerhard Huber[1], Sebastian Deffner[2], Eric Lutz[2] und Ferdinand Schmidt-Kaler[1] — [1]Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, D-89069 Ulm — [2]Department of Physics, University of Augsburg, D-86135 Augsburg

Wir stellen ein Schema vor [1], mit dem ein experimentell bisher noch nicht verifiziertes, bemerkenswertes Ergebnis aus der Quantenthermodynamik überprüft werden kann. Die Jarzynski-Gleichung [2] erlaubt es, Änderungen der freien Energie eines Systems unter beliebig schnellen Potentialänderungen [3] exakt zu berechnen. Der Bewegungszustand eines einzelnen kalten Ions in einer segmentierten Paul-Falle kann geeignet präpariert und sein Bewegungszustand mit solcher Präzision vermessen werden, dass es möglich ist, die zur Überprüfung der Jarzynski-Gleichung benötigte Arbeitsverteilung [4] zu rekonstruieren. Das geschieht mit einem „Phononen-Filter“, der quantenoptisch mittels Laserpulsen realisiert wird und auf nichtdestruktiver Fluoreszenzdetektion beruht [1]. Unser Schema zeigt, dass gefangene Ionen ein ideales System für experimentelle Untersuchungen von Prozessen der Nichtgleichgewichts-Thermodynamik darstellen.

[1] G. Huber et al., Phys. Rev. Lett. **101**, 070403 (2008)
[2] C. Jarzynski, Phys. Rev. Lett. **78**, 2690 (1997)
[3] G. Huber et al., New J. Phys. **10**, 013004 (2008)
[4] S. Deffner and E. Lutz, Phys. Rev. E **77** 021128 (2008)

Q 58.4 Fr 11:15 VMP 6 HS-A

Simulation of an Acoustic Black Holes on an Ion Ring — •Birger Horstmann[1], Benni Reznik[2], Diego Porras[1], and Ignacio Cirac[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Department of Physics and Astronomy, Tel Aviv University, Ramat Aviv 69978, Israel

In this talk we present results on the simulation of acoustic black holes on an ion ring. Ion rings, which have already been realized experimentally, represent ion chains with periodic boundary conditions. If the ions are rotating with a stationary and inhomogeneous velocity profile, regions can appear, where the ion velocity exceeds the group velocity of the phonons. In these regions phonons are trapped like photons in black holes.

Exploiting this analogy known for hydrodynamic systems, we give evidence for the prediction of the thermal distribution of Hawking radiation and present a realistic experimental scenario to measure Hawking radiation. Thus, we propose for the first time an experiment to detect Hawking radiation in a discrete analogue of space time with a nonlinear dispersion relation.

Q 58.5 Fr 11:30 VMP 6 HS-A

Deterministic reordering of $^{40}Ca^{+}$ ions in a linear, segmented Paultrap — •Maximilian Harlander[1], Michael Brownnutt[1], Felicity Splatt[1], Wolfgang Hänsel[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Innsbruck, Austria

Segmented ion traps are one of the most promising candidates for a quantum computer technology. In such a system, ions must be shuttled and sorted into different arrangements, dependent on the algorithm being used [1]. The ability to deterministically reorder ions within a linear string is therefore a crucial building block for ion quantum computation in segmented traps. Earlier experiments have demonstrated a success rate of 24% for the exchange of two ions in complex trap structures with junctions [2].

In this experiment, we perform the exchange of two $^{40}Ca^{+}$ ions in a linear, segmented surface ion trap by rotating the ion string about its centre. Using a simple trap structure, rotations can be achieved by applying appropriate DC voltages in addition to the strictly-linear RF potential. An exchange fidelity of 98% is obtained, and the ion heating is below 1 meV per exchange. This method has also been shown to work with ions of differing masses. [1] D. Kielpinski, C. Monroe, and D.J. Wineland, Nature **417** 709 (2002) [2] W.K. Hensinger, S. Olmschenk, D. Stick, D. Hucul, M. Yeo, M. Acton, L. Deslauriers, and C. Monroe, Appl.Phys.Lett **88** 034101 (2006)

Q 58.6 Fr 11:45 VMP 6 HS-A

Coupling trapped ions via transmission lines — Sankaranarayanan S[1], Sönke Möller[1], Rob Clark[2], •Nikos Daniilidis[1], and Hartmut Häffner[1,3] — [1]Institut für Quantenoptik und Quanteninformation Österreichische Akademie der Wissenschaften, Innsbruck, Austria — [2]Center for Ultracold Atoms, Massachusetts Institute of Technology, Cambridge, MA, USA — [3]Department of Physics, University of California, Berkeley, CA, USA

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

We are investigating the feasibility of these experiments on microfabricated planar traps. These offer the possibility of multiple independently tunable trapping regions on the same device. We are characterizing the behavior of gold-on-sapphire planar traps in terms of heating rates and micromotion compensation stability. In addition, we discuss trap operation and heating rates in the presence of a floating conductor. The latter will serve as the coupling electrode in experiments aiming at exchange of the motional states of ions in neighboring trapping regions.

Q 59: Ultrakalte Atome, Ionen und BEC V (mit A)

Zeit: Freitag 10:30–12:30 Raum: VMP 6 HS-C

Das Programm der Sitzung ist unter A 36 zu finden.

Q 60: Quanteneffekte: Dekohärenz

Zeit: Freitag 10:30–12:30 Raum: VMP 6 HS-D

Q 60.1 Fr 10:30 VMP 6 HS-D

Towards homodyne tomography of atomic states — •Jürgen Appel, Anne Louchet, Ulrich Busk Hoff, Daniel Oblak, Patrick Windpassinger, Niels Kjaergaard, and Eugene Polzik — Niels Bohr Institute, Copenhagen, Denmark

The collective enhancement of the coupling between light and atomic ensembles provides a mapping of the quadrature operators of the light field onto quasi-spin variables of atoms. This enables the demonstration of central building blocks of quantum technology such as entanglement, quantum memory, single-photon generation and teleportation. Recently [1] we presented a light shot noise limited method to perform quantum non-demolition measurements of the atomic state, and thus conditionally prepared an entangled and spin squeezed state of 10^5 atoms. I will report about our recent progress towards using this dispersive probing method for performing full tomography of the atomic quasi-spin state, in analogy to homodyne detection of light. We investigate the effect of our QND probing on the coherence between the atomic states and analyze the effect of phase noise of our microwave oscillator on these measurements.

[1] J. Appel et al. Arxiv 0810.3545 (2008)

Q 60.2 Fr 10:45 VMP 6 HS-D

Non-destructive quantum state measurements — •Patrick Windpassinger, Daniel Oblak, Ulrich Hoff, Jürgen Appel, Niels Kjaergaard, and Eugene S. Polzik — QUANTOP, Niels Bohr Institute, Copenhagen, Denmark

Quantum non-demolition probing of a collective atomic (pseudo)-spin is a powerful instrument in quantum information processing and control. We present a method for non-destructive probing on the clock transition of laser-cooled, dipole trapped Cs atoms. The phase shift imposed by the atomic sample on an off-resonant probe laser beam is determined with a Mach-Zehnder interferometer.

The non-destructive probing also allows to follow online the evolution of the population difference of the Cs-atom clock states when subjected to microwave fields. This allows us to observe Rabi oscillations on the clock transition non-destructively over an extended period of time, which should yield a significant improvement of the signal-to-noise ratio compared to the traditional fluorescence-based destructive probing. The talk focusses specifically on the the effect of the probe-induced inhomogeneous light-shift and of the destructive probe-induced spontaneous photon scattering.

[1] P. Windpassinger et. al, Phys. Rev. Lett. 100, 103601 (2008)
[2] P. Windpassinger et. al, New J. Phys. 10, 053032 (2008)
[3] D. Oblak et. al, EPJ D 50, 67 (2008)

Q 60.3 Fr 11:00 VMP 6 HS-D

Identifying and probing complex environments with optomechanical systems — •Konrad Kieling[1], Alexey Trubarov[2], Markus Aspelmeyer[2], and Jens Eisert[1] — [1]Institut für Physik and Astronomie, Universität Potsdam, Potsdam, Germany — [2]Institut für Quantenoptik und Quanteninformation, Vienna, Austria

Optomechanical systems offer the perspective of driving mechanical modes to close to the quantum ground state by a suitable radiation pressure coupling to the light field of a cavity. In this work, we study the influence of complex thermal baths to which the mechanical mode is coupled, and discuss effects of non-Ohmic damping. Complementary to efforts of cooling down the mirror to observe quantum mechanical behaviour, a new perspective of using such systems will be presented. We will discuss ideas of using the mechanical mirror at a finite temperature as an ultrasensitive device to probe properties of complex baths – which are unaccessible so far. This is done without making any possibly unjustified assumptions: Using the device as a black box in systems identification, one can think of certifiably and quantitatively probing properties of decohering environments.

Q 60.4 Fr 11:15 VMP 6 HS-D

Qubit protection in nuclear-spin quantum dot memory —

•Zoltan Kurucz[1,2], Jakob M. Taylor[3], Mikhail D. Lukin[4], and Michael Fleischhauer[1] — [1]Fachbereich Physik, Univ. of Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Physics and Astronomy, University of Aarhus, DK-8000 Aarhus — [3]Dept. of Physics, MIT, Cambridge, MA 02139, USA — [4]Dept. of Physics, Harvard Univ. Cambridge, MA 02138, USA

Nuclear spins in semiconductor nanostructures are excellent candidates for storing quantum information. While they are largely decoupled from their environment and have long intrinsic lifetimes, the hyperfine interaction with electron spins allows one to access ensembles of nuclear spins in a controlled way. In particular, the quantum state of an electron spin can be coherently mapped onto the nuclear spins constituting a quantum dot, thus giving rise to a collective quantum memory [1]. Nevertheless, memory lifetimes are limited, e.g., by dipole-dipole interactions among the nuclei. In the talk we demonstrate that the presence of the electron can substantially reduce the decoherence of this collective memory. The hyperfine-induced dynamic Stark shift energetically isolates the storage states from the rest of the Hilbert space and protects them against nuclear spin flips and spin diffusion. We show that our scheme is robust against the deleterious effects of inhomogeneous Knight shift and we also analyze the case when the nuclear spins are not perfectly polarized.

[1] J. M. Taylor, C. M. Marcus, M. D. Lukin, Phys. Rev. Lett. 90, 206803 (2003); J. M. Taylor, A. Imamoglu, M. D. Lukin, Phys. Rev. Lett. 91, 246802 (2003)

Q 60.5 Fr 11:30 VMP 6 HS-D

Decoherence of multiparticle entanglement — •Otfried Gühne[1], Fabian Bodoky[2], and Miriam Blaauboer[2] — [1]Inst. für Quantenoptik und Quanteninformation, ÖAW, A-6020 Innsbruck — [2]Kavli Institute of Nanoscience, Delft University of Technology, NL-2628 CJ Delft

Decoherence of quantum states is a fundamental obstacle for implementations of quantum information processing. Therefore, it is interesting to know how the entanglement of a multiparticle quantum state is affected by decoherence and how this depends on the state and the number of qubits. This is, however, difficult to investigate, since most entanglement measures are practically impossible to compute for mixed states.

In this contribution we present a method to determine the decay of quantum correlations as quantified by the geometric measure of entanglement under the influence of decoherence. With this, one can compare the robustness of entanglement in GHZ, cluster, W and Dicke states of four qubits and show that the Dicke state is most robust. Furthermore, the method allows to compare different decoherence models and to investigate the scaling of the entanglement decay for an increasing number of particles.

Q 60.6 Fr 11:45 VMP 6 HS-D

Emergence of pointer states in a non-perturbative environment — •Marc Busse and Klaus Hornberger — Arnold Sommerfeld Center for Theoretical Physics, Ludwigs-Maximilians-Universität München

The influence of environmental degrees of freedom on a quantum system typically leads to a superselection of a specific set of robust system states, called pointer states. Most characteristically, any superposition of these states gets rapidly mixed, while the only stable states are the pointer states themselves.

We study the emergence and dynamics of pointer states in the motion of a quantum test particle affected by collisional decoherence. We demonstrate that the complete set of pointer states is obtained by the solitonic solutions of the nonlinear equation suggested in [1]. They yield the expected probabilities, and move according to the corresponding classical equations of motion. In contrast to linear coupling models, the pointer basis turns out to be non-Gaussian, with a width determined by both the mean free path and the thermal de-Broglie wavelength of the gas environment. This result allows us to estimate the coherence length of atoms in interacting thermal gases.

[1] L. Diosi and C. Kiefer, Phys. Rev. Lett. 85, 3553 (2000).

Q 60.7 Fr 12:00 VMP 6 HS-D

Scalability of GHZ and random-state entanglement in the presence of decoherence — •de Melo Fernando[1], Leandro Aolita[2], Daniel Cavalcanti[2], Antonio Acin[2,3], Alejo Salles[4,1], Markus Tiersch[1], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg — [2]ICFO - Institut de Ciències Fotòniques — [3]ICREA - Institució Catalana de Recerca i Estudis Avançats — [4]Instituto de Física, Universidade Federal do Rio de Janeiro

We derive analytical upper bounds for the entanglement of generalized Greenberger-Horne-Zeilinger (GHZ) states locally coupled to dephasing, depolarizing, and thermal reservoirs. The derivation is carried out under very weak constraints, and holds for any convex quantifier of entanglement.

The obtained bounds reveal an exponential entanglement decay with the number of qubits – the robustness of the generalized GHZ states decreases exponentially with the system size. This poses a severe limitation to many quantum communication protocols.

A comparison between the entanglement decay of randomly generated states with the GHZ family shows that the former decays slower, thus violating the previously obtained bounds. Furthermore, the random state's entanglement is *more robust* against noise for *larger* system size.

Q 60.8 Fr 12:15 VMP 6 HS-D

Decoherence of the electron spin of NV-centers in Diamond — •Florian Rempp[1], Norikazu Mizuochi[2], Phillipp Neumann[1], Johannes Beck[1], Vincent Jacques[1], Petr Siyushev[1], K. Nakamura[3], D. Twichen[4], H. Watanabe[5], S. Yamasaki[6], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]Universität Stuttgart, germany — [2]University of Tsukuba, Japan — [3]Tokyo Gas Co., Tokyo, Japan — [4]Element Six Ltd., Ascot, UK — [5]AIST, Tsukuba, Japan — [6]AIST, Tsukuba, Japan

Nitrogen-vacancy color centers (NV-center) in diamond with proximal ^{13}C nuclear spins are one of the promising candidates for solid state quantum computers.

One of the main assets of the NV-center is the optical accessibility of single spins while showing exceptional long T_1 and T_2 times due to low residual spin density and the fact, that nearly no phonons are exited at room temperature.

We measured the T_2^* for various NV-centers at different concentrations of ^{1}3C and found good agreement with a pure dipole-dipole-interaction Model.

Q 61: Laserentwicklung: Halbleiterlaser

Zeit: Freitag 10:30–12:30 Raum: VMP 8 HS

Q 61.1 Fr 10:30 VMP 8 HS

Ein Festkörper-Lasersystem zur Erzeugung kontinuierlicher Lyman-α Strahlung — •Martin Scheid, Daniel Kolbe, Frank Markert und Jochen Walz — Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz

Durch Vier-Wellen-Mischen in Quecksilberdampf kann kontinuierliche kohärente Strahlung im Vakuum-Ultraviolett bei 121,56 nm (Lyman-α) produziert werden. Diese soll zur Laserkühlung von magnetisch gefangenem Antiwasserstoff verwendet werden. Das ist eine wichtige Vorraussetzung für die künftige Präzisionsspektroskopie an Antiwasserstoff. Im Vortrag wird das Festkörper-Lasersystem zur Erzeugung der drei benötigten leistungsstarken Fundamentalstrahlen bei 254 nm, 408 nm und 546 nm vorgestellt. Bis zu 800 mW ultraviolette Strahlung bei 254 nm wird durch Frequenzvervierfachung eines Yb:YAG Scheibenlasers in zwei aufeinander folgenden externen Überhöhungsresonatoren produziert. 300 mW blaues Licht bei 408 nm wird durch Frequenzverdopplung eines Titan:Saphir Lasers in einem externen Überhöhungsresonator erzeugt. Um bis zu 4 W grünes Licht bei 546 nm zu erhalten, wird ein Yb-Faserlaser in einem externen Überhöhungsresonator frequenzverdoppelt.

Q 61.2 Fr 10:45 VMP 8 HS

Spectro-Temporal Gain-Switching Dynamics of a InGaAs Quantum-Dot Laser — •Lukas Drzewietzki[1], Stefan Breuer[1], George The[2], Mariangela Gioannini[2], Wolfgang Elsässer[1], Ivo Montrosset[2], Mark Hopkinson[3], and Michael Krakowski[4] — [1]Institut für Angewandte Physik, TU-Darmstadt, Schloßgartenstr. 7, 64289 Darmstadt, Germany — [2]Dipartimento di Elettronica, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino — [3]Department of Electronic and Electrical Engineering, University of Sheffield, Sheffield S1 3JD, United Kingdom — [4]Alcatel-Thales III-V Lab, Route de Nozay, 91461 Marcoussis, France

Self-assembled quantum dots (QD) are a distribution of zero-dimensional structures and provide discrete energy levels. Implemented as the active medium in a diode laser they lead to improved characteristics compared to bulk or quantum-well devices like low threshold current and high gain bandwidth. Due to their multiple discrete population levels QD-Lasers (QDL) are also able to perform two-state lasing. We present spectrally resolved picosecond measurements of the gain-switching dynamics of a QD-laser at different temperatures and current steps. Also spectrally resolved continuous-wave (CW) measurements are carried out. We report on the existence and interaction of the ground and excited state (GS, ES) emission in CW and pulsed operation. Both operation regimes are compared and the influence of the operation parameters on the emission dynamics are discussed. The presented measurements are compared to numerical simulations obtained with a multi-population model.

Q 61.3 Fr 11:00 VMP 8 HS

Intensity noise of polarisation stablized VCSELs — •Andreas Molitor[1], Martin Blazek[1], Johannes Michael Ostermann[2], Rainer Michalzik[2], and Wolfgang Elsässer[1] — [1]Institute of Applied Physics, Darmstadt University of Technology, Schloßgartenstr 7, 64289 Darmstadt, Germany — [2]Institute of Optoelectronics, University of Ulm, Albert-Einstein-Allee 45, 89069 Ulm, Germany

VCSELs are reliable, low-cost light sources for optical datacom applications. Etching a grating into the surface Bragg mirror enables polarisation control [1]. We experimentally investigate the intensity noise properties of VCSELs with different surface grating parameters.

For well-selected grating parameters [2], Orthogonal Polarisation Suppression ratios of greater than 20 dB and spectra Sidemode Suppression ratios up to 30 dB are achieved. The Intensity noise is measured via a direct detection setup. For various pump currents radiofrequency spectra of the photo current are recorded and normalized to the Shot Noise level. The influence of the surface grating on the intensity noise behavior is investigated by polarisation resolved measurements. For the surface grating VCSELs we find a noise reduction in the strong polarisation of more than 10 dB compared to a reference VCSEL without grating. The influence of the polarisation and spatial mode structure on the intensity noise will be discussed in detail with respect to theory.

[1] J.M. Ostermann et al., Opt. Commun 246, 511 (2005)
[2] C. Fuchs et al., IEEE J. Quantum Electron. QE-43, 1227 (2007)

Q 61.4 Fr 11:15 VMP 8 HS

Zeitliche und spektrale Charakterisierung von ps-Pulsen aus Diodenlaser-MOPA-Systemen zur effizienten Frequenzkonversion — •Andreas Lenhard, Thorsten Ulm, Florian Harth und Johannes L'Huillier — Technische Universität Kaiserslautern, Fachbereich Physik, Erwin-Schrödinger-Straße 46, 67663 Kaiserslautern

Mit aktiv- und passiv-modengekoppelten Einstreifen-Diodenlasern wurden ps-Pulse mit mittleren Leistungen von 20 mW und 3 GHz Wiederholrate erzeugt. Im nachfolgenden Trapezverstärker wurde die Leistung in den Wattbereich erhöht. Durch den Trapezverstärker wird mit einem M^2-Wert von etwa 1,3 eine deutlich bessere Strahlqualität als mit Breitstreifenverstärkern erreicht. Das System eignet sich damit zur effizienten Frequenzkonversion. Mit einer Pulsspitzenleistung von über 30 W wurden im Einfachdurchgang durch einen PPLN-Kristall Pulse im sichtbaren Spektralbereich bei 460 nm mit mittleren Leistungen von mehr als 550 mW erzeugt. Diese Leistung entspricht einer Konversionseffizienz von über 26%.

Mit einem SHG-FROG Verfahren wurden zeitlich- und spektral hochaufgelöste Untersuchungen von aktiv- und passiv-modengekoppelten Pulsen aus dem Diodenlaser-MOPA-System durchgeführt. Auf Basis dieser Erkenntnisse wurde das System für eine effiziente Frequenzverdopplung der Strahlung optimiert. Am Verlauf der Phase lässt sich der Einfluss der Ladungsträgerdynamik im Halbleiter beobachten. Es wird gezeigt, wie die Betriebsparameter die zeitliche und spektrale Form der Pulse beeinflussen.

Q 61.5 Fr 11:30 VMP 8 HS

Erzeugung von 190 fs Pulsen mit einem InGaAs-AlGaAs Halbleiterscheibenlaser — •Peter Klopp[1], Uwe Griebner[1], Martin Zorn[2] und Markus Weyers[2] — [1]Max-Born-Institut, Berlin, Germany — [2]Ferdinand-Braun-Institut, Berlin, Germany

Intensive Anstrengungen sind darauf gerichtet von der großen Verstärkungsbandbreite von Halbleitermedien für die Erzeugung ultrakurzer Pulse zu profitieren. Pulsdauern von 310 fs und 390 fs wurden für Quantentrog-Kantenemitter- und Quantenpunkt-Laser erzielt. Kürzere Pulse mit einer Dauer von 290 fs wurden kürzlich mit optisch gepumpten, Halbleiterscheibenlasern (SDL) demonstriert [1]. Wir berichten über die Erzeugung von nahezu bandbreitenbegrenzten sub-200 fs Pulsen mit SDL. Die oberflächenemittierende Verstärkungsstruktur besteht aus 4 InGaAs-Quantentrögen (QWs) in unregelmäßiger Anordnung. Die Absorption der 840 nm Diodenlaser-Pumpstrahlung erfolgt in Al-gradierten GaAs-Barrieren, welche sich zwischen den QWs befinden [1]. Zur passiven Modenkopplung dient ein oberflächennah (2 nm) positionierter sättigbarer InGaAs single-QW auf einem Bragg-Spiegel. Pulse mit einer Dauer von 190 fs konnten ohne weitere Elemente zur Dispersionskontrolle im Resonator generiert werden. Bei einer Pulsfolgefrequenz von 3 GHz wird eine mittlere Leistung von 5 mW im Wellenlängenbereich um 1035 nm erzielt. Ein entscheidender Parameter zur Erzeugung der nahezu Fourier-limitierten Pulse ist die spektrale Position des Absorptionsmaximums relativ zum Verstärkungsmaximum.

[1] P. Klopp et al., Opt. Express 16, 5770 (2008).

Q 61.6 Fr 11:45 VMP 8 HS

Passiv modengekoppeltes Oszillator-Verstärker-System zur Erzeugung von Pulsdauern unter 500 fs mittels externer Pulskompression — •Thorsten Ulm, Florian Harth, Andreas Lenhard und Johannes L'huillier — Technische Universität Kaiserslautern, Fachbereich Physik, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern

Femtosekundenlaser mit mittleren Leistungen von bis zu 1 W haben vielfältige wissenschaftliche und technische Anwendungen. Hybrid-integrierte Diodenlaser ermöglichen Ultrakurzpulslaser mit geringer Größe und hoher Effizienz.

Durch passive Modenkopplung werden in einem Oszillator Pulse mit einer spektralen Breite von 4,4 nm und einer Dauer von 10 ps erzeugt. Sie werden in einem Trapezverstärker auf eine Leistung von 1,4 W verstärkt. Durch Pulskompression wird die Dauer der Pulse auf 401 fs verkürzt. Dies entspricht dem 1,5-fachen des Zeit-Bandbreite-Limits. Die mittlere Leistung beträgt 757 mW, die Spitzenleistung 647 W.

Dieses Ergebnis wurde durch eine Anpassung des Oszillator-Verstärker-Systems an den nachfolgenden Gitterkompressor erzielt. Um einen möglichst linearen Frequenz-Chirp zu erhalten, wurde u.a. die Methode des *Colliding Pulse Mode-locking* untersucht. Durch einen externen Resonator lässt sich der Treffpunkt der umlaufenden Pulse im Übergangsbereich von Gewinn- und Absorbersektion verschieben. Da Gewinn- und Absorbtionssättigung unterschiedliche Brechungsindexvariationen erzeugen, lässt sich so der Chirp für die externe Kompression optimieren.

Q 61.7 Fr 12:00 VMP 8 HS

Monolithischer Ringresonator mit PPLN Kristall zur effizienten Frequenzverdopplung eines cw-Diodenlasers bei 976 nm — •Danilo Skoczowsky, Andreas Jechow und Ralf Menzel — Universität Potsdam, Institut für Physik / Photonik, Karl-Liebknecht-Str. 24-25, 14476 Potsdam-Golm

Mit Hilfe von externen Resonatoren konnten die spektralen und lateralen Strahleigenschaften von Breitstreifen-Diodenlasern deutlich verbessert werden. Die so stabilisierten Diodenlaser sind sehr gut für eine effiziente Frequenzverdopplung z. B. mit periodisch gepolten Lithiumniobat-Kristallen (PPLN) geeignet.

Über die Erhöhung der Leistungsdichte im nichtlinearen Kristall kann die Effizienz der Frequenzverdopplung deutlich gesteigert werden. Dafür wurde ein Lasersystem bestehend aus zwei optisch gekoppelten Resonatoren entwickelt. Der treibende Resonator basiert auf einem Breitstreifenlaser in einer Littrow-Anordnung. Der zweite Resonator ist als monolithischer Ringresonator aufgebaut und besteht aus vier Spiegeln, zwei GRIN-Linsen und einem 10 mm langen PPLN-bulk-Kristall. Alle Teile sind monolithisch auf einem Glassubstrat aufgebaut. Die Baugröße des Resonators wurde so klein wie möglich gehalten, wobei der PPLN-Kristall das limitierende Bauelement war. Damit vereint dieser Resonator hohe Stabilität und einfache Justage.

Die Kopplung der beiden Resonatoren erfolgt rein optisch ohne aktive Stellelemente oder Regelschleifen. Erste Experimente zeigten eine gute Kopplung zwischen beiden Resonatoren, wobei eine Ausgangsleistung von 120 mW blaues Licht bei 488 nm generiert werden konnte.

Q 61.8 Fr 12:15 VMP 8 HS

A Solid State Laser System for Production of Antihydrogen via Double-Charge Exchange — •Andreas Müllers, Frank Markert, Martin Scheid, Daniel Kolbe, and Jochen Walz — Johannes Gutenberg Universität Mainz, Institut für Physik

A two-stage semiconductor laser system has been developed for the excitation of Cesium atoms to Rydberg states. The first transition from $6S_{1/2}$ to $6P_{3/2}$ requires laser-light with a wavelength of 852 nm. This is provided by a grating-stabilized laser-diode. For excitation to Rydberg-states, a frequency doubled master-oscillator power-amplifier (mopa) system is used. The mopa-system consist of a grating stabilized laser-diode with an anti-reflection coated front facet and a tapered-amplifier. For second-harmonic generation, a compact resonator with a optical length of only 15 cm has been set up. It emits laser light with a wavelength of 511 nm, corresponding to an excitation to the $37D_{5/2}$-state. Due to the wide tunability of the used semiconductor lasers, Rydberg states from n=20 (517 nm) up to the ionization limit (508 nm) are accessible.

The laser system has been developed for the double-charge-exchange production of antihydrogen as performed by the ATRAP collaboration at CERN. Rydberg-cesium interacts with positrons to form Positronium $Cs^* + e^+ \rightarrow Ps^* + Cs^+$. Antihydrogen is then produced by interaction with antiprotons $Ps^* + \bar{p} \rightarrow \bar{H}^* + e^-$. The lasers have been installed at CERN and have shown reliable performance under beam-time conditions.

Q 62: Photonik II

Zeit: Freitag 14:00–16:30 Raum: Audi-A

Q 62.1 Fr 14:00 Audi-A

Entspiegelung von Quarzglas für den UV-Bereich durch statistische Oberflächenstrukturen — •Marcel Schulze, Ernst-Bernhard Kley und Andreas Tünnermann — Institut für Angewandte Physik, Friedrich-Schiller-Universität Jena

In vielen Anwendungsbereichen der Optik werden konventionelle Antireflexbeschichtungen mehr und mehr durch Antireflexnanostrukturen ersetzt, welche eine wesentlich höhere Bandbreite besitzen und, insbesondere bei Kunststoffoptiken, eine preiswertere Entspiegelungsalternative darstellen. Problematisch ist jedoch immer noch die Realisierung auf Quarzglasoptiken, sowie die Ausdehnung in den UV-Bereich. Hierfür wurde ein Prozess entwickelt, der die reproduzierbare und schnelle Herstellung von statistisch verteilten Nanostrukturen in Quarzglas erlaubt, ohne dass aufwändige Lithographieprozesse notwendig sind.

Dabei wird ein Plasmaätzprozess genutzt, bei dem es unter bestimmten Prozessbedingungen zur Bildung von statistisch verteilten Nanostrukturen kommt. Durch die Wahl der Prozessparameter (Druck, Temperatur, HF-Leistung, Gasart und -zusammensetzung, Ätzzeit) kann Einfluss auf die Größe der Nanostrukturen und damit auf die Entspiegelungswirkung genommen werden. Es wurden Strukturen mit lateralen Größen von unter 50 nm hergestellt. Diese wirken entspiegelnd bis in den UV-Bereich. Der Transmissionsgrad des Quarzglases konnte auf über 99% im Bereich 350 bis 560 nm gesteigert werden.

Q 62.2 Fr 14:15 Audi-A

Drahtgitterpolarisator für den UV-Spektralbereich — •Thomas Weber, Hans-Jörg Fuchs, Ernst-Bernhard Kley und Andreas Tünnermann — Institut für Angewandte Physik, Friedrich-Schiller-Universität Jena

Die Polarisierung von Licht bis in den UV-Bereich ist für verschiedenste Anwendungen von zunehmendem Interesse, beispielsweise der Spektroskopie oder der höchstauflösenden Mikroskopie. Drahtgitterpolarisatoren sind kompakte und gut integrierbare Bauteile, die eine breitbandige Polarisierung von Licht bis hin zu Wellenlängen unter 300 nm ermöglichen.

Die Polarisierung von Licht wird im Drahtgitterpolarisator durch dessen optisch anisotropes Verhalten erzielt, wobei es bei entsprechender Gestaltung des Gitters zu einer Transmission der TM-Polarisation und einer Reflexion bzw. Absorption der TE-Polarisation kommt. Für die Realisierung einer möglichst hohen Effizienz des Polarisators muss dessen Gitterperiode so klein sein, dass bei Lichteinfall aus beliebiger Richtung lediglich die 0. Beugungsordnung ausbreitungsfähig ist (ein so genanntes Zero-order-Gitter). Zur Realisierung eines Polarisators für eine Wellenlänge von beispielsweise 300 nm muss die Gitterperiode folglich im Bereich von 100 nm liegen. Weiterhin kommt lediglich Aluminium als Gittermaterial in Frage und es muss ein hohes Aspektverhältnis der Struktur erzielt werden.

Wir präsentieren ein Herstellungsverfahren und die optische Funktion eines breitbandigen und bis in den UV-Bereich einsetzbaren Polarisators.

Q 62.3 Fr 14:30 Audi-A

Realisierung einer monolithischen dielektrischen mikrostrukturierten Oberfläche mit 99,9% Reflektivität — •Frank Brückner, Ernst-Bernhard Kley und Andreas Tünnermann — Institut für Angewandte Physik, Friedrich-Schiller-Universität Jena

Hochreflektierende Spiegel sind wichtige Komponenten hochempfindlicher interferometrischer Aufbauten wie z.B. zur Gravitationswellendetektion oder der Erzeugung verschränkter Testmassen. Für diese Anwendungen müssen die Spiegel neben geringsten optischen auch geringste mechanische Verluste aufweisen. Dielektrische Vielschichtsysteme erfüllen diese Anforderungen nicht, da die hohe mechanische Güte des Substrats (z.B. Silizium) aufgrund der Kombination unterschiedlicher Materialien erheblich reduziert wird. Alternative Spiegelarchitekturen sind als resonante Wellenleitergitter bekannt, welche mit Hilfe einer mikrostrukturierten hochbrechenden Schicht auf einem niedrigbrechenden Substrat hohe Reflektivitäten erreichen. Somit ist noch eine Schicht eines substratfremden Materials erforderlich. Ein kürzlich von uns vorgestellter neuer Ansatz der Mikrostrukturierung einer dielektrischen Oberfläche verzichtet vollständig auf eine Beschichtung und stellt damit eine rein monolithische Implementierung resonanter Wellenleitergitter dar, wodurch die Güte des Substrats nur minimal gestört wird. Die Strukturierung der Oberfläche resultiert dabei in T-förmigen Stegen eines Subwellenlängengitters. Wir präsentieren die erste experimentelle Realisierung dieser Strukturen in Silizium, wobei für die resonante Reflexion unter senkrechter Inzidenz ein Rekordwert von 99.9% bei einer Wellenlänge von 1550 nm gemessen wurde.

Q 62.4 Fr 14:45 Audi-A

Oszillationen und Solitonengehalt von Impulsen in Glasfasern mit alternierender Dispersion — •Haldor Hartwig, Alexander Hause, Michael Böhm und Fedor Mitschke — Universität Rostock, Institut für Physik, Universitätsplatz 3, 18051 Rostock

Optische Solitonen in dispersionsalternierenden Fasern werden seit einiger Zeit in der Datenübertragung eingesetzt. In diesen Fasern folgt die Impulsform dem periodischen Wechsel der Dispersion der Faser. Wie in der Literatur mehrfach beschrieben, treten aber auch auf erheblich längerer Skala Oszillationen auf. Da das Problem analytisch schwer zu fassen ist, war die Ursache dieser Oszillationen bislang unverstanden. Wir setzen das kürzlich eingeführte Verfahren der "Soliton-Radiation Beat Analysis" (SRBA, [1]) ein, das speziell Oszillationen bei der Solitonenausbreitung auswertet. Daraus können Schlussfolgerungen auf den Solitonengehalt gezogen werden. Wir stellen dabei fest, dass Solitonen in dispersionsalternierenden Glasfasern zusammengesetzte Objekte sind, deren Konstituenten miteinander schweben können. Diese Schwebungen treten bei Abweichung von der idealen Impulsform auf und sind als Oszillationen sichtbar.

Q 62.5 Fr 15:00 Audi-A

Wechselwirkung von Solitonen in dispersionsalternierenden Glasfasern: Bildung des Solitonenmoleküls — •Alexander Hause, Haldor Hartwig, Michael Böhm und Fedor Mitschke — Universität Rostock, Institut für Physik, Universitätsplatz 3, 18051 Rostock

Die Existenz stabiler Verbundzustände aus optischen Solitonen in Glasfaserstrecken mit periodisch wechselnder Dispersion konnte von uns kürzlich nachgewiesen werden[1]. Die phasensensitive Charakterisierung dieser so genannten Solitonenmoleküle lieferte Hinweise auf die Phasendynamik als Ursache der Bindung des Moleküls[2].

Hier setzt ein störungstheoretisches Modell an, das das typische Verhalten benachbarter Solitonen und die Bindung des Solitonenmoleküls in dispersionsalternierenden Glasfasern erklären kann[3]. Abhängig vom Abstand und den veränderlichen Parametern der Solitonen in der Faser ergibt sich eine Änderung der Mittenfrequenz der wechselwirkenden Impulse. Bei kleineren Abständen führt dies zu einer Abstoßung und bei größeren Abständen zu einer Anziehung. Dies definiert bei einem bestimmten Abstand einen stabiles Gleichgewicht. Die Vorhersagen des Modells wurden wurden mit numerischen Simulationen und experimentellen Daten verglichen und zeigen eine gute Übereinstimmung.

[1] M. Stratmann et al., Phys. Rev. Lett. **95**, 143902 (2005)
[2] A. Hause et al., Phys. Rev. A **75**, 063836 (2007)
[3] A. Hause et al., Phys. Rev. A **78**, 063817 (2008)

Q 62.6 Fr 15:15 Audi-A

Self-induced Waveguides in Photopolymers Based On Plexiglass With Phenanthrenequinone — •Vladislav Matusevich, Elen Tolstik, and Oleg Kashin — Institute of Applied Optics, Friedrich-Schiller-University, Max-Wien-Platz 1, 07743 Jena, Germany

We present theoretical and experimental investigations of the self-trapping effect in photopolymers based on plexiglass with phenanthrenequinone. We show for the first time that it is possible to generate self-induced waveguides in this photopolymer. The behaviour of light propagation is explained with diffusion mechanisms of molecular redistribution. The waveguides are generated at 514nm (optimal Ar-laser power 10-50mW). Generation time is about 2-3 minutes. The waveguides can be fixated by UV curing illumination and can stay stable for years.

Q 62.7 Fr 15:30 Audi-A

Photonics 3D Gratings in Photopolymers — •Florian Büchau, Christian Müller, Alexander Schlösser, and Susanna Orlic — Optical Technologies Lab, Technische Universität Berlin

A new approach for advanced optical sensing elements based on light diffraction of 3D refractive index gratings is presented. Periodic crystal-like structures are generated by multiple beam interference combined with holographic recording. At least four collimated laser beams are overlapped in a photosensitive polymer layer to generate a periodic 3D structure. Sequential angle-multiplexed recording of 1D gratings allows for realizing any particular grating geometry. Different 3D photonic gratings are characterized with respect to their spatial and spectral diffraction properties. The analysis and characterization provide a feedback for optimizing the exposure process and parameters. Optical properties and transformations are investigated using a white light source and RGB lasers. An optical imaging setup has been constructed to display the optical functionalities of light induced 3D gratings.

Q 62.8 Fr 15:45 Audi-A

Optical characterization of photosensitive organic materials for photonic systems — •Soner Emec, Timo Feid, Sven Frohmann, Christian Müller, and Susanna Orlic — Optical Technologies Lab, Technische Universität Berlin, Germany

Diffractive optical elements with application specific tailored properties can be fabricated by light induced alternation of the material*s refractive index. Holographic polymers or photoresists are typically used for permanent optical structurization. Today photostructurable media become core elements of photonic systems with innovative capabilities. We investigate different classes of organic photosensitive materials in order to optimize the interaction between the material and an opto-electronic system around. Some exemplary applications are microholographic data storage, 3D nano/micro structuring, and optical patterning for advanced security features. Key issues include dynamic material response, spectral and temporal grating development, influence of the light intensity distribution, effects of pre-exposure and post-curing, etc. Materials under investigation are cationic and free radical polymerization systems, liquid crystalline polymer nanocomposites, and photoresist systems.

Q 62.9 Fr 16:00 Audi-A

Chemical Nanonscopy of Artificial Membranes — •Fouad Ballout[1], Henning Krassen[2], Ilona Kopf[1], Kenichi Ataka[2], Erik Bründermann[1], Joachim Heberle[2], and Martina Havenith[1] — [1]Ruhr-Universität Bochum, Fakultät für Chemie & Biochemie, Lehrstuhl für Physikalische Chemie II — [2]Universität Bielefeld, Fakultät für Chemie, Arbeitsgruppe Biophysikalische Chemie

Scanning near-field infrared microscopy (SNIM) provides a chemical and structural mapping of surface composition on the nanometer scale by combining the advantages of IR spectroscopy with the high spatial resolution of an atomic force microscope (AFM). This non-invasive, label-free imaging technique is of great interest in biology since it allows one to study biological materials by utilizing their chemical fingerprint without the need for dyes.

We have performed near-field measurements of an oriented membrane protein (Cytochrome c Oxidase) re-integrated in artificial lipid bilayers.

For the measurement, we used a LN2 cooled CO-Laser as an infrared radiation source covering the frequency range (1600-1800 1/cm), which includes the amide I band of the protein (1658 1/cm) and the C=O stretching mode of the lipids (1740 1/cm). Using a homebuilt scanning near-field microscope we were able to record simultanously nanoscale topography and near-field images as a function of laser frequency. An advanced image processing of the topography and the near-field image provided the evaluation of a frequency dependent contrast showing spectroscopic signatures.

Q 62.10 Fr 16:15 Audi-A

Raman gepumpter Fourier-Domänen modengekoppelter (FDML) Laser mit Anwendungen in der Optischen Kohärenztomographie — •Thomas Klein, Wolfgang Wieser, Benjamin Biedermann, Christoph Eigenwillig und Robert Huber — Lehrstuhl für BioMolekulare Optik, Fakultät für Physik, Ludwig-Maximilians-Universität München

Optische Kohärenztomographie (Optical Coherence Tomography, OCT) ist ein mittlerweile etabliertes bildgebendes Verfahren in der medizinischen Diagnostik. Durch die vor kurzem erfolgte Einführung von Fourier-Domänen modengekoppelten (Fourier Domain Mode Locking, FDML) Glasfaserlasern konnte die Aufzeichnungsgeschwindigkeit von OCT Systemen deutlich erhöht werden.

Bis jetzt wurden alle bekannten FDML Laser mit optischen Halbleiterverstärkern (Semiconductor Optical Amplifier, SOA) implementiert. In diesem Vortrag wird ein FDML Laser mit Raman Verstärker vorgestellt. Im Gegensatz zu SOA getriebenen FDML Lasern weist der Raman-FDML keinen ASE (Amplified Spontaneous Emission) Hintergrund auf und lässt sich potentiell durch Pump-Multiplexen besser skalieren. Zusätzlich kann erstmals ein Cavity Ring-Down des FDML Lasers beobachtet und dadurch die Stationarität des FDML Betriebes bewiesen werden.

Trotz des begrenzten Durchstimmbereiches von 30nm ist der Raman-FDML Laser aufgrund der erreichten Bildqualität und Kohärenzlänge eine denkbare Alternative zu SOA-FDML Systemen.

Q 63: Quanteninformation: Quantencomputer

Zeit: Freitag 14:00–16:15 Raum: VMP 6 HS-A

Q 63.1 Fr 14:00 VMP 6 HS-A

Optimal Control of Open Quantum Systems: Markovian and non-Markovian — •Thomas Schulte-Herbrüggen[1], Andreas Spörl[1], Patrick Rebentrost[2,3], Frank Wilhelm[3], and Steffen Glaser[1] — [1]Technical University Munich (TUM), 85747 Garching — [2]Harvard University, Cambridge MA, USA — [3]Institute for Quantum Computation (IQC), Waterloo, Canada

For realistic examples of Markovian and non-Markovian open quantum systems we show how optimal controls obtained numerically [1] typically cut errors by one order of magnitude [2,3,4]. The examples include spin- and pseudo-spin systems, e.g., capacitively coupled charge qubits. The setting can easily be generalised to arbitrary N-level systems. — We sketch the relation between time-optimal and relaxation-optimised controls in the light of new pictures emerging in terms of Lie semigroups [5]. — Implications for quantum CISC-compilation [6] in large systems (≥100 qubits) are given as well as an outlook on how

to assemble CISC modules in a decoherence-protected way.

[1] Khaneja et al., J. Magn. Reson. 172, 296-305 (2005); Schulte-Herbrüggen et al., PRA 72, 042331 (2005).
[2] Spörl et al., PRA 75, 012302 (2007)
[3] Schulte-Herbrüggen et al., quant-ph/0609037
[4] Rebentrost et al., quant-ph/0612165
[5] Dirr et al., arXiv:0811.4195
[6] Schulte-Herbrüggen et al., arXiv:0712.3227

Q 63.2 Fr 14:15 VMP 6 HS-A

Quantum gates between atoms coupled by a nano-wire — •David Dzsotjan[1,2] and Michael Fleischhauer[1] — [1]Fachbereich Physik, Technische Universität Kaiserslautern, Germany — [2]Research Institute for Particle and Nuclear Physics, XII. Konkoly-Thege ut. 29-33, H1525, Budapest, PO Box 49, Hungary

We investigate the long-range coupling of single atoms placed close to the surface of a metallic, cylindrical nanowire. 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], [2], 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. We find furthermore that there is an optimal, sub-wavelength emitter-wire distance where the coupling to the plasmon modes is maximal due to the losses originating from circulating currents. When two emitters are placed along the wire, we observe a strong, wire-mediated long-range interaction. As a result of this, super- and subradiance can occur over distances large compared to the resonant wavelength. Using this effect, one can construct quantum gates and in duce entanglement among qubits along the wire. As a specific application, we propose a scheme for constructing a phase gate by a wire-mediated interaction of two lambda atoms.

[1]. D.E. Chang, A.S. Sorensen, P.R. Hemmer, and M.D. Lukin, Phys. Rev. Lett. 97, 053002 (2006) [2]. D.E. Chang, A.S. Sorensen, P.R. Hemmer, and M.D. Lukin, Phys. Rev. B 76, 035420 (2007) [3]. A.V. Akimov, A. Mukherjee, C.L. Yu, D.E. Chang, A.S. Zibrov, P.R. Hemmer, H. Park, and M.D. Lukin, Nature 450, 402 -406 (2007) [4]. L.-W. Li, M.-S. Leong, T.-S. Yeo, and P.S. Kooi, J. Electromagn. Waves Appl. 14, 961 (2000) [5]. V.V. Klimov, M. Ducloy, Phys. Rev. A 69, 013812 (2004)

Q 63.3 Fr 14:30 VMP 6 HS-A

Demonstration of a geometric two ion/qubit phase gate on the radial modes of motion — •Thomas Huber[1], Hector Schmitz[2], Christian Schneider[1], Martin Enderlein[1], and Tobias Schaetz[1] — [1]Max-Planck-Institut für Quantenoptik — [2]LMU München

Phonons in a linear chain of ions can provide interactions/a data bus between spins/qubits for quantum simulations(QS)/computation(QC). So far, experimentalists only exploit the axial degree of freedom in linear traps, i.e. the phonons of the axial normal modes of motion. We want to open up the radial degrees of freedom, exploring the (dis)advantages with respect to QC and QS. For an increasing amount of ions it becomes, for example, more difficult to place the ions at the correct relative positions to experience identical laser phases of a standing or travelling axially propagating wave, which provides the conditional motional excitations. Pushing the ions radially renders the system insensitive to the mutual ion distance. Additionally, the frequencies of the radial modes can be adjusted to be similar. The required ground state cooling of all motional modes might hence be possible by one common cooling cycle. To calibrate our interactions for future QS, we implemented a two-qubit phase gate with a fidelity exceeding 90%. We are able to laser-cool five ions to the radial motional ground states, a first step towards simulations with increased amounts of ion spins required in QS of systems of interest, like the Bose-Hubbard Hamiltonian. It also gives perspectives to 2D lattices of spins provided in potential surface trap arrays.

Q 63.4 Fr 14:45 VMP 6 HS-A

Dynamic polarization of single nuclear spins in a room temperature diamond — •Philipp Neumann, Vincent Jacques, Johannes Beck, Fedor Jelezko, and Jörg Wrachtrup — 3. Physikalisches Institut, Universität Stuttgart, Germany

Recently, room temperature readout of single nuclear spins in diamond has been achieved by coherently mapping nuclear spin states onto the electron spin of a single NV color center. This has been the basis for spectacular experiments in quantum information science, ranging from the implementation of a nuclear-spin-based quantum register, a conditional two-qubit CNOT gate and recently the generation of Bell and GHZ states with extraordinarily long coherence times.

However, most of these experiments were performed without any deterministic polarization of nuclear spin states. This random initialization unavoidably decreases the success rate of all local operations as $1/2^N$ where N is the number of qubits.

We report a versatile method to efficiently polarize single nuclear spins in diamond, which is based on optical pumping of a single NV color center and mediated by a level-anti crossing in its excited state. A nuclear spin polarization higher than 98% is achieved at room temperature for the ^{15}N nuclear spin associated to the NV center. Furthermore we show simultaneous deterministic initialization of two nuclear spins (^{13}C and ^{15}N) close to a NV defect, which provides efficient initialization of a three qubit quantum register including the electron spin. Such robust control of nuclear spin states is a key ingredient for further scaling up nuclear-spin based quantum registers in diamond.

Q 63.5 Fr 15:00 VMP 6 HS-A

Simple quantum algorithms at room temperature using a 3-qubit register in diamond — •Johannes Beck[1], Phillip Neumann[1], Norikazu Mizuochi[2], Matthias Steiner[1], Florian Rempp[1], Vincent Jacques[1], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart, D-70550 Stuttgart, Germany — [2]Graduate School of Library, Information and Media Studies, University of Tsukuba, 1-2 Kasuga, Tsukuba-City, Ibaraki 305-8550, Japan

A small quantum register in diamond consisting of a single Nitrogen-Vacancy center electron spin coupled to two ^{13}C nuclear spins has already been used to create robust multipartite entanglement in form of GHZ- and W-States at room temperature [1]. Now, focus is set upon experimental realization of elementary quantum applications, showing the feasibility of simple quantum algorithms at ambient conditions using such a quantum register. Transformation of Bell states one into another is demonstrated, corresponding to Alice's operational part in a potential superdense coding protocol. Furthermore, a report on the progress regarding implementation of Deutsch's algorithm with two qubits will be given.

[1] P. Neumann et al., *Multipartite Entanglement Among Single Spins in Diamond*, Science **320,** 1326 (2008)

Q 63.6 Fr 15:15 VMP 6 HS-A

Measurement-Based Quantum Computation in Realistic Spin-1 Chains — •Joseph M. Renes[1], Gavin Brennen[2], Stephen D. Bartlett[3], and Akimasa Miyake[4] — [1]TU Darmstadt, Germany — [2]Macquarie University, Sydney, Australia — [3]University of Sydney, Sydney, Australia — [4]Perimeter Institute, Waterloo, Canada

We study the measurement-based computational abilities of ground states of spin-1 chains near the AKLT point, as recently proposed by Brennen and Miyake [1]. In this hybrid scheme individual qubit gates are performed by measurement while two-qubit gates are performed by dynamically coupling different chains. The gapped spectrum of the chains is expected to help suppress decoherence in realistic implementations, such as atoms or polar molecules in optical lattices. We show that the approach taken by Doherty and Bartlett to characterize the computational power of nearly-cluster state quantum computers [2] can be profitably adapted to this case, avoiding the need to keep track of the exponentially-many computational paths. Numerical analysis shows that arbitrary single-qubit operations can be faithfully executed over a reasonably wide parameter range of bilinear-biquadratic Hamiltonians near the AKLT point. Furthermore, we find that the Doherty-Bartlett approach leads directly to the use of string order parameters, showing a connection between computational questions and the traditional theoretical study of condensed matter, where these parameters arise.

[1] Brennen and Miyake, Phys. Rev. Lett. 101, 010502 (2008). [2] Doherty and Bartlett, arXiv:0802.4314v1 [quant-ph].

Q 63.7 Fr 15:30 VMP 6 HS-A

Scaling of passive quantum memories — •Fernando Pastawski, Alastair Kay, Norbert Schuch, and Juan Ignacio Cirac — Max-Planck-Institut für Quantenoptik Hans-Kopfermann-Str. 1, D-85748 Garching, Deutschland

Fault tolerance theorems state that it is possible to construct reliable (active) memories from unreliable components given resources such ass fresh ancillas. Furthermore, recent proposals claim that some many-body Hamiltonians may act as passive memories, asymptotically allowing reliable storage of quantum information. We explore different error models for such Hamiltonians and information encodings and obtain some no-go results in the absence of entropy extraction mechanisms.

Q 63.8 Fr 15:45 VMP 6 HS-A

Most quantum states are too entangled to be useful as computational resources — •David Gross[1], Steve Flammia[2], and Jens Eisert[3] — [1]Technical University of Braunschweig — [2]Perimeter Institute for Theoretical Physics, Waterloo — [3]University of Potsdam

It is often argued that entanglement is at the root of the speedup for quantum compared to classical computation, and that one needs a sufficient amount of entanglement for this speedup to be manifest. In measurement-based quantum computing (MBQC), the need for a highly entangled initial state is particularly obvious. Defying this intuition, we show that quantum states can be too entangled to be useful for the purpose of computation. We prove that this phenomenon occurs for a dramatic majority of all states: the fraction of useful n-qubit pure states is less than $\exp(-n^2)$. Computational universality is hence a rare property in quantum states. This work highlights a new aspect of the question concerning the role entanglement plays for quantum computational speed-ups. The statements remain true if one allows for certain forms of post-selection and also cover the notion of CQ-universality. We identify scale-invariant states resulting from a MERA constructrion as likely candidates for physically relevant states subject to this effect.

Q 63.9 Fr 16:00 VMP 6 HS-A

Interacting electrons, Density Functional Theory, and Quantum Merlin Arthur — •Norbert Schuch[1] and Frank Verstraete[2] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Institut für Theoretische Physik, Universität Wien, Wien, Austria

One of the central problems in quantum mechanics is to find the ground state energy of a system of electrons interacting via the Coulomb potential. Since its introduction by Hohenberg, Kohn, and Sham, Density Functional Theory (DFT) has become the most widely used and successful method for simulating systems of interacting electrons, making their original work one of the most cited in physics. In this letter, we show that the field of computational complexity imposes fundamental limitations on DFT, as an efficient description of the associated universal functional would allow to solve any problem in the class QMA (the quantum version of NP) and thus particularly any problem in NP in polynomial time. This follows from the fact that finding the ground state energy of the Hubbard model in an external magnetic field is a hard problem even for a quantum computer, while given the universal functional it can be computed efficiently using DFT. This provides a clear illustration how the field of quantum computing is useful even if quantum computers would never be built.

Q 64: Quanteneffekte: Verschränkung

Zeit: Freitag 14:00–16:30 Raum: VMP 6 HS-D

Q 64.1 Fr 14:00 VMP 6 HS-D

Violation of local realism with freedom of choice — •Thomas Scheidl[1,2], Rupert Ursin[1,2], Johannes Kofler[1,2], Sven Ramelow[1,2], Xiaosong Ma[1,2], Thomas Herbst[1,2], Lothar Ratschbacher[1,2], Alessandro Fedrizzi[1,2], Nathan Langford[1,2], Thomas Jennewein[1,2], and Anton Zeilinger[1,2] — [1]Faculty for 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

The predictions of quantum mechanics can be in striking contradiction with local realism if entanglement exists between distant systems. Bell's theorem shows that local realistic theories place a strong restriction on observable correlations between different systems in experiments, giving rise to Bell's inequality. This allows an experimental test of whether nature itself agrees with local realism or quantum mechanics. To derive his inequality, Bell made three assumptions: realism, locality, and freedom of choice. In experimental Bell test, there may be "loopholes" which allow observed violations to still be explained by local realistic theories. Many Bell tests so far have closed individual loopholes, specifically the locality loophole and the fair-sampling loophole. However, the loophole related to Bell's freedom-of-choice assumption was not yet addressed experimentally. Here we report an experiment using entangled photons, which for the first time closes this loophole and simultaneously closes the locality loophole. It is also the first to close two of the three crucial loopholes at the same time.

Q 64.2 Fr 14:15 VMP 6 HS-D

Entangled Quantum Systems in Number Theory — •Rüdiger Mack and Wolfgang P. Schleich — Institute for Quantum Physics, Ulm University

There is an evident connection between quantum mechanics and number theory. Simply think of Shor's algorithm or quantum billards. In important function in number theory is the ζ-function of Riemann and a fundamental concept of quantum theory are entangled systems. We bring these two elements together and depict analytic continuation in mathematics in terms of a physical system.

We present a method to evaluate the ζ-function by preparing an appropriate quantum system. We emphasize the point where entanglement comes to play a role.

Q 64.3 Fr 14:30 VMP 6 HS-D

2D Spatial Entanglement Characterization of Biphotons — •Dietmar Korn, Dirk Puhlmann, Sebastian Wander, Robert Elsner, and Martin Ostermeyer — Institute for Physics and Astronomy, University of Potsdam, Potsdam, Germany

Several schemes in quantum imaging rely on multi-photon absorption. Therefore a detailed knowledge of the temporal and spatial correlations of the photons used is desired.

We investigate the correlations of space-momentum entangled biphotons. A pair of photons is generated by type II parametric down conversion and subsequently a biphoton is created utilizing a Hong-Ou-Mandel interference. To obtain a complete mapping of the biphoton's space and momentum cross sections, the near and far field of the crystal is analysed by a Hanbury-Brown-Twiss like setup with two single mode fiber probes, one in each path behind a beam splitter.

The fibre probes, having a mode-field diameter of $5\mu m$, can be moved independently over an area of $20\mu m$ x $20\mu m$ onto which the near / far field of the crystal plane has been mapped. By evaluating the coincidence photon count rate with respect to the probe positions [1] a product of variances in space and momentum can be derived which shows a strong violation of the classical correlation bound [2].

[1] Howell, J.C. et al., *Phys. Rev. Lett.* **92**, 210403(2004).
[2] Mancini, S. et al., *Phys. Rev. Lett.* **88**, 120401(2002).

Q 64.4 Fr 14:45 VMP 6 HS-D

Dissociation-induced entanglement in the motion of material particles — •Clemens Gneiting and Klaus Hornberger — Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians-Universität München

The controlled dissociation of Feshbach molecules permits one to generate pairs of counterpropagating atoms that are entangled in their motional degrees of freedom. Sequences of dissociation pulses may result in delocalized single-particle states that can be manipulated by addressing individual spatial components. We describe a scheme based on dissociating trapped ultracold Feshbach molecules into an atom guide and discuss possible tests of non-classicality that would be made possible by choosing appropriate dissociation pulses. In particular, the generation of 'dissociation-time' entangled atom pairs, processed by subsequent Mach-Zehnder interferometric devices, permits to violate a Bell inequality based only on the motional entanglement of the particles [1].

[1] C. Gneiting and K. Hornberger, Phys. Rev. Lett. (2008), in press

Q 64.5 Fr 15:00 VMP 6 HS-D

Structures in entanglement dynamics — •Markus Tiersch, Fernando de Melo, and Andreas Buchleitner — Physikalisches Institut der Albert-Ludwigs-Universität, Hermann-Herder-Str. 3, D-79104 Freiburg, Germany

Understanding the dynamics of entanglement that is exhibited by a quantum system constitutes a major step in the venture to harvest this quantum effect in potential applications, and to elaborate the role that entanglement plays in real world settings. Interesting dynamics include collective coherent driving and general decoherence processes.

Without resorting to the phenomenological treatment of specific examples, we present *general* features of the structure underlying the dynamics of entanglement. Starting from low dimensional systems where algebraic properties of some entanglement monotones allow for an "entanglement equation of motion" [1,2] we continue, using topological and measure theoretic approaches [3], to typical behaviour exhibited in the thermodynamic limit.

[1] T. Konrad, F. de Melo, M. Tiersch, C. Kasztelan, A. Aragão, A. Buchleitner, Nature Phys. **4**, 99 (2008).

[2] M. Tiersch, F. de Melo, A. Buchleitner, Phys. Rev. Lett. **101**, 170502 (2008).

[3] M. Tiersch, F. de Melo, A. Buchleitner, arXiv:0810.2506.

Q 64.6 Fr 15:15 VMP 6 HS-D

Testing the spin-statistics theorem with a pair of entangled particles — •Christian Roos[1] and Hartmut Häffner[1,2] — [1]Institut für Quantenoptik und Quanteninformation, Otto-Hittmair-Platz 1, 6020 Innsbruck, Österreich — [2]Dept. of Physics, University of California, Berkeley, CA 94720, USA

We discuss how the fundamental quantum statistical property of two identical particles can be directly accessed. For this we propose to entangle the two particles by using their internal degrees of freedom and then to exchange their positions conditioned on their respective internal state. Interfering the internal states locally, allows to distinguish fermionic from bosonic statistics, even if the particles' wave function overlap vanishes at all times. Possible experimental realizations using trapped ions or neutral atoms are outlined.

Q 64.7 Fr 15:30 VMP 6 HS-D

Coherent single surface-plasmon transport in a nanowire coupled to double quantum dots — •Guang-Yin Chen[1,2], Yueh-Nan Chen[3], Niel Lambert[4], Florian Mintert[2], Der-San Chuu[5], and Andreas Buchleitner[2] — [1]Institute of Physics, National Chiao Tung University, Hsinchu 300, Taiwan — [2]Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, Hermann-Herder-Strasse 3, D-79104 Freiburg, Germany — [3]Department of Physics and National Center for Theoretical Sciences, National Cheng-Kung University, Tainan 701, Taiwan — [4]Digital Materials Lab, Single Quantum Dynamics Research Group, FRS, Riken, Wako, Saitama 351-0198, Japan — [5]Department of Electrophysics, National Chiao Tung University, Hsinchu 300, Taiwan

We theoretically study coherent single surface-plasmon transport in a nanowire strongly coupled to two quantum dots. Using a real-space Hamiltonian we find analytical expressions for the transmission and reflection coefficients and dot-dot entanglement. Our results show that remotely entangled states can be created if the separation between the two dots is equal to multiple half-wavelength of the plasmon. Furthermore, by applying classical laser pulses to the quantum dots, the entangled states can be stored in metastable states which are decoupled from the surface plasmons. We also investigate dissipative effects due to "non-connecting"surface-plasmon modes.

[1] J.T. Shen and S. Fan, Phys. Rev. Lett. 95, 213001 (2005).

[2] D. E. Chang, A. S. Sørensen, E. A. Demler, and M. D. Lukin, *Nature Physics* **3**, 807 (2007).

Q 64.8 Fr 15:45 VMP 6 HS-D

Steady state entanglement in the mechanical vibrations of two dielectric membranes — •Michael Hartmann[1,2,3] and Martin Plenio[2,3] — [1]Technische Universität München, Physik Department, 85748 Garching, Germany — [2]Institute for Mathematical Sciences, Imperial College London, United Kingdom — [3]QOLS Blackett Laboratory, Imperial College London, United Kingdom

We consider two dielectric membranes suspended inside a Fabry-Perot-cavity, which are cooled to a steady state via a drive by suitable classical lasers. We show that the vibrations of the membranes can be entangled in this steady state. They thus form two mechanical, macroscopic degrees of freedom that share steady state entanglement.

Q 64.9 Fr 16:00 VMP 6 HS-D

Generation of Long-lived Entanglement on Demand in Remote Qubits — •Uwe Schilling[1], Christoph Thiel[1], Thierry Bastin[2], Enrique Solano[3], and Joachim von Zanthier[1] — [1]Institut für Optik, Information und Photonik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany — [2]Institut de Physique Nucléaire, Atomique et de Spectroscopie, Université de Liège, Liège, Belgium — [3]Departamento de Química Física, Universidad del País Vasco – Euskal Herriko Unibertsitatea, Bilbao, Spain

We propose a scheme for the generation of entanglement between localized atoms with either a two-level or a Λ internal level structure. By measuring in the photons incoherently scattered off the atoms in the far field, we find that the atoms may be entangled *remotely* and *to an arbitrary degree*. For both level structures, the amount of entanglement between the particles is tunable by two easily accessible and independent experimental parameters. In case of the Λ level structure, it is found that the degree of entanglement generated can be quantified simply by the relative orientation of two polarization filters in equivalence to the well-known Malus' Law.

Q 64.10 Fr 16:15 VMP 6 HS-D

Creation and control of atomic entanglement by means of optical cavities — •Denis Gonta[1] and Stephan Fritzsche[2,3] — [1]Max–Planck–Institut für Kernphysik, Postfach 103980, D–69029 Heidelberg — [2]Physikalisches Institut der Universität Heidelberg, Philosophenweg 12, D-69120 Heidelberg — [3]Frankfurt Institute for Advanced Studies, Ruth-Moufang-Str. 1, D-60438 Frankfurt am Main

Cavity QED provides an excellent tool to control the interaction between two distant neutral atoms, for example, when the atoms pass through the cavity and are coupled simultaneously to the same cavity mode. This opens a route towards the implementation of entanglement and quantum gates via cavity-mediated atom-atom interactions.

In this contribution, a scheme is proposed to generate a entangled state between two (Λ-type) four-level atoms, which are interacting effectively by means of an off-resonant optical cavity and a laser beam. We show how the degree of entanglement for two atoms passing subsequently through the cavity depends on their velocity and the (initial) distance between the atoms. In addition, we suggest schemes to implement various two-qubit gates within the framework of the proposed atom-cavity-laser setup. For all these schemes, we display and discuss the atomic velocities and inter-atomic distances for which these gates are realized.

Q 65: Laseranwendungen: Lebenswissenschaften

Zeit: Freitag 14:00–16:30 Raum: VMP 8 HS

Q 65.1 Fr 14:00 VMP 8 HS

Photo-dynamics of Roseoflavin in Aqueous and Organic Solvents — •Peyman Zirak[1], Alfons Penzkofer[1], Tilo Mathes[2], and Peter Hegeman[2] — [1]Institut II - Experimentelle und Angewandte Physik, Universität Regensburg, Universitätsstrasse 31, D-93053 Regensburg, Germany — [2]Institut für Biologie /Experimentelle Biophysik, Humboldt Universität zu Berlin, Invalidenstraße 42, D-10115 Berlin, Germany

Roseoflavin (8-dimethylamino-8-demethyl-D-riboflavin) in aqueous and organic solvents is studied by optical absorption spectroscopy, fluorescence spectroscopy, and fluorescence decay kinetics. A solvent polarity dependent absorption shift is observed. The fluorescence quantum yield is low and solvent dependent (e.g. 0.0005 in neutral water and 0.032 in benzene). The fluorescence decay shows a bi-exponential dependence (ps to sub-ps fast time constant, and 100 ps to a few ns slow time constant). The photo-dynamics is explained in terms of fast intra-molecular charge-transfer (diabatic electron transfer) from the dimethylamino electron donor group to the pteridin carbonyl electron acceptors followed by intra-molecular charge recombination. The fast fluorescence component is due to direct locally excited-state emission, and the slow fluorescence component is due to delayed locally excited state emission and charge transfer state emission.

Q 65.2 Fr 14:15 VMP 8 HS

Zweiphotonenmikroskopie und Second Harmonic Generation an quervernetzter Kaninchenaugenhornhaut — •Alexander Krüger[1], Abd Alkawas[1], Marine Hovakimyan[2], Diego Ramirez[1], Oliver Stachs[2], Maria Kröger[2], Rudolf Guthoff[2] und Alexander Heisterkamp[1] — [1]Laser Zentrum Hannover e.V, Germany — [2]Universitätsaugenklinik Rostock, Germany

Bei der Augenkrankheit Keratokonus kommt es zu einer kegelförmigen Ausstülpung der Hornhaut (Kornea). Um die Kornea mechanisch zu stabilisieren und die Progression der Krankheit zu stoppen, wird als Behandlung eine Quervernetzung durch Riboflavin und UVA-Bestrahlung durchgeführt. Um die Auswirkung auf die Hornhaut ohne Anfärbung studieren zu können, wurde ein spezielles Mehrphotonenmikroskop aufgebaut. Die dreidimensionale Bildgebung der Korneae basiert auf der Zweiphotonenanregung der Autofluoreszenz und der optisch nichtlinearen Erzeugung der zweiten Harmonischen (Second Harmonic Generation, SHG) mit einem Femtosekundenlaser. Die SHG-Detektion erfolgt in Vorwärts- und Rückwärtsrichtung. Erste Ergebnisse an zuvor quervernetzten Kaninchenaugen zeigen eine deutliche Autofluoreszenz des Epithelzellplasmas auf den ersten 50 μm Tiefe und ebenso des Keratozytenplasmas im darunter liegenden Stroma (bis 300 μm). Rückwärts- und Vorwärts-SHG unterscheiden sich insofern, als die hornhauttypischen gekreuzten Collagen-Lamellen nur in den Vorwärts-SHG-Signal nachweisbar sind. In quervernetzter Kornea zeigt sich eine verminderte Dichte und Form der Keratozyten.

Q 65.3 Fr 14:30 VMP 8 HS

Photodynamics of blue-light-regulated phosphodiesterase BlrP1 protein from ***Klebsiella pneumoniae*** — •Amit Tyagi[1], Alfons Penzkofer[1], Julia Griese[2], Ilme Schlichting[2], Natalia V. Kirienko[3], and Mark Gomelsky[3] — [1]Institut II - Experimentelle und Angewandte Physik, Universität Regensburg, Universitätsstrasse 31, D-93053 Regensburg, Germany — [2]Max-Planck-Institut für medizinische Forschung, Abteilung Biomolekulare Mechanismen, Jahnstrasse 29, D-69120 Heidelberg, Germany — [3]Department of Molecular Biology, University of Wyoming, Laramie, Wyoming 82071, USA

The blue light-regulated phosphodiesterase BlrP1 protein from the enteric bacterium *Klebsiella pneumoniae* consists of a BLUF (sensor of blue light using FAD) and an EAL (E = Glu, A = Ala, L = Leu) domain. The full-length protein, BlrP1, and its BLUF domain, BlrP1_BLUF, are characterized by optical absorption and emission spectroscopy. The cofactor FAD in its oxidized redox state (FAD_{ox}) is brought from the dark-adapted receptor state to the 10 nm red-shifted putative signalling state by violet light exposure. The recovery to the receptor state occurs with a time constant of about 1 min. The quantum yield of signalling-state formation is about 0.17 for BlrP1_BLUF and about 0.08 for BlrP1. The fluorescence efficiency of the FAD_{ox} cofactor is small due to photo-induced reductive electron transfer. Prolonged light exposure converts FAD_{ox} in the signalling state to the fully reduced hydroquinone form $FAD_{red}H^-$ and causes low-efficient chromophore release with subsequent photo-degradation.

Q 65.4 Fr 14:45 VMP 8 HS

Entwicklung eines OCT-gestützten Endoskops zur kontaktfreien Untersuchung von Kehlkopferkrankungen — •Nadine Rohrbeck[1], Henning Wisweh[1], Kathrin Alexandrov[2] und Holger Lubatschowski[1] — [1]Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover — [2]Medizinische Hochschule Hannover, Carl-Neuberg-Str. 1, 30625 Hannover

Ein OCT-gestütztes Endoskop bietet eine Diagnosemöglichkeit zur Untersuchung von Kehlkopferkrankungen in Echtzeit, um Aussagen über oberflächennahe Tiefenstrukturen zu erhalten. Bisher gibt es kein routinemäßiges Verfahren zur Untersuchung der Tiefenstruktur der Stimmlippe. Die optische Kohärenztomographie (OCT) eignet sich als nichtinvasives optisches Bildgebungsverfahren für die Stimmlippendiagnostik, da es in vivo und in Echtzeit Schichtbilder innerhalb einer Tiefe von 1 mm mit Auflösungen im μm-Bereich liefert.

Das OCT-gestützte Endoskop vereint einen OCT-Strahlengang und eine Videobildgebung, so dass gleichzeitig Informationen der feingeweblichen Struktur der Stimmlippe auf der Schleimhautoberfläche sowie die Tiefenausdehnung der Gewebeschichten dargestellt werden können. Eine elektromechanische Fokussiereinheit ermöglicht einen flexiblen Arbeitsabstand für das Endoskop, so wird der Strahlengang individuell an die Anatomie des Patienten angepasst. Da Bewegungen während der medizinischen Untersuchung mit Hilfe von OCT Bewegungsartefakte hervorrufen, wurden verschiedene OCT-Messmethoden untersucht, um die Auswirkungen auf die Bildqualität zu beurteilen.

Q 65.5 Fr 15:00 VMP 8 HS

Optische Kohärenztomographie (OCT) als Bildgebungssystem für die Femtosekunden-Laserapplikation — •Marko Heidrich, Ole Massow und Holger Lubatschowski — Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover, Germany

Das Konzept des sehenden Skalpells beruht auf der Vereinigung der nichtinvasiven optischen 3D-Bildgebung eines OCT-Systems mit der berührungslosen Bearbeitung von Proben mit einem Femtosekunden-Laser. Ziel hierbei ist die räumliche Darstellung von Proben, mit deren Hilfe die Schnittkontur definiert werden kann. Das Schneiden basierend auf Ultrakurzpulslasern bietet die Möglichkeit aufgrund der nichtlinearen Wechselwirkung in Gewebe (Photodisruption) unterhalb der Oberfläche mit einer Präzision von wenigen μm Material zu trennen. Die Kombination aus OCT mit einem Auflösungsvermögen im μm-Bereich und Laser-Schneiden ermöglicht es ohne den bisherigen Gerätewechsel und damit ohne Verlust der Präzision relativ zu in der Probe befindlichen Strukturen zu schneiden und mit Hilfe derselben Optiken die Probe zu untersuchen.

Das sehende Skalpell besteht aus einem 3D Fourier Domain OCT-System in dessen Strahlengang ein Ultrakurzpulslaser eingekoppelt wird, so dass die Probe alternierend mit dem OCT-System begutachtet und mit dem fs-Laser bearbeitet werden kann. In diesem Vortrag soll der Aufbau des auf das sehende Skalpell angepassten OCT-Systems und die Charakterisierung der Systemeigenschaften vorgestellt werden.

Q 65.6 Fr 15:15 VMP 8 HS

Real time en face Fourier-domain optical coherence tomography with direct hardware frequency demodulation — Benjamin Biedermann, •Wolfgang Wieser, Christoph Eigenwillig, and Gesa Palte — Ludwig-Maximilians-Universität, München, Deutschland

Optical coherence tomography (OCT) is a novel method for 3d imaging of biomedical tissue. Recently, the introduction of rapidly wavelength swept Fourier-domain mode locked (FDML) lasers enabled dramatically increased imaging speeds allowing complete 3d data sets to be acquired in a second.

In contrast to the slower time-domain OCT, the extraction of en-face projections in fast swept-source OCT systems (ss-OCT) typically involves complex post-processing: data resampling, numerical spectral shaping, Fourier transformation and summation over parts of each depth scan.

This talk presents a novel **cost-effective real-time en-face imaging technique** using ss-OCT but **without any of the mentioned computation steps**: A *k*-space linear FDML laser combined with an adaptive feedback loop provides a spectrally-shaped swept laser source. Hardware-demodulation extracts the signal corresponding to a certain depth in the tissue.

Q 65.7 Fr 15:30 VMP 8 HS

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

^{13}CO ist ein nichtradioaktives Isotopolog und macht etwa 1,1% der natürlichen CO Zusammensetzung aus. CO entsteht im Körper beim Abbau von roten Blutkörperchen und kommt in der Ausatemluft in Konzentrationen weniger ppm vor. Eine isotopologenselektive ^{13}CO-Analyse der Atemluft erlaubt so beispielsweise die CO-Aufnahme des Körpers zu untersuchen und dabei CO-Konzentrationen bzw. CO-Mengen zu verwenden, die unterhalb der zulässigen Höchstwerte liegen. Die Cavity Leak-Out Spektroskopie bietet die Möglichkeit zur isotopologenselektiven Analyse. Das eingesetzte System ermöglicht sowohl eine atemzugsaufgelöste ^{13}CO-Detektion aus der Atemluft als auch die Analyse aus biologischen Proben unter Verwendung eines CO-Gaslasers im mittleren Infrarot (ca. 5μm) bei einer Nachweisgrenze von 0,7ppb$\cdot$Hz$^{-1/2}$. Mit Hilfe der ^{13}CO-Atemanalyse, in Kombination mit weiteren spirometrischen Daten, wird der Zusammenhang zwischen dem exhalierten ^{13}CO und der Carboxyhämoglobinkonzentration (Hb^{13}CO) im Blut untersucht. Daraus folgend soll eine Methode zur minimalinvasiven Bestimmung der Hämoglobingesamtmasse entwickelt werden, mit deren Hilfe u.a. Blutdopingsünder entlarvt werden könnten. Im Rahmen des Vortrags sollen das Messsystem und erste Ergebnisse präsentiert werden.

Q 65.8 Fr 15:45 VMP 8 HS

Kurzpulslaser basierte Transfektion von Suspensionszellen —
•Manuel Beckschebe[1], Judith Baumgart[1], Heiko Meyer[1], Hugo Murua Escobar[2], Anaclet Ngezahayo[3], Holger Lubatschowski[1] und Alexander Heisterkamp[1] — [1]Laser Zentrum Hannover e.V., Hollerithallee 8, Hannover — [2]Kleintierklinik, Tierärztliche Hochschule, Bischofsholer Damm 15, Hannover — [3]Institut für Biophysik, Leibniz Universität, Herrenhäuserstr. 2, Hannover

Das Einbringen von DNA in eukaryotische Zellen wird als Transfektion bezeichnet. Für ein kurzzeitiges Öffnen der Zellmembran werden kurze Pulse im nahinfraroten Wellenlängenbereich stark auf die Membran fokussiert. Die DNA kann somit in die Zelle hinein diffundieren. Dieses Verfahren hat sich bereits als besonders schonend und effektiv herausgestellt und ist u.a. für Primär- und Stammzellen sehr gut geeignet. Für diese Methode muss allerdings jede Zelle einzeln anvisiert und manipuliert werden, so dass die Transfektion einer hinreichend großen Zellpopulation sehr zeitaufwendig ist.

Wir präsentieren einen Ansatz, um Zellen in Suspension automatisch mittels optischer Pinzette relativ zum Fokus des Kurzpulslasers zu positionieren. Dazu werden sie in einem Mikrofluidikkanal in einem Linienfokus der optischen Pinzette aufgereiht. Somit werden die Suspensionszellen im Vorbeifließen am Fokus des Kurzpulslasers transfiziert. Durch eine geeignete Kanalgeometrie können zusätzlich die transfizierten Zellen von unbehandelten getrennt werden, so dass der Anteil der erfolgreich transfizierten Zellen in dem sortierten Volumen maximiert wird.

Q 65.9 Fr 16:00 VMP 8 HS

Plasmonen basierte Lasertransfektion — •Holger Fehlauer, Markus Schomaker, Holger Lubatschowski und Alexander Heisterkamp — Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover

Eine zentrale Anwendung der Molekularbiologie ist das Einbringen von Fremd-DNA in Zellen. Eine Alternative zu den konventionellen Methoden der Zellpermeabilisierung ist die Lasertransfektion durch Plasmonen. Plasmonen entstehen durch Absorption von resonantem Laserlicht an Nanopartikeln oder Nanopartikeloberflächen. Die Plasmonen basierte Lasertransfektion bietet die Möglichkeit eines hohen Durchsatzes, da, durch eine schwache Laserfokussierung, eine große Fläche und damit viele Zellen bestrahlt werden. Durch das Verwenden von biokompatiblen Goldnanopartikeln (GNP) und einer geringen Laserfluenz wird eine schädigungsarme Transfektion erreicht.

Für die Transfektion werden Zellen mit GNP inkubiert, welche durch einen Fs Laser angeregt werden. Daraufhin können große Moleküle, wie DNA, in die Zellen eindringen. Um die Transfektioneffizienz zu prüfen, wird Fremd-DNA eingebracht, welche zur Synthetisierung des Green-Fluoresence-Proteins in den Zellen führt und 24 Stunden nach Einbringen über Fluoreszenz nachgewiesen wird.

In den durchgeführten Versuchen wird der Einfluss verschiedener Faktoren auf die Transfektionsrate untersucht, um optimale Transfektionsparameter zu evaluieren. Diese Faktoren sind Größe und Konzentration der GNPs, sowie Wellenlänge und Energie des Laserlichtes.

Q 65.10 Fr 16:15 VMP 8 HS

Optisches Sortieren von Primärzellen in einem Mikrofluidik-Chip — •Christina Krämer[1], Heiko Meyer[1], Judith Baumgart[1], Raoul Lorbeer[1], Detlev Rath[2], Holger Lubatschowski[1] und Alexander Heisterkamp[1] — [1]Laser Zenrum Hannover e.V., Hollerithallee 8, 30419 Hannover — [2]Bunderforschungsanstalt für Landwirtschaft, Höltystraße 10, 31535 Neustadt

In der Biologie sowie in der Medizin ist es häufig erforderlich, verschiedene Zellarten voneinander zu trennen. Das Sortieren mit Hilfe einer optischen Falle bietet eine schädigungsfreie Alternative zu dem herkömmlichen Verfahren der Durchflusszytometrie, welche durch das benötigte elektrische Feld vorwiegend die Zellmembran schädigt. Daher eignet sich optisches Sortieren besonders gut für sensible Primärzellen.

Die optische Falle in Form eines Linienfokus wurde mittels eines Nd:YAG Lasers (1064nm, cw) und eines optischen Systems basierend auf Zylinderlinsen oder einem SLM generiert. Dieser Linienfokus übt unter einem Winkel von 30° eine Kraft im pN-Bereich aus, so dass Partikel von einigen μm Größe abgelenkt werden können. Durch die Verwendung eines IR-Lasers wird auf Grund der Eigenschaften von biologischem Gewebe lineare Absorption und somit thermische Schädigungen an den Zellen reduziert.

Durch Integration eines Mikrofluidik-Chips soll das Sortierverfahren automatisiert und simultan visuell kontrolliert werden. Durch Variation verschiedener Systemparameter, wie Laserleistung oder Strömungsgeschwindigkeit werden Durchflussrate und Sortiergenauigkeit optimiert.