Q 51: Ultracold Atoms I

Time: Thursday 14:30–16:30 Location: P 104

Group Report Q 51.1 Thu 14:30 P 104

Optical traps for single ions and Coulomb crystals — •Leon Karpa, Julian Schmidt, Alexander Lambrecht, Pascal Weckesser, Yannick Minet, Fabian Thielemann, Markus Debatin, and Tobias Schaetz — Physikalisches Institut, Albert-Ludwigs Universität Freiburg, Germany

We demonstrate optical trapping of $^{138}Ba^{+}$ ions without residual rf-confinement for durations of up to 3 s, an improvement in lifetime by 3 orders of magnitude compared to recent experiments[1],[2]. With the trapping probability approaching unity for durations of 100 ms combined with low heating and electronic decoherence rates our results establish optical ion trapping as a novel and robust tool for the manipulation of cold trapped ions, e.g. in atom-ion interaction experiments[3].

The presented approach can also be applied for all-optical trapping of Coulomb crystals which we demonstrate by spectroscopy of a crystal excited within the optical trap. We discuss possible applications of our results in the fields of ultracold chemistry and structural quantum phase transitions.

[1] C. Schneider, M. Enderlein, T. Huber and T. Schaetz, Nat. Photon. **4**, 772 (2010)
[2] Huber, A. Lambrecht, J. Schmidt, L. Karpa and T. Schaetz, Nat. Commun. **5**, 5587 (2014)
[3] see e.g.: A. Grier, M. Cetina, F. Orucevic, and V. Vuletic, PRL **102**, 223201 (2009)

Q 51.2 Thu 15:00 P 104

Fictitious magnetic field gradients in optical microtraps as an experimental tool for interrogating and manipulating cold atoms — •Yijian Meng, Bernhard Albrecht, Christoph Clausen, Alexandre Dareau, Philipp Schneeweiss, and Arno Rauschenbeutel — TU Wien/Atominstitut, VCQ, Vienna, Austria

Optical microtraps provide a strong spatial confinement for laser-cooled atoms. They can, e.g., be realized with strongly focused trapping light beams or the optical near fields of nano-scale waveguides and photonic nanostructures. Atoms in such traps often experience strongly spatially varying AC Stark shifts which are proportional to the magnetic quantum number of the respective energy level. These inhomogeneous fictitious magnetic fields can cause a displacement of the trapping potential that depends on the Zeeman state. Hitherto, this effect was mainly perceived as detrimental. However, it also provides a means to probe and to manipulate the motional state of the atoms in the trap by driving transitions between Zeeman states. Furthermore, by applying additional real or fictitious magnetic fields, the state-dependence of the trapping potential can be controlled. Here, using laser-cooled atoms that are confined in a nanofiber-based optical dipole trap, we employ this control in order to tune the microwave coupling of motional quantum states. We record corresponding microwave spectra which allow us to infer the trap parameters as well as the temperature of the atoms. Finally, we reduce the mean number of motional quanta in one spatial dimension to 0.3(1) by microwave sideband cooling.

Q 51.3 Thu 15:15 P 104

An atomic erbium Bose-Einstein condensate generated in a quasistatic optical dipole trap — •Daniel Babik, Jens Ulitzsch, Roberto Röll, and Martin Weitz — Institut für Angewandte Physik, Wegelerstraße 8, 53115 Bonn

We report on the generation of a Bose-Einstein condensate of erbium atoms in a quasistatic optical dipole trap in an experiment aimed at the study of physics of strong light-induced gauge fields. In alkali atoms with their S-ground state configuration in far detuned laser fields with detuning above the upper state fine structure splitting the trapping potential is determined by the scalar electronic polarizability. In contrast for an erbium quantum gas with its L $>$ 0 electronic ground state, the trapping potential for inner-shell transitions also for far detuned dissipation-less trapping laser fields becomes dependent on the internal atomic state (i.e. spin). It is expected to reach much longer coherence times with erbium in spin-dependent optical lattice experiments and for far detuned Raman manipulation in comparison with alkali atoms.

In our experiment an erbium atomic beam is decelerated by a Zeeman slower using radiation tuned to the 400.91 nm transition of atomic erbium. Following work by the Innsbruck group, we trap erbium atoms in a narrow-line magneto-optical trap near 582.84 nm. Subsequently, we load erbium atoms into the quasistatic dipole potential generated by a focused beam near 10.6 μm wavelength provided by a CO2-laser and cool atoms evaporatively to quantum degeneracy. In the future, we plan to investigate topological states and strong synthetic magnetic fields with the rare earth atomic quantum gas.

Q 51.4 Thu 15:30 P 104

State-dependent transport of neutral atoms in two dimensions — •Gautam Ramola, Stefan Brakhane, Geol Moon, Max Werninghaus, Carsten Robens, Richard Winkelmann, Alexander Knieps, Wolfgang Alt, Dieter Meschede, and Andrea Alberti — Institut für Angewandte Physik, Bonn, Germany

Discrete time quantum walks (DTQWs) offer a versatile platform for exploring quantum transport phenomena involving the delocalization of pseudo-spin-1/2 particles on a lattice. Our recently built 2D state-dependent optical lattice setup provides an ideal platform to simulate topologically protected edge state transport using DTQWs in two dimensions [1]. The 2D quantum simulator makes use of polarization-synthesized lattice beams to deterministically transport neutral Cs atoms based on their internal state [2]. Furthermore, a high numerical aperture (NA = 0.92) objective lens [3] is used for imaging and addressing atoms with single site resolution, enabling us to create sharp boundaries between different topological domains. I will report on the experimental realization of the polarization synthesized optical lattice in two dimensions and on the most recent results.

[1] T. Groh et al. Robustness of topologically protected edge states in quantum walk experiments with neutral atoms, Phys. Rev. A **94** (2016)
[2] C. Robens et al. Fast, high-precision optical polarization synthesizer for ultracold-atom experiments, arXiv:1611.07952 (2016)
[3] C. Robens et al. A high numerical aperture (NA = 0.92) objective lens for imaging and addressing of cold atoms, arXiv:1611.02159 (2016)

Q 51.5 Thu 15:45 P 104

Robustness of Topologically Protected Edge States in Quantum Walk Experiments with Neutral Atoms — •Thorsten Groh[1], Stefan Brakhane[1], Wolfgang Alt[1], Dieter Meschede[1], Janos Karoly Asbóth[2], and Andrea Alberti[1] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, D-53115 Bonn, Germany — [2]Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Hungarian Academy of Sciences, H-1525 Budapest, P.O. Box 49, Hungary

Discrete time quantum-walks (DTQWs) with trapped ultracold atoms offer a versatile platform for the experimental investigation of topological insulator materials. An experimental proposal based on neutral atoms in spin-dependent optical lattices to realize one- and two-dimensional discrete-time quantum walks (DTQWs) with spatial boundaries between distinct Floquet topological phases is presented.

The robustness of topologically protected edge states arising at the boundaries separating distinct topological domains is analyzed in the presence of experimentally induced decoherence. Under realistic decoherence conditions, the experimental feasibility to observe unidirectional, dissipationless transport of matter waves along topological boundaries is investigated. [1]

[1] T. Groh, S. Brakhane, W. Alt, D. Meschede, J. K. Asbóth, and A. Alberti, "Robustness of topologically protected edge states in quantum walk experiments with neutral atoms," Phys. Rev. A 94, 013620 (2016).

Q 51.6 Thu 16:00 P 104

Implementing supersymmetric dynamics in ultracold atom systems — •Martin Lahrz, Christof Weitenberg, and Ludwig Mathey — Universität Hamburg, Hamburg, Germany

Supersymmetry plays an essential role in solvable quantum mechanical problems, ranging from the hydrogen atom to soliton physics. The solvability of these systems can be traced back to supersymmetric partner Hamiltonians and their isospectral features. In this talk, we propose a detailed experimental setup for ultracold atom systems to realize such a pair of supersymmetric Hamiltonians. To test their supersymmetric relation, we propose a Mach–Zehnder interference experiment that can be realized with current technology. It compares the dynamics of a coherently split wave packet under these Hamiltonians. The contrast of the resulting interference pattern gives a sharp signal if the Hamiltonians form a supersymmetric pair. This proposal establishes ultracold atom dynamics and matter–wave interferometry as a device to test sophisticated features of quantum mechanical systems with clarity.

Q 51.7 Thu 16:15 P 104

The PRIMUS-Project; an optical dipole trap under microgravity — •Christian Vogt[1], Sascha Kulas[1,2], Andreas Resch[1], Sven Herrmann[1], Claus Lämmerzahl[1], and the PRIMUS-Team[1,3] — [1]ZARM, Universität Bremen — [2]JPL, Pasadena, USA — [3]Institut für Quantenoptik, LU Hannover

Matter wave interferometry in microgravity offers the potential of largely extended interferometry times and thus precision measurements with much increased sensitivity. Motivated by this prospect, a large effort is currently underway to advance the necessary technology and perform first such atom optical experiments on microgravity platforms such as drop towers, zero-g airplanes or sounding rockets. The QUANTUS collaboration has thereby established a magnetic chip trap as a compact and efficient source of matterwaves for such microgravity cold atom experiments. Within the PRIMUS experiment we pursue another approach and set up an optical dipole trap as an alternative source for matter wave interferometry in microgravity. While this comes with additional technical challenges, it also offers several benefits, such as the possible application of Feshbach resonances, improved harmonicity of the trap or the trapping of all mF states. To implement the dipole trap we use a high power laser at 1960nm wavelength and load atoms directly from a Rb magneto optical trap. Here we will report on the current status and first results from the project. The PRIMUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50 WM 1642.