Q 21: Ultracold Atoms (Trapping and Cooling)

Time: Tuesday 14:00–16:00 Location: f442

Group Report Q 21.1 Tue 14:00 f442

Ultracold atom-ion mixtures in optical light fields — •Pascal Weckesser[1], Fabian Thielemann[1], Daniel Hönig[1], Julian Schmidt[1,2], Kai Lok Lam[1], Markus Debatin[1,3], Leon Karpa[1], and Tobias Schaetz[1] — [1]Albert-Ludwigs-Universität Freiburg, Germany — [2]Laboratoire Kastler Brossel Paris, France — [3]Universität Kassel, Germany

During the past decades ultracold atoms and ions have been two important pillars in atomic and molecular physics. Recently several groups have combined both systems trying to prepare the mixture at ultracold temperatures. Using optical dipole traps for ions [1] provides a new pathway to achieve these ultracold mixtures, as this approach overcomes the intrinsic micromotion heating effects of a conventional Paul trap [2], currently limiting most experiments.

In this talk, we present our experimental setup combining $^{138}Ba^{+}$ ions with either ^{6}Li or ^{87}Rb atoms. For the former case we present first sympathetic cooling measurements within a Paul trap and discuss the micromotion induced limitation. For the latter case we show how this limitation can be overcome by transferring both atoms and ions in a combined optical dipole trap [3]. These new findings allow the investigation of new phenomena, such as atom-ion Feshbach resonances or the formation of new mesoscopic molecular states.

[1] A. Lambrecht et al., Nature Photonics 11.11 (2017): 704.
[2] M.Cetina et al., Phys.Rev.Lett. 109,253201 (2012)
[3] J. Schmidt et al., arXiv:1909.08352 (2019).

Q 21.2 Tue 14:30 f442

Erste Ergebnisse eines deterministischen Einzelionen-Mikroskops und Ionen-Springbrunnens — •Felix Stopp, Henri Lehec und Ferdinand Schmidt-Kaler — QUANTUM, Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Einzelne laser- und sympathetisch mitgekühlte Ionen, die deterministisch aus einer linearen Paulfalle extrahiert werden, erlauben neuartige Methoden der Mikroskopie [1], der Implantation [2] und der Abtastung von Oberflächen zur Untersuchung des Stern-Gerlach-Effekts [3]. Wir präsentieren ein hochstabiles Einzelionen-Mikroskop, um die gesamte Bandbreite der oben genannten Anwendungen zu bearbeiten. Wir stellen die deterministische Extraktion von Ionen mit niedrigen Energien von ≥ 40 eV vor. Um Quantenzustände nach Wechselwirkungen auslesen zu können, speichern wir ein einzelnens Ion, welches dann aus der Falle beschleunigt, an einem externen elektrischen Potential reflektiert, wieder in die Falle zurückbeschleunigt und dort gefangen und nachgewiesen wird.

[1] G. Jacob et al., Phys. Rev. Lett. **117**, 043001 (2016)
[2] K. Groot-Berning et al., Phys. Rev. Lett. **123**, 106802 (2019)
[3] C. Henkel et al., New J. Phys. **21**, (2019)

Q 21.3 Tue 14:45 f442

Real-time imaging of single laser-cooled atoms coupled to a nanoscale optical waveguide — Yijian Meng[1], •Christian Liedl[2], Sebastian Pucher[1,2], Arno Rauschenbeutel[1,2], and Philipp Schneeweiss[1,2] — [1]VCQ, TU Wien – Atominstitut, Stadionallee 2, 1020 Wien, Austria — [2]Department of Physics, Humboldt-Universität zu Berlin, 10099 Berlin, Germany

Here, we demonstrate single-atom sensitive imaging of atoms coupled to the evanescent mode of an optical nanofiber in real-time. Degenerate Raman cooling is used to keep the atoms close to the motional ground state of the nanofiber-based trapping sites [1] and to generate the atomic fluorescence signal for imaging. We obtain a signal-to-noise ratio sufficient to identify an atom within 100 ms, allowing us to record movies of single atoms with up to 30 frames during one experimental run.

When, e.g., two atoms are coupled to the nanofiber, their emission into the waveguide can interfere constructively or destructively, depending on the inter-atomic distance. Using our imaging technique, we measure this effect and obtain good agreement with expectations.

Our results enable a new level of control for cold-atom based nanophotonic systems. For example, by post-selecting measurements on a certain number of atoms, also complex light-matter interaction phenomena can be understood atom by atom. Moreover, our findings provide the basis for live, position-resolved feedback onto the experimental system.

[1] Y. Meng et al., Phys. Rev. X 8, 031054 (2018).

Q 21.4 Tue 15:00 f442

Slowing Krypton with Permanent Magnets — •Ergin Simsek, Carsten Sieveke, Pablo Woelk, Daniel Voigt, Malte Peters, and André Lohde — Carl Friedrich von Weizsäcker-Zentrum für Naturwissenschaft und Friedensforschung (ZNF), Universität Hamburg

Krypton is an excellent indicator for the detection of nuclear reprocessing activities and ground water dating. The Atom Trap Trace Analysis (ATTA) promises to be the next generation instrument for measuring the concentration of Krypton isotopes in air and water samples. Here the concentration is determined by measuring the capture rate in a MOT setup. For precooling the atoms to velocities below the MOT capture limit the use of a Zeeman slower is a suitable option. Due to the rapid development of magnetic materials in recent time, permanent magnets are now an attractive alternative to the commonly used magnetic coils for the generation of a strong and precisely shaped magnetic field. Our setup combines a purely optical preparation of metastable Krypton and a Zeeman Slower with transversal magnetic field in Halbach configuration, consisting of several small Neodym magnets. The transversal shape of the field makes it necessary to carefully prepare the atoms into the correct Zeeman sublevel. Here we present a thorough evaluation of our setup with respect to beam forming, metastable generation, state preparation and beam deceleration and analyse its suitability for ATTA.

Q 21.5 Tue 15:15 f442

Evaluation of precooling Krypton for a Zeeman slower — •André Lohde, Ergin Simsek, Carsten Sieveke, Pablo Woelk, and Daniel Voigt — Carl Friedrich von Weizsäcker-Zentrum für Naturwissenschaft und Friedensforschung (ZNF), Universität Hamburg

Krypton is an excellent indicator for the detection of nuclear reprocessing activities and ground water dating. The Atom Trap Trace Analysis (ATTA) promises to be the next generation instrument for measuring the concentration of Krypton isotopes in air and water samples. Here the concentration is measured by measuring the capturing rate in a MOT setup. For precooling the atoms to velocities below the MOT capture limit we use a Zeeman slower. The necessary beam forming is done with a capillary system and transverse laser cooling. The crucial preparation into the metastable state is done optically. We are aiming towards a short Zeeman slower setup so the beam diverges less and the atoms can be trapped more efficiently. Consequently at room temperature a large portion of the atoms are above the capture limit of the Zeeman slower. Liquid nitrogen or thermoelectric precooling increases the number of atoms below the capture limit. Additionally the metastable preparation efficiency is enhanced but also the beam forming by the capillary system is altered. In this talk we present precooling Krypton with both approaches, firstly a thermoelectric cooling and secondly liquid nitrogen cooling. We also give an evaluation based on simulations and measurements on how precooling enhances the efficiencies at different stages of our setup.

Q 21.6 Tue 15:30 f442

Optical trapping and optical delta-kick collimation of atom chip based BECs — •Simon Kanthak[1], Martina Gebbe[2], Matthias Gersemann[3], Sven Abend[3], Ernst M. Rasel[3], Markus Krutzik[1,4], and the QUANTUS team[1,2,3,4,5] — [1]Institut für Physik, HU Berlin — [2]ZARM, Universität Bremen — [3]Institut für Quantenoptik, LU Hannover — [4]Ferdinand-Braun-Institut, Berlin — [5]Institut für Physik, JGU Mainz

Inertial sensors based on matter wave interferometry highly benefit from low expansion rates and extended interrogation times of delta-kick collimated BECs. While atom chip technology allows for fast and efficient BEC production in compact setups, optical dipole traps offer various advantages compared to magnetic traps in the context of controlling the atomic interactions via Feshbach fields or in the reduction of the expansion rates via optical delta-kick collimation with improved harmonic potentials. To combine the benefits of both trap types, we realized a hybrid trap geometry consisting of a single beam dipole trap at 1064 nm in the vicinity of an atom chip. We report on our results of the efficient preparation and transfer of a ^{87}Rb BEC from an atom chip trap into a dipole trap and demonstrate the capability of optical delta-kick collimation.

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Q 21.7 Tue 15:45 f442

An Optical Dipole Trap in a Drop Tower - the Primus Project

— •Christian Vogt[1], Marian Woltmann[1], Sven Herrmann[1], Claus Lämmerzahl[1], and The Primus-Team[1,2] — [1]University of Bremen, Center of Applied Space Technology and Microgravity (ZARM), 28359 Bremen — [2]Institut für Quantenoptik, LU Hannover

Atom interferometers based on cold atoms have been turned into effective tools to measure weakest forces in the last decades. The sensitivity of these devices scales with the square of interrogation time, normally limited by the time of free fall. Operating atom interferometers in microgravity, like in the drop tower in Bremen, can extend this time from hundreds of milliseconds to several seconds. The leading technology for ultra-cold atoms in microgravity is based on so called atom chips, generating magnetic traps with low power consumption. We focus on an alternative approach based on an optical dipole trap. These come with several advantages like the ability to trap all magnetic sub-states or apply Feshbach resonances. This talk will present recent results from the optical trapping of atoms in microgravity and highlight the benefits of a combined approach including atom chip and dipole trap. The PRIMUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number DLR 50 WM 1642.