Q 63: Ultracold Atoms (Trapping and Cooling)

Time: Friday 10:30–12:30 Location: S SR 211 Maschb.

Q 63.1 Fri 10:30 S SR 211 Maschb.

A 2D-MOT with metastable Krypton: An evaluation — •Pablo Woelk, Carsten Sieveke, Ergin Simsek, and Markus Kohler — 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.

Challenging for a MOT setup with metastable noble gas atoms is the effective preparation into the metastable state. Usually this excitation is RF-driven, making it necessary to flush the vacuum system for hours after each measurement to avoid cross contamination.

An all optical excitation into the metastable state promises to reduce the measurement time by one order of magnitude. The question arises whether a 2D-MOT is an efficient instrument for optically excited metastable atoms, as it has proven to be for many other elements.

Here we present a thorough evaluation of our 2D-MOT/3D-MOT setup in combination with VUV plasma lamps for the excitation into the metastable state and analyze the suitability of these setups.

Q 63.2 Fri 10:45 S SR 211 Maschb.

BECCAL - Atom Optics with BECs on the ISS — •Dennis Becker[1], Kai Frye[1], Christian Schubert[1], Sven Abend[1], Waldemar Herr[1], Ernst M. Rasel[1], and BECCAL Team[1,2,3,4,5,6] — [1]IQ, LU Hannover — [2]U Ulm — [3]HU Berlin — [4]FBH Berlin — [5]JGU Mainz — [6]ZARM U Bremen

The NASA-DLR Bose-Einstein condensate and Cold Atom Laboratory (BECCAL) is a joint multi-user, multi-purpose facility to exploit the unique microgravity conditions on the International Space Station (ISS) for experiments with condensed Rb and K atoms in regimes inaccessible on ground. In microgravity, no gravitational sag acts on an atomic ensemble and it stays at rest with respect to its environment. This enables an extended time of flight in free fall at the order of seconds to tens of seconds. These two aspects are essential for the various experiments enabled by BECCAL.

The system will be based on an atom chip for efficient evaporation and excellent control of the quantum degenerate atomic clouds. The setup will provide a variety of trapping potentials including static and RF-dressed magnetic as well as red- and blue-detuned optical potentials. BECCAL will serve as a platform to realize experiments in atom optics, physics of quantum degenerate gases, their mixtures, and atom interferometry. Here, we present an insight on some of the proposed experiments and the current status of the project.

The BECCAL project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under the grant numbers 50 WP 1431 and 1700.

Q 63.3 Fri 11:00 S SR 211 Maschb.

The Design of a Laser System for BECCAL - a Quantum Gas Experiment on the ISS — •Victoria Henderson[1], Ahmad Bawamia[2], André Wenzlawski[3], Jean-Pierre Marburger[3], Andreas Wicht[2], Patrick Windpassinger[3], Markus Krutzik[1,2], Achim Peters[1,2], and the BECCAL Team[1,2,3,4,5,6,7] — [1]HU Berlin — [2]Ferdinand-Braun-Institut, Berlin — [3]JGU, Mainz — [4]LU Hannover — [5]ZARM, Bremen — [6]DLR, Bremen — [7]Universität Ulm

BECCAL (BEC - Cold Atom Laboratory) is a cold atom experiment designed to be operated on the ISS. It is a collaboration between DLR and NASA, built upon a heritage of sounding rocket and drop tower experiments as well as NASA's CAL. This multi-user facility will enable us to explore fundamental physics research with Rb and K BECs and ultra-cold atoms in microgravity, facilitating prolonged timescales and ultra-low energy scales compared to those achievable on Earth.

The complexity of the light fields required presents a unique challenge for laser system design, especially in terms of the stringent size weight and power limitations. To meet this we combine micro-integrated diode lasers (from FBH) with Zerodur boards of miniaturized free-space optics (from JGU), all interconnected via fibre optics. These technologies have proven their reliability in many qualification tests. We will present the current design of the BECCAL laser system, alongside the requirements, concepts and heritage that has formed it.

This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR50WP1702.

Q 63.4 Fri 11:15 S SR 211 Maschb.

Evaporative cooling in an optical dipole trap in microgravity — •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. To take full advantage of the free fall time a fast atom preparation is required, where colder atomic clouds lead to smaller error contributions in the phase estimation. Evaporative cooling both determines the final temperature and in most cases limits the cooling cycle. While the process on ground is driven by gravity, measurements in microgravity revealed no significant differences in performance where the key is called the dimension of evaporation. This talk will be about recent results of evaporative cooling in microgravity. Furthermore techniques for fast and effective evaporation from optical dipole traps on ground and their applicability to microgravity environments on the example of the PRIMUS experiment will be discussed. The PRIMUS-Project is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economic Affairs and Energy (BMWi) under grant number DLR 50 WM 1642.

Q 63.5 Fri 11:30 S SR 211 Maschb.

Harmonizing the Magnetic Trap Oscillator — •Bastian Zapf and Reinhold Walser — Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstr. 4a, 64289 Darmstadt

Experiments with Bose-Einstein condensates in space [1] use microelectronic chips to provide magnetic trapping fields. These so-called atom chips [2] consist of lithographically printed planar wire structures, with modern chips containing up to a few hundred individually controllable current-carrying wires. Since there are no free currents in the trapping region, the field can locally be derived from a scalar potential which is conveniently expanded into multipoles [3]. This yields a compact description of the magnetic field, suitable for straightforward communication with experimenters and highly useful for efficient computation. We discuss ways to characterize and control the anharmonicity of trapping potentials.

[1] D. Becker et. al., *Space-borne Bose-Einstein condensation for precision interferometry*, Nature, **562** 391 (2018).
[2] J. Reichel and V. Vuletic, *Atom Chips*, Wiley-VCH (2011).
[3] T. Bergeman et. al., *Magnetostatic trapping fields for neutral atoms*, Phys. Rev. A, **35** 1536 (1987).

Q 63.6 Fri 11:45 S SR 211 Maschb.

QUANTUS-2 - Utilizing quadrupole mode excitation to gain ultra-low expansion rates of an atomic ensemble — •Merle Cornelius[1], Sven Herrmann[1], Claus Lämmerzahl[1], and the QUANTUS-Team[1,2,3,4,5,6] — [1]ZARM, Universität Bremen — [2]Institut für Quantenoptik, LU Hannover — [3]Institut für Physik, JGU Mainz — [4]Institut für Physik, HU Berlin — [5]Institut für Quantenphysik, Universität Ulm — [6]Institut für angewandte Physik, TU Darmstadt

Highly sensitive quantum sensors based on atom interferometry enable precision measurements for various applications. Their sensitivity benefits from long interferometers times in the range of seconds, which in turn require ultra-low expansion rates of the atomic ensemble, typically realized by magnetic lensing (delta-kick collimation).

QUANTUS-2 is a high-flux BEC source operating in microgravity at the drop tower in Bremen. Our setup utilizes an atom chip and enables rapid BEC production. On the downside the resulting cylindrically shaped magnetic lens only allows for a good collimation in the two radial directions. We solve this problem by exciting quadrupole modes to collimate the axial direction, thus achieving three dimensional expansion rates in the order of 100 μm/s, which corresponds to a thermal temperature below 100 pK. Hence we provide an ideal source for highly sensitive atom interferometry on long time scales.

The QUANTUS 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 50WM1555.

Q 63.7 Fri 12:00 S SR 211 Maschb.

A single-laser alternating-frequency magneto-optical trap — •Benjamin Wiegand[1], Bastian Leykauf[1], Klaus Döringshoff[1], Y Durvasa Gupta[1], Achim Peters[1,2], and Markus Krutzik[1,2] — [1]Institut für Physik, HU Berlin — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin

The miniaturization of cold atom systems is of key importance for experiments on small satellite platforms that put high demands on size, weight and power consumption as well as for future commercial applications. In that regard, the laser system plays an important role as each laser requires driving electronics, temperature stabilization and light distribution modules.

In this talk, we present a simple technique for a magneto-optical trap (MOT) that is driven by a single laser only: the alternating-frequency MOT (AF-MOT) uses an agile light source that targets cooling and repumping transitions sequentially by tuning the current of the laser diode. We report on the experimental demonstration of such a system for ^{87}Rb and ^{85}Rb based on a micro-integrated extended cavity diode laser (ECDL) and present the results of its characterization in terms of atom numbers, atomic density and cloud temperature for different operation parameters.

This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant numbers DLR50WM1857 and DLR50WP1702 as well as by the profile partnership project between Humboldt University of Berlin and the National University of Singapore.

Q 63.8 Fri 12:15 S SR 211 Maschb.

Realistic simulations of Bose-Einstein condensates in magnetic traps on graphics processing units — •Lev Plimak and Reinhold Walser — Institut fuer Angewandte Physik, Technische Universitaet Darmstadt, Hochschulstr. 4a, 64289 Darmstadt

Experiments with Bose-Einstein condensates in microgravity [1] allow for much longer expansion times than similar experiments in gravity. This poses a new challenge for the numerical-simulation community. In particular, asymmetry and anharmonicity of real magnetic traps may play a deciding role in matching theory to the experiment. Distributed computing on graphical processing units [2] (GPUs) is a natural environment for such simulations.

We present results of a direct simulation of the Rb87 condensate in the QUANTUS-2 release trap [1]. The trap potential is calculated using the actual QUANTUS-2 chip geometry without simplifications of any kind. Mathematical methods suited for the GPU environment are discussed.

[1] D. Becker et. al., Space-borne Bose-Einstein condensation for precision interferometry}, Nature, 562 391 (2018).

[2] https://en.wikipedia.org/wiki/
General-purpose_computing_on_graphics_processing_units