Q 17: Kalte Atome: Fallen und Kühlung

Time: Monday 16:30–19:00 Location: V7.02

Q 17.1 Mon 16:30 V7.02

Towards a two-species quantum degenerate gas of ^{6}Li and ^{133}Cs atoms and molecules — •Marc Repp, Rico Pires, Juris Ulmanis, Robert Heck, Romain Müller, Stefan Schmidt, and Matthias Weidemüller — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg

The ability to precisely control the interactions of a Bose-Fermi mixture of ^{133}Cs and ^{6}Li at phase-space densities close to quantum degeneracy allows one to study many different aspects of few- and many-body physics in the most extreme alkali atom combination. The extremely large mass-difference of Li and Cs results in the smallest scaling factor of all alkali combinations for the appearance of universal Efimov states [1,2] of 4.88 for ^{133}Cs$_2$^{6}Li [3] (cf. to 22.7 for homonuclear mixtures). The talk will present the design and the current status of our experimental apparatus for achieving higher phase-space densities. The scheme of a double-species Zeeman slower that allows to subsequently decelerate Cs and Li atoms from an atomic oven to the capture velocities of the MOTs will be shown. After further cooling the Cs atoms via Raman side band cooling, both species are transferred into dipole traps where forced evaporative cooling will bring the samples to quantum degeneracy. The possibility of tuning interaction strengths via magnetic fields would enable the study of interspecies Efimov states of Li and Cs.

[1] V. Efimov, Sov. J. Nuc. Phys. 12, 589 (1971)
[2] E. Braaten & H.-W. Hammer, Annals of Physics 322, 120 (2007)
[3] J. P. D'Incao & B. D. Esry, Phys. Rev. A 73, 030703 (2006)

Q 17.2 Mon 16:45 V7.02

Microwave guiding of electrons in planar quadrupole guides — •Johannes Hoffrogge, Jakob Hammer, and Peter Hommelhoff — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching bei München

We study the guiding of free space electrons in an AC quadrupole guide [1]. Combining the electrode pattern of a surface electrode Paul trap with microwave transmission line structures on a planar substrate leads to exceptionally tight transverse confinement. With microwave driving frequencies, radial trap frequencies in the gigahertz range can be realized. This allows for the precise control of the trajectories of slow electrons with kinetic energies of a few electron volts by means of purely electric fields. We provide a detailed study, both experimentally and numerically, of the kinematics of the electrons and its dependence on the driving parameters of the guide. We also discuss more complex electrode structures like beam splitting elements for guided electrons as well as elements with longitudinal extensions larger than the driving wavelength. These require to consider traveling wave effects in the electrode layout [2]. The combination of a quadrupole electron guide with a single atom tip field emitter as an electron source should allow for the direct preparation of electrons in low lying quantum states of the transverse harmonic oscillator potential. This would enable new guided matter-wave experiments with electrons.

[1] J. Hoffrogge, R. Fröhlich, M. A. Kasevich and P. Hommelhoff, *Phys. Rev. Lett.* **106**, 193001 (2011)
[2] J. Hoffrogge and P. Hommelhoff, *New J. Phys.* **13**, 095012 (2011)

Q 17.3 Mon 17:00 V7.02

Shaping the evanescent field of an optical nano-fiber for cold atom trapping — •Ciaran Phelan, Tara Hennessy, and Thomas Busch — Physics Department, University College Cork, Cork, Ireland / Quantum Systems Unit, OIST, Okinawa, Japan

Optical nano-fibers have a number of striking properties which have recently led to their use as a means of trapping neutral atoms. The small diameter of the fiber results in most of the power transmitted in the fiber being contained in the evanescent field. Furthermore, the confinement of the guided fiber modes means that the fiber mode can maintain its profile over a much greater distance than the Rayleigh range of the equivalent free space mode.

Recently, a number of schemes for trapping neutral atoms in the evanescent field have been proposed. One of these involves combining the effect of a red detuned (with respect to the trapped atom's transition frequency) attractive field and a blue detuned repulsive field to form a cylindrical potential minimum surrounding the fiber.

By counter-propagating two red detuned fiber modes with opposite helical phase terms, an interference pattern is formed in the evanescent field. This, when combined with a repulsive fundamental mode, causes the splitting of the circularly symmetric ring trap into an array of traps located on a circle surrounding the fiber. This one dimensional array of traps, with sub-wavelength spacing between the traps has the potential to form a Mott insulator on a ring surrounding the fiber.

Q 17.4 Mon 17:15 V7.02

Creating atom-number states around tapered optical fibres by loading from an optical lattice — •Tara Hennessy and Thomas Busch — University College Cork, Republic of Ireland

We present a scheme where the evanescent field around a sub-wavelength diameter tapered nanofibre is combined with the periodic potential of an optical lattice. We show that when the fibre is aligned perpendicularly to the transverse plane of a two-dimensional optical lattice the evanescent field around the fibre can be used to create a time-dependent potential which locally melts the lattice potential.

We first describe the disturbance of the lattice due to scattering of the lattice beams on the fibre, then show how the attractive van der Waals potential close to the surface can be compensated by a blue-detuned evanescent field and finally characterise the resulting atomic samples in the melted part of the lattice. This scheme allows access to a regime in which a small number of particles can be addressed locally without disturbing the rest of the lattice. Furthermore, if the environment around the fibre is given by a well ordered Mott-Insulator state, the melting of the lattice transfers a controllable and well-defined number of atoms from the individual lattice sites around the fibre into the fibre potential. The resulting state is therefore number squeezed and can be used for applications in quantum information or metrology.

Q 17.5 Mon 17:30 V7.02

Interplay of cavity and EIT-cooling with neutral atoms in an optical resonator — •René Reimann, Wolfgang Alt, Tobias Kampschulte, Sebastian Manz, Seokchan Yoon, and Dieter Meschede — Institutfür Angewandte Physik der Universität Bonn, Wegelerstr. 8,53115 Bonn

The motional properties of single atoms inside an optical resonator can be changed significantly by the simultaneous interaction with a near-resonant control light field and a weak probing field coupled to the resonator. Following our findings in the case of electromagnetically induced transparency (EIT) with a single neutral atom [1] we investigate the roles of EIT cooling and cavity cooling within our system. We identify cooling and heating regions associated with the EIT-dark state or the atom-cavity dressed states [2]. By this the dressed states of the system and their dependency on the single- and two-photon-detunings can be investigated experimentally.

Further we show a qualitative difference in the cooling dynamics between one and two atoms coupled to the optical resonator.

[1] T. Kampschulte *et al.*, Phys. Rev. Lett. **105**, 153603 (2010)
[2] M. Bienert *et al.*, arXiv, 1109.1666v1 (2011)

Q 17.6 Mon 17:45 V7.02

Cooling of a trapped atomic two-level system in a driven optical resonator — •Marc Bienert and Giovanna Morigi — Universität des Saarlandes, Theoretische Physik, D-66041 Saarbrücken, Germany

We investigate the cooling dynamics of the motional degree of freedom of a single atom which is trapped inside an optical resonator in the limit of small mechanical coupling. The atomic dipole interacts with a single mode of the cavity, which is weakly pumped by an external laser. Such a configuration shows several parameter regions, where interference between motional and cavity degrees of freedom can occur. We identify the parameter regions where efficient cooling can be found, identify the underlying physical processes, and present the cooling rate and final temperature for optimal choices of the parameters.

Q 17.7 Mon 18:00 V7.02

Cavity cooling below the recoil limit — •Matthias Wolke, Hans Kessler, Jens Klinder, and Andreas Hemmerich — Institut für Laser-Physik, Universität Hamburg, Germany

We study the controlled excitation of a Bose-Einstein-condensate (BEC) into momentum states of $\pm 2\hbar k$ and the cooling back to zero momentum. In our system a BEC of ^{87}Rb is dispersively coupled to the mode of an ultra-high-finesse standing wave cavity with narrow linewidth ($\approx 9\,$kHz). Exploiting the cavity enhanced scattering we deposit energy ($4E_{recoil} \approx h \cdot 14\,$kHz) into the BEC by illuminating it with a laser blue detuned to the cavity resonance. This can be reversed by switching the detuning to the red flank of the cavity and thereby cool the atoms efficiently down to zero momentum.

Q 17.8 Mon 18:15 V7.02

Realization of a two-species ^{40}K and ^{87}Rb 2D+MOT — •Tracy Li[1,2], Lucia Duca[1], Monika Schleier-Smith[1,2], Martin Boll[2], Martin Reitter[1], Jens Philipp Ronzheimer[1], Ulrich Schneider[1], and Immanuel Bloch[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

Confining quantum degenerate fermions in an optical lattice realizes a highly tunable system for simulating condensed matter phenomena that are difficult to probe in real solids. The evaporative cooling process used to produce quantum degenerate fermions is facilitated by capturing a large number of atoms in the preceding magneto-optical trap (MOT). Optimizing the evaporative cooling process is essential to reaching the low entropies needed to approach, for example, anti-ferromagnetically ordered states in the fermionic Hubbard model. To this end, we have realized a two-species 2D+MOT and two-species 3D-MOT for fermionic ^{40}K and bosonic ^{87}Rb in our experiment [1, 2]. The 2D+MOT is a pre-cooling stage and generates a collimated, continuous beam of atoms for more efficient loading into the two-species 3D-MOT. We present the implementation and characterization of the two-species 2D+MOT. We observe collisional losses in the two-species 3D-MOT and ameliorate these losses using a dark SPOT MOT for ^{40}K. With this setup, we achieve atom numbers of 1x10^{8} ^{40}K and 7x10^{10} ^{87}Rb in the two-species 3D-MOT.

[1] Dieckmann et.al., PRA 58, 3891 (1998).
[2] Ridinger et.al., Eur. Phys. J. D 65, 223-242 (2011).

Q 17.9 Mon 18:30 V7.02

Realization of a magneto-optical trap for erbium atoms — •Jens Ulitzsch, Henning Brammer, Riad Bourouis, and Martin Weitz — Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, 53115 Bonn

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

We report on progress in an ongoing experiment directed at the generation of an atomic erbium Bose-Einstein condensate by evaporative cooling in a far detuned optical dipole trap. In the present stage of the experiment, a magneto optical trap (MOT) for this rare earth metal atom has been realized, loaded from a Zeeman-slowed atomic beam. The experiment uses a single laser frequency tuned to the red of the $400,91nm$ cooling transition. No repumping radiation is required for the MOT operation, despite the complex energy level structure of the erbium atom.

Q 17.10 Mon 18:45 V7.02

Zeeman slower with permanent magnets — •Stefan Vogt, Stephan Falke, Uwe Sterr, and Christian Lisdat — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

A Zeeman slower offers a high flux of cold atoms and thus is a useful tool for many experimental setups. Especially for experiments that require atom trapping with a high repetition rate, such as neutral atom clocks, a Zeeman slower is the best choice. However, the high power consumption caused by the field coils of a typical slower design is a drawback in terms of thermal management and transportability.

Not only transportable setups for clock comparisons between laboratories but also the operation of optical clocks in space [1] call for compact setups with low power consumption, e.g., by using permanent magnets instead of field coils [2,3]. In our approach, we use a pattern of standard-size NdFeB magnet blocks to create a field identical to that of the Zeeman slower of our stationary strontium lattice clock.

By allowing both radial displacement and angular tilt of the blocks, we achieve a magnetic field that is oriented parallel to the atomic beam throughout the slower. The tilt reduces the magnetic field behind the slower.

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[1] S. Schiller *et al.*, Exp. Astron. 23, 573 (2009).
[2] Y. Ovchinikov, Optics Communications 276, 261 (2007).
[3] P. Cheiney *et al.*, Rev. Sci. Instrum. 82, 063115 (2011).