Q 2: Ultracold Atoms: Trapping and Cooling (with A)

Time: Monday 14:00–16:00 Location: A 320

Q 2.1 Mo 14:00 A 320

Shortcut to adiabaticity: fast optimal frictionless atom cooling in harmonic traps — •Andreas Ruschhaupt — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany

A method is proposed to cool down atoms in a harmonic trap as in a perfectly slow adiabatic expansion but in a much shorter time. This is achieved by designing the time dependence of the trap frequency, the harmonic trap may even become an expulsive parabolic potential in some time interval. The resulting cooling times have no fundamental lower bound and are shorter than previous minimal times using optimal-control bang-bang methods and real frequencies.

Ref.: [1] Xi Chen, A. Ruschhaupt, S. Schmidt, A. del Campo, D. Guery-Odelin and J. G. Muga, arXiv:0910.0709v1 [quant-ph]

[2] J. G. Muga, Xi Chen, A. Ruschhaupt and D. Guery-Odelin, J. Phys. B: At. Mol. Opt. Phys. 42 (2009) 241001 (FTC)

Q 2.2 Mo 14:15 A 320

Fiber-pigtailed atoms — •Daniel Reitz, Rudolf Mitsch, Melanie Müller, Eugen Vetsch, Samuel T. Dawkins, and Arno Rauschenbeutel — QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz

We present our recent results on trapping laser-cooled cesium atoms around a subwavelength-diameter optical nanofiber. The atoms are localized in the evanescent field in a 1d optical lattice, created by blue- and a red-detuned laser beams, launched through the fiber. We detect the atoms by measuring the absorption of a weak resonant probe beam, sent through the fiber, which couples to the atoms via the evanescent field. Remarkably, the ensemble of 2000 trapped atoms is optically dense. Furthermore, we demonstrate a fiber-based optical conveyor belt. For this purpose, the two counter-propagating red-detuned beams are mutally detuned, thereby setting the optical lattice in motion and transporting the atoms along the fiber. Finally, we demonstrate an interferometric measurement of the optical phase shift due to the atomic ensemble. Our technique opens the route towards the direct integration of laser-cooled atomic ensembles within fiber networks, an important prerequisite for large scale quantum communication schemes. Moreover, it is ideally suited to the realization of hybrid quantum systems that combine atoms with, e.g., solid state quantum devices.

Financial support by the ESF (EURYI Award) and the Volkswagen Foundation (Lichtenberg Professorship) is gratefully acknowledged.

Q 2.3 Mo 14:30 A 320

Laser cooling of a magnetically guided ultra cold atom beam — •Anoush Aghajani-Talesh, Markus Falkenau, Valentin Volchkov, Axel Griesmaier, and Tilman Pfau — Universität Stuttgart, 5. Physikalisches Institut

We report on the transverse laser cooling of a magnetically guided beam of ultra cold chromium atoms. Radial compression by a tapering of the guide is employed to adiabatically heat the beam. Subsequently, heat is extracted from the atom beam by a two-dimensional optical molasses perpendicular to it, resulting in a significant increase of atomic phase space density. A magnetic offset field is applied to prevent optical pumping to untrapped states. Our results demonstrate that by a suitable choice of the magnetic offset field, the cooling beam intensity and detuning, atom losses and longitudinal heating can be avoided. Final temperatures below 65 μK have been achieved, corresponding to an increase of phase space density in the guided beam by more than a factor of 30. We discuss the resulting implications for the loading of a optical dipole trap from the beam [1].

[1] A Aghajani-Talesh, M Falkenau, A Griesmaier, and T Pfau. A proposal for continuous loading of an optical dipole trap with magnetically guided ultra cold atoms. *J. Phys. B.* **42** 245302 (2009).

Q 2.4 Mo 14:45 A 320

A miniaturized microwave guide for electrons — •Johannes Hoffrogge and Peter Hommelhoff — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching bei München

We are currently setting up an experiment aiming at guiding electrons in an AC quadrupole guide. The use of miniaturized trapping structures allows for an exceptional tight confinement in the transverse direction. In combination with a single atom tip as electron source, electron injection near the transverse ground state of motion may become feasible. This would lead to a well-defined motional quantum system with potential applications in, e.g. electron interferometry. While ion traps are driven at radiofrequencies, the stable confinement of electrons demands operation at microwave frequencies because of their much higher charge to mass ratio. This can be accomplished by the combination of the electrode layout of a microfabricated planar Paul trap with that of a microwave transmission line on a planar substrate. In stark contrast to the case of ion traps, for a guide with a length comparable to the wavelength of the driving field, the microwave guiding properties of the trap structure become important. Here, we show results of a detailed microwave analysis of a planar five wire structure driven at 1 GHz. As another important element of the experiment, an optimized incoupling structure for a smooth transition from the field free region to the trapping field will be dicussed. We also present experimental results of a first realization with trap frequencies around 100 MHz and radial trap dimensions of several hundred micrometers.

Q 2.5 Mo 15:00 A 320

Stopping particles of arbitrary velocities with an accelerated wall — •Sönke Schmidt[1], J. Gonzalo Muga[2], and Andreas Ruschhaupt[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany — [2]Departamento de Quimica Fisica, UPV-EHU, Bilbao, Spain

We propose a method to stop a pulse of particles with different velocities by making them collide with an accelerated wall with trajectory proportional to the square root of time. We discuss the ideal one-dimensional case. Then we generalize the model to three dimensions and different geometries of the potential wall to give a more realistic description. Finally we show the efficiency of the method.

Q 2.6 Mo 15:15 A 320

Kalte neutrale Quecksilberatome in einer MOT — •Sebastian Siol, Patrick Villwock, 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 sich fangen und kühlen lassen. Die fermionischen Isotope eignen sich zur Untersuchung eines neuen optischen Zeitstandards. Zusätzlich bietet eine magneto-optische Falle die Möglichkeit durch Photoassoziation translatorisch kalte Hg-Dimere herzustellen und in den vibratorischen Grundzustand zu kühlen.

Die Sättigungsintensität des Kühlübergangs bei 253,7 nm beträgt 10,2 mW/cm^2, bei einer natürlichen Linienbreite von 1,27 MHz. Durch die zweistufige externe Frequenzverdopplung eines Yb:YAG Scheibenlasers bei 1014,9 nm kann eine UV-Leistung von bis zu 280 mW bereitgestellt werden. Zur Frequenzstabilisierung des Lasers wird ein entsprechendes Fehlersignal durch dopplerfreie Sättigungsspektroskopie in Kombination mit Frequenzmodulationsspektroskopie generiert. Es wurden Atomzahlen von bis zu (3,2±0,3)x10^6 erreicht. Bei einem mittleren Wolkenradius von (250±18) μm entspricht dies einer Atomdichte von (4,8±1,4)x10^{10} Atome/cm^3.

Neben der experimentellen Realisierung der magneto-optischen Falle werden die jüngsten Ergebnisse sowie interessante Anwendungsmöglichkeiten diskutiert.

Q 2.7 Mo 15:30 A 320

Manipulation of atoms with optical tweezers — •Lukas Brandt, Cecilia Muldoon, Tobias Thiele, Jian Dong, and Axel Kuhn — University of Oxford, Clarendon Laboratory, Parks Road, Oxford OX1 3PU, UK

In many implementations of quantum information processing schemes, the control of individual qubits relies on the ability to arbitrarily manipulate, address and couple individual information carriers, like single atoms or single photons. Here, we report on a novel dipole-trapping experiment that will ultimately allow to trap single neutral atoms in separate dipole traps and to displace them individually.

In order to reach a high degree of control on single atoms, we are implementing a scheme that enables us to trap ^{87}Rb atoms in an array of individual optical dipole-traps. These dipole-traps are created by imaging the surface of a digital light-modulator. The light-modulator is a digital micro-mirror device (DMD) whose surface consists of 1024 x 768 micro-mirrors. The micro-mirrors can be individually switched. By switching the micro-mirrors, the dipole-trap array can be dynamically rearranged. The DMD is imaged by an isoplanatic optical system [1], which is diffraction limited with a numerical aperture of NA=0.5 and thus is able to focus the light to a submicron spot size.

Recently we have observed trapping of atoms in separate dipole traps. This is the first step towards an array of trapped individual atoms.

[1] E. Brainis et. al., Optics Communication 282, 465 (2009)

Q 2.8 Mo 15:45 A 320

Laser cooling of atoms by collisional redistribution of radiation — •Anne Sass, Ulrich Vogl, and Martin Weitz — Institut für Angewandte Physik der Universität Bonn, Wegelerstraße 8, D-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. We experimentally demonstrate cooling of an atomic gas by collisional redistribution of fluorescence, a technique based on the atomic two level system, using rubidium atoms subject to 200 bar of argon 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 $k_{\mathrm{B}}T$ is extracted from the dense atomic sample. We presently achieve cooling in a heated gas from an initial temperature of $410\,^{\circ}\mathrm{C}$ down to $-120\,^{\circ}\mathrm{C}$ temperature in the laser beam focus. 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.