Q 58: Ultracold Atoms: Trapping and Cooling 2

Time: Friday 10:30–13:00 Location: HSZ 02

Q 58.1 Fri 10:30 HSZ 02

CPT and EIT - Dark state resonances in interacting systems — •Hanna Schempp[1], Georg Günter[1], Christoph S. Hofmann[1], Thomas Amthor[1], Matthias Weidemüller[1], Jonathan D. Pritchard[2], Daniel Maxwell[2], Alex Gauguet[2], Kevin J. Weatherill[2], Matthew P.A. Jones[2], Charles S. Adams[2], Sevilay Sevinçli[3], Cenap Ates[3], and Thomas Pohl[3] — [1]Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg — [2]Department of Physics, Durham University, Rochester Building, South Road, Durham DH1 3LE, United Kingdom — [3]Max-Planck-Institut für Physik Komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden

Coherent Population Trapping (CPT) and the related phenomenon of Electromagnetically Induced Transparency (EIT) are paradigms for quantum interference effects. EIT involving a Rydberg state has recently been studied experimentally [1] and has also attracted much interest in the context of quantum information processing [2]. In this work we compare experiments on CPT [3] and EIT [4] in Rydberg gases with controlled interparticle interactions. We present many-body calculations which take the resulting interparticle correlations into account.

[1] A. K. Mohapatra et al., PRL 98 113003 (2007)
[2] M. Müller et al., PRL 102 170502 (2009)
[3] H. Schempp et al., PRL 104 173602 (2010)
[4] J.D. Pritchard et al., PRL 105 193603 (2010)

Q 58.2 Fri 10:45 HSZ 02

Enhanced Optical Nonlinearities with Cold Rydberg Gases — •Sevilay Sevinçli[1], Cenap Ates[2], and Thomas Pohl[1] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, 01187 Dresden, Germany — [2]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, United Kingdom

Owing to the high sensitivity of Rydberg atoms to external fields and to interactions among themselves, ultracold Rydberg gases provide an ideal system for nonlinear optics. Here, we present a quantum and a classical many-body approach to describe interaction effects on the propagation of classical light pulse in an Rydberg-EIT medium. The nonlinear susceptibility shows perfect match between the two methods and is shown to exhibit a universal scaling behavior.

We further propose a microvawe dressing scheme, that allows to modify the interactions between Rydberg atoms, and thereby control the optical properties of the gas. In particular, this allows to greatly enhance genuine three-body interactions, giving rise to large fifth-order nonlinearities. Finally, we present an analytical derivation of the optical susceptibility, providing an intuitive picture for these effects.

Q 58.3 Fri 11:00 HSZ 02

Homodyne Detection of Matter Wave — •Stefan Rist[1] and Giovanna Morigi[2,3] — [1]NEST, Scuola Normale Superiore & Istituto di Nanoscienze - CNR, Piazza dei Cavalieri 7, I-56126 Pisa, Italy — [2]Departament de F\'isica, Universitat Aut\'onoma de Barcelona, E-08193 Bellaterra, Spain — [3]Theoretische Physik, Universit\"at des Saarlandes, D-66041 Saarbr\"ucken, Germany

We present a scheme which allows one for measuring the mean value of the atomic field operator of an ultracold bosonic gas. The scheme we consider is an extension of the experimental setups in [1,2] where atoms were outcoupled of two Bose-Einstein condensates by means of Bragg-scattering. Our scheme is the matter-wave analogon of homodyne detection in optics, where a quantum field is superposed at a beam splitter to a local oscillator. In our case the local oscillator is a Bose-Einstein condensate, from which atoms are outcoupled by means of two Raman lasers, and superimposed with the atoms outcoupled from the atomic system to determine.

The measurement is performed in the light scattered into one of of the Raman beams which is shown to be proportional to the mean value of the field operator of the atomic system. We provide two examples, such as the measurement of the temperature of a Bose-Einstein condensate and of the superfluid fraction in an optical lattice.

[1] M. Saba et al. Science 307, 1945 (2005).
[2] Y.~Shin et al. Phys. Rev. Lett. 95, 170402 (2005).

Q 58.4 Fri 11:15 HSZ 02

A Double-Species 2D+MOT for Potassium and Rubidium — •Lucia Duca[1], Tracy Li[1], Martin Boll[1], Jens Philipp Ronzheimer[1], Ulrich Schneider[1], and Immanuel Bloch[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 München — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching

In recent years there has been a growing interest in the realization of low entropy phases of the Fermi-Hubbard model using ultracold fermions in optical lattices. One of the requirements for achieving e.g. anti-ferromagnetic order is to reduce the initial temperature below T/T_F<0.065 [1]. This requires a careful elimination of all heating sources and an optimization of all cooling steps.

Within a new experimental setup that is currently under construction, we use a double-species 2D+MOT [2] for ^{40}K and ^{87}Rb as an atomic source of slow atoms. Compared to the use of dispensers, this pre-cooling stage allows us to operate the 3D MOT at pressures below 10^{-10} mbar while simultaneously speeding up the experimental cycle and increasing the number of trapped K atoms that will be available for evaporative cooling. We present our 2D+MOT setup and our first experimental results.

[1] Fuchs et.al., arXiv: 1009.2759v1
[2] Dieckmann et.al., PRA 58, 3891 (1998).

Q 58.5 Fri 11:30 HSZ 02

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

We present the transverse confinement and guiding of electrons in a linear AC quadrupole guide operated at microwave frequencies. The guiding potential is generated by the electrode pattern of a microfabricated planar Paul trap. This facilitates the combination with microwave transmission lines patterned on the same substrate to achieve the high driving frequencies necessary for stable electron confinement. In a proof-of principle experiment [1] we demonstrate successfull guiding in an electrically short device by conducting laterally confined electrons along a curved trajectory. The guide is operated at 1 GHz driving frequency and generates a two dimensional potential with 150 MHz trapping frequency 500 μm away from the surface. We also characterize the guiding behaviour of this device in terms of trap depth and stability and compare it to numerical particle tracking simulations. The precise control over the electrons and the possibility to easily scale the trapping potential to more complicated structures opens a wide range of applications. With a single atom tip as electron source, it might become feasible to directly inject electrons into the transverse ground state of motion of the guide. When combined with beam splitting devices this will enable experiments like guided electron interferometry or the controlled interaction of confined electrons.

[1] J. Hoffrogge, R. Frohlich and P. Hommelhoff - submitted (2010)

Q 58.6 Fri 11:45 HSZ 02

Ultracold atoms in disordered quantum potential — •Hessam Habibian[1,2], Wolfgang Niedenzu[3], Helmut Ritsch[3], and Giovanna Morigi[1,2] — [1]Grup d'Optica, Departament de Física, Universitat Autònoma de Barcelona, E-08193 Bellaterra, Barcelona, Spain — [2]Theoretische Physik, Universität des Saarlandes, D-66041 Saarbrücken, Germany — [3]Institut für Theoretische Physik, Universität Innsbruck, A-6020 Innsbruck, Austria

We study the self-organized atomic patterns which emerge by mechanical effect of light in an optical resonator when the atoms are driven by a laser. The laser wave vector is at a tilted angle from the axis of the cavity such that the light scattered by each atom has a (pseudo-)random phase. Depending on the intensity of the laser and the angle with the cavity axis, the atomic crystal may exhibit defects. We study the quantum ground state of the system in this configuration.

Q 58.7 Fri 12:00 HSZ 02

Laserkühlung von dichten atomaren Alkali-Edelgas-Mischungen durch kollisionsinduzierte Fluoreszenzredistribution — •Anne Sass, Ulrich Vogl, Simon Hasselmann und Martin Weitz — Institut für Angewandte Physik der Universität Bonn, Wegelerstraße 8, D-53115 Bonn

Der Grundgedanke, Materie mit Licht zu kühlen, wurde erstmals 1929 von Peter Pringsheim vorgestellt. Seither haben sich Doppler-Kühlung dünner atomarer Gase und zuletzt Anti-Stokes-Kühlung von Festkörpern als sehr erfolgreiche Anwendungen dieses Konzeptes herausgestellt. Das hier vorgestellte Verfahren der stoßinduzierten Redistributionskühlung stellt einen neuartigen Laserkühlmechanismus basierend auf atomaren Zwei-Niveau-Systemen dar. Wir berichten über Experimente zur Kühlung von Alkali-Edelgas-Mischungen in einer Hochdrucksichtzelle bei einigen hundert bar Druck. Kollisionen im dichten Gas ermöglichen die Absorption eines rot verstimmt eingestrahlten Laserstrahls, der spontane Zerfall erfolgt nah an der ungestörten Resonanz. Die so pro Kühlzyklus aus dem atomaren Ensemble extrahierte Energie liegt in der Größenordnung der thermischen Energie kT; die Dichte des gekühlten Gases ist um mehr als zehn Größenordnungen höher als die typischen Werte in Experimenten zur Doppler-Kühlung. Aktuell erreichen wir in unseren Experimenten relative Temperaturänderungen um 120 K und 527 K für unterschiedliche Alkaliatomspezies. Zukünftig gilt es, das Kühlprinzip auch auf molekulare Gase anzuwenden und die technische Anwendbarkeit des Verfahrens, etwa für Kryokühler, zu überprüfen.

Q 58.8 Fri 12:15 HSZ 02

A hexapole-compensated magneto-optical trap on a mesoscopic atom chip — •Stefan Jöllenbeck[1], Jan Mahnke[1], Richard Randoll[1], Manuela Hanke[1], Ilka Geisel[1], Wolfgang Ertmer[1], Jan Arlt[2], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Department of Physics and Astronomy, Aarhus University

We realized a magneto-optical trap (MOT) on a mesoscopic chip structure which will be used as a starting point for experiments to trap and transport atoms in a magnetic conveyor belt.

Our MOT setup consists of nine millimeter-scale wires which generate a quadrupole field with minimized distortions. The wires are placed outside of our vacuum system above a steel foil which forms one wall of our vacuum chamber. A gold coating on the vacuum side of this foil allows for the standard mirror MOT configuration. Together with a pre-cooled beam from a 2D$^+$-MOT, we achieve an initial loading rate of 8.4×10^{10} atoms/s and a final number of 8.7×10^9 captured atoms within 300 ms.

Since the MOT can be operated by only local magnetic fields, the wire structure will support a serialized production of Bose-Einstein condensates in the magnetic conveyor belt.

Q 58.9 Fri 12:30 HSZ 02

Reconstructing the Wigner function of an atomic ensemble — •Roman Schmied and Philipp Treutlein — Departement Physik, Universität Basel, Schweiz

At the core of quantum information technology lies the deterministic and robust generation of entanglement. The accurate measurement of this entanglement is central for advancing the techniques for entanglement generation. For this we have developed a novel method which allows us to reconstruct the Wigner function of the total pseudospin of a large ensemble of ultracold atoms from tomographic data. We illustrate the method with experimental data from a spin-squeezed cloud of ^{87}Rb atoms.

Q 58.10 Fri 12:45 HSZ 02

Optimized magnetic lattices for ultracold atomic ensembles — •Roman Schmied[1], Dietrich Leibfried[2], Robert Spreeuw[3], and Shannon Whitlock[4] — [1]Departement Physik, Universität Basel, Schweiz — [2]National Institute of Standards and Technology, Boulder, CO, USA — [3]Van der Waals–Zeeman Instituut, Universiteit van Amsterdam, The Netherlands — [4]Physikalisches Institut, Universität Heidelberg

Atom chips provide a versatile and reliable laboratory for quantum-mechanical experiments with ultracold atoms. The next generation of atom chips calls for a dramatic increase in the complexity of the spatially structured electromagnetic fields required for trapping and manipulating these atoms. We introduce a general method* for designing tailored lattices of magnetic microtraps for ultracold atoms on the basis of patterned permanently magnetized films. A fast numerical algorithm is used to automatically generate patterns that provide optimal atom confinement while respecting the desired lattice topology and trap parameters. This will allow atom-chip based quantum technology to be extended to arrays of microtraps with state-dependent potentials, opening the way to constructing quantum processors and quantum simulators through interacting ultracold atoms.

* R. Schmied *et al.*, New J. Phys. **12**, 103029 (2010)