A 40: Ultracold Atoms II (with Q)

Time: Friday 14:30–16:30 Location: P 104

A 40.1 Fri 14:30 P 104

Realization of a dual-species MOT for dysprosium and potassium — •C. Ravensbergen[1,2], S. Tzanova[1,2], M. Kreyer[2], E. Soave[2], A. Werlberger[2], V. Corre[1,2], E. Kirilov[2], and R. Grimm[1,2] — [1]IQOQI, Austrian Academy of Sciences, Innsbruck, Austria — [2]Insitute for Experimental Physics, University of Innsbruck, Innsbruck, Austria

We report on the first realization of a dual-species magneto-optical trap that combines strongly magnetic lanthanide atoms (Dy) with an alkali species (K). Advanced cooling techniques in the form of narrow-line laser cooling and grey-molasses cooling give us favorable starting conditions to reach quantum degeneracy. With fermionic and bosonic isotopes of both species, our system offers a great wealth of isotopic mixtures. We are particularly interested in new Fermi-Fermi mixtures. These are expected to exhibit exotic quantum phases and novel pairing mechanisms, including for example mass-imbalanced pairing or a fermionic superfluid with a Fermi surface modified by the dipolar interactions.

A 40.2 Fri 14:45 P 104

Towards a Perpetual Bose-Einstein Condensate — •Shayne Bennetts, Chun-Chia Chen, Benjamin Pasquiou, and Florian Schreck — Institute of Physics, University of Amsterdam, Amsterdam, The Netherlands

Production of Bose-Einstein condensates (BECs) has always been a two stage process, first laser cooling a gas sample, then cooling evaporatively until degeneracy is reached. As a result, BECs and devices based on BEC such as atom lasers are pulsed. Applications like atom interferometers would benefit greatly from a perpetual source of condensate. We are developing such a perpetual source in which we separate the cooling stages in space rather than time and protect the condensate from scattered photons using distance, baffles and a "transparency" beam. We have now demonstrated a perpetual MOT of 2×10^9 ^{88}Sr atoms with temperatures as low as 20μK on a 7.4-kHz wide laser cooling transition with a continuous loading rate of 7×10^8 atoms/s. Using a different set of parameters and location we have also demonstrated a perpetual MOT of 2×10^8 ^{88}Sr at 2μK with a loading rate of 9×10^7 atoms/s which we have successfully loaded into a dipole trap. By switching to the 0.5% abundance ^{84}Sr isotope we are able to evaporate to BECs of 3×10^5 ^{84}Sr atoms. Critically, for the second location we have validated the effectiveness of our architecture in protecting a BEC from scattered broad-linewidth laser cooling light, which is used in the first cooling stages. These are crucial steps towards demonstrating a perpetual BEC and atom laser.

A 40.3 Fri 15:00 P 104

Optimization of modulation transfer spectroscopy on the rubidium D2 line — •Tilman Preuschoff, Patrick van Beek, Florian Ehmann, Malte Schlosser, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany

Highly stable laser sources with narrow linewidths are of great importance for experiments in the field of atom physics. Frequency-stabilized external-cavity diode lasers are a cost efficient and compact realization of suitable sources. Sub-Doppler spectroscopy techniques provide high resolution atomic references. Among them, the modulation transfer spectroscopy (MTS) scheme is significant due to the non-linear four-wave-mixing transfer process which offers a particularly high accuracy and signal bandwidth.

We present recent experimental and theoretical investigations of the MTS technique on the ^{85}Rb D2 line in an AOM-based setup. The obtained line shape is in good agreement with the theoretical description. Numerical simulations show that an optimal combination of signal amplitude and slope at the reference frequency is achieved in the regime of high modulation indices and frequencies. Within the experimentally available parameter regime this optimum is accessible. We demonstrate a frequency stabilization providing an effective linewidth below 200 kHz and a long-term stability better than 100 kHz in 15 h. The MTS scheme is compared to the frequency modulation spectroscopy scheme implemented in a similar optical setup based on inexpensive DDS signal generation and standard lock-in techniques.

A 40.4 Fri 15:15 P 104

Nonergodic diffusion of single atoms in a periodic potential — •Daniel Adam[1], Farina Kindermann[1], Andreas Dechant[2], Tobias Lausch[1], Daniel Mayer[1], Felix Schmidt[1], Steve Haupt[1], Michael Hohmann[1], Nicolas Spethmann[1], Eric Lutz[2], and Artur Widera[1] — [1]TU Kaiserslautern, Department of Physics, Kaiserslautern, Germany — [2]Friedrich-Alexander-Universität, Department of Theoretical Physics, Erlangen, Germany

Diffusion is ubiquitous in nature, and related models are essential to many fields in science, technology and society, including life sciences, traffic or financial market theory. The most prominent model for diffusion is Brownian motion. The hallmarks of this are a linearly increasing mean squared displacement (MSD); a Gaussian distributed step distance distribution; a stationary value for the autocorrelation function of single particle trajectories; and established ergodicity. Here, we engineer a system of a single atom in a periodic potential, which is coupled to a photon bath. We observe diffusion of the atom in the lattice, driven by random photon scattering events. While the dynamics exhibits a linear increase of the MSD for all times, we find that ergodicity is not established even for long timescales. Moreover, we observe a different timescale on which the step distribution approaches Gaussianity. Our experimental results for equilibrium systems are in excellent agreement with analytical predictions of a continuous time random walk model with exponential distance and waiting time distribution. Our results may be helpful for the interpretation of related observations in biological systems.

A 40.5 Fri 15:30 P 104

Measuring correlations of cold-atom systems using multiple quantum probes — •Michael Streif[1,2], Andreas Buchleitner[2], Dieter Jaksch[1,3], and Jordi Mur-Petit[1] — [1]Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU, United Kingdom — [2]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg, Germany — [3]Centre for Quantum Technologies, National University of Singapore, 3 Science Drive 2, 117543 Singapore

The remarkable advances in experiments with ultracold bosonic atoms in optical lattices have triggered several possibilities to study the physics of many-body quantum systems. A common issue in most experiments is the destructive nature of the measurement method. For this reason, in recent times, ancillary quantum systems have been used as quantum probes. We here present a non-destructive method to probe a complex quantum system using multiple impurity atoms as quantum probes. It is demonstrated that non-local two-point correlation functions can be determined by accessing a coherence element of the density matrix of the impurities. In particular, for contact interactions between probes and system, our protocol yields the many-body density-density correlation function.

A 40.6 Fri 15:45 P 104

Cavity-induced quantum phases of ultracold atoms in commensurate potentials — •Benjamin Bogner, Giovanna Morigi, and Heiko Rieger — Theoretical Physics Saarland University, 66123 Saarbrücken, Germany

We analyse the quantum phases of bosonic atoms, which are tightly confined by a one-dimensional optical lattice and interact with the long-range potential induced by the coupling with an optical resonator. Their dynamics is described by an extended Bose-Hubbard model, where the cavity field induces long-range density-density interactions in the form of the square of the even-odd site occupation balance. The interplay of this potential with nearest neighbor hopping and onsite repulsion is analyzed by means of quantum Monte-Carlo simulations. The phase diagram is determined as a function of the hopping amplitude, the chemical potential, and the strength of the long-range cavity interaction, rescaled by the onsite potential strength, displaying superfluid, supersolid, Mott insulator, and density-wave regions phases. A comparison is drawn with the phase diagram of the extended one-dimensional Bose-Hubbard-model with only nearest-neighbour interactions.

A 40.7 Fri 16:00 P 104

Semiclassical theory of synchronization-induced cooling —

•Simon B. Jäger[1], Stefan Schütz[1,2], Minghui Xu[3,4], Jinx Cooper[3,4], Murray J. Holland[3,4], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]icFRC, IPCMS (UMR 7504), ISIS (UMR 7006), Université de Strasbourg and CNRS, 67000 Strasbourg, France — [3]JILA, National Institute of Standards and Technology and Department of Physics, University of Colorado, Boulder, Colorado 80309-0440, USA — [4]Center for Theory of Quantum Matter, University of Colorado, Boulder, Colorado 80309, USA

We analyse the cooling dynamics of the motion of atoms confined inside an optical cavity, in the regime in which the atoms are incoherently pumped and the dipoles can synchronize. Our study is performed in the semiclassical regime and assuming that cavity decay is the largest rate characterizing the dynamics. We show that the cooling dynamics consists of three regimes. First hot atoms are individually cooled by the cavity friction forces. After this stage, motion and internal degrees of freedom evolve and the motion is further cooled until the dipoles synchronize. In this latest stage, when the dipoles are sychronized dipole-dipole correlations are stationary and the motion is further cooled to temperatures which are limited by the pump rate. In this regime spin and atomic position are correlated, such that the internal excitations oscillate spatially with the cavity standing wave forming an effective antiferromagnetic order. We discuss the limits of the semiclassical treatment and its extension to a full quantum mechanical model.

A 40.8 Fri 16:15 P 104

Sympathetic cooling of quantum simulators — •Meghana Raghunandan and Hendrik Weimer — Institut für Theoretische Physik, Leibniz Universität Hannover

We discuss the possibility of maximizing the cooling of a quantum simulator by controlling the system-environment coupling such that the system is driven into the ground state. We make use of various analytical tools such as effective operator formalism [1] and the quantum master equations to exactly solve the model of an Ising spin chain consisting of N particles coupled to a radiation field. We maximize the cooling by finding the dependence of the effective rate of transitions of the various excited states into the ground state. We show that by adding a single dissipative qubit, we already get quite substantial cooling rates.

[1] Effective operator formalism for open quantum systems. Phys. Rev. A 85, 032111