Q 10: Quantum Gases: Bosons II

Time: Monday 16:30–19:00 Location: E 001

Q 10.1 Mo 16:30 E 001

Towards an all-optical ^{87}Rb BEC for atom interferometry — •Maic Zaiser, Jonas Hartwig, Dennis Schlippert, Vyacheslav Lebedev, and Ernst Maria Rasel — Leibniz Universität Hannover - Institut für Quantenoptik;

We present studies of loading and evaporative cooling of pre-cooled ^{87}Rb atoms in a crossed optical dipole trap (ODT) formed by a Thulium-doped fiber laser at 2 μm wavelength and 50 W output power. The atomic source for loading the ODT consists of a two-stage design, where a three dimensional magneto-optical trap (3D MOT) is loaded by a 2D MOT. With this setup, we reach very quick loading (less than 500 ms) with high initial atom numbers and phase space densities in the ODT, a prerequisite for successful evaporative cooling to BEC with high atom numbers.

This work is motivated by the ultra-low temperatures feasible in BEC, thus potentially improving the accuracy of matter wave interferometers for precision measurements, such as e.g. a quantum test of the equivalence principle. Optical dipole traps make a fast production of BEC possible allowing for a high repetition rate in an interferometer. Additionally, dipole traps are able to trap all m_F-substates, especially $m_F = 0$, being insensitive to magnetic fields in first order.

Q 10.2 Mo 16:45 E 001

Bose-Einstein condensation of an alkaline earth element: ^{40}Ca — •Sebastian Kraft, Felix Vogt, Oliver Appel, Fritz Riehle, and Uwe Sterr — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

We have achieved Bose-Einstein condensation of ^{40}Ca [1], the first for an alkaline earth element. Due to the large ground state s-wave scattering length and associated large three body losses an optimized loading and cooling scheme was necessary to condense about $2 \cdot 10^4$ atoms. Our cooling scheme consisting of a two-stage magneto-optical trap and subsequent forced evaporation in a crossed dipole trap at magical wavelength allows to reach degeneracy within less than 3 s. Here we present the optimized route to BEC and discuss future applications.

[1] S. Kraft, F. Vogt, O. Appel, F. Riehle, and U. Sterr, Phys. Rev. Lett. **103**, 130401 (2009).

Q 10.3 Mo 17:00 E 001

Bose-Einstein condensation of strontium — •Simon Stellmer[1,2], Meng Khoon Tey[1], Bo Huang[1,2], Rudolf Grimm[1,2], and Schreck Florian[1] — [1]Institut für Quantenoptik und Quanteninformation, 6020 Innsbruck, Austria — [2]Universität Innsbruck, 6020 Innsbruck, Austria

We report on the attainment of Bose-Einstein condensation with ultracold strontium atoms. We use the ^{84}Sr isotope, which has a low natural abundance but offers excellent scattering properties for evaporative cooling. Accumulation in a metastable state using a magnetic-trap, narrowline cooling, and straightforward evaporative cooling in an optical trap lead to pure condensates containing 1.5×10^5 atoms. This puts ^{84}Sr in a prime position for experiments on quantum-degenerate gases involving atomic two-electron systems.

Furthermore, we report on recent advances towards a degenerate Fermi gas of ^{87}Sr. Ideas of future experiments related to quantum simulation and ultracold SrRb molecules will also be discussed in the talk.

Q 10.4 Mo 17:15 E 001

Bose-Einstein condensates in micro-optical potentials — •Thomas Lauber, Johannes Küber, Oliver Wille, Martin Hasch, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

The goal of our experiments is to study the coherence properties of Bose-Einstein condensates in micro-optical potentials. We use an 'all-optical' BEC of rubidium, which we prepare in a crossed dipole trap, generated by a 1070nm fiber laser. The atoms are loaded directly from a magneto-optical trap and are evaporatevly cooled to quantum degeneracy in the dipole trap by simply ramping down the laser power.

We create the optical micro-potentials by using microfabricated lenses illuminated with off-resonant laser light, either red- or blue-detuned. We implement various types of lenses, including microlens arrays, cylindrical lens arrays and a ring shaped lens. These lenses allow the creation of potentials that can be used as beam splitters, wave guides or mirrors for atoms on a sub-millimeter scale. The ring lens for example suggests the implentation of a one-dimensional geometry with periodic boundary conditions. As a tool to move the atoms along the waveguides, we use Bragg scattering to split or transfer the BEC in different momentum states.

We are going to report on the current status of our experiments.

Q 10.5 Mo 17:30 E 001

Landau-Zener dynamics between pairwise coupled 1d-tubes — •Yu-Ao Chen[1,2], Stefan Trotzky[1], Ute Schnorrberger[1], Sebastian Huber[3], Ehud Altman[3], and Immanuel Bloch[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, Schellingstasse 4, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany — [3]Department of Condensed Matter Physics, The Weizmann Institute of Science, Rehovot, 76100, Israel

Non-equilibrium dynamics attracted a lot of recent interest. The departure from standard statistical mechanics is studied in a large variety of systems, at the heart of which lies the very fundamental setup of two levels undergoing an anti-crossing, knowing as the famous Landau-Zener (LZ) problem. Non-interacting atoms in a double well with tunable energy difference provide a generic two-mode system to study the dynamics of a LZ sweep. We experimentally realize a generalized LZ problem in an array of pairwise coupled tubes with interacting ultracold ^{87}Rb atoms in an optical superlattice potential. We investigate the impact of interactions and dimensionality on the sweep fidelity for sweeps in the ground state and in the excited state. The results show that interactions in the tubes improve the fidelity for sweeps in the ground state. For sweeps in the excited state we find relaxation of the system which can be explained in terms of one-dimensional low-energy excitations along the tubes, providing an intrinsic bath for thermalization.

Q 10.6 Mo 17:45 E 001

Cold Atoms in Minibands: Bloch-Zener Oscillations and Band Spectroscopy — •Sebastian Kling, Tobias Salger, Christopher Grossert, and Martin Weitz — Institut für Angewandte Physik, Wegelerstr.8 , 53115 Bonn, Germany

We report on experiments with an atomic ^{87}Rb condensate in a biharmonic optical lattice potential. The biharmonic potential is realized with a combination of a standing wave lattice potential of $\lambda/2$ spatial periodicity and a lattice of $\lambda/4$ periodicity generated by the dispersion of multiphoton Raman transitions. Such lattices allow for realizing a tunable miniband structure for the condensate. Minibands are formed in the band structure if the second band gap is larger than the first one. In this special case the conventional single band approximation for the dynamics is not valid any more and instead a multiband analysis is required. We have investigated experimentally the dynamics of the minibands by observing Bloch-Zener-Oscillations in momentum space. We have furthermore coherently split atomic wavepackets by tunneling at the bandgaps and observed an interference signal after subsequent recombining. This band interference allows for a novel bandgap spectroscopy.

Q 10.7 Mo 18:00 E 001

Emergence of semifluxons in 0-π-0 junctions as a topological state change — •Reinhold Walser[1], Michael Grupp[2], Wolfgang Schleich[2], Oliver Crasser[2], Reinhold Kleiner[3], and Edward Goldobin[3] — [1]Institut für Angewandte Physik, TU Darmstadt — [2]Institut für Quantenphysik, Universität Ulm — [3]Physikalisches Institut, Universität Tübingen

By continuously increasing the spatial extend of the π-region in a long 0-π-0 Josephson junction, one can dynamically induce the appearance of semifluxons starting with a flat-phase state. Thus, we can control the topological nature of a quantum system with an external parameter. This interesting topological quantum state is related to ordinary quantized magnetic flux in superconductors or vortices in superfluid systems, however it has accrued only π-phase winding. In here, we present a generic, analytical model of the phenomenon and demonstrate its implementation in the context of ultra-cold matter waves using optical junctions.

Q 10.8 Mo 18:15 E 001

Exact Quantum Dynamics of a Bosonic Josephson Junction — •Kaspar Sakmann, Alexej I. Streltsov, Ofir E. Alon, and Loerenz S. Cederbaum — Theoretische Chemie, Physikalisch-Chemisches Institut, Universität Heidelberg, Deutschland

The quantum dynamics of a one-dimensional bosonic Josephson junction is studied by solving the time-dependent many-boson Schrödinger equation numerically exactly. Already for weak interparticle interactions and on short time scales, the commonly employed mean-field and many-body methods are found to deviate substantially from the exact dynamics. The system exhibits rich many-body dynamics such as enhanced tunneling and a novel equilibration phenomenon of the junction depending on the interaction, which is attributed to a quick loss of coherence.

Q 10.9 Mo 18:30 E 001

Cold and hot finite quantum systems in contact: energy flow and temperature equilibration — •Alexey V. Ponomarev, Sergey Denisov, and Peter Hanggi — Institute of Physics, University of Augsburg, Germany

Relaxation toward the canonical state is commonly attributed to a situation where a small system of interest is coupled to a huge one (the Universe, a heat bath, etc). Here we focus on the case of two identical quantum systems composed of a finite number of bosons. Both the systems are initially prepared in Gibbs states at different temperatures, $\rho_A(T_A)$ and $\rho_B(T_B)$, and isolated from the external environment. Then the systems are brought into a thermal contact.

We demonstrate that the energy starts to flow from a "hot" system to a "cold" one until the system energies equilibrate. There are two possible distinguishable relaxation regimes. In the first regime, each of the systems evolves toward the state characterized by the arithmetic average of their initial density matrices, $\rho_A(T_A)/2 + \rho_B(T_B)/2$. The second regime substantiates what we would expect from the equilibration of two big, classical bodies: (i) both the quantum systems relax to the thermal (Boltzmann) states with equal temperatures; and (ii) the relaxation process has a quasistatic character, i. e. each system passes through a chain of intermediate thermal (Boltzmann) states. With that, we show for the first time that a non-equilibrium thermodynamic process can be reproduced within an isolated finite bipartite quantum system.

Q 10.10 Mo 18:45 E 001

Single Cs Atoms Interacting with an Ultracold Rb Cloud — •Nicolas Spethmann, Wolfgang Alt, Shincy John, Oskar Fetsch, Claudia Weber, Artur Widera, and Dieter Meschede — Institut für Angewandte Physik, 53115 Bonn, Deutschland

While single Cs atoms can be coherently controlled to a high degree, in these systems coherent interactions are still challenging to obtain. In contrast, in quantum gases coherent interactions naturally emerge whereas manipulation and detection with single particle control is still not routinely performed.

We aim on combining the advantages of both methods by controlled immersion of single and few Cs atoms in an ultracold cloud of Rb atoms. We trap single and few Cs atoms in a high-gradient magneto-optical trap (MOT) and observe the loading dynamics through fluorescence detection. A Rb ensemble is cooled in a magnetic trap and then transferred to a crossed dipole trap at the position of the Cs MOT. In this purely optical trap the Rb can be further cooled to quantum degeneracy. By transferring the Rb to a magnetic field insensitive state, it is possible to switch on the single atom MOT without affecting the Rb cloud. We will report on the status of using the single atoms to probe the Rb cloud in various temperature regimes.