Q 18: Ultra-cold atoms, ions and BEC II

Time: Tuesday 10:30–12:45 Location: BAR 106

Q 18.1 Tue 10:30 BAR 106

Feshbach resonances of harmonically trapped atoms — •Philipp-Immanuel Schneider, Yulian V. Vanne, and Alejandro Saenz — AG Moderne Optik, Humboldt-Universität zu Berlin, Newtonstraße 15, 12489 Berlin

Confined ultracold atoms with their interaction controlled by a magnetic Feshbach resonance (MFR) have vast and intriguing applications e.g. for studying new phases of matter, performing quantum information processing, or simulating condensed matter Hamiltonians. Employing a short-range two-channel description we derive an analytic model of atoms in isotropic and anisotropic harmonic traps at an MFR. On this basis we obtain an analytic expression for the admixture of the resonant bound state and a parameterization of the energy-dependent scattering length which differs from the one previously employed [1]. We validate the model by comparison to full numerical calculations for ^{6}Li-^{87}Rb and explain quantitatively the experimental observation of a resonance shift of trapped gases and of trap-induced molecules in exited bands and band gaps of an optical lattice.

[1] Z. Idziaszek and T. Calarco, Phys.Rev.A **74**, 022712 (2006).

[2] P.-I. Schneider, Y. V. Vanne, and A. Saenz, eprint arXiv:1005.5306

Q 18.2 Tue 10:45 BAR 106

an electron-ion crystal in a linear Paul trap — •Weibin Li and Igor Lesanovsky — School of Physics and Astronomy, The University of Nottingham, Nottingham NG7 2RD, UK

Trapping of charged particles has undergone significant advancements in the past decades. Today ions can be controlled with extreme precision in various traps at the quantum level. This has attracted enormous attentions, due to a broad variety of possible applications, for example, in precisions measurements and quantum computation. Traditional ion traps can confine either positively or negatively charged particles while the opposite charge is repelled. We demonstrate that a single electron can be trapped in the centre of a metastable doubly charged ion crystal in a linear Paul trap. A uniform magnetic field is applied in the axial direction, which tightly confines electron in the radial directions, and stabilises the system. At equilibrium, the system is approximated by coupled harmonic oscillators. We discuss the stability properties and the dynamics of the system. Our study illuminates possibilities for coherently manipulating oppositely charged particles simultaneously in linear Paul traps. This has the potential to highlight new perspectives for quantum simulators that use electrons as fundamental constituents and thus are of fundamental interest in condensed matter physics.

Q 18.3 Tue 11:00 BAR 106

Influence of reduced dimensionality on ultracold atoms — •Simon Sala[1,2] and Alejandro Saenz[1] — [1]Institut für Physik, Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin — [2]Kirchhoff-Institut für Physik, Ruprecht-Karls Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg

Low-dimensional systems of ultracold atoms show unique quantum signatures which are not present in the three dimensional case. Two topical examples in the quasi 1D regime are the fermionization of Bosons, i.e. strongly repulsive Bosons acquire fermionic properties, and the appearance of a confinement-induced resonance (CIR)[1]. Recently both effects were experimentally observed [2,3]. Quasi one-dimensional systems are realized by a tight confinement in two spatial directions freezing out two degrees of freedom. We present a theoretical treatment of two atoms in quasi one-dimensional traps using a full six-dimensional exact diagonalization technique [4]. Coupling effects due to anharmonicity of the trapping potential and the resulting effects on a CIR are investigated. Especially the experimental observed [3] splitting of CIR positions in completely anisotropic traps is an open question we try to answer.

[1] M. Olshanii, Phys. Rev. Lett. **81**, 938 (1998)

[2] B. Paredes et al., Nature **429**, 277 (2004)

[3] Haller et al., Phys. Rev. Lett. **104**, 153202 (2010)

[4] S. Grishkevich, A. Saenz, Phys. Rev. A **80**, 013403 (2009)

Q 18.4 Tue 11:15 BAR 106

Single Cs Atoms Interacting with an Ultracold Rb Gas — •Nicolas Spethmann[1], Shincy John[1], Farina Kindermann[1], Amir Moqanaki[1], Claudia Weber[1], Dieter Meschede[1], and Artur Widera[2,1] — [1]Institut für Angewandte Physik, Wegelerstr. 8, 53115 Bonn — [2]Technische Universität Kaiserslautern, Fachbereich Physik, Erwin-Schrödinger-Str., 67663 Kaiserslautern

We immerse single Cs atoms into a many body systems consisting of cold and ultracold Rb gases in order to use the single Cs atom as a sensitive probe for inter-species interaction and as an agent to manipulate the quantum gas.

In order to study ground state collisions between a single Cs atom and a quantum degenerate Rb gas we have developed techniques to combine a quantum gas with a single trapped neutral atom. For this purpose, an optically trapped Rb BEC is prepared in the magnetic field insensitive $F = 1$, $m_F = 0$ state. Then single Cs atoms are loaded into a superimposed 1D-lattice, which exerts a strong potential for Cs atoms and a weak potential for Rb. At ultralow temperatures and with negligible scattering of photons, ground state collions between the single atom and the quantum gas determine the interaction. This enables (coherent) probing and manipulation of the BEC by the single atom. We will report on the ground state interactions between single Cs atoms and a quantum gas and our recent progress controlling the single atom inside the quantum gas.

Q 18.5 Tue 11:30 BAR 106

Probing an ultracold atomic crystal with matter waves — Bryce Gadway, Daniel Pertot, Jeremy Reeves, and •Dominik Schneble — Department of Physics & Astronomy, Stony Brook University, Stony Brook, NY 11794, USA

We explore the scattering of matter waves from ultracold atoms held in an optical lattice. By “shining” a one-dimensional Bose gas onto an atomic Mott insulator (target), we observe Bragg diffraction peaks that reveal the target’s crystalline structure. We find a systematic dependence of the Bragg intensity on the degree of atom localization, and recover a transition to coherent momentum and energy exchange (“Newton’s cradle”) in the limit of free target atoms. Neutral-atom diffraction can serve as a novel experimental technique for probing atomic many-body systems.

Q 18.6 Tue 11:45 BAR 106

Correlated phases of bosons in tilted, frustrated lattices — •Susanne Pielawa, Takuya Kitagawa, Erez Berg, and Subir Sachdev — Physics Department, Harvard University, Cambridge, MA 02138, USA

The search for correlated quantum phases of cold atoms in optical lattices has focused mainly on entangling the spin degrees of freedom on different lattice sites. We show that there are also rich possibilities for correlated phases in the density sector, and these are likely to be readily accessible by tilting Mott insulators into metastable states. It has been previously shown that a Mott insulator in a potential gradient undergoes an Ising quantum phase transition when the potential drop per lattice spacing is close to the repulsive interaction energy [1]. Here we theoretically study bosons in tilted, frustrated, two-dimensional lattices. The phases we find include phases with charge density order, a sliding Luttinger liquid phase, and a liquid-like ground state with no broken lattice symmetry.

[1] S. Sachdev, K. Sengupta, and S. M. Girvin, Phys. Rev. B 66, 075128 (2002).

Q 18.7 Tue 12:00 BAR 106

Injection locking of a trapped-ion phonon laser - the detection of ultraweak forces — •Sebastian Knünz[1], Maximilian Herrmann[1], Valentin Batteiger[1], Guido Saathoff[1], Kerry Vahala[2], Theodor W. Hänsch[1], and Thomas Udem[1] — [1]MPQ, Garching, Germany — [2]Caltec, Pasadena, USA

A single trapped ion, addressed by both a red-detuned cooling laser and a blue-detuned pump laser can exhibit stable oscillatory motion with a well defined threshold. We have shown that this oscillation is the result of stimulated emission of center-of-mass phonons, providing saturable amplification of the motion. We show that the dynamics of this "phonon laser" are surprisingly sensitive to external fields; we demonstrate phase synchronization ("injection locking") to an external signal by applying forces as weak as 5 yN (yocto=10^{-24}). This enormous sensitivity might allow the detection of the nuclear spin of a single atom or molecule.

Q 18.8 Tue 12:15 BAR 106

Nucleation of solitons in a quasi-1D Bose-Einstein condensate: the Kibble-Zurek mechanism — •Gor Nikoghosyan, Adolfo del Campo, Alex Retzker, and Martin Plenio — Institut für Theoretische Physik, Albert-Einstein Allee 11, Universität Ulm, D-89069 Ulm

Finite-rate cooling of a quasi-1D thermal atomic cloud leads to the spontaneous nucleation of solitons during Bose-Einstein condensation (BEC). We study whether the dynamics of the transition can be described in terms of equilibrium properties using the Kibble-Zurek mechanism (KZM), and simulate the process within the stochastic Gross-Pitaevskii equation. We propose a novel method to detect the density of solitons in a quasi-1D BEC. This method is based on the measurement of the second order correlation function which enables the detection of solitons without knowing their location. The dependence of the density of solitons on the cooling rate of the atomic cloud for realistic experimental conditions is numerically analyzed, and agrees with the KZM only when this is extended to account for the inhomogeneous nature of the condensation arising from the external trapping potential.

Q 18.9 Tue 12:30 BAR 106

Propagation of a wave-packet in a nonlinear and disordered medium in two dimensions — •Georg Schwiete[1] and Alexander Finkelstein[2] — [1]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, Germany — [2]Texas A&M University, College Station, USA

We develop an effective theory of wave-packet propagation in a nonlinear and disordered medium. The theory is formulated in terms of a nonlinear diffusion equation. Despite its apparent simplicity this equation describes novel phenomena which we refer to as "locked explosion" and "diffusive" collapse. The equation can be applied to such distinct physical systems as laser beams propagating in disordered photonic crystals or Bose-Einstein condensates expanding in a disordered environment.