Q 38: Ultracold Atoms, Ions and BEC III (with A)

Time: Wednesday 11:00–13:00 Location: M/HS1

Q 38.1 Wed 11:00 M/HS1

Space charge dynamics and diffraction with ultracold electron and ion bunches — •Robert Scholten, Dene Murphy, Rory Speirs, Dan Thompson, Joshua Torrance, Richard Taylor, Andrew McCulloch, and Ben Sparkes — School of Physics, University of Melbourne, Australia

Cold electron and ion sources based on photoionisation of laser cooled atoms provide a unique system for investigating Coulomb interactions within complex charged particle bunches and for high coherence diffractive imaging. Space-charge driven expansion in charged particle beams is of critical importance for applications including electron and ion microscopy, mass spectrometry, synchrotrons and x-ray free electron lasers, and in electron diffraction where space-charge effects constrain the capacity to obtain diffraction information. Self-field effects are often difficult to observe because of thermal diffusion with traditional sources. Cold atom sources produce ions with temperatures of a few mK, such that subtle space-charge effects are apparent. We illustrate the capabilities through detailed investigation of a complex ion bunch shape, showing collective behaviour including high density caustics and shockwave structures arising from long-range interactions between small charge bunches. We also demonstrate ultra-fast diffraction with cold electrons.

Q 38.2 Wed 11:15 M/HS1

Single particle dynamics in ultracold environments — •Paula Ostmann and Walter Strunz — Tu Dresden , Institut für Theoretische Physik, Deutschland

We investigate the quantum dynamics of a single ion which is immersed into a Bose-Einstein condensate. The ultracold environment acts as a refrigerator, and thus, the influence on the motion of the molecule or ion is dissipative. For a theoretical description, simple phenomenological master equation approaches are widely used to describe the ensuing damped quantum dynamics. Instead of calculating the particle dynamics itself, our focus lies on a more detailed description of the environment and the particle-environment interaction. We aim to describe the effective dynamics of the damped particle dynamics using the full bath correlation function instead of a simple damping rate. In this way we gain a more thorough theoretical understanding of properties of quantum matter, such as superfluidity, when acting as an environment.

Q 38.3 Wed 11:30 M/HS1

Beyond Mean-Field Dynamics of Ultracold Bosonic Atoms in Lattices — •Axel U.J. Lode and Christoph Bruder — Department of Physics, University of Basel, Klingelbergstr. 82, CH-4056 Basel, Switzerland

The dynamics of ultracold bosons in optical lattices is a rich field with many fundamental physics questions and applications. Cold atoms in lattices represent a very versatile tool for the quantum simulation of various other states of matter. Theoretical methods for the treatment of the dynamics in one-dimensional lattices are available, but despite the large interest in the field, to date no reliable theoretical method to describe the dynamics of two- and three-dimensional systems has been formulated. An application of the multiconfigurational time-dependent Hartree method for bosons (MCTDHB, see http://ultracold.org) to describe the dynamics of the Bose-Hubbard Hamiltonian yields reliable predictions with a controlled error for the dynamics in one-, two-, and three-dimensional systems and therefore fills in this gap. The theory is introduced and example applications of beyond mean-field dynamics are discussed.

Q 38.4 Wed 11:45 M/HS1

Optical trapping of Barium ions for ion-atom collision experiments — •Julian Schmidt[1], Alexander Lambrecht[1], Georg Hoppe[1], Leon Karpa[1,2], and Tobias Schaetz[1] — [1]Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, Hermann-Herder-Strasse 3, 79104 Freiburg, Germany — [2]Freiburg Institute for Advanced Studies (FRIAS), Albertstrasse 19, 79104 Freiburg, Germany

Optical trapping of ions has been demonstrated recently [1,2]. In these experiments, the trapping beam is tuned close to the atomic resonance and off-resonant scattering resulted in severe recoil heating. We now present a recent experiment [3] in which we use a far-detuned optical dipole trap to trap a single Barium ion without any rf confinement, reducing recoil heating by four orders of magnitude.

We also describe a novel technique for micromotion compensation [3], in which the tightly focused optical trapping laser creates a position dependent ac-Stark shift. We can then measure the position of the ion with high resolution, allowing us to compensate stray fields to below 9mV/m.

In our improved setup, the optically trapped ion can be overlapped with a cloud of cold Rb atoms trapped inside in a magneto-optical and bichromatic optical dipole trap. This should allow us to avoid rf induced heating effects inherent to hybrid atom-ion traps [4].

[1] C. Schneider et al., Nat. Photon. 4, 772-775 (2010)
[2] M. Enderlein et al., Phys. Rev. Lett. 109, 233004 (2012)
[3] T. Huber et al., Nat. Comms 5, 5587 (2014)
[4] M. Cetina et al., Phys. Rev. Lett. 109, 253201 (2012)

Q 38.5 Wed 12:00 M/HS1

Expansion of ultracold bosons in anisotropic two-dimensional optical lattices — •Konstantin Krutitsky[1], Friedemann Queisser[2], Patrick Navez[3], and Ralf Schützhold[1] — [1]Fakultät für Physik, Universität Duisburg-Essen, Duisburg, Germany — [2]Department of Physics, University of British Columbia, Vancouver, Canada — [3]Department of Physics, University of Crete, Greece

Motivated by experiments on the expansion of ultracold ^{39}K atoms in anisotropic two-dimensional optical lattices [1], we present a systematic theory of this phenomenon. Initially, the atoms are prepared in the Mott-insulator state with one atom per lattice site in a finite spatial region determined by a harmonic trap. The expansion is initiated by switching-off the harmonic potential and decreasing the amplitude of the optical lattice. The system is described by an anisotropic Bose-Hubbard Hamiltonian with local interaction and two in general different tunneling rates J_1 and J_2. We investigate the dependence of the expansion speed on the lattice anisotropy J_1/J_2 and the effects of multiple occupancy of the lattice sites. Our method is based on the truncated system of equations for the local and nonlocal reduced density matrices which allows efficient treatment of large lattice systems not only in one dimension but also in higher dimensions [2,3].

[1] J. P. Ronzheimer et al, Phys. Rev. Lett. **110**, 205301 (2013)
[2] F. Queisser, K. V. Krutitsky, P. Navez, and R. Schützhold, Phys. Rev. A **89**, 033616 (2014)
[3] K. V. Krutitsky, P. Navez, F. Queisser, and R. Schützhold, EPJ Quantum Technology **1**:12 (2014)

Q 38.6 Wed 12:15 M/HS1

Fast Dynamics of a Fermi Impurity — Marko Cetina[1], •Michael Jag[1,2], Rianne Lous[1,2], Rudolf Grimm[1,2], Rasmus Sørensen[3], and Georg Bruun[3] — [1]IQOQI, Österreichische Akademie der Wissenschaften, Innsbruck, Austria — [2]Inst. für Experimentalphysik, Universität Innsbruck, Innsbruck, Austria — [3]Department of Physics and Astronomy, University of Aarhus, Aarhus, Denmark

We use Ramsey and spin-echo spectroscopy to probe the dynamics of a ^{40}K impurity in a degenerate Fermi sea of ^{6}Li atoms. At slow timescales (t>200 μs), the evolution of the impurity is dominated by elastic collisions with the background ^{6}Li atoms. The measured rate of elastic collisions as a function of the interaction strength and temperature is in very good agreement with the Fermi liquid picture. We employ a laser-induced resonance shift to rapidly vary the interaction strength and perform quenches of the impurity into the strongly interacting regime. At very short times after the quench (t<20 μs), we observe quantum dynamics of the impurity interacting with the Fermi sea. This investigation opens the possibility to observe the pairing dynamics in a Fermi gas and the formation of polaron states.

Q 38.7 Wed 12:30 M/HS1

Reactive collisions of Ba^+ and Rb — •Joschka Wolf, Artjom Krükow, Amir Mohammadi, Amir Mahdian, and Johannes Hecker Denschlag — Universität Ulm, Institut für Quantenmaterie, Albert-Einstein-Allee 45, D-89069 Ulm, Deutschland

We investigate the reactive collisions of a laser-cooled trapped ^{138}Ba$^+$ ion, with an ultracold cloud of optically trapped ^{87}Rb atoms. At atom densities of $10^{11} - 10^{12}$ we observe a quadratic density dependence of the ion loss rate, indicating three body-recombination of the ion with two Rb atoms. We do not observe two-body charge transfer, in contrast to other measurements, see [1] or [2]. We have also studied the dependence of the reaction rates in terms of collision energies. The rate constant for three body recombination scales as $K_3 \propto E^{-(0.5\pm0.1)}$, which is in rough agreement with a prediction of the group of Chris Greene. Interestingly, we do not observe molecular ions as reaction products after three-body recombination. However, we have some evidence that secondary reactions occur, which might lead to molecular dissociation.

[1] Zipkes et al, PRL **105**, **133201 (2010)** [2] Haze et al, arxiv **1403.5091 (2014)**

Q 38.8 Wed 12:45 M/HS1

Raman sideband cooling of quantum degenerate Li-6

— •Martin Boll[1], Timon Hilker[1], Katharina Kleinlein[1], Ahmed Omran[1], Guillaume Salomon[1], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str.1, 85748 Garching — [2]Ludwig-Maximilians-Universität München, Fakultät für Physik, Schellingstraße 4, 80799 München

The ability of single-site resolved detection in optical lattice experiments had huge impact on the study of strongly correlated bosonic systems. In our experiment we plan to apply similar techniques to fermionic Li-6. However for strongly correlated fermions there does not yet exist an imaging technique which combines a sufficient ratio of signal to noise while keeping each atom trapped on its original lattice site.

In this talk we present our approach, employing degenerate Raman sideband cooling. We discuss our progress using a far detuned optical lattice to pin the atomic distribution while performing Raman sideband cooling and compare to our results of a near resonant lattice, only 85 GHz detuned with respect to the D1 transition of Li-6.