A 32: Ultra-cold atoms, ions and BEC III (with Q)

Time: Thursday 11:00–13:00 Location: f107

A 32.1 Thu 11:00 f107

Toolbox for tunable ion-ion interactions in a 2D surface trap — •Henning Kalis, Frederick Hakelberg, Matthias Wittemer, Manuel Mielenz, Ulrich Warring, and Tobias Schaetz — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

Geometrical frustration has turned out to be a machanism for inducing exotic quantum disordered phases [1], whose dynamics can not be adressed efficiently on classical computers. To get around this difficulty we follow Feynman's approach of quantum simulations [2]. We chose a bottom up approach based on trapped $^{25}Mg^{+}$ ions [3]. Static and real-time control of the motional degrees of freedom has been demonstrated in a triangular surface trap with 80 μm inter-ion distance [4]. In our setup we have three dictinct trap sites seperated by 40 μm, aranged in an equilateral triangle. We report on different techniques for analysis of the motional mode orientations, that represent the key ingredient for a tunable ion-ion interaction.

[1] Moessner, R. & Sondhi, S. L, Phys. Rev. B **63**, 224401 (2001).
[2] R.P. Feynman, Int. J. Theor. Phys., VoL **21**, Nos. 6/7, (1982).
[3] Schaetz et al., New J. Phys. **15**, 085009 (2013).
[4] Mielenz et. al., In Preperation

A 32.2 Thu 11:15 f107

Purity oscillations in Bose-Einstein condensates with balanced gain and loss — Dennis Dast, Daniel Haag, •Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart, Germany

We present a new generic feature of $\mathcal{PT}$-symmetric Bose-Einstein condensates by studying the many-particle description of a two-mode condensate with balanced gain and loss. This is achieved using a master equation in Lindblad form whose mean-field limit is a $\mathcal{PT}$-symmetric Gross-Pitaevskii equation. It is shown that the purity of the condensate's single-particle density matrix periodically drops to small values but then is nearly completely restored. This indicates that during the oscillations the particles leave the single-particle orbital of the condensed phase and return afterwards to an almost perfect mean-field state. We show that this has a direct impact on the average contrast in interference experiments which periodically vanishes and recurs.

A 32.3 Thu 11:30 f107

Local Ionization of Ultracold Gases by Femtosecond Laser Pulses — •Bernhard Ruff[1,3], Philipp Wessels[1,2], Juliette Simonet[1,2], Klaus Sengstock[1,2], and Markus Drescher[1,3] — [1]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany — [2]Zentrum für Optische Quantentechnologien, Hamburg, Germany — [3]Institut für Experimentalphysik, Hamburg, Germany

The combination of ultracold atomic systems and ultrafast laser pulses promises insight into the coherence properties of macroscopic dissipative quantum systems and enables the preparation of hybrid quantum systems through local ionization of atoms in strong laser fields.

We report on the investigation of ultracold ^{87}Rb gas exposed to femtosecond laser pulses at 515 nm wavelength and 290 fs pulse duration. The light pulses ionize atoms of the atomic cloud within the focus region (7 μm waist) of the beam via two-photon absorption. The number of ions generated can be controlled by tuning the intensity or the wavelength of the laser pulses. The remaining atoms are detected by resonant absorption imaging either in situ or after time of flight.

Atomic losses evident as a hole in the trapped cloud are evaluated and show a non-linear increase with respect to the pulse energy corroborating the generation of ions in a multiphoton process. Additionally results on the relaxation dynamics of thermal clouds and condensates after exposure to a single pulse will be discussed as well as further perspectives on the detection of charged fragments.

A 32.4 Thu 11:45 f107

Measurements of spectral functions of ultra-cold atoms in a speckle potential — •Vincent Denechaud, Valentin Volchkov, Mukhtar Musawwadah, Jérémie Richard, Alain Aspect, and Vincent Josse — Laboratoire Charles Fabry - Institut d'Optique, Palaiseau, France

We present a spectroscopic study of ultra-cold atomic states in a disordered potential created by a laser speckle. Atoms are first prepared in a spin state which is insensitive to disorder. In a second step, a radio-frequency spin-flip towards a disorder-sensitive spin state is performed. The transfer rate $A(E,k)$ of such operation is referred to as spectral function, which correspond to the probability of populate an atomic state with a momentum k and an energy E within the disorder [1].

Measurements of such spectral function for various disorder configurations will be presented and discussed. We will highlight two kinds of regimes : the so-called "classical" disorder where the atomic states are shaped by the fluctuations of the random potential, and the "quantum" disorder where the states are dominated by tunelling effects. We will also explore peculiar features of spectral functions for a repulsive or an attractive speckle potential.

In principle, the spin-flip transfer allows us to create states with narrow energy distributions within the disorder. This paves the way to a precise study of the metal/insulator Anderson phase transition [2].

[1] M.I.Trappe et al, J.Phys.A: Math.Theor.48, 245102 (2015)
[2] A.Lagendijk et al, Physics Today, 62, 24 (2009)

A 32.5 Thu 12:00 f107

Dynamics of strongly correlated fermions—first principle results for two and three dimensions — •Niclas Schlünzen, Sebastian Hermanns, Jan-Philip Joost, and Michael Bonitz — CAU Kiel, Germany

Quantum transport of strongly correlated fermions is of central interest in condensed matter physics. While the stationary expansion dynamics have recently been measured with cold atoms in two-dimensional (2D) optical lattices [1], ab initio simulations have been limited, so far, to 1D setups. Using the nonequilibrium Green functions method with the T-matrix approximation [2,3], it becomes possible to precisely predict the fermionic quantum dynamics for 2D and 3D [4]. The simulations give access to the short-time dynamics, including the spatially resolved build-up of correlations, as well as the long-time limit of the expansion. The latter is investigated concerning the differences between 1D, 2D and 3D and the dependence of the expansion velocity on the particle number N, for which a universal scaling is discovered. These predictions can be verified experimentally using the recently developed fermionic atom microscopes.

[1] U. Schneider *et al.*, Nat. Phys. **8**, 213 (2012)
[2] K. Balzer and M. Bonitz, *NEGF Approach to Inhomogeneous Systems*, Lecture Notes in Physics (Springer, 2013)
[3] M. P. von Friesen *et al.*, Phys. Rev. B **82**, 155108 (2010)
[4] N. Schlünzen, S. Hermanns, M. Bonitz, and C. Verdozzi, arXiv:1508.02947 (2015)

A 32.6 Thu 12:15 f107

A High-Speed Single Ion Beam Source using a Cold Atom Beam and Rydberg Blockade — •Benjamin Sparkes, Richard Taylor, Dene Murphy, Rory Speirs, Dan Thompson, Joshua Torrancd, Andrew McCulloch, and Robert Scholten — School of Physics, University of Melbourne, Melbourne, Australia

We propose a novel single ion source based on Rydberg excitation from a cold atom beam. This source will have the ability to place ions into target surfaces with high precision due to their low temperature, allowing for the possibility of new types of nanofabricated devices and processes in material sciences. For instance, it could be used for ion implantation in solid-state quantum computers, as well as for high-resolution ion microscopy and lithography. The ideal single ion source would be fast, precise and fully deterministic, but current technologies are either slow or stochastic. Combining our second generation cold atom-beam based ion source with the phenomena of Rydberg blockade and stimulated Raman adiabatic passage (STIRAP) will allow us to overcome these issues to create a source that is fast, heralded and quasi-deterministic.

We will present simulations of the proposed single ion beam source as well as our latest experimental results demonstrating high-efficiency excitation using STIRAP in our MOT-based cold atom electron and ion source, with a total efficiency of 60% (peak efficiency of 80%).

A 32.7 Thu 12:30 f107

Topological bands in cold gases — •Sebastian Weber, David Peter, and Hans Peter Büchler — Institute for Theoretical Physics III, University of Stuttgart, 70550 Stuttgart, Germany

Topological band structures are the basis for interesting phenomena like integer and fractional topological insulators that are of high research interest. Recently it has been demonstrated that topological bands characterized by a Chern number can be realized with dipolar exchange interaction [1].

We present a proposal for the implementation of this idea using Rydberg atoms. We analyze finite geometries and investigate the appearance of edge states as a signature of topological bands. In particular, we search for minimal systems that show experimentally accessible edge states.

We study the robustness of edge states to lattice defects. Remarkably, it turns out that their stability allows the realization of interesting systems in optical lattices with slight imperfections. We can increase the robustness further if we use cutoff potentials that suppress the interaction on small length scales. This method paves the way for a novel continuum model that exhibits topological bands.

[1] D. Peter et al., *Topological flat bands with Chern number $C = 2$ by dipolar exchange interactions*, Phys. Rev. A **91**, 053617 (2015)

A 32.8 Thu 12:45 f107

Satellite-borne quantum test of the weak equivalence principle — •Naceur Gaaloul, Christian Schubert, Sina Loriani, Wolfgang Ertmer, and Ernst Maria Rasel — Leibniz University of Hanover, Germany

The high sensitivity of atom interferometer sensors makes it a promising tool for performing tests of fundamental theories. One timely challenge is to experimentally bound an eventual violation of the weak equivalence principle (WEP), a corner stone of General Relativity, by tracking the trajectories of two different atomic species in free fall. When operating on a satellite, the interferometry time of few seconds would allow to target an inaccuracy of $10^{-}15$ in differential acceleration between two atomic ensembles of different masses. In this presentation, we present the principle of such a measurement based on the use of a degenerate mixture of potassium and rubidium atoms. Several experimental arrangements have to be made in order to tackle a space operation and mitigate for significant systematic effects. This concept is proposed as a medium-size mission in the frame of the Cosmic Vision program of the European Space Agency.