Q 38: Ultra-cold atoms, ions and BEC II (with A)

Time: Wednesday 14:30–16:30 Location: f303

Q 38.1 Wed 14:30 f303

Time-resolved Scattering of a Single Photon by a Single Atom
— •Victor Leong[1,2], Mathias Alexander Seidler[1], Matthias Steiner[1,2], Alessandro Cerè[1], and Christian Kurtsiefer[1,2] — [1]Centre for Quantum Technologies, National University of Singapore, 3 Science Drive 2, Singapore 117543 — [2]Department of Physics, National University of Singapore, 2 Science Drive 3, Singapore 117542

The efficiency of light-matter interfaces between single photons and single atoms depends on the bandwidth and temporal shape of the single photon, and is crucial for realistic implementations of many quantum information protocols. In particular, an exponentially rising single photon is predicted to excite a single atom with a higher efficiency compared to any other temporal shape [1].

A four-wave mixing photon pair source, in conjunction with an asymmetric cavity, generates heralded single photons of tunable bandwidth with exponentially decaying or rising shapes [2,3]. We combine the photon pair source with a trapped single atom and investigate the free space scattering for different bandwidths and temporal shapes.

We study the scattering dynamics by measuring the atomic emission and the reduction in the number of transmitted photons. We observe that the atomic absorption dynamics are imprinted in the single-photon excitation mode.

[1] Y. Wang et al., PRA **83**, 063842 (2011)
[2] B. Srivathsan et al., PRL **111**, 123602 (2013)
[3] B. Srivathsan et al., PRL **113**, 163601 (2014)

Q 38.2 Wed 14:45 f303

Fermi-Bose mixture of ^{6}Li and ^{41}K
— Rianne S. Lous[1,2], •Isabella Fritsche[1,2], Bo Huang[1], Michael Jag[1,2], Marko Cetina[1,2], Jook T.M. Walraven[1,3], and Rudolf Grimm[1,2] — [1]Inst. for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Science, Austria — [2]Inst. for Experimental Physics, University of Innsbruck, Austria — [3]Van der Waals-Zeeman Institute, Institute of Physics, University of Amsterdam, Amsterdam, Netherlands

We report on the production of a double-degenerate, strongly mass-imbalanced Fermi-Bose mixture of ^{6}Li and ^{41}K. In our experimental sequence the potassium atoms are sympathetically cooled by the lithium atoms, which are evaporatively cooled in an optical dipole trap at a magnetic field of 1190 G. We obtain 10^4 ^{41}K atoms with a 33 % BEC fraction and a $T/T_F \approx 0.1$ with 10^5 Li atoms in each spin state. We are currently implementing a species-selective optical dimple potential to increase the BEC fraction. This paves the way to observing the collective behavior of two coupled superfluids with strong mass imbalance. We also scan the magnetic field in a region from 0 G to 1200 G and we observe multiple interspecies Feshbach resonances, which can be exploited for interaction control in strongly interacting Fermi-Bose mixtures.

Q 38.3 Wed 15:00 f303

Interaction-free measurements with ultracold atoms
— Jan Peise[1], •Bernd Lücke[1], Luca Pezzé[2], Frank Deuretzbacher[1], Wolfgang Ertmer[1], Jan Arlt[3], Augusto Smerzi[2], Luis Santos[1], and Carsten Klempt[1] — [1]Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Istituto Nazionale di Ottica (INO), Consiglio Nazionale delle Ricerche (CNR), and European Laboratory for Non-Linear Spectroscopy (LENS), 50125 Firenze, Italy — [3]QUANTOP, Institut for Fysik og Astronomi, Aarhus Universitet, 8000 Arhus C, Denmark

Interaction-free measurements (IFMs) permit the detection of an object without the need of any interaction with it. Existing proposals for IFMs demand a single-particle source. Here, we realize a new many-particle IFM concept based on an indirect quantum Zeno effect in an unstable spinor Bose-Einstein condensate. For IFMs, it is necessary to discriminate between zero and a finite number of particles. We overcome this considerable experimental challenge by implementing an unbalanced homodyne detection for ultracold atoms. This new technique achieves single-particle sensitivity and serves as an important tool for future experiments in the field of quantum atom optics.

Q 38.4 Wed 15:15 f303

Resonant quantum dynamics of few ultracold bosons in periodically driven finite lattices
— •Simeon Mistakidis[1], Thomas Wulf[1], Antonio Negretti[1,2], and Peter Schmelcher[1,2] — [1]Zentrum fuer Optische Quantentechnologien, Universitaet Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universitaet Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

The out-of-equilibrium dynamics of few ultracold bosons in periodically driven one-dimensional optical lattices is investigated. Our study reveals that the driving enforces the bosons in different wells to oscillate in-phase and to exhibit a dipole-like mode. A wide range from weak-to-strong driving frequencies is covered and a resonance-like behaviour of the intra-well dynamics is discussed [1]. In the proximity of the resonance a rich intraband excitation spectrum is observed. The single particle excitation mechanisms are studied in the framework of Floquet theory elucidating the role of the driving frequency. The impact of the interatomic repulsive interactions is examined in detail yielding a strong influence on the tunneling period and the excitation probabilities. Finally, the dependence of the resonance upon a variation of the tunable parameters of the optical lattice is examined. Our analysis is based on the ab-initio Multi-Configuration Time-Dependent Hartree Method for bosons.

[1] S. I. Mistakidis, T. Wulf, A. Negretti, and P. Schmelcher, J. Phys. B: Atomic, Molecular and Optical Physics, 48(24), 244004 (2015).

Q 38.5 Wed 15:30 f303

Transport through Bose-Einstein condensates with vortices
— •Lukas Schwarz, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Vortex solutions of the nonlinear Schrödinger equation, which describes Bose-Einstein condensates in a mean-field approximation as well as several other physical systems such as optical lattices, have attracted wide interest in the last years. In these systems complex potentials can be used to effectively describe gain and loss effects. If this gain and loss is spatially separated but balanced, the underlying Hamiltonian is $\mathcal{PT}$ symmetric. We investigate Bose-Einstein condensates in such a non-Hermitian $\mathcal{PT}$ symmetric external potential with the goal to find vortices describing a net transport through the condensate. Due to the $\mathcal{PT}$ symmetry truly stationary solutions with real eigenvalues exist in spite of a coherent and balanced in- and outcoupling of atoms. We present vortex solutions of a two-dimensional Bose-Einstein condensate trapped in different potentials with varying in- and outcoupling.

Q 38.6 Wed 15:45 f303

temperature measurement of a BEC with tunable interaction by in-situ imaging using semi-classical and hartree-fock model
— •Pierre Jouve — University of Nottingham UK

Various model of differing complexity can be used to model the density of Bose-Einstein condensate (BEC) in an harmonic trap to extract quantities such as temperature and chemical potential. We present two diff*erent method, the semi-classical thermal cloud and Hartree Fock model. We demonstrate that the Hatree-Fock method leads to more accurate result for temperature of the system close to Tc, the Bose-Einstein condensation temperature transition.

Q 38.7 Wed 16:00 f303

Towards Ultracold Interaction and Chemistry - Ba$^+$ and Rb in an optical dipole trap
— •Alexander Lambrecht, Julian Schmidt, Pascal Weckesser, Leon Karpa, and Tobias Schaetz — Universitaet Freiburg

Examining collisions of atoms and ions at extremely low temperature will permit gaining information about the corresponding sympathetic cooling rates and subsequent quantum effects, such as cluster formation of an ion binding atoms within the common $1/r^4$ potential[1]. In the last years several experimental groups investigated cold collisions between atoms and ions, leading to a better understanding of the atom-ion interaction [2-5]. Our approach to reach the regime of ultracold interaction is to precool a Ba$^+$ ion, trapped in a convential Radio-Frequency (RF) trap by Dopper cooling. By transfering the ion into an optical dipole trap[6], followd by sympathetic cooling via an ambient Rb MOT we plan to overcome the current limitations set by heating due to RF micromotion. We describe our apparatus and present first experimental results on optical trapping of ions and atoms.

[1] R. Côté et al., Phys. Rev. Lett. 89, 093001 (2002)
[2] A. Härter et al., Contemp. Phys. 55, 33 (2014)
[3] A.T. Grier et al., Phys. Rev. Lett. 102, 223201 (2009)
[4] L. Ratschbacher et al., Nature Phys. 8, 649 (2012)
[5] F. H. J. Hall et al., Mol. Phys. 111, 1683-1690 (2013)
[6] T. Huber et al., Nat. Comm. 5, 5587 (2014)

Q 38.8 Wed 16:15 f303

Satisfying the Einstein-Podolsky-Rosen criterion with massive particles — Jan Peise[1], Ilka Kruse[1], •Karsten Lange[1], Bernd Lücke[1], Luca Pezzè[2], Jan Arlt[3], Wolfgang Ertmer[1], Klemens Hammerer[4], Luis Santos[4], Augusto Smerzi[2], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [2]QSTAR, INO-CNR and LENS, Firenze, Italy — [3]Institut for Fysik og Astronomi, Aarhus Universitet, Denmark — [4]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany

Entanglement was first discussed in the thought experiment of Einstein, Podolsky, and Rosen (EPR). They considered a quantum-mechanical state consisting of two maximally correlated particles. A measurement of one subsystem seemingly allows for a prediction of the second subsystem with a precision beyond the Heisenberg uncertainty relation. We utilize spin-changing collisions in a ^{87}Rb BEC to generate a two-mode entangled state. By employing an atomic homodyne detection, we verify the EPR correlation according to Reid's criterion. We find an EPR entanglement parameter of 0.18 which is 2.4 standard deviations below the threshold of 1/4. This demonstration of continuous-variable EPR correlations is the first realization with massive particles [1]. Furthermore, the state is fully characterized by a tomographic reconstruction of the underlying many-particle quantum state. This reconstruction is obtained via a Maximum Likelihood algorithm.

[1] J. Peise et al., *Nat Commun* **6**, 8984 (2015)