A 23: Ultra-cold atoms, ions and BEC IV (with Q)

Time: Wednesday 14:30–16:30 Location: C/HSW

A 23.1 Wed 14:30 C/HSW

A single Rydberg atom as a chemistry reaction center in a Bose-Einstein condensate — •Michael Schlagmüller, Huan Nguyen, Karl Magnus Westphal, Kathrin Kleinbach, Fabian Böttcher, Tara Cubel Liebisch, Robert Löw, Sebastian Hofferberth, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Germany

A single Rydberg atom can be excited in the center of a Bose-Einstein condensate (BEC), and act as a single impurity in a quantum gas. The high density and low temperature of BECs leads to a fascinating testbed of electron-neutral atom interactions and ion-neutral atom interactions. For a Rydberg state with a principal quantum number of 100, there are thousands of ground-state atoms with which the Rydberg electron interacts, leading to a shift of the Rydberg line which can be used e.g. to observe the BEC phase transition. In addition, collisions between the ionic core of the Rydberg atom with the neighboring ground-state atoms can be studied and can even lead to the formation of ionic molecules. We report on recent findings of ion-neutral-neutral ground-state recombination in this ultra-cold quantum chemistry regime.

A 23.2 Wed 14:45 C/HSW

Creation and Characterization of Quantum Synchronization in Trapped Ion Phonon-Lasers — Michael Hush, •Weibin Li, Sam Genway, Igor Lesanovsky, and Andrew Armour — School of Physics and Astronomy, University of Nottingham, Nottingham NG7 2RD, United Kingdom

We investigate quantum synchronization theoretically in a system consisting of two cold ions in microtraps. The ions' motion is damped by a standing-wave laser whilst also being driven by a blue-detuned laser which results in self-oscillation. Working in a non-classical regime, where these oscillations contain only a few phonons and have a sub-Poissonian number variance, we explore how synchronization occurs when the two ions are weakly coupled using a probability distribution for the relative phase. We show that strong correlations arise between the spin and vibrational degrees of freedom within each ion and find that when two ions synchronize their spin degrees of freedom in turn become correlated. This allows one to indirectly infer the presence of synchronization by measuring the ions' internal state.

A 23.3 Wed 15:00 C/HSW

Stability and Tunneling Dynamics of a Dark-Bright Soliton Pair in a Harmonic Trap — •Evangelos T. Karamatskos[1], Jan Stockhofe[1], Panayotis G. Kevrekidis[2,3], and Peter Schmelcher[1,4] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg — [2]University of Massachusetts, Amherst, USA — [3]Los Alamos National Laboratory, USA — [4]The Hamburg Centre for Ultrafast Imaging

We consider a binary repulsive Bose-Einstein condensate in a harmonic trap in one spatial dimension and investigate particular solutions consisting of two dark-bright solitons. There are two different stationary solutions characterized by the phase difference in the bright component, in-phase and out-of-phase states. We show that above a critical particle number in the bright component, a symmetry breaking bifurcation of the pitchfork type occurs that leads to a new asymmetric solution. These three different states support different small amplitude oscillations, characterized by an almost stationary density of the dark component and a tunneling of the bright component between the two dark solitons. Within a suitable effective double-well picture, these can be understood as the characteristic features of a Bosonic Josephson Junction (BJJ). For larger deviations from the stationary states, the simplifying double-well description breaks down due to the feedback of the bright component onto the dark one, causing the solitons to move. In this regime we observe intricate anharmonic and aperiodic dynamics, exhibiting remnants of the BJJ phase space.

E.T. Karamatskos et al., arXiv:1411.3957

A 23.4 Wed 15:15 C/HSW

Solution of the Fröhlich polaron problem at intermediate couplings — •Fabian Grusdt[1,2,3], Yulia E. Shchadilova[4,3], Alexey N. Rubtsov[5,4], and Eugene Demler[3] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Kaiserslautern, Germany — [3]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA — [4]Russian Quantum Center, Skolkovo 143025, Russia — [5]Department of Physics, Moscow State University, 119991 Moscow, Russia

We develop a renormalization group approach for analyzing Fröhlich polarons and apply it to a problem of impurity atoms immersed in a Bose-Einstein condensate (BEC) of ultra cold atoms. Polaron energies obtained by our method are in excellent agreement with recent diagrammatic Monte Carlo calculations [Vlietinck et al., arXiv:1406.6506] for a wide range of interaction strengths. We show analytically that the energy of the Fröhlich polaron in a BEC is logarithmically UV divergent, and present a regularization scheme. This allows us to make predictions for the polaron energy, which can be tested in future experiments. Furthermore we calculate the effective mass of polarons and find a smooth crossover from weak to strong coupling regimes. Our method can be generalized to non-equilibrium polaron problems.

A 23.5 Wed 15:30 C/HSW

Vortices in a toroidal Bose-Einstein condensate with a rotating weak link — Aleksander Yakimenko[1], •Yuriy Bidasyuk[2,3], Michael Weyrauch[2], Yevgeniy Kuriatnikov[1], and Stanislav Vilchinskii[1] — [1]Department of Physics, Taras Shevchenko National University of Kyiv, Kyiv, Ukraine — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Bogoliubov Institute for Theoretical Physics, Kyiv, Ukraine

Recent series of experiments on atomic Bose-Einstein Condensates (BECs) in toroidal traps with a rotating weak link demonstrated possibilities to controllably generate and destroy persistent currents in such systems [K.C. Wright et. al. Phys. Rev. Lett. 110, 025302 (2013), S. Eckel et.al. Nature 506, 200 (2014)]. Motivated by these experiments, we investigate deterministic discontinuous jumps between quantized circulation states in a toroidal BEC. These phase slips are induced by vortex excitations created by a rotating weak link. We analyze influence of a localized condensate density depletion and atomic superflows, governed by the rotating barrier, on the energetic and dynamical stability of the vortices in the ring-shaped condensate. We simulate in a three-dimensional dissipative mean field model the dynamics of the condensate using parameters similar to the experimental conditions. We investigate in detail the vortex dynamics which leads to the observed phase slips and demonstrate the crucial role of moving vortex-antivortex dipoles in this process. Moreover, we consider the dynamics of the stirred condensate far beyond the experimentally explored region and reveal surprising manifestations of complex vortex dynamics.

A 23.6 Wed 15:45 C/HSW

Bose-Einstein Condensation of Dysprosium — •Matthias Schmitt, Thomas Maier, Holger Kadau, Matthias Wenzel, Clarissa Wink, Axel Griesmaier, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Strongly dipolar quantum gases enable the observation of many-body phenomena with anisotropic, long-range interaction. The element with the strongest magnetic dipole moment is dysprosium. It is a rare-earth element with a complex energy level structure with several possible cooling transitions. We have prepared samples of dysprosium atoms at $10\,\mu$K in a magneto-optical trap by laser cooling on a narrow transition at 626 nm. We load these cooled atoms into an optical dipole trap and transport them to a glass cell with high optical access. To finally reach quantum degeneracy we perform evaporative cooling in a crossed optical dipole trap. We create a BEC with up to N=20000 atoms at a critical temperature of 100 nK.

Additionally, we perform a trap-loss spectroscopy and observe Fano-Feshbach resonances within a magnetic field range of 70 G. We study quantum chaotic behaviour similar to investigations done with erbium atoms [1] and observe the onset of quantum chaos as a function of magnetic field.

[1] A. Frisch et al., Nature **507**, 475-479 (2014)

A 23.7 Wed 16:00 C/HSW

Two-channel model of Penning ionization of cold metastable neon atoms — •Christian Cop and Reinhold Walser — Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstr. 4a, 64289 Darmstadt

At present, many experiments are geared towards Bose-Einstein-Condensation of other elements besides the alkalies; rare-earth-gases, composite molecules and metastable noble gases. At the Technical University of Darmstadt, the group of G. Birkl investigates experimentally the prospects to condense metastable neon atoms (Ne*) [1]. The high internal energy of Ne* (∼16eV) leads to loss rates through Penning ionization (PI). Spin-polarized samples are expected to have lower loss rates than unpolarized samples since PI is forbidden here. For Ne*, suppression of PI has been observed. Interestingly, the bosonic isotopes ^{20}Ne* and ^{22}Ne* behave very differently; suppression ratios deviate by one order of magnitude and scattering lengths differ in sign.

To explain these differences we set up a two-channel model. The colliding Ne* atoms are subject to quantum-statistical effects which we include by adapting already existing single-channel models [2]. We present our results and show that they are in good agreement with the measurements.

[1] G. Birkl et al., *Cold and trapped metastable noble gases*, Rev. Mod. Phys., **84**, 175-210 (2012).

[2] C. Orzel et al., *Spin polarization and quantum-statistical effects in ultracold ionizing collisions*, Phys. Rev. A, **59**, 1926 (1998).

A 23.8 Wed 16:15 C/HSW

Many-Body Simulations of Ultracold 1D Atom-Ion Quantum Systems — •Johannes Schurer[1,2], Peter Schmelcher[1,2], and Antonio Negretti[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We consider a trapped ensemble of interacting bosonic atoms in which a single strongly trapped ion is immersed. We focus on effects induced by the atom-ion interaction as the emergence of an additional length scale and the impact of bound states onto the properties of the system. Our study is carried out by means of the multilayer-multiconfiguration time-dependent Hartree method for bosons, a numerical exact method to calculate many-body quantum dynamics. As a first step, enabled through the development of a model interaction potential for the atom-ion interaction, we analyze the influence of the atom-atom interaction strength and the number of atoms on the ground state properties (see [1]). Further, we propose experimental viable strategies for the verification of our findings. Hereupon, we investigate the dynamics following a spontaneous creation of an ion in the atomic cloud. The additional length scale in the system becomes clearly apparent and we show the necessity of the description beyond a Gross-Pitaevskii type approach. These investigations serve as first building blocks for the understanding of hybrid atom-ion systems expected to exhibit intriguing phenomena as e.g. formation of molecular ions and ion induced density bubbles.

[1] Phys. Rev. A 90, 033601 (2014)