Q 48: Quantum Gases: Effects of Interactions

Time: Thursday 10:30–12:45 Location: SCH 251

Q 48.1 Thu 10:30 SCH 251

Charge exchange reactions between a single $^{138}Ba^+$ ion and an ultracold sample of neutral ^{87}Rb atoms — •Arne Härter, Artjom Krükow, Stefan Schmid, Wolfgang Schnitzler, and Johannes Hecker Denschlag — Universität Ulm, Institut für Quantenmaterie, Albert-Einstein-Allee 45, D-89069 Ulm, Deutschland

Using a novel hybrid apparatus which allows for the simultaneous trapping of laser-cooled ions and ultracold neutral atoms, we investigate the interaction of a single trapped $^{138}Ba^+$ ion with an optically confined atomic sample of ^{87}Rb atoms [1]. After initially trapping the Ba^+ ion in a linear Paul trap, it is then injected into the Rb cloud, giving rise to elastic and inelastic collisions. In the latter case, we mainly observe charge exchange reactions of the type $Ba^+ + Rb \rightarrow Ba + Rb^+$, which are studied as a function of various parameters such as the interaction time and the density of the atomic sample. Understanding the dynamics of such reactions could allow for the realization of a charged quantum gas, which offers intriguing perspectives for a variety of novel experiments, such as charge transport in the ultracold domain [2], the formation of novel atom-ion bound states [3], polaron-type physics [4] or the production of cold, charged molecules in a well-defined quantum state [5].

[1] S. Schmid *et al.*, Phys. Rev. Lett. **105**, 133202 (2010)
[2] R. Côté, Phys. Rev. Lett. **85**, 5316 (2000)
[3] R. Côté *et al.*, Phys. Rev. Lett. **89**, 093001 (2002)
[4] F. M. Cucchietti *et al.*, Phys. Rev. Lett. **96**, 210401 (2006)
[5] P. F. Staanum *et al.*, Nature Phys. **6**, 271 (2010)

Q 48.2 Thu 10:45 SCH 251

Dipolar Bose-Einstein Condensates with Weak Disorder — •Christian Krumnow[1] and Axel Pelster[2] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

We consider a homogeneous dipolar Bose-Einstein condensate in the presence of weak quenched disorder within mean-field theory. By solving perturbatively at first the underlying Gross-Pitaevskii equation and performing then disorder ensemble averages, we derive the disorder-induced depletion of the condensate density. Furthermore, we obtain the result that the anisotropy of the two-particle interaction is passed on to both the superfluid density and the sound velocity at zero temperature. For a small dipolar interaction the superfluid depletion for a motion parallel or perpendicular to the dipoles is larger than the condensate depletion in accordance with the Huang-Meng theory of Bose-Einstein condensates with pure contact interaction [1]. For a sufficiently strong dipolar interaction, however, the superfluid depletion for a motion parallel to the dipoles becomes smaller than the condensate depletion. This astonishing finding supports that the tiny Bose-Einstein condensates, which are localized in the respective minima of the random potential, have a finite localization time [2].

[1] K. Huang and H. F. Meng, Phys. Rev. Lett. **69**, 644 (1992).
[2] R. Graham and A. Pelster, Int. J. Bif. Chaos **19**, 2745 (2009).

Q 48.3 Thu 11:00 SCH 251

Nonlocal quantum superposition states via scattering of a bright quantum matter wave soliton — •Bettina Gertjerenken and Christoph Weiss — Institute of Physics, Carl von Ossietzky University, 26111 Oldenburg, Germany

Scattering of a quantum matter wave soliton on a barrier in a one-dimensional geometry can lead to mesoscopic quantum superposition states [1]. On the two-particle level the mathematically justified effective potential approach [1] can be numerically compared with the exact quantum dynamics and an excellent agreement for an experimentally realistic approximately Gaussian potential has already been shown [2]. Further investigations of the effective potential approach will be presented.

[1] C. Weiss and Y. Castin, Phys. Rev. Lett. 102, 010403 (2009).
[2] C. Weiss, Laser Phys. 20, 665 (2010).

Q 48.4 Thu 11:15 SCH 251

Homogeneous Bose-Einstein Condensate with Weak Disorder — •Vladimir Luković[1], Antun Balaž[1], and Axel Pelster[2] — [1]Scientific Computing Laboratory, Institute of Physics Belgrade, University of Belgrade, Pregrevica 118, 11080 Belgrade, Serbia — [2]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

We determine the thermodynamic properties of a homogeneous superfluid dilute Bose gas in presence of weak quenched disorder. To this end we solve perturbatively the underlying Gross-Pitaevskii equation and perform then disorder ensemble averages for the respective physical quantities of interest. In the first order with respect to the disorder we reproduce the seminal results of Huang and Meng, which were originally derived within a Bogoliubov theory around a disorder averaged background field [1]. Afterwards, we determine both the condensate and the superfluid depletion as well as the equation of state and the sound velocity also in the subsequent second order and evaluate them for different disorder correlation functions.

[1] K. Huang and H. F. Meng, Phys. Rev. Lett. **69**, 644 (1992).

Q 48.5 Thu 11:30 SCH 251

Towards coherent control of collisions in metastable neon — •Jan Schütz, Alexander Martin, Thomas Feldker, Holger John, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

We investigate the collisional interactions of laser cooled, metastable neon (Ne*). The most remarkable feature of Ne* is its high internal energy. Since the internal energy exceeds half of the ionization energy it enables ionizing collisions, namely Penning and associative ionization. The resulting ions as well as Ne* can be detected with high efficiency and accurate time resolution using electron multipliers. This enables us to gain a close insight into collisional interactions.

We are exploring a method to manipulate the ionization cross-sections by preparing the atoms in superposition states of $^3P_2$ Zeeman sublevels. Due to the interference of different collision channels this is proposed to modify the cross-sections of Penning and associative ionization for certain superpositions. We prepare the desired superposition states using radio frequency pulses in combination with the AC Stark shift of a laser. We report on the status of the experiment.

Q 48.6 Thu 11:45 SCH 251

Variational calculations for anisotropic solitons in dipolar Bose-Einstein condensates — •Rüdiger Eichler, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, Germany

We present variational calculations using a Gaussian trial function to calculate the ground state of the Gross-Pitaevskii equation and to describe the dynamics of the quasi-two-dimensional solitons in dipolar Bose-Einstein condensates. Furthermore we extend the ansatz to a linear superposition of Gaussians improving the results for the ground state to exact agreement with numerical grid calculations using imaginary time and split-operator method. We are able to give boundaries for the scattering length and estimate the temperature at which the solitons would be stable in a future experiment. By dynamical calculations with coupled Gaussians we are able to describe the rather complex behavior of the thermally excited solitons. The discovery of dynamically stabilized solitons indicates the existence of such BECs at experimentally accessible temperatures.

Q 48.7 Thu 12:00 SCH 251

Stability of Bose-Einstein condensates: Variational and numerical approach — •Manuel Kreibich, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

We analyze the stability of Bose-Einstein condensates by two methods: First by solving the Bogoliubov-de Gennes equations which yields the numerically exact stability eigenvalues. Second with the ansatz of coupled Gaussians within the framework of the time dependent variational principle. For the lowest eigenvalues we find good agreement. However, not all Bogoliubov eigenmodes can be described by the simple ansatz of coupled Gaussians. We modify the original ansatz in such a way that the complete Bogoliubov eigenspectrum can be obtained.

Q 48.8 Thu 12:15 SCH 251

Multi-shooting algorithm for the calculation of the bounce trajectory in Bose-Einstein condensates with attractive 1/r-interaction — •Kai Marquardt, Jörg Main, and Günter Wun-

ner — 1. Institut für Theoretische Physik, Universität Stuttgart

Bose-Einstein condensates of cold dilute atomic gases with attractive 1/r-interaction are well described by the Gross-Pitaevskii equation (GP). We solve the GP by a time-dependent variational principle using an ansatz of superimposed Gaussians. The condensates can decay from the metastable ground state into a collapsing state due to macroscopic quantum tunneling. To determine the tunneling rates we calculate the bounce trajectory in imaginary time by a multi-shooting algorithm.

Q 48.9 Thu 12:30 SCH 251

Macroscopic quantum tunnelling and bounce solutions of Bose-Einstein condensates with dipolar interaction — •Torsten Schwidder, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

Macroscopic quantum tunnelling is discussed for Bose-Einstein condensates with dipolar interaction. The decay of a metastable groundstate into a collapsing wave function is investigated in a time-dependent variational approach to the nonlinear Gross-Pitaevskii equation. For a superposition of Gaussian wave functions the bounce trajectory is computed in imaginary time using a multi-shooting algorithm and tunnelling rates are calculated.