Q 70: Ultracold Atoms, Ions and BEC V (with A)

Time: Friday 11:00–13:15 Location: M/HS1

Q 70.1 Fri 11:00 M/HS1

Probing superfluidity of Bose-Einstein condensates via stirring — •Vijay Pal Singh[1,2], Wolf Weimer[2], Kai Morgener[2], Jonas Siegl[2], Klaus Hueck[2], Niclas Luick[2], Henning Moritz[2], and Ludwig Mathey[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We investigate the superfluid behavior of a Bose-Einstein condensate of ^{6}Li molecules. In the experiment the condensate is stirred by a small attractive potential along a circular path. The moving potential produces almost no heating when its velocity is below the critical velocity v_c. The rate of induced heating increases steeply above v_c. The observed critical velocity, however, is smaller than the Bogoliubov speed of sound. To understand this, we perform numerical simulations and identify the factors that reduce v_c. The critical velocity is influenced by the finite temperature, the inhomogeneous density along the strongly confined direction, the circular instead of linear motion of the stirring potential, and the finite depth of the potential. The simulated critical velocities with experimental parameters are in excellent agreement with the experimentally measured ones.

Q 70.2 Fri 11:15 M/HS1

Cavity-Optomechanics with cold atoms: Quantum mechanical oscillators coupled by a cavity-mediated optical spring — •Nicolas Spethmann[1,2], Jonathan Kohler[1], Sydney Schreppler[1], Lukas Buchmann[1], and Dan Stamper-Kurn[1] — [1]University of California, Berkeley — [2]Universität Kaiserslautern

A complex quantum system can be constructed by coupling simple quantum elements to one another. Oscillators comprised of the collective motion of ultracold, neutral atoms are excellent model systems in the quantum regime. However, neutral atoms inherently exhibit only weak interactions, so that it is a challenge to create tuneable, long-range coupling. Such interactions can be induced employing photons in a cavity containing the ultracold atoms. Because of the decay of cavity photons, such a coupling necessarily leads to measurement back-action noise being imparted onto the oscillators.

We demonstrate cavity-mediated coupling between two near-groundstate oscillators composed of ultracold Rb atoms trapped inside a high-finesse cavity. We observe phase-coherent transfer of excitation between the oscillators. At the same time, we detect the motional noise of the oscillators to monotonically increase with coupling time due to back-action. We show that this back-action noise exhibits two-oscillator correlations, reflecting the properties of the coupled mode system during cavity-mediated interaction. Our results point to the potential, and also the challenge, of coupling quantum oscillators with light.

Q 70.3 Fri 11:30 M/HS1

Loschmidt Echo in Fock Space — •Thomas Engl[1], Julien Dujardin[2], Peter Schlagheck[2], Juan Diego Urbina[1], and Klaus Richter[1] — [1]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany — [2]Département de Physique, Université de Liège, 4000 Liège, Belgium

The Loschmidt echo is a measure of stability of a quantum system with respect to an external perturbation. While for single particle systems the Loschmidt echo has been extensively studied [1], for the fundamental issue of quantum stability in interacting many-body systems only few, mainly numerical, results are available [2]. However, the recent development of methods to describe many-body quantum systems in the semiclassical regime [3], allows to attack analytically this difficult problem.

Here, we consider bosonic atoms in an optical lattice well described by a Bose-Hubbard model, where the perturbation is given by a small difference of the on-site energies. In the disordered case, we compute both the amplitude and the modulus square of the Loschmidt echo using the new semiclassical methods. Our analytical results show excellent agreement when compared to numerical calculations.

[1]A. Goussev, R. A. Jalabert, H. M. Pastawski and D. A. Wisniacki, Loschmidt echo. Scholarpedia **7**, 11687 (2012)

[2]J. D. Bodyfelt, M. Hiller, and T. Kottos, Europhys. Lett. **78**, 50003 (2007)

[3]T. Engl, J. Dujardin, A. Argüelles, P. Schlagheck, K. Richter and J. D. Urbina, Phys. Rev. Lett. **112**, 140403 (2014)

Q 70.4 Fri 11:45 M/HS1

Sympathetic cooling of ions in radio frequency traps beyond the critical mass ratio — •Pascal Weckesser, Bastian Höltkemeier, Henry Lopez, and Matthias Weidemüller — Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg

Sympathetic cooling has become a powerful and universal method for preparing ultracold ions confined in radio frequency traps. We theoretically investigate the possibility of using laser-cooled atoms as a buffer gas. Recent theories indicate that cooling of ions in radio frequency traps is limited by the mass ratio of the coolant and the ion.

We present an approach to overcome the this mass ratio limitation. By performing Monte-Carlo simulations we find universal solutions for the ion's steady state at all mass ratios. A detailed description of these solutions and the corresponding cooling limit for experimental applications will be presented.

Q 70.5 Fri 12:00 M/HS1

Two-photon ionization of a Bose-Einstein condensate — •Bernhard Ruff[1,2], Alexander Grote[3], Harald Blazy[3], Harry Krüger[3], Hannes Duncker[3], Jasper Krauser[3], Juliette Simonet[3], Philipp Wessels[1,3], Klaus Sengstock[1,3], and Markus Drescher[1,2] — [1]Centre for Ultrafast Imaging, Hamburg, Germany — [2]Institut für Experimentalphysik, Hamburg, Germany — [3]Zentrum für optische Quantentechnologien, Hamburg, Germany

Hybrid quantum systems involving ultracold atoms and ions have undergone a spectacular development in the past years. Many approaches have been pursued to prepare such systems amoung which the combination of atom and ion traps, photoionization schemes or electron impact ionization.

We report on the investigation of a ^{87}Rb condensate interacting with femtosecond laser pulses at 515 nm wavelength. The light pulses ionize atoms of the condensate within the focus region (7 μm waist) of the beam via two-photon absorption. The number of produced ions can be controlled by tuning the intensity or the wavelength of the laser pulses. We work in a regime where several thousands of ions are created in the quantum gas. The remaining atoms are detected by resonant absorption imaging, either in situ or after time-of-flight, which allows extracting the number of atoms and their temperature. First results on the relaxation of the condensate after interacting with one femtosecond laser pulse will be discussed.

Q 70.6 Fri 12:15 M/HS1

Critical quasienergy states in driven many-body systems — Victor Manuel Bastidas[1], •Georg Engelhardt[1], Pedro Pérez-Fernández[2], Malte Vogl[3], and Tobias Brandes[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Departamento de Física Aplicada III, Escuela Superior de Ingeniería, Universidad de Sevilla, Camino de los Descubrimientos s/n, ES-41092 Sevilla, Spain — [3]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany

We discuss singularities in the spectrum of driven many-body spin systems. In contrast to undriven models, the driving allows us to control the geometry of the quasienergy landscape. As a consequence, one can engineer singularities in the density of quasienergy states by tuning an external control. We show that the density of levels exhibits logarithmic divergences at the saddle points, while jumps are due to local minima of the quasienergy landscape. We discuss the characteristic signatures of these divergences in observables like the magnetization, which should be measurable with current technology [1].

[1] V.M. Bastidas, G. Engelhardt, P. Pérez-Fernández, M. Vogl, and T. Brandes. arXiv:1410.5281 (To appear in Phys. Rev. A)

Q 70.7 Fri 12:30 M/HS1

Critical temperatures in a gas of Sodium spin-1 atoms — •Tilman Zibold, Vincent Corre, Camille Frapolli, Andrea Invernizzi, Jean Dalibard, and Fabrice Gerbier — Collège de France, 11 place Marcelin Berthelot, 75005 Paris, France

We investigate the Bose-Einstein condensation of a gas of Sodium atoms with spin degree of freedom. The phase transition of the different Zeeman components to the condensed phase occurs in general at different critical temperatures, depending on the (conserved) total magnetization of the sample and quadratic Zeeman energy. The higher critical temperature simply corresponds to the condensation of the majority component. The two lower ones correspond to the appearance of magnetic ordering and generally depend more strongly on direct and exchange interactions. We measure this effect for different magnetizations and in different magnetic fields with good agreement with simple theoretical models.

Q 70.8 Fri 12:45 M/HS1

Interaction-free measurements with ultracold atoms — Jan Peise[1], •Bernd Lücke[1], Luca Pezzé[2], Frank Deuretzbacher[3], Wolfgang Ertmer[1], Jan Arlt[4], Augusto Smerzi[2], Luis Santos[3], and Carsten Klempt[1] — [1]Institut für Quantenoptik, 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]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [4]QUANTOP, Institut for Fysik og Astronomi, Aarhus Universitet, 8000 Arhus C, Denmark

In contrast to our intuition, possible events can influence our physical reality even if they do not occur. This is particularly well illustrated by the idea of interaction-free measurement (IFM), which permits the detection of an object without the need of any interaction with it. We use the quantum Zeno effect in a spinor Bose-Einstein condensate to demonstrate a new scheme for interaction-free measurements. Highly efficient single-atom detection - a major requirement for IFM - is reached via the unprecedented realization of an unbalanced homodyne detection with ultracold atoms. Our experiments provide the first realization of the long-sought indirect quantum Zeno effect and demonstrate IFM efficiencies surpassing all previous realizations, since our many-particle scheme is inherently robust against losses and decoherence that strongly plague the single-particle variants.

Q 70.9 Fri 13:00 M/HS1

Bose-Einstein condensation in classically frustrated optical lattices — •Peter Janzen[1,2], Wen-Min Huang[1,2,3], and Ludwig Mathey[1,2,3] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, Hamburg 22761, Germany

We investigate Bose-Einstein condensation in a classically frustrated triangular lattice geometry, as realized recently in experiment [1]. In this system, the single particle dispersion has two distinct minima in the Brillouin zone. Therefore, in addition to a continuous $U(1)$ symmetry, a discrete $\mathbb{Z}_2$ symmetry can be broken upon condensation. We derive a general effective action for systems with these symmetries. Using a renormalization group approach, we investigate the critical behavior of this effective action. We find that for the triangular lattice geometry, the condensed state breaks the $\mathbb{Z}_2$ symmetry. Also, we find that the transition is of first order, unlike Bose-Einstein condensation in free space, which is a continuous phase transition.

[1] J. Struck, M. Weinberg, C. Ölschläger, P. Windpassinger, J. Simonet, K. Sengstock, R. Höppner, P. Hauke, A. Eckardt, M. Lewenstein, and L. Mathey, Nature Physics **9**, 738 (2013).