Q 43: Ultra-cold atoms, ions and BEC II

Time: Thursday 10:30–12:30 Location: V47.02

Q 43.1 Thu 10:30 V47.02

Pomeranchuk effect and spin-gradient cooling of Bose-Bose mixtures in an optical lattice — •Yongqiang Li, Reza Bakhtiari, Liang He, and Walter Hofstetter — Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, 60438 Frankfurt/Main, Germany

We theoretically investigate finite-temperature thermodynamics and demagnetization cooling of two-component Bose-Bose mixtures in a cubic optical lattice, by using bosonic dynamical mean field theory (BDMFT). We calculate the finite-temperature phase diagram, and remarkably find that the system can be *heated* from the superfluid into the Mott insulator at low temperature, analogous to the Pomeranchuk effect in ^{3}He. This provides a promising many-body cooling technique. We examine the entropy distribution in the trapped system and discuss its dependence on temperature and an applied magnetic field gradient. Our numerical simulations quantitatively validate the spin-gradient demagnetization cooling scheme proposed in recent experiments.

Q 43.2 Thu 10:45 V47.02

Raman cooling in a 1D lattice with additional radial confinement — •Andreas Steffen, Noomen Belmechri, Sebastian Hild, Andrea Alberti, Wolfgang Alt, and Dieter Meschede — Institut für angewandte Physik, Wegelerstr. 8, Bonn

Quantum information technology requires the interaction of qubits to realize devices like quantum cellular automata or phenomena like molecular bound states in quantum walks. For atoms in optical lattices, it is implemented most conveniently by controlled cold collisions, which requires the preparation of the atoms in the vibrational 3D ground state to achieve a well-defined interaction phase. We present current results on cooling single atoms in a 1D optical lattice with enhanced radial confinement. Two optically phase-locked Raman lasers have been built to couple different motional states. To meet the Lamb-Dicke criterion to cool the motion in the radial directions of our 1D lattice geometry, we overlap a repulsive hollow-core beam created by a phase mask. This increases the radial trap frequency by a factor of ten, allowing resolved Raman sideband cooling.

Q 43.3 Thu 11:00 V47.02

Quantum phases of Bose-Bose mixtures in a triangular lattice — •Liang He[1], Yongqiang Li[1], Sebastian D. Huber[2], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Goethe Universität Frankfurt (Main), Germany — [2]Department of Condensed Matter Physics, The Weizmann Institute of Science, Rehovot 76100, Israel

Geometric frustration arises when magnetic interactions between different spins on a lattice are incompatible with the underlying crystal geometry. Motivated by recent experimental progress in making non-bipartite optical lattices [1], we investigate the zero-temperature quantum phases of a Bose-Bose mixture in a triangular lattice, using bosonic dynamical mean field theory (BDMFT) [2]. We map out the ground state phase diagram of the system which contains spin-ordered phases, weak charge density wave, superfluid, and supersolid phases. The effects of geometric frustration on the spin-ordered phases and phase transitions between different spin-ordered phases are also discussed.

[1] C. Becker et al., New J. Phys. **12**, 065025 (2010); W. S. Bakr et al., Science **329**, 547 (2010); Gyu-Boong Jo et al., arXiv:1109.1591.

[2] K. Byczuk et al., Phys. Rev. B 77, 235106 (2008); A. Hubener et al., Phys. Rev. B **80**, 245109 (2009); W. J. Hu et al., Phys. Rev. B **80**, 245110 (2009); Y. Li et al., Phys. Rev. B **84**, 144411 (2011).

Q 43.4 Thu 11:15 V47.02

Investigation of $\mathcal{PT}$ symmetry in a model of a Bose-Einstein condensate — •Holger Cartarius and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart, Germany

The observation of $\mathcal{PT}$ symmetry in a coupled optical wave guide system that involves a complex refractive index has been demonstrated impressively in the recent experiment by Rüter et al. [1]. This is, however, only an optical analogue of a quantum system, and it would be highly desirable to observe the manifestation of $\mathcal{PT}$ symmetry and its resulting properties also in a real, experimentally accessible, *quantum* system. Following a suggestion by Klaiman et al. [2], we investigate a $\mathcal{PT}$ symmetric arrangement of a Bose-Einstein condensate in a double δ well potential, where in one well cold atoms are injected while in the other particles are extracted from the condensate.

[1] C. E. Rüter, K. G. Makris, R. El-Ganainy, D. N. Christodoulides, M. Segev, and D. Kip, Nature Physics 6, 192 (2010)

[2] S. Klaiman, U. Günther, and N. Moiseyev, Phys. Rev. Lett. 101, 080402 (2008)

Q 43.5 Thu 11:30 V47.02

Light-cone-like spreading of correlations in a quantum many-body system — Marc Cheneau[1], Peter Barmettler[2], Dario Poletti[2], Manuel Endres[1], •Peter Schauss[1], Takeshi Fukuhara[1], Christian Gross[1], Immanuel Bloch[1,3], Corinna Kollath[2,4], and Stefan Kuhr[1,5] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching — [2]Département de physique théorique, Université de Genève, 1211 Geneva, Switzerland — [3]Ludwig-Maximilians-Universität, 80799 München — [4]Centre de physique théorique, École Polytechnique, CNRS, 91128 Palaiseau, France — [5]University of Strathclyde, SUPA, Glasgow G4 0NG, UK

How fast can correlations spread in a quantum many-body system? Based on the seminal work by Lieb and Robinson, it has recently been shown that several interacting many-body systems exhibit an effective light cone that bounds the propagation speed of correlations. The existence of such a "speed of light" has profound implications for condensed matter physics and quantum information, but has never been observed experimentally. In this talk I will report on the time-resolved detection of propagating correlations in an interacting quantum many-body system. By quenching a one-dimensional quantum gas in an optical lattice, we have revealed how quasiparticle pairs transport correlations with a finite velocity across the system, resulting in an effective light cone for the quantum dynamics. These results open important perspectives for understanding relaxation of closed quantum systems far from equilibrium as well as for engineering efficient quantum channels necessary for fast quantum computations.

Q 43.6 Thu 11:45 V47.02

Progress and Outlook on Optically Trapped Ions — •Thomas Huber[1,2], Martin Enderlein[1,2], Christian Schneider[1,2], Michael Zugenmaier[2], Magnus Albert[1,2], and Tobias Schätz[1,2] — [1]Max-Planck-Institut für Quantenoptik — [2]Albert-Ludwigs-Universität Freiburg

In 2010 we trapped a Mg^+ ion in an optical dipole trap for the first time [1]. Compared to conventional ion traps optically trapped ions are promising in several ways: For example to study ultra-cold atom-ion collisions not suffering from micromotion-induced heating [2] and as potentially scalable systems with long-range interaction for quantum simulations.

The aim of quantum simulation is to study the complex dynamics of a quantum system by simulating it with an easier controllable one. One of the bottlenecks that still have to be passed is the scalability of the controllable systems. Next to ions in surface RF traps, ions or ions and simultaneously atoms trapped in optical lattices seem to be promising candidates. In this talk we will report on our results on confining a single ion in an one dimensional optical lattice.

Furthermore we will report on our proposals on optically trapping Ba^+ ions. Due to the transition wavelength in the visible regime this element offers several advantages. Recently it had been shown in a hybrid (RF + optical) trap, that Ba^+ is a good candidate to be sympathetically cooled by a cloud of ultracold Rb Atoms.

[1]Schneider et al., Nat. Photonics 4(2010)

[2]Cormick et al., New J. Phys. 13 (2011)

Q 43.7 Thu 12:00 V47.02

Variational treatment of Faraday and resonant waves in Bose-Einstein condensates — •Alexandru Nicolin — Horia Hulubei National Institute for Physics and Nuclear Engineering, 30 Reactorului, Magurele 077125, Romania

The dynamics of Faraday and resonant waves in trapped Bose-Einstein condensates is analyzed by variational means. These waves can be excited by modulating periodically either the strength of the magnetic trap or the atomic scattering length. To study their dynamics, we develop a variational model that describes consistently both the bulk part of an inhomogeneous cigar-shaped condensate and small-amplitude, small-wavelength surface waves. The main ansatz used in the variational treatment is tailored around a set of Gaussian envelopes and we show extensions for the high-density regime using a q-Gaussian function. Finally, we show explicitly that for drives of small amplitude, the two methods of obtaining surface waves are equivalent, and we discuss the existing experimental results.

Q 43.8 Thu 12:15 V47.02

Ballistic expansion of interacting fermions in one-dimensional optical lattices — •Stephan Langer[1], Martin J. A. Schuetz[2], Ian P. McCulloch[3], Ulrich Schollwöck[1], and Fabian Heidrich-Meisner[1] — [1]LMU München — [2]MPQ Garching — [3]U Queensland, Brisbane, Australia

In most quantum quenches, no net particle currents arise. Access to studying transport properties can be gained by letting a two-component Fermi gas that is originally confined by the presence of a trapping potential expand into an empty optical lattice. In recent experiments, this situation was addressed in 2D and 3D optical lattices [1]. We focus on the 1D case in which an exact numerical simulation of the time-evolution is possible by means of the DMRG method. Concretely, we study the expansion in the 1D Hubbard model with repulsive interactions, driven by quenching the trapping potential to zero, and we concentrate on the most direct experimental observable, namely density profiles [2]. In the strict 1D case, we identify conditions for which the expansion is ballistic, characterized by an increase of the cloud's radius that is linear in time. This behavior is found whenever initial densities are smaller or equal to one, both for the expansion from box and harmonic traps. We make quantitative predictions for the expansion velocity as a function of onsite repulsion and initial density that can be probed in experiments.

[1] Schneider et al., arXiv:1005.3545
[2] Langer et al., arXiv:1109.4364