Q 4: Ultra-cold atoms, ions and BEC I

Time: Monday 10:30–12:45 Location: BAR 106

Q 4.1 Mon 10:30 BAR 106

Scattering of a polarizable atom by an absorbing nanowire — •Martin Fink, Johannes Eiglsperger, Harald Friedrich, and Javier Madroñero — Physik Department (T30a), TU München, Germany

In view of the intense attention currently given to systems involving nanotubes at very low temeratures, we study the fundamental process of scattering a cold, polarizable atom by an infinite cylindrical conducting wire. We formulate a method offering a practicable way of numerically calculating the exact nonretarded electrostatic van der Waals potential with any desired accuracy, see Ref. [1]. Using this method, we are able to calculate numerically the scattering properties for an absorbing nanowire by assuming incoming boundary conditions at the surface. We present calculations, e.g. of the s-wave scattering length which characterizes the behaviour of these properties in the near-threshold region. This is the first calculation of atom-wire scattering, which is based on a theoretically founded potential and on the two-dimensional nature of the problem.

[1] M. Fink et al., Physical Review A **81**, 062714 (2010).

Q 4.2 Mon 10:45 BAR 106

Universality of s-wave scattering phase shifts beyond the effective-range expansion — •Alexander Kaiser, Tim-Oliver Müller, and Harald Friedrich — Physik Department, TU München, Germany

The properties of scattering states at low energies in deep potentials with a homogeneous attractive tail $V(r) = -\hbar^2\beta_\alpha^{\alpha-2}/(2\mu r^\alpha)$ with $\alpha > 2$ are strongly related to the location of the bound states just below the dissociation threshold. It has been shown that the non-integer part $\Delta_{\rm th}$ of the threshold quantum number determines the scattering length [1] as well as the semiclassical behaviour [2] of the scattering phase shift at intermediate energies. With a new method we derived a formula for the scattering phase shift, accurately describing the whole energy range from threshold to the semiclassical regime, $\tan(\delta_0) = A_s/A_c \sin(\phi_s - \phi_{\rm sr})/\cos(\phi_s - \phi_{\rm sr})$, where A_s/A_c, ϕ_s and ϕ_c are universal functions of energy, which depend on the potential tail (i.e. α) alone and $\phi_{\rm sr}$ contains a single parameter $\Delta_{\rm th}$, accounting for all short range effects. The bound states below threshold are given by the quantization function [3], $F_{\rm tail}(E_n) = n_{\rm th} - n$, so that the whole energy spectrum around the dissociation threshold is determined by the scattering length.

[1] G. Gribakin and V. Flambaum, *Phys. Rev. A* **48**, 546 (1993).
[2] G. Gribakin et al., *Phys. Rev. A* **59**, 1998 (1999).
[3] P. Raab and H. Friedrich, *Phys. Rev. A* **7**8, 022707 (2008).

Q 4.3 Mon 11:00 BAR 106

Three bosons in two dimensions — •Kerstin Helfrich and Hans-Werner Hammer — HISKP(Theorie) und BCTP, Universität Bonn

In this talk I discuss two-dimensional atomic gases exhibiting a large two-body scattering length. In an effective field theory framework we are able to calculate observables up to next-to-leading order, i.e. with the inclusion of the two-body effective range. We are especially interested in three-body observables such as the binding energies, the atom-dimer scattering length and the three-body recombination rate.

Q 4.4 Mon 11:15 BAR 106

Interaction Driven Interband Tunneling of Bosons in the Triple Well — •Lushuai Cao[1], Ioannis Brouzos[1], Sascha Zöllner[2], and Peter Schmelcher[1] — [1]Zentrum für Optische Quantentechnologien, Luruper Chaussee 149, D-22761 Hamburg, Germany — [2]Niels Bohr International Academy, Niels Bohr Institute, Blegdamsvej 17, DK-2100 Copenhagen, Denmark

We study the tunneling of a small ensemble of strongly repulsive bosons in a one-dimensional triple-well potential. The usual treatment within the single-band approximation suggests suppression of tunneling in the strong interaction regime. However, we show that several windows of enhanced tunneling are opened in this regime. This enhanced tunneling results from higher band contributions, and has the character of interband tunneling. It can give rise to various tunneling processes, such as single-boson tunneling and two-boson correlated tunneling of the ensemble of bosons, and is robust against deformations of the triple well potential. We introduce a basis of generalized number states including all contributing bands to explain the interband tunneling, and demonstrate various processes of interband tunneling and its robustness by numerically exact calculation.

Q 4.5 Mon 11:30 BAR 106

A fundamental limit to spin-exchange optical pumping of ^{3}He nuclei — •H.R. Sadeghpour, T.V. Tscherbul, P. Zhang, and A. Dalgarno — ITAMP, Harvard-Smithsonian CfA, Cambridge, MA 02138

The existence of a fundamental limit to the efficiency of spin-exchange optical pumping of ^{3}He nuclei by collisions with spin-polarized alkali-metal atoms is established. Using accurate *ab initio* calculations of molecular interactions and scattering properties, requiring no adjustable parameters, it is demonstrated that attainable polarization of ^{3}He nuclei by spin-exchange collisions with K atoms is limited by the anisotropic hyperfine interaction. The theory is specifically applied to the spin-exchange between potassium and ^{3}He. In a complementary calculation, it is suggested that it may be possible to overcome this limit by using atomic silver (Ag) as a collision partner in spin-exchange optical pumping experiments.

Q 4.6 Mon 11:45 BAR 106

Rotons and Supersolids in Rydberg-dressed BECs — •Nils Henkel and Thomas Pohl — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, 01187 Dresden

We study a BEC where atoms are off-resonantly coupled to high Rydberg states with strong van der Waals interaction. We find that this leads to effective ground state interactions which, in turn, lead to the formation of a crystalline structure in the BEC. Comparisons to Quantum Monte Carlo simulations at finite temperatures demonstrate the survival of a significant superfluid fraction, i.e. the emergence of a Supersolid state in the BEC. This excellent agreement proves the applicability of our Mean-Field theory. Therefore, we then extend our Mean-Field investigation to rotating BECs and find similar structures as in the stationary case. There appears however a nontrivial competition between supersolid order and an Abrikosov vortex lattice due to rotation. Shedding light on this competition, the resulting phase diagram will be discussed.

Q 4.7 Mon 12:00 BAR 106

Mesoscopic Transport of Ultracold Atoms in Optical Lattices — •Martin Bruderer and Wolfgang Belzig — Fachbereich Physik, Universität Konstanz, D-78457 Konstanz, Germany

Transport of quantum gases is attracting considerable attention, both on a theoretical and experimental level, in part because ultracold atoms confined to optical lattices can be coherently manipulated and detected on microscopic scales. In particular, substantial technological progress has opened the way for a bottom-up approach to mesoscopic transport in optical lattices, in which case the coherence in certain parts of the system is deliberately destroyed. We show based on a specific setup, namely two incoherent atomic reservoirs connected by a short optical lattice, that mesoscopic phenomena such as, e.g., phonon assisted transport, coherent suppression of tunneling and non-adiabatic quantum pumping can be realized with ultracold atoms. For our analysis in the tight-binding regime we use the non-equilibrium Green's functions formalism extended to include the time dependence of the reservoirs.

Q 4.8 Mon 12:15 BAR 106

Phase diagrams for spin-1 bosons in an optical lattice — •Ming-Chiang Chung[1,2] and Sungkit Yip[2] — [1]Physics Division, National Center for Theoretical Science, Hsinchu, 30013, Taiwan — [2]Institute of Physics, Academia Sinica, Taipei 11529, Taiwan

The phase diagrams of a polar spin-1 Bose gas in a three-dimensional optical lattice with linear and quadratic Zeeman effects both at zero and finite temperatures are obtained within mean-field theory. The phase diagrams can be regrouped to two different parameter regimes depending on the magnitude of the quadratic Zeeman effect Q. For large Q, only a first-order phase transition from the nematic (NM) phase to the fully magnetic (FM) phase is found, while in the case of small Q, a first-order phase transition from the nematic phase to the partially magnetic (PM) phase, plus a second-order phase transition from the PM phase to the FM phase is obtained. If a net magnetization in the system exists, the first-order phase transition causes a coexistence of two phases and phase separation: for large Q, NM and FM phases and for small Q, NM and PM phases. The phase diagrams in terms of net magnetization are also obtained

Q 4.9 Mon 12:30 BAR 106

Magnetism and Phase Separation in SU(3) Symmetric Multi-species Fermi Mixtures — •Irakli Titvinidze[1], Antonio Privitera[1,2], Soon-Yong Chang[3,4], Sebastian Diehl[3], Mikhail Baranov[3], Andrew Daley[3], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Goethe-Universität, Frankfurt am Main, Germany — [2]Dipartimento di Fisica, Università di Roma La Sapienza, Roma, Italy — [3]IQOQI of the Austrian Academy of Sciences, Innsbruck, Austria, — [4]Department of Physics, The Ohio State University, Columbus, OH 43210, USA

We study the phase diagram of a SU(3) symmetric mixture of three-species fermions in a lattice with attractive interactions and the effect on the mixture of an effective three-body constraint induced by three-body losses. We address the properties of the system in $D \geq 2$ by using dynamical mean-field theory and variational Monte Carlo techniques. The phase diagram of the model shows a strong interplay between magnetism and superfluidity. In the absence of three-body constraint (no losses), the system undergoes a phase transition from a color superfluid phase to a trionic phase, which shows additional charge density modulations at half-filling. Outside of the particle-hole symmetric point the color superfluid phase has always a finite polarization, leading to phase separation in systems where the total number of particles in each species is conserved. The three-body constraint strongly disfavors the trionic phase, stabilizing a (fully magnetized) color superfluid phase also at strong coupling. With increase of the temperature we observe a transition to a non-magnetized $SU(3)$ Fermi liquid phase.