DY 15: Controlling Dirty Bosons: Disorder Effects on BECs

Time: Tuesday 14:30–16:45 Location: MA 001

DY 15.1 Tue 14:30 MA 001

Bose-Einstein Condensates in Strongly Disordered Traps — •Thomas Nattermann[1] and Valery Pokrovsky[2] — [1]Institut für theoretische Physik der Universität zu Köln — [2]Department of Physics, Texas A&M University, USA

A Bose-Einstein condensate in an external potential consisting of a superposition of a harmonic and a random potential is considered theoretically. From a semi-quantitative analysis we find the size, shape and excitation energy as a function of the disorder strength. For positive scattering length and sufficiently strong disorder the condensate decays into fragments each of the size of the Larkin length L. This state is stable over a large range of particle numbers. The frequency of the breathing mode scales as 1/Lˆ2. For negative scattering length a condensate of size L may exist as a metastable state. These findings are generalized to anisotropic traps.

DY 15.2 Tue 14:45 MA 001

Ultracold bosons in lattices with disorder created by "heavy"impurities — Konstantin V. Krutitsky[1], Michael Thorwart[2], Reinhold Egger[2], and •Robert Graham[1] — [1]Fachbereich Physik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg, Germany — [2]Institut für Theoretische Physik IV, Heinrich-Heine-Universität Düsseldorf, Germany

Quantum phases of ultracold bosons with repulsive interactions in optical lattices in the presence of disorder are investigated. The disorder is assumed to be caused by the interaction of the bosons with impurity atoms having a large effective mass. The system is described by the Bose-Hubbard Hamiltonian with on-site energies which have a discrete probability distribution. The phase diagram at zero temperature is calculated using several methods like a strong-coupling expansion, an exact numerical diagonalization, a Bose-Fermi mapping, as well as two different versions of a mean-field theory.

DY 15.3 Tue 15:00 MA 001

Dipole Oscillations of a Bose-Einstein Condensate in Presence of Defects and Disorder — •Tobias Paul, Mathias Albert, Nicolas Pavloff, and Patricio Leboeuf — Laboratoire de Physique Théorique et Modèles Statistiques, Universite Paris Sud

We study the dipole oscillations of a weakly interacting BEC, confined in a harmonic cigar-shaped trap with a tight transverse confinement but a shallow axial trapping frequency in presence of an external defect or random potential. Our main result is a new, global picture characterizing the dynamical properties of the dipole oscillations, where different regimes of condensate dynamics are observed: For small-amplitude dipole oscillations we demonstrate that the BEC-flow is superfluid and the dipole oscillations are almost undamped, but the external potential induces a small shift of the oscillations frequency. When the center of mass motion reaches a critical velocity the superfluid behavior breaks down and one enters a regime of dissipative dynamics characterized by a strong damping of the dipole oscillations. We show that the onset of this domain is marked by the emergence of gray solitons. For large-amplitude oscillations a regime of quasi-dissipationless transport is found where the creation of elementary excitations is strongly oppressed. We discuss our findings in the context of recent experimental observation [1,2,3] and address the question under which circumstances Anderson localization is of relevance for these systems.

[1] C. Fort et al., Phys. Rev. Lett. 95, 170410 (2005)
[2] J. E. Lye et al., Phys. Rev. A 75, 061603 (2007)
[3] P. Engels and C. Atherton, Phys. Rev. Lett. 99, 160405 (2007

DY 15.4 Tue 15:15 MA 001

Disorder physics in atomic mixtures — •Oleksandr Fialko and Klaus Ziegler — Universität Augsburg

Mixtures of different atomic species represent complex quantum systems with competing degrees of freedom. They can be created either by filling two types atoms in an optical lattice [1,2] or by allowing an atomic cloud to form molecules due to attractive interatomic interaction [3,4]. The competing degrees of freedom can lead to competing quantum phases, phase transitions, phase separation, and correlation induced disorder. We discuss various systems with elastic and inelastic scattering, quantum phases, and the possibility of Anderson localization.

[1] C. Ates and K. Ziegler, Phys. Rev. A 71, 063610 (2005)
[2] K. Ziegler, Nucl. Phys. A 790, 718c (2007)
[3] K. Ziegler, Laser Physics 15, 650 (2005)
[4] O. Fialko, Ch. Moseley and K. Ziegler, Phys. Rev. A 75, 053616 (2007)

DY 15.5 Tue 15:30 MA 001

Tracking Bogoliubov excitations in correlated disorder — •Cord A. Müller and Christopher Gaul — Physikalisches Institut, Universität Bayreuth, 95440 Bayreuth, Germany

In order to study the interplay of interaction and disorder in atomic BECs, we investigate the transport properties of Bogoliubov excitations in the presence of correlated spatial potential fluctuations [1]. In two dimensions, we find that the scattering cross-section of Bogoliubov excitations by an elementary obstacle has a node, which can be explained analytically in the hydrodynamic description. We further explore the consequences for the multiple-scattering regime in a correlated disordered potential by calculating relevant transport lengths.

[1] R.C. Kuhn et al, New J. Phys. 9, 161 (2007)

DY 15.6 Tue 15:45 MA 001

Critical Temperature of Dirty Bosons — •Ben Klünder, Axel Pelster, and Robert Graham — Fachbereich Physik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg, Germany

We consider a dilute Bose gas moving in a harmonic trap with a superimposed frozen random potential which arises in experiments either artifically with laser speckles or naturally in wire traps. The critical temperature, which characterizes the onset of Bose-Einstein condensation, depends on the disorder realization within the ensemble. Therefore, we introduce an effective grand-canonical potential from which we determine perturbatively the disorder averages of both the first and second moment of the critical temperature in leading order. We discuss our results for a finite number of particles by assuming a Gaussian spatial correlation for the quenched disorder potential.

DY 15.7 Tue 16:00 MA 001

Many-body diffusion in disordered potentials — •Sandro Wimberger — Institut für Theoretische Physik, Universität Heidelberg, D-69120 Heidelberg

Ongoing experiments with Bose-Einstein condensates are studying the quantum transport of ultracold atoms in disordered potentials. Going beyond the currently investigated regimes, we predict a crossover between regular and quantum chaotic dynamics as a function of the disorder strength. Our spectral approach is based on the Bose-Hubbard model describing the motion of strongly interacting bosonic atoms in deep potentials. Our statistical predictions on the spectral properties are readily observable by monitoring the evolution of typical experimental initial states.

DY 15.8 Tue 16:15 MA 001

The Bose-Fermi-Hubbard model as a step to the disordered Bose-Hubbard-Model — •Alexander Mering and Michael Fleischhauer — Fachbereich Physik, Technische Universitaet Kaiserslautern

The influence of disorder on the ground-state phase diagram of the Bose-Hubbard model (BHM) is of long standing experimental and theoretical interest and yet not completely understood. We present analytical and numerical results for the Bose-Hubbard model with a binary disorder distribution resulting from the admixture of a heavy fermionic species as quasi-static impurities to the system. We find that for quenched and annealed disorder the phase diagram can be understood in terms of compressible, partial-compressible and incompressible phases. Numerical calculations using the density matrix renormalization group show that the partially compressible phases have a Bose-glass character. We also discuss the Bose-Fermi-Hubbard model in the limit of fast fermions where a finite lattice size leads to effects reminiscent of the BHM with a boxed disorder distribution.

DY 15.9 Tue 16:30 MA 001

Stochatical Mean Field Theory for the Disordered Bose Hubbard Model — •Ulf Bissbort and Walter Hofstetter — Institut

für Theoretische Physik, JWG Universität Frankfurt am Main

We develop a systematic extension of the usual site decoupling mean field theory for the disordered Bose Hubbard model, extending the self-consistency condition to account for disorder induced inhomogeneity of the mean field parameter, by using a probability distribution. This method is capable of describing the Bose glass in the thermodynamic limit at T=0 and recovers the usual MFT in the limit of vanishing disorder, as well as the arithmetically averaged MFT in the limit of infinite dimensions, where the Bose glass border shifts to JZ=0. Phase diagrams are presented for a box disorder distribution and the limit of strong disorder is discussed.