Q 7: Quantengase: Bosonen im Gitter I

Zeit: Montag 14:00–16:00 Raum: VMP 6 HS-A

Q 7.1 Mo 14:00 VMP 6 HS-A

Light Scattering by Ultracold Atoms in Optical Lattices — •Stefan Rist[1], Giovanna Morigi[1], and Chiara Menotti[2] — [1]Departament de Fisica, Universitat Autonoma de Barcelona — [2]BEC-INFM Dipartimento di Fisica, Università di Trento

Light scattering by an ultracold atomic gas in a one-dimensional optical lattice is theoretically studied, when the atoms are probed by a weak laser. We analyze the intensity of the scattered light as a function of the angle of emission for different values of the tunneling rate, spanning from the superfluid to the Mott-insulator phase. We show how the excitation spectrum of the many body system can be measured by observing of the scattered light intensity as a function of the scattering angle and photon frequency. We identify different features in the first order coherence of the scattered light, depending on whether the atoms are in the Mott-insulator or superfluid state. We discuss our results with respect to previous studies, where the structure form factor was evaluated by a time-of-flight measurement [1] and where light scattering by ultracold atoms in an optical lattice was determined, neglecting the tunneling rate [2].

[1] A.M. Rey et al., Phys. Rev. A 72, 023407 (2005)
[2] I.B.Mekhov et al., Phys. Rev. Lett. 98, 100402 (2007)

Q 7.2 Mo 14:15 VMP 6 HS-A

Bose-Hubbard phase diagram with arbitrary integer filling — •Niklas Teichmann[1], Dennis Hinrichs[1], Martin Holthaus[1], and Andre Eckardt[2] — [1]Institut für Physik, Carl von Ossietzky Universität, D-26111 Oldenburg, Germany — [2]ICFO-Institut de Ciències Fotòniques, E-08860 Castelldefels (Barcelona), Spain

We study the transition from a Mott insulator to a superfluid in the Bose-Hubbard model for a square (2D) and cubic (3D) lattice at zero temperature, employing the method of the effective potential. Converting Kato's perturbation series into a numerical algorithm capable of reaching high orders, we obtain accurate critical parameters – also for high integer filling factors, which have remained hard to obtain with other methods. Our technique allows us to monitor both the approach to the mean-field limit by considering spatial dimensionalities $d > 3$, and to the limit of high filling, which refers to an array of Josephson junctions.

Q 7.3 Mo 14:30 VMP 6 HS-A

Bosons in 1D Optical Superlattices: Computing the Phase Diagram from Experimental Parameters — •Felix Schmitt, Markus Hild, and Robert Roth — Institut fuer Kernphysik, Technische Universitaet Darmstadt

We determine the exact zero-temperature phase-diagram of bosonic atoms in a one-dimensional optical superlattice for different experimental setups [T. Stoeferle et al., Phys. Rev. Lett. 92 130403 (2004); J. E. Lye et al., Phys. Rev. A 75 061603 (2007)] directly using the experimental superlattice amplitudes as control parameters. To this end the site-dependent Hubbard parameters, i.e. hopping, two-particle interaction, and on-site energy, are extracted via a single-particle bandstructure calculation from the amplitudes of the standing waves forming the two-color superlattice potential. The many-particle problem is then solved with the finite-size density matrix renormalization group (DMRG) technique. This procedure offers the possibility to study observables like the visibility of the interference fringes directly as function of the experimental parameters.

Q 7.4 Mo 14:45 VMP 6 HS-A

Attractively bound pairs in the Bose-Hubbard model and anti-ferromagnetism — •Bernd Schmidt[1], Michael Bortz[1], Sebastian Eggert[1], David Petrosyan[2], and Michael Fleischhauer[1] — [1]Fachbereich Physik, Technische Universität Kaiserslautern, D-67663 Kaiserslautern, Germany — [2]Institute of Electronic Structure & Laser, FORTH, 71110 Heraklion, Crete, Greece

We consider a periodic lattice loaded with pairs of bosonic atoms tightly bound to each other via a strong attractive on-site interaction that exceeds the inter-site tunneling rate. An ensemble of such lattice-dimers is accurately described by an effective Hamiltonian corresponding to the extended Hubbard model with strong repulsive interaction between the nearest neighbor sites corresponding to the anisotropic XXZ model. We calculate numerically and analytically the ground-state phase diagram for this system exhibiting incompressible phases, corresponding to an empty and a fully filled lattice (ferromagnetic phases) and a half-filled alternating density crystal (anti-ferromagnetic phase), separated from each other by compressible phases. In a 1D finite lattice the compressible phases show characteristic oscillatory modulations on top of the anti-ferromagnetic density profile and in density-density correlations. A kink model is derived which provides a simple and quantitative explanation of these features. The large-wavelength properties of the system can be described in terms of a Luttinger liquid.The relevant Luttinger parameter K is obtained exactly using the Bethe Ansatz. Density-density as well as first-order correlations are calculated and shown to be in excellent agreement with numerical results obtained with density matrix renormalization group methods.

Q 7.5 Mo 15:00 VMP 6 HS-A

Ginzburg-Landau Theory for Quantum Phase Transitions in Bosonic Lattices — Barry Bradlyn[1], •Francisco Ednilson Alves dos Santos[2], and Axel Pelster[2,3] — [1]Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA — [2]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [3]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

We work out a Ginzburg-Landau theory for investigating quantum phase transitions in lattice Bose systems at arbitrary temperature [1]. To this end we expand the grand-canonical free energy as a double power series in both the tunneling and a symmetry breaking source term. Then an order parameter field is introduced, and the underlying effective action is derived via a Legendre transformation. Determining the Ginzburg-Landau expansion to first order in the tunneling term, expressions for the Mott insulator–superfluid phase boundary, condensate density, average particle number, and compressibility are derived. Additionally, excitation spectra in the ordered phase are found by considering both longitudinal and transverse variations of the order parameter. Although our effective action approach yields the same Mott insulator - superfluid phase boundary to first order in the tunneling than standard mean-field theory, our predictions turn out to be superior to the mean-field results deeper into the superfluid phase.

[1] B. Bradlyn, F.E.A. dos Santos, and A. Pelster, Phys. Rev. A (in press), eprint: `arXiv:0809.0706`.

Q 7.6 Mo 15:15 VMP 6 HS-A

Quantum chaos and entanglement in the Bose-Hubbard model — •Michael Lubasch[1] and Sandro Wimberger[1,2] — [1]Institute for Theoretical Physics, Philosophenweg 19, 69120 Heidelberg — [2]Graduate School of Fundamental Physics, Albert-Ueberle Str. 3-5, 69120 Heidelberg

It was first shown by *Kolovsky and Buchleitner* in [Europhys. Lett. 68 (2004), 632-638] that the spectral statistics of the Bose-Hubbard model can exhibit quantum chaos. In their work they investigated the distribution of energy level spacings in the spectrum. We derive a reliable method to differentiate between the regular and the chaotic regime via complete detection of avoided-crossings. These are energy levels that come very close to each other but never touch and their presence is characteristic for the chaotic regime.

Quantum entanglement also allows to separate the two regimes. However for a correct description the indistinguishability of the bosons and a superselection rule for constant global particle number have to be taken into account.

Q 7.7 Mo 15:30 VMP 6 HS-A

Valence Bond States : Link models and scattering experiments — Enrique Rico[1], •Robert Hübener[2,3], Simone Montangero[4,5], Niall Moran[6], Bogdan Pirvu[1], Jiri Vala[6,7], and Hans Briegel[2,3] — [1]Fakultät für Physik, Universität Wien, Austria — [2]ITP, Universität Innsbruck, Austria — [3]IQOQI Innsbruck, Austria — [4]Institut für Quanteninformationsverarbeitung, Universität Ulm, Germany — [5]NEST-CNR-INFM and Scuola Normale Superiore, Pisa, Italy — [6]National University of Ireland, Maynooth, Ireland — [7]Dublin

Institute for Advanced Studies, Ireland

An isotropic anti-ferromagnetic quantum state on a two-dimensional square lattice is characterized by symmetry arguments only. By construction, this quantum state is the result of an underlying valence bond structure without breaking any symmetry in the lattice or spin spaces. The physical relevance of the model is motivated. A comparison of the model to known anti-ferromagnetic Mott-Hubbard insulators is given by means of the two-point equal-time correlation function obtained i) numerically from the suggested state and ii) experimentally from neutron scattering on cuprates in the anti-ferromagnetic insulator phase. Ref: arXiv:0811.1049

Q 7.8 Mo 15:45 VMP 6 HS-A

Phase diagram of the two-dimensional spin-1/2 XY anisotropic triangular lattice — •Roman Schmied[1], Philipp Hauke[1], Tommaso Roscilde[2], and J. Ignacio Cirac[1] — [1]MPI für Quantenoptik, Garching, Germany — [2]Ecole Normale Supérieure de Lyon, France

Quantum simulators promise to further our understanding of condensed-matter systems which are currently at or beyond the limits of computational methods. One such system is the two-dimensional spin-1/2 XY anisotropic triangular lattice [1], which we have studied using several techniques (Lanczos diagonalization, spin waves, and PEPS [2]). We present its proposed temperature-dependent phase diagram, which includes 1D and 2D Néel ordered phases, a 2D spiraling ordered phase, and several spin-liquid phases. The zero-temperature quantum phase transitions between ordered phases appear to acquire a universal discontinuous structure, passing through a short-range spin-liquid phase similar to what has been predicted for the analogous Heisenberg model. At finite temperatures, Kosterlitz-Thouless and spin-melting transitions complete the picture. We also present preliminary results on the J1-J2-J3 model.

[1] R. Schmied et al., NJP 10 (2008) 045017
[2] F. Verstraete and J. I. Cirac, arXiv:cond-mat/0407066v1