Q 11: Quantengase: Bosonen im Gitter II

Zeit: Montag 16:30–18:00 Raum: VMP 6 HS-A

Q 11.1 Mo 16:30 VMP 6 HS-A

Bragg Spectroscopy in Optical Lattices — •Philipp T. Ernst, Sören Götze, Jasper S. Krauser, Karsten Pyka, and Klaus Sengstock — Insitut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Physics with quantum gases in optical lattices is a dynamically evolving field of fundamental research and particularly well suited to provide an experimental interface between quantum optics and solid state physics. Many novel quantum phases have been predicted in these systems. However, their detection and analysis, especially the characterization of their excitation spectrum, still remains challenging.

Here we report on high resolution momentum-resolved spectroscopy of the excitation spectrum of an ultracold bosonic gas in an optical lattice for the first time. Using Bragg diffraction in 2D and 3D lattice geometries, we show systematic measurements of the dispersion relation of the first and second band over the whole first Brillouin zone varying the lattice depth. The results clearly show the influence of interaction on the excitation spectrum as well as the sensitivity to density and particle numbers. Changing pulse area and probing time provides an insight into the dynamics of these systems.

Our measurements demonstrate high resolution Bragg spectroscopy in optical lattices to be a powerful technique which offers a wide range of applications, from perspectives on detecting new phases to the preparation of specific momentum states as a starting point for further investigations.

Q 11.2 Mo 16:45 VMP 6 HS-A

RPA Studies of Dynamic Response of Ultracold Bose Gases in 1D Optical Lattices — •Markus Hild, Panagiota Papakonstantinou, Felix Schmitt, and Robert Roth — Institut für Kernphysik, Technische Universität Darmstadt, 64289 Darmstadt

We study the dynamic response of ultracold Bose gases in one-dimensional optical lattices based on the Bose-Hubbard model (BHM) using a generalized random-phase approximation. Our aim is to simulate Bragg-spectroscopy experiments using modulated optical lattice potentials to probe the system [PRL 92 (2004) 130403, PRL 98 (2007) 130404]. We compare the response function obtained at different levels of the RPA scheme with results from a linear response analysis based on the full eigenspectrum of the BHM. The evolution of the response as a function of interaction strength and lattice size is investigated. The results are in very good agreement with experiments and due to the minimal numerical effort RPA emerges as a powerfull tool to gain insights on the dynamics of bosonic lattice systems at experimentally relevant system sizes.

Q 11.3 Mo 17:00 VMP 6 HS-A

Direct Observation of Multi-Band Physics using Quantum Phase Diffusion in 3D Optical Lattices — •Sebastian Will[1], Thorsten Best[1], Simon Braun[1], Ulrich Schneider[1], Lucia Hackermüller[1], Dirk-Sören Lühmann[2], and Immanuel Bloch[1] — [1]Johannes Gutenberg-Universität Mainz — [2]Universität Hamburg

In recent years ultracold bosonic atoms in optical lattices have proven their potential to simulate quantum systems, that are known from condensed matter physics. This was prominently demonstrated by the realisation of the superfluid to Mott insulator transition and has been theoretically described by the Bose-Hubbard model. Its underlying Hamiltonian is restricted to the single, energetically lowest band. However, recent theoretical studies have emphasized, that the interatomic interaction may bring multi-band effects into play and considerably modify the behaviour of the system. In our experiment we have trapped a Bose-Einstein condensate of ^{87}Rb atoms in a 3D optical lattice with minimal underlying harmonic confinement. Through rapid increase of the lattice depth, we have been able to prepare coherent superpositions of atom number states on each site. While tunnelling is strongly suppressed, the dynamical evolution of the system shows a continuous collapse and revival of the phase of the matterwave field, the period of which is determined by the onsite interaction energy. Up to 80 revivals of the matterwave field have been detectable. The observed dynamics give clear indication of multi-band physics beyond the single-band Hubbard model, our data being in excellent agreement with theoretical calculations obtained with the method of exact diagonalization.

Q 11.4 Mo 17:15 VMP 6 HS-A

Quantitative measurement of the downshift of the critical temperature for Bose-Einstein condensation in an optical lattice — •Trotzky Stefan, Schnorrberger Ute, Thompson Jeff, and Bloch Immanuel — Universität Mainz

In the last years, experiments with ultracold quantum gases in optical lattices have developed in many directions, while various theoretical and numerical approaches have been proposed. The variety of Hamiltonians realizable in the experiments shows a large overlap with condensed matter systems. Therefore, the possibility to simulate large-scale quantum systems in the laboratory and to extract observables relevant for condensed matter physics provides a strong motivation for the work in this field. Full quantitative understanding of the usually inhomogeneous experimental systems, however, is extremely demanding for realistic system sizes.

Here, we present a quantitative measurement of the critical temperature T_c for Bose-Einstein condensation in a periodic potential and reveal the downshift of T_c upon approaching the critical interaction strenght for the transition from a superfluid to a Mott insulator. A direct comparison to ab initio quantum Monte-Carlo simulations for our trap parameters and particle numbers is used to verify the evaluation method. This comparison also enables us to check the adiabaticity of the loading process and to quantify non-adiabatic heating in the experimental system.

Q 11.5 Mo 17:30 VMP 6 HS-A

An Optical Microscope for 2D Quantum Gases — •Simon Fölling, Jonathon Gillen, Waseem Bakr, Amy Peng, Peter Unterwaditzer, and Markus Greiner — Department of Physics, Harvard University and Harvard-MIT Center for Ultracold Atoms, Cambridge, MA 02138, USA

Ultracold quantum gases are used as models for studying fundamental questions of modern condensed matter physics with atomic physics experiments. They allow for creating very clean implementations of complex many-body systems, and can enable the realization of tools for manipulating and probing the gas which are not available for classical condensed matter systems. We will present the implementation of an experiment that enables the preparation of a cold quantum gas in a single, strongly two-dimensional trapping potential. The atoms are located a few micrometers from a glass surface, allowing for optical access with a very high numerical aperture of NA=0.8. This enables us to image and manipulate the quantum gas with a resolution on the scale of 500 nm, for example by generating optical lattices by direct projection through the lens and flourescence imaging inside the trap.

Q 11.6 Mo 17:45 VMP 6 HS-A

Coherent control of dressed matter waves in strongly driven periodic potentials — •Oliver Morsch[1], Alessandro Zenesini[1], Hans Lignier[1,2], Donatella Ciampini[1], and Ennio Arimondo[1] — [1]CNR-INFM and Università di Pisa, Largo Pontecorvo 3, 51267 Pisa, Italy — [2]PhLAM, Université de Lille, 59655 Villeneuve d'Ascq cedex, France

We demonstrate experimentally that matter waves in one-, two- and three-dimensional optical lattices can be "dressed" and thus given new properties by strongly driving the periodic potentials. In the driven lattices the tunneling probability and the tunneling phase between adjacent lattice sites become a function of the driving parameters [1]. We identify regimes in which the parameters of the driving can be changed in time without exciting the system, thus allowing coherent and adiabatic following. This coherent control is then used in order to reversibly induce the superfluid-Mott insulator phase transition by changing the strength of the driving [2]. Our findings pave the way towards detailed studies of driven quantum systems, in particular the conditions for adiabatic following, and suggest new methods for controlling matter waves.

[1] H. Lignier et al., Phys. Rev. Lett. 99, 220403 (2007). [2] A. Eckardt et al., Phys. Rev. Lett. 95, 260404 (2005).