Q 46: Quantengase: Optische Gitter 4

Time: Thursday 14:00–16:00 Location: V53.01

Q 46.1 Thu 14:00 V53.01

Experimental realization of resonating valence bond states with ultracold bosonic atoms in arrays of optical plaquettes — •Marcos Atala[1,2], Monika Aidelsburger[1,2], Yu-Ao Chen[1,2], Sylvain Nascimbène[1,2], Stefan Trotzky[1,2], Belén Paredes[3], and Immanuel Bloch[1,2] — [1]Fakultät für Physik, Ludwig-Maximilian-Universität, Schellingstrasse 4, 80798 München, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [3]Fakultät für Physik and Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilian-Universität, 80333 München, Germany

The concept of resonating valence bond state lies at the heart of fundamental many-body quantum physical phenomena, such as high temperature superconductivity and topological quantum computation. In this talk we will present our results on direct experimental evidence of a valence bond quantum resonance with ultracold bosonic atoms. The atoms are manipulated using a superlattice structure, creating a three-dimensional array of independent four-site plaquettes. Furthermore, we will show how resonating valence bond states with s- and d-wave symmetry can be created and characterized. These two states constitute a minimum basis of a topologically protected qubit.

Q 46.2 Thu 14:15 V53.01

Chiral and hidden ordered phases of ultracold bosonic atoms in zig-zag lattice geometries — •Sebastian Greschner, Temo Vekua, and Luis Santos — Institut für theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany

Recent experimental advances in controlling motional degrees of freedom of ultracold bosonic atoms in triangular lattices have opened the possibility of simulation of frustrated quantum antiferromagnetism. In this context we discuss properties of ultracold bosonic atoms in a quasi one dimensional frustrated zig-zag lattice geometry, which exhibit a rich ground state quantum phase diagram including chiral superfluid and chiral insulators. We present numerical and field theoretical results, that show that due to the frustration induced by the zig-zag geometry, even very small interactions will immediately lead to insulating phases. Furthermore in this setup an effective three-body hard-core interaction, which has been been shown to be induced by strong dissipative processes, may lead to the emergence of a Haldane-insulator phase for bosons even in the absence of long range dipolar interactions. In the presence of dipolar interactions further non-trivial phases are formed, including a double-Haldane phase.

Q 46.3 Thu 14:30 V53.01

Simple spin model for many-body resonant tunneling — •Julia Link, Carlos Parra-Murillo, and Sandro Wimberger — Institute for Theoretical Physics and HGSFP, University Heidelberg

Interesting phenomena can be studied by using the Bose-Hubbard model due to the interplay between the kinetic and interparticle interaction energy of ultracold atoms loaded into optical lattices. An example system is the Wannier problem, characterized by the presence of inter- and intraband oscillations arising from an additional tilting (Stark-)force. We consider a two-band model approximation, in which resonant tunneling between the bands is reached at specific values of the tilt. It is shown that the original problem can be mapped onto an effective hamiltonian for a spin-$\frac{1}{2}$ chain in a transverse magnetic field. This effective model can be integrated analytically, and thus the characteristic revival times of the interband band transitions can be computed in terms of the parameters of the system [1].

[1] P. Plötz, P. Schlagheck, and S. Wimberger, Eur. Phys. J. D **63**, 47-53 (2011)

Q 46.4 Thu 14:45 V53.01

Strongly Interacting Fermions in Optical Lattices — •Valentin Kasper and Christof Wetterich — Institut für Theoretische Physik, Universität Heidelberg

We investigate the thermodynamic properties of strongly interacting fermionic atoms trapped in an optical lattice. The strong coupling physics at a Feshbach resonance requires that we consider effects of the full band structure going beyond the fermionic single-band Hubbard model. We extend previous mean field calculations using the Functional Renormalization Group. This way the phase diagram at zero temperature is established.

Q 46.5 Thu 15:00 V53.01

The Bose-Hubbard model with localized particle losses — •Kosmas Kepesidis and Michael Hartmann — Technical University of Munich, Physics Department 1, Munich, Germany

In this work, we consider the one-dimensional Bose-Hubbard model with particle losses at one lattice site. Ultra-cold bosonic atoms in a one-dimensional optical lattice can provide a possible realization. Focusing an electron beam on a single site can generate the one-site particle losses. The atoms will be ionized when scattered by the electrons of the beam and the ions can be driven off the lattice by a uniform electric field. For the description of this system, we derive an effective Born-Markov master equation treating the dissipative lattice site as a quantum environment. We first investigate the case where the system is a perfect superfluid. We find that when the dissipative site is located exactly in the middle of the lattice, half of the bosons of an initially homogeneous particle distribution, are not affected by the dissipation. A physical interpretation of this result is that the surviving particles interfere destructively when they tunnel to the location of the defect and therefore never reach the lossy site. When we include interactions, the phase coherence is destroyed and all particles will eventually decay. However, this process could be slowed down by appropriate tuning of the parameters. Finally, we consider the case where the lossy site is not at the center of the chain and we investigate whether there is a slow-down of particle losses, for some range of the parameters.

Q 46.6 Thu 15:15 V53.01

Repulsively bound pairs of bosons and fermions in an optical lattice — •Eva Katharina Rafeld, Bernd Schmidt, and Walter Hofstetter — Institut für Theoretische Physik, Goethe-Universität Frankfurt am Main

We systematically derive and classify effective multi-particle Hamiltonians of repulsively (and attractively) bound pairs of atoms (so-called dimers) in an optical lattice. Specifically we consider boson-fermion pairs, pairs of different bosons or pairs of spinful fermions. In one spatial dimension we investigate properties of interacting dimers using the Time Evolving Block Decimation method (TEBD): we study the ground state phase diagram of the effective dimer models by analyzing the density distribution in a 1d box as well as in a 1d harmonic trap, and we calculate correlators and structure factors to determine the ordering of the different phases. We compare our numerical results for the effective dimer models with those of the full Hamiltonians and with analytic predictions. We also perform time-dependent simulations, analyzing the dynamics of small dimer clusters.

Q 46.7 Thu 15:30 V53.01

Multi-orbitally extended Hubbard models for optical lattices — •Ole Jürgensen, Dirk-Sören Lühmann, and Klaus Sengstock — Institut für Laser-Physik, Universität Hamburg

For the theoretical investigation of ultracold atoms in optical lattices, Hubbard models are frequently applied. These models are typically restricted to on-site interactions and the lowest single-particle orbital. We show that higher orbitals and off-site interactions can have a significant influence on optical lattice systems as indicated in recent experiments [1-3].

In particular, interactions of particles on neighboring sites, so-called bond-charge interactions, lead to an additional non-negligible tunneling. Within a fully correlated treatment, we perform a multi-orbital renormalization [4,5] to derive an extended Hubbard model.

Using this effective occupation-dependent Hubbard model, we compute the phase diagram of the superfluid to Mott-insulator transition for bosonic atoms and Bose-Fermi mixtures [4]. We find considerable deviations from the standard Hubbard model. The obtained results allow for new insight in the fundamental behavior of ultracold atoms in optical lattices beyond the commonly applied Hubbard model.

[1] T. Best et al., Phys. Rev. Lett. 102, 030408 (2009)
[2] S. Will et al., Nature (London) 465, 197 (2010)
[3] J. Heinze et al., Phys. Rev. Lett. 107, 135303 (2011)
[4] D.-S. Lühmann et al., arxiv: 1108.3013
[5] U. Bissbort et al., arxiv: 1108.6047

Q 46.8 Thu 15:45 V53.01

Photodissociation of $^{40}K_2$ Feshbach molecules —
•Simon Braun[1], Liam Cook[2], Ulrich Schneider[1], Lucia Hackermüller[3], Sebastian Will[4], Thorsten Best[5], Philipp Ronzheimer[1], Michael Schreiber[1], Paul Julienne[6], and Immanuel Bloch[1] — [1]Ludwig-Maximilians-Universität München — [2]University College London — [3]University of Nottingham — [4]MIT Cambridge — [5]Universität Innsbruck — [6]NIST Gaithersburg

One requirement to study many-body phenomena with ultracold atoms in optical lattices is a sufficiently long lifetime and low enough heating rate of the atomic samples in the optical potentials. In the case of blue-detuned optical lattice potentials, one of the main loss and heating mechanisms is given by light-assisted collisions on doubly occupied lattice sites. Due to the similarity of the two-particle on-site wavefunction to that of Feshbach molecules, light-assisted collisions directly correspond to the photodissociation of Feshbach molecules.

We present a thorough measurement of the photodissociation spectrum of $^{40}K_2$ Feshbach molecules in a broad detuning range on the blue-detuned side of the atomic D2 transition. We compare our measurements with a multichannel calculation, obtaining excellent agreement. We obtain information about both the initial Feshbach molecule wavefunction and the exit channel Born-Oppenheimer potential and can construct an excited state potential energy model that is consistent with previous experimental observations.

The measurements enable us to choose the wavelength of our optical lattice laser such that light-assisted losses are minimized.