Q 5: Quantum Gases: Bosons I

Time: Monday 11:30–13:00 Location: P/H2

Q 5.1 Mon 11:30 P/H2

Towards multi-body entanglement in optical lattices — •Hanning Dai[1,2], Bing Yang[1,2], Xiaofan Xu[1], Andreas Reingruber[1], Qi Shen[2], Zhensheng Yuan[2], and Jianwei Pan[1,2] — [1]Physikalisches Institut, University Heidelberg — [2]Hefei National Laboratory for Physical Science at Microscale and Department of Modern Physics, University of Science and Technology of China

Neutral atoms in optical lattices have the advantage of a natural scalability towards large qubit numbers and a weak coupling to the environment, leading to long decoherence time. However, the creation of multi-partite entanglement and the unambiguous characterization of it in optical lattices still remain challenging.

Here we propose an experiment towards the perparation of a 4-qubit GHZ-type state in an optical plaquette and introduce the progress of the project. Recently, by using two superlattices along perpendicular directions, a four-site optical plaquettes have been realized. By employing a spin-dependent superlattice, one can achieve state initialization as well as spin and site resolved addressing and detection, the key prerequisites to prepare and observe multi-body correlations in optical lattices.

Q 5.2 Mon 11:45 P/H2

Observation of entanglement dynamics in a one dimension optical lattice — •Sebastian Hild[1], Jae-Yoon Choi[1], Takeshi Fukuhara[1], Peter Schauss[1], Johannes Zeiher[1], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München, Schellingstraße 4, 80799 München, Germany

Two component ultra cold bosonic gases in optical lattices are an excellent system to simulate quantum spin dynamics in Heisenberg chains. Near perfect initialization is achieved using a single component Mott insulating state where single site addressing techniques can be used to manipulate the local spin population. Quantum as well as thermal fluctuations cause a residual hole probability in the initial state and the impact on coherent spin transport is on open question. We experimentally show that coherent spin transport under these conditions is indeed possible. Propagation of a single spin impurity results in entanglement spreading along the spin chain which we directly detect by measuring the concurrence between pairs of lattice sites.

Q 5.3 Mon 12:00 P/H2

Experimental realization of a Bose-Hubbard model with long-range interactions — •Renate Landig, Lorenz Hruby, Nishant Dogra, Rafael Mottl, Tobias Donner, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zürich, Switzerland

The combination of strongly correlated systems with long-range interactions gives rise to rich physics with a variety of complex phases, which are often very little understood. Realizing such systems with ultracold atoms offers the perspective to address open questions in a highly controlled way. For example, in the case of cavity-mediated long-range interactions, the competition with short-range interactions is expected to lead to a supersolid, a charge density wave as well as a checkerboard Mott insulating phase.

In our experiment, we couple the external degree of freedom of a quantum gas of Rb-87 to an optical high-finesse cavity. When increasing the cavity-mediated long-range interactions, the quantum gas exhibits a phase transition from a superfluid to a self-organized state with checkerboard density modulation. We measure the dynamic structure factor, which captures the energy and lifetime of elementary excitations, as well as the amount of density fluctuations and correlations via cavity-enhanced inelastic scattering of photons. For strong short-range interactions, achieved by loading the atoms into additional optical lattices, we observe a density-modulated state without coherence, which we associate with a Mott insulating checkerboard phase. We demonstrate first experimental results on the phase diagram of a Bose-Hubbard model with long-range interactions.

Q 5.4 Mon 12:15 P/H2

Effect of cavity-mediated long-range interactions on the Mott insulator- superfluid transition — •Nishant Dogra[1], Ferdinand Brennecke[2], Rafael Mottl[1], Lorenz Hruby[1], Renate Landig[1], Sebastian Huber[3], Tobias Donner[1], and Tilman Esslinger[1] — [1]HPF D4, Quantum Optics Group, Institute for Quantum Electronics, ETH Zurich,Otto-Stern-Weg-1,Zurich-8093, Swizerland — [2]Physikalisches Institut, Universität Bonn, Wegelerstrasse 8, Bonn-53115 — [3]HIT K 23.4, Institute for Theoretical Physics, ETH Zurich, Wolfgang-Pauli-Strasse 27, Zurich-8093

The transversal illumination of a strongly coupled BEC-cavity system by a laser field leads to a phase transition from a superfluid to a supersolid phase due to the competition between the kinetic energy and the cavity-mediated long-range interactions. We theoretically study the effect of a 3D classical optical lattice on this system which enhances the strength of the short-range interactions and hence introduces another competing energy scale. This system can be mapped to an extended Bose-Hubbard model. In the limit where the classical lattice is commensurate with the cavity generated dynamical lattice, we solve this system using different mean-field approaches. Besides the Mott-insulator and the superfluid phases exhibited by the Bose-Hubbard model, the cavity-mediated long-range interactions give rise to a charge density wave insulator and a supersolid phase. We also calculate the excitation spectrum of the different phases and relate it to the nature of the transition between them. We further briefly discuss the status of the experimental implementation of this scheme.

Q 5.5 Mon 12:30 P/H2

A novel experiment for coupling a Bose-Einstein condensate with two crossed cavity modes — •Andrea Morales, Julian Leonard, Philip Zupancic, Tilman Esslinger, and Tobias Donner — ETH Zurich, Institute for Quantum Electronics, Quantum Optics Group

Cavity QED has proven to be a very attractive research area to explore many-body physics using quantum degenerate gases. Over the last decades, the coupling of single atoms, cold ensembles of atoms and BEC to single modes of the electromagnetic field has been successfully exploited and investigated. To push the research further in this direction we built a novel system involving two intersecting cavities. With this setup we are able to couple a BEC of 87-Rb atoms to two spatially distinct modes of the electromagnetic field. The ultracold cloud is optically transported into the crossed cavity setup by means of a novel designed optical dipole trap involving focus-tunable lenses. Our lens setup allows to change the position of the trap while keeping its waist, and therefore the overall trapping conditions, constant.

We report on recent progress on the implementation of a cavity setup involving two high-finesse optical resonators intersecting under an angle of 60°. The mirrors have been fabricated in order to spatially approach them, thus obtaining maximum single atom coupling rates of several MHz. This setup will allow us to study the coherent interaction of a BEC and the two cavity modes both in internal lambda-level transitions and in spatial self-organization processes in dynamical hexagonal lattices.

Q 5.6 Mon 12:45 P/H2

Experimental reconstruction of Wilson loops in a honeycomb lattice — •Martin Reitter[1,2], Tracy Li[1,2], Lucia Duca[1,2], Eugene Demler[3], Manuel Endres[3], Immanuel Bloch[1,2], Monika Schleier-Smith[4], and Ulrich Schneider[1,2] — [1]Ludwig-Maximilians-Universität, München, DE — [2]MPQ, Garching, DE — [3]Harvard University, Cambridge, USA — [4]Stanford University, Palo Alto, USA

A wide range of many-body phenomena, such as the integer quantum Hall effect and the existence of robust conducting edge states in topological insulators, arise due to the topological properties of the energy bands of a solid. For a single band, these properties can be probed using adiabatic Berry phases. For multiple bands, this information is encoded in the eigenvalues of Wilson loops, which are non-Abelian generalizations of Berry phases. We present an experimental reconstruction of the Wilson loop using Bloch oscillations in a graphene-like optical lattice. Combined with existing methods, this allows for the full characterization of the geometric structure of the bands and the reconstruction of, e.g., the Z_2 invariant, which cannot be extracted from Berry phase measurements alone.