Q 11: Cold atoms III - optical lattices (joint session A/Q)

Time: Monday 14:00–15:30 Location: K 0.011

Q 11.1 Mon 14:00 K 0.011

Quantum simulation of lattice gauge theories using Wilson fermions — •Torsten V. Zache[1], Philipp Hauke[1,2], Fred Jendrzejewski[2], Florian Hebenstreit[3], Markus Oberthaler[2], and Jürgen Berges[1] — [1]Institut für Theoretische Physik, Philosophenweg 16, 69120 Heidelberg — [2]Kirchhoff-Institut für Physik, Im Neuenheimer Feld 227, 69120 Heidelberg — [3]Institute for Theoretical Physics, Sidlerstr. 5, CH-3012 Bern

Gauge theories play an essential role in the formulation of microscopic quantum field theories, e.g. QED or QCD. Their analytical treatment is typically limited to the perturbative regime and numerical simulations are strongly hampered by the sign problem. Recently, quantum simulators based on cold atomic gases in optical lattices have been proposed to circumvent these issues. Most proposals rely on the lattice regularization of gauge theories (LGT) via staggered fermions. Since the regularization is not unique, we propose to exploit this freedom to simplify the implementation of LGTs. We find that the choice of Wilson fermions reduces the complexity of the gauge interactions in one spatial dimension to a minimum and use this result to devise an optimized implementation of QED using a mixture of bosons and fermions in a tilted optical potential. We further perform benchmarking real-time lattice simulations with realistic experimental parameter sets, which indicate that the non-perturbative nature of electron-positron pair production due to the Schwinger mechanism can be resolved even quantitatively. We conclude that the quantum simulation of QED in the continuum limit is possible with state-of-the art technology.

Q 11.2 Mon 14:15 K 0.011

Chimera patterns in conservative systems and ultracold atoms with mediated nonlocal hopping — •Hon-Wai Lau[1,2,3], Jörn Davidsen[3], and Christoph Simon[2] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, D-01187 Dresden — [2]Institute for Quantum Science and Technology and Department of Physics and Astronomy, University of Calgary, Calgary, Alberta, Canada T2N 1N4 — [3]Complexity Science Group, Department of Physics and Astronomy, University of Calgary, Canada T2N 1N4

Chimera patterns, characterized by coexisting regions of phase coherence and incoherence, have been experimentally demonstrated in mechanical, chemical, electronic, and opto-electronic systems. The patterns have so far been studied in non-conservative systems with dissipation. Here, we show that the formation of chimera patterns can also be observed in conservative Hamiltonian systems with nonlocal hopping in which both energy and particle number are conserved. We further show the physical mechanism and the implementation in ultracold atomic systems: Nonlocal spatial hopping over up to tens of lattice sites with independently tunable hopping strength and on-site nonlinearity can be implemented in a two-component Bose-Einstein condensate with a spin-dependent optical lattice, where the untrapped component serves as the matter-wave mediating field. The present work highlights the connections between chimera patterns, nonlinear dynamics, condensed matter, and ultracold atoms.

Q 11.3 Mon 14:30 K 0.011

Interorbital spin exchange in a state-dependent optical lattice — •Luis Riegger[1,2], Nelson Darkwah Oppong[1,2], Moritz Höfer[1,2], Diogo Rio Fernandes[1,2], Immanuel Bloch[1,2], and Simon Fölling[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Ludwig-Maximilians-Universität, München

We report on the observation of tunable interorbital spin exchange in the presence of a state-dependent optical lattice for the ground state and metastable clock state of fermionic ytterbium-173. The optical lattice potential is independent of the nuclear spin and preserves the SU(N)-symmetry of the interactions, typical for alkaline-earth-like atoms. In the state-dependent lattice, excited-state and ground-state atoms act as localized and mobile magnetic moments. The large difference in the interaction strength for spin-triplet and singlet states leads to spin-exchanging dynamics between the magnetic moments mediated by exchange processes similar to those in the Anderson impurity model. Moreover, we find that the external confinement can be used to resonantly tune the exchange dynamics. This makes our system a promising platform for the study of Kondo- and Kondo-lattice-type physics.

Q 11.4 Mon 14:45 K 0.011

Observation of Feshbach resonances between alkali and closed-shell atoms — •Vincent Barbé[1], Alessio Ciamei[1], Lukas Reichsöllner[1], Benjamin Pasquiou[1], Florian Schreck[1], Piotr Zuchowski[2], and Jeremy Hutson[3] — [1]University of Amsterdam, The Netherlands — [2]Nicolaus Copernicus University, Poland — [3]Durham University, United Kingdom

Magnetic Feshbach resonances are widely used to tune interactions of ultracold atoms or to magneto-associate pairs of atoms into diatomic molecules. Such resonances have been observed and used extensively for pairs of open-shell atoms, but were never detected for pairs of alkali and closed-shell atoms. Here we demonstrate experimentally the existence of such resonances in mixtures of ^{87}Sr or ^{88}Sr with ^{87}Rb [1]. Two of the coupling mechanisms involved in these Feshbach resonances were theoretically investigated in previous works [2], and in addition we discover a new form of anisotropic coupling between rotating molecular states and s-wave scattering states. This opens a route towards the magneto-association of Rb and Sr into open-shell, strongly polar molecules in an optical lattice.

[1] V. Barbé *et al.*, arXiv:1710.03093 (2017).
[2] P. Żuchowski *et al.*, Phys. Rev. Lett. 105, 153201 (2010).

Q 11.5 Mon 15:00 K 0.011

Robust features of Bose-Hubbard eigenstates dressed by a cavity — •Jonas Mielke, Laurent de Forges de Parny, and Andreas Buchleitner — Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, D-79104, Freiburg, Germany

The coherent dressing by a cavity field allows to induce long-range interactions between otherwise only locally interacting bosons in optical lattices [1]. Most studies did so far address ground state properties like long-range phase coherence and spatial ordering [2,3], while also the excitation spectrum of these systems can be expected to exhibit nontrivial structural features. We present a complete map of the system states' characteristic structural features, across the entire excitation spectrum, which generalizes standard ground state phase diagrams, for minimal system sizes. We discuss the physical mechanisms which define the smooth demarcation lines between different structural properties in parameter space, and analyse relevant scaling properties with the system size.

[1] C. Maschler, I. Mekhov, and H. Ritsch, Eur. Phys. J. D,46, 545-560 (2008);
[2] R. Landig, L. Hruby, N. Dogra, M. Landini, R. Mottl, T. Donner, and T. Esslinger, Nature 532, 476 (2016);
[3] T. Flottat, L. de Forges de Parny, F. Hébert, V.G. Rousseau, and G.G. Batrouni, Phys. Rev. B 95, 144501 (2017).

Q 11.6 Mon 15:15 K 0.011

Metastability and avalanche dynamics in strongly-correlated gases with long-range interactions — •Nishant Dogra, Lorenz Hruby, Manuele Landini, Katrin Kröger, Tobias Donner, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

We experimentally study the stability of a bosonic Mott-insulator against the formation of a density wave induced by long-range interactions. The Mott-insulator is created in a quantum degenerate gas of 87-Rubidium atoms, trapped in a three-dimensional optical lattice. The gas is located inside and globally coupled to an optical cavity. This causes interactions of global range, mediated by photons dispersively scattered between a transverse lattice and the cavity. The scattering comes with an atomic density modulation, which is measured by the photon flux leaking from the cavity. We initialize the system in a Mott-insulating state and then quench the global coupling strength. We observe that the system falls into either of two distinct final states. One is characterized by low photon flux, signaling a Mott insulator, and the other is characterized by high photon flux, which we associate with a density wave. Ramping the global coupling slowly, we observe a hysteresis loop between the two states. From the increasing photon flux monitored during the switching process, we find that several thousand atoms tunnel to a neighboring site on the time scale of the single particle dynamics which can be understood as an avalanche tunnelling process in the Mott-insulating region.