Q 66: Ultracold Matter (Fermions) II (joint session Q/A)

Time: Friday 11:00–13:00 Location: HS V

Invited Talk Q 66.1 Fri 11:00 HS V

Enhancing pair tunneling in the Hubbard model by Floquet engineering — •Andrea Bergschneider — Physikalisches Institut, University of Bonn, Bonn, Germany

The Fermi-Hubbard model has been very successful in describing quantum phases that emerge from the interplay between single-particle tunneling and on-site interaction. The simulation of phenomena in solid state systems, however, often requires additional coupling terms, such as explicit pair tunneling, which is exponentially suppressed in the simple Hubbard model.

We extend our optical lattice by a superlattice to go beyond the simple Fermi-Hubbard model. By time-periodic modulation of the system, we engineer an effective Hamiltonian with sizable explicit pair tunneling [1]. In our scheme suppresses single-particle tunneling while simultaneously realizing an effectively interacting systems tunable from a regime with density-assistant tunneling to pair tunneling. These findings may bring the realization of novel quantum phases based on pairing mechanisms within reach.

[1] Klemmer et al., arXiv 2404.08482, accepted in Phys. Rev. Lett.

Q 66.2 Fri 11:30 HS V

Using ultracold Fermi gases to theoretically probe atomic scattering properties — •Nikolai Kaschewski[1], Axel Pelster[1], and Carlos A. R. Sá de Melo[2] — [1]Department of Physics and Research Center OPTIMAS RPTU Kaiserslautern-Landau, Germany — [2]School of Physics, Georgia Institute of Technology, Atlanta, USA

In cold atomic gases microscopic details of interactions are thought to be irrelevant as the interaction range is much smaller than typical inter-particle spacings. Thus, in a degenerate quantum gas of neutral atoms interactions are modelled as contact interaction potentials ignoring properties besides scattering lengths. In other fields, for instance in nuclear physics, the shape of the interaction potential is believed to play a larger role due to high densities [1]. So far no methods currently exist to directly probe interatomic interactions as in nuclear physics.

Here we present a theoretical method to introduce leading-order effects of the interatomic potential shape, i.e. the effective range, by generalizing Bethe's theory of nuclear scattering [2] to ultracold atomic gases. Using a degenerate BCS-type Fermi gas at low temperature as an example we show, that the influence of the effective range for most thermodynamic properties adds a small correction to the zero-range theory. However, our qualitative investigation reveals that quantities, like correlation functions, capture the short-range behaviour of the gas and hence are sensitive to changes in the effective range parameter offering a prospect to measure the effective range.

[1] M. Jin, M. Urban and P. Schuck, Phys. Rev. C 82, 024911 (2010) [2] H. A. Bethe, Phys. Rev. 76, 38 (1949)

Q 66.3 Fri 11:45 HS V

Nonequilibrium states in the periodically driven transverse field Ising model — •Larissa Schwarz[1], Simon B. Jäger[2], Imke Schneider[1], and Sebastian Eggert[1] — [1]Physics Department and Research Center OPTIMAS, University of Kaiserslautern-Landau, 67663, Kaiserslautern, Germany — [2]Physikalisches Institut, University of Bonn, Nussallee 12, 53115 Bonn, Germany

We study the non-equilibrium dynamics of the one-dimensional transverse field Ising model under periodic driving. Using Floquet theory, we derive the steady states of the driven model for a fixed driving amplitude and identify Floquet modes that emerge from strong resonant dressing of the eigenstates of the undriven system. Studying the real time evolution and comparing it with Floquet theory, we find that the system evolves into superpositions of Floquet states, where the ramping rate of the driving amplitude influences the occupation of higher Floquet bands. We also compute the two-point correlation functions, which show oscillations in position space that can be tuned with the driving frequency. Our results highlight how periodic driving can be used to create complex non-equilibrium states.

Q 66.4 Fri 12:00 HS V

Strong correlations in a Fermi-Hubbard quantum simulator — •Dorothee Tell for the MPQ Fermi-Hubbard microscope experiment and theory-Collaboration — Max Planck Institute of Quantum Optics, Garching, Germany

In the low temperature regime of strongly-correlated materials, a variety of interesting effects can be observed, described theoretically by the Fermi Hubbard model. For example, since the discovery of cuprate high-temperature superconductors, both theoretical and experimental efforts have been made to identify this region in the phase diagram. We can explore the "pseudogap" phase at higher temperature and lower doping than the predicted superconductors, making it a precursor for their exploration.

Here we describe a quantum gas microscope with single-site and spin resolution which we use as a 2D Fermi Hubbard simulator. By preparing this system at various temperatures and doping levels we explore a parameter region where pseudogap signatures are expected to emerge. Various levels of doping the system with holes or doublons are demonstrated. Furthermore, we demonstrate precise thermometry using a comparison of experimental nearest-neighbor correlations and numeric determinant Quantum Monte Carlo simulations.

Q 66.5 Fri 12:15 HS V

Quantum gas microscopy of strongly correlated states in the pseudogap phase of the Fermi-Hubbard model — •Thomas Chalopin for the MPQ Fermi-Hubbard microscope experiment and theory-Collaboration — Université Paris-Saclay, Institut d'Optique Graduate School, CNRS, Laboratoire Charles Fabry, Palaseau, France — Max Planck Institute of Quantum Optics, Garching, Germany

In correlated materials such as high-T_C cuprate superconductors, strong electron-electron interactions give rise to a rich low-temperature phase diagram which heavily depends on doping. The pseudogap phase, in particular, emerges in the underdoped region of cuprates below a temperature T^*, and is often considered to be a precursor of the superconducting state at lower temperature. Numerous theoretical and numerical studies have furthermore established the presence of a pseudogap in the Fermi-Hubbard model, a simplified model of interacting lattice fermions that captures some of the key properties of cuprates.

In this talk, I will present a systematic exploration of the Fermi-Hubbard model using a quantum gas microscope in a regime of parameters associated to the opening of a pseudogap. We measure sizable spin and charge connected correlations up to order 5 and reveal the emergence of a strongly correlated regime at low-temperature and low-doping which matches well theoretical predictions for T^*.

Q 66.6 Fri 12:30 HS V

Floquet-engineered pair transport in the Fermi Hubbard model — Friedrich Hübner[1], Christoph Dauer[2], Sebastian Eggert[2], Corinna Kollath[1], and •Ameneh Sheikhan[1] — [1]Physikalisches Institut, University of Bonn, Nussallee 12, 53115 Bonn, Germany — [2]Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

We investigate the transport properties of a Fermi-Hubbard chain with an impurity which is formed by a site with a periodically modulated chemical potential. We determine the transmission through this impurity in dependence of the modulation frequency and strength for a single particle and a pair of fermions. We find that the pair transmission has a very distinct behaviour from the single particle transmission. Different situations can occur, where only the single particle or the pair are transmitted or filtered out.

Q 66.7 Fri 12:45 HS V

Formation of Cavity-Polaritons via Higher-Order Van Hove Singularities — •Igor Gianardi[1], Michele Pini[2], and Francesco Piazza[2] — [1]Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden, Germany — [2]Institute of Physics, Universität Augsburg, 86159 Augsburg, Germany

Polaritons are hybrid quasi-particles that blend matter and light properties. We consider their realization here through the hybridization of interband particle-hole excitations from an insulating phase with a cavity photon at sub-gap frequencies, where absorption is suppressed. The strength of the hybridization is driven by the Van Hove singularity in the joint density of states at the band gap: the stronger the singularity, the greater the photon hybridization with interband excitations. One way to enhance the Van Hove singularity strength is by reducing the system's dimensionality, such as using one-dimensional nanowires [1]. Alternatively, a promising approach involves tailoring a non-parabolic momentum dispersion of the bands around the gap to implement a higher-order Van Hove singularity (HOVHS). Building on this intuition, we propose to employ ultracold atom platforms and leverage the tunability of optical lattices to engineer two-dimensional gapped phases with non-trivial band dispersions at the gap. Our findings position ultracold atoms in cavities as an ideal platform to explore the emerging field of Van Hove polaritonics, opening a new route to quantum nonlinear optics.

[1] K. B. Arnardottir et al., Phys. Rev. B 87, 125408 (2013)