Q 53: Quantum Gases: Fermions I

Time: Thursday 14:30–16:45 Location: e001

Q 53.1 Thu 14:30 e001

Exploring a Strongly Interacting Fermi gas in a 2D lattice — •Luca Bayha, Ralf Klemt, Puneet Murthy, Mathias Neidig, Martin Ries, Gerhard Zürn, and Selim Jochim — Physikalisches Institut, Universität Heidelberg

In this talk we will present our current progress and ideas on exploring a two-component Fermi gas in the BEC-BCS crossover in a 2D square lattice.

Our starting point is a quasi-2D gas of deeply bound bosonic Li6 dimers, which are cooled to the superfluid phase. This sample is then loaded into a superimposed square lattice, where at shallow lattice depths we observe the appearance of additional peaks in the momentum distribution indicating superfluidity. For deeper lattices and low enough temperatures this system becomes insulating. By tuning the scattering length the type of this insulator can be smoothly changed from a band insulator of free fermions to a Mott insulator of repulsively interacting bosonic molecules. This change manifests itself in the different correlations between the particles, in both the spin and spatial degrees of freedom. These correlations can be accessed from atomic fluctuations in the momentum distribution. Thus we plan to investigate the (anti)correlations of atom shot-noise in the momentum distribution to reveal the character of the different insulating states.

Q 53.2 Thu 14:45 e001

Antiferromagnetic Heisenberg Spin Chain of a Few Cold Atoms in a One-Dimensional Trap — Simon Murmann[1], •Frank Deuretzbacher[2], Gerhard Zürn[1], Johannes Bjerlin[3], Daniel Becker[4], Stephanie Reimann[3], Luis Santos[2], Thomas Lompe[1], and Selim Jochim[1] — [1]Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg — [2]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover — [3]Mathematical Physics and NanoLund, LTH, Lund University, SE-22100 Lund, Sweden — [4]I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstr. 9, 20355 Hamburg

We report on the deterministic preparation of antiferromagnetic Heisenberg spin chains consisting of up to four fermionic atoms in a one-dimensional trap [1]. These chains are stabilized by strong repulsive interactions between the two spin components without the need for an external periodic potential [2]. We independently characterize the spin configuration of the chains by measuring the spin orientation of the outermost particle in the trap and by projecting the spatial wave function of one spin component on single-particle trap levels. Our results are in good agreement with a spin-chain model for fermionized particles and with numerically exact diagonalizations of the full few-fermion system.

[1] S. Murmann et al., PRL 115, 215301 (2015)
[2] F. Deuretzbacher et al., PRA 90, 013611 (2014)

Q 53.3 Thu 15:00 e001

Imaging transport of neutral atoms using a scanning probe microscope — •Samuel Häusler[1], Sebastian Krinner[1], Dominik Husmann[1], Martin Lebrat[1], Charles Grenier[2], Shuta Nakajima[3], Jean-Philippe Brantut[1], and Tilman Esslinger[1] — [1]Institute for Quantum Electronics, ETH Zürich, 8093 Zürich, Switzerland — [2]Laboratoire de Physique, ENS de Lyon, 69364 Lyon, France — [3]Department of Physics, Graduate School of Science, Kyoto University, Kyoto 606-8502, Japan

We implement a scanning probe technique to image the transport of ultracold fermions through a quantum point contact. A "tip" is created with a tightly focused, repulsive laser beam, and moved and shaped using a Digital Mirror Device. By scanning its position and monitoring the subsequent variations of conductance, we retrieve spatially resolved information on the transport, like in scanning gate microscopy applied to solid state devices [1].

The scanning gate pictures are compared with ab-initio simulations for a non-interacting Fermi gas. The method is readily extended to strongly interacting fermions where superfluidity enhances the contrast.

[1] M.A. Eriksson, et al. Appl. Phys. Lett. 69 671 (1996)

Q 53.4 Thu 15:15 e001

Spin transport of ultracold fermions through a quantum point contact — •Martin Lebrat[1], Sebastian Krinner[1], Dominik Husmann[1], Samuel Häusler[1], Charles Grenier[2], Jean-Philippe Brantut[1], and Tilman Esslinger[1] — [1]Institute for Quantum Electronics, ETH Zürich, 8093 Zürich, Switzerland — [2]Laboratoire de Physique, ENS de Lyon, 69364 Lyon, France

We report on the first measurement of spin conductance through a quantum point contact (QPC) with ultracold fermions. Experimentally, we prepare two clouds of ^{6}Li atoms with opposite populations in two different hyperfine states, connect them by a narrow, optically-shaped constriction, and monitor the atomic flow in a spin-resolved way to infer spin conductance. In absence of interactions, conductance is expected to reach a quantum of $1/h$ whenever the Fermi wavelength is comparable to the transverse dimensions of the constriction.

As attractive interactions are increased towards the BEC-BCS crossover, we observe a non-monotonic behaviour of the spin conductance as a function of atomic density around the QPC, which is consistent with the appearance of a superfluid gap. For weaker interactions in the normal phase, we measure a reduction of conductance from the conductance quantum $1/h$, that can be attributed to one-dimensional scattering within the QPC between excitations of opposite spins.

Q 53.5 Thu 15:30 e001

Formation and dynamics of anti-ferromagnetic correlations in tunable optical lattices — •Michael Messer[1], Daniel Greif[1,2], Gregor Jotzu[1], Frederik Görg[1], Rémi Desbuquois[1], and Tilman Esslinger[1] — [1]Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland — [2]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

Ultracold fermions in optical lattices are an ideal toolbox for studying quantum magnetism in the Hubbard model. In this model many questions on the low-temperature phase diagram still remain open, both for simple cubic and square configurations, as well as for more complex lattice geometries. Besides a highly controlled approach to studying the thermodynamic properties cold atoms can also give insight into the dynamic properties of the system in the low entropy regime.

In our experiment we load a two-component, repulsively interacting fermionic quantum gas of K-40 into a tunable-geometry optical lattice. We observe anti-ferromagnetic spin correlations on neighboring sites in both isotropic 3D cubic and more complex lattice geometries for very low temperatures. In addition we study the strength of the spin correlations in a crossover between distinct geometries. Furthermore, we investigate the formation and redistribution time of spin correlations by dynamically changing the lattice geometry.

Q 53.6 Thu 15:45 e001

Persistent currents of massless Dirac fermions with interactions — •Johannes Jünemann[1,2] and Matteo Rizzi[1] — [1]Johannes Gutenberg-Universität, 55099 Mainz, Germany — [2]Graduate School Materials Science in Mainz, 55128 Mainz, Germany

The persistent current response of ring-shaped materials to a piercing magnetic flux is a traditional topic in condensed matter: the effect of impurities/disorder and/or interactions have been thoroughly studied. Little attention has been however devoted to systems with Dirac-cone dispersion relation at the Fermi-level, and the few available results are focused on the non-interacting case. Here we investigate the scaling of the current and its response (the so-called orbital magnetic response or Drude weight) with respect to system-size and interaction-strength in a (quasi-)1D ring filled with massless Dirac fermions. We present both analytical results and numerical results obtained using so-called binary tree-tensor networks. We envisage an implementation via a Creutz ladder Hamiltonian with periodic boundary conditions, as made possible in cold-atomic setups by laser-assisted transfer processes (spin-flips, complex hopping, spin-orbit coupling) and recent progresses in shaping trapping potentials.

Q 53.7 Thu 16:00 e001

Quench Dynamics in Spin Chains from Discrete Truncated Wigner Approximations — •Stefanie Czischek[1], Halil Cakir[1], Markus Karl[1], Michael Kastner[2], Markus K. Oberthaler[1], and Thomas Gasenzer[1] — [1]Kirchhoff-Institut für Physik, INF 227, 69120 Heidelberg, Germany — [2]Institute of Theoretical Physics, University of Stellenbosch, Stellenbosch 7600, South Africa

We study the dynamical build-up of correlations after sudden quenches in spin chains using the novel discrete truncated Wigner approximation. In particular, we consider quenches from large external fields to the vicinity of the quantum critical point within the paramagnetic phase. We calculate correlation lengths and regard their time evolution at different distances from the critical point. For the transverse field Ising chain, we find that the discrete truncated Wigner approximation is in good agreement with exact analytical and numerical results. Furthermore, our results show that the correlation function takes the form given by a generalized Gibbs ensemble already after short times and small relative distances. Since the generalized Gibbs ensemble usually describes the behaviour for asymptotically large times and distances, this is in contrast to expectations. Thus, our results suggests that the effects of universal dynamics are accessible on experimentally realizable timescales.

Q 53.8 Thu 16:15 e001

Measuring the scaling exponent of strongly interacting 2D gases — •Jonas Siegl, Niclas Luick, Klaus Hueck, Wolf Weimer, Kai Morgener, Thomas Lompe, and Henning Moritz — Institut für Laserphysik,Hamburg, Deutschland

The critical behaviour exhibited by two-dimensional systems has profound impact on phenomena ranging from superfluidity in liquid helium films to high temperature superconductivity. It is intriguing that 2D systems with a continuous symmetry can become superfluid at all, since true long-range order is precluded by thermal fluctuations. Instead, the celebrated Berezinskii, Kosterlitz and Thouless (BKT) theory predicts that below the superfluid transition the first order coherence decays algebraically with no characteristic length scale. Such scale free behaviour is typically only encountered at the critical point, whereas in 2D systems it is predicted to persist down to zero temperature, making them critical throughout.

Here, we locally probe the phase fluctuations of strongly correlated 2D gases of composite bosons. We determine the scaling exponent characterising the algebraic decay as a function of phase space density: during a short expansion along the strongly confined direction the phase fluctuations responsible for the algebraic decay are transformed into density fluctuations. We image the resulting density distribution and extract the scaling exponent from the power spectrum. The results are in excellent agreement with BKT theory, from which we can deduce the superfluid density locally. Our results extend the study of BKT theory towards the strongly interacting regime of ferminonic superfluidity.

Q 53.9 Thu 16:30 e001

Observation of the Berezinskii-Kosterlitz-Thouless transition in an ultracold Fermi gas — •Puneet Murthy[1], Igor Boettcher[2], Luca Bayha[1], Dhruv Kedar[1], Mathias Neidig[1], Martin Ries[1], Andre Wenz[1], Gerhard Zürn[1], and Serlim Jochim[1] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, 69120 Heidelberg — [2]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, 69120 Heidelberg

We report on the experimental investigation of the first-order correlation function of a trapped Fermi gas across the quasi-two-dimensional BEC-BCS crossover. We demonstrate that even in the inhomogeneous trapped system, the correlation function shows a qualitative change in behavior from an exponential to power law decay. The extracted scaling exponents show substantial deviations from BKT theory for homogeneous systems. Furthermore, we find the maximal scaling exponent at the transition to show no dependence on interaction strength, suggesting that the corresponding phase transitions lie in the same universality class. On the BEC side, our findings are validated by Quantum Monte Carlo computations for bosons. Near the resonance, the observed algebraic decay is not captured by the bosonic picture, indicating the crossover to a fermionic superfluid.