Q 4: Quantum gases: Fermions

Time: Monday 10:30–12:15 Location: DO24 Reuter Saal

Q 4.1 Mon 10:30 DO24 Reuter Saal

Conduction Properties of Ultracold Fermions — •Dominik Husmann, Sebastian Krinner, David Stadler, Jean-Philippe Brantut, and Tilman Esslinger — Institut für Quantenelektronik, ETH Zürich, Schweiz

Out-of-equilibrium measurements on cold-atom systems pose an important experimental challenge for the understanding of many phenomena encountered in condensed matter physics. We present a fermionic ^{6}Li cold-atom system that allows the measurement of the conductance through a narrow constriction in a two-terminal setup. Our system is analogous to and inspired by electronic transport through mesoscopic structures in solids. The system consists of two macroscopic reservoirs of ultracold ^{6}Li atoms, which are connected by a mesoscopic narrow channel. Upon inducing a bias to the chemical potential of the two reservoirs, a particle current through the channel sets in, which restores thermal equilibrium. The dynamics of the relaxation process is analogous to the discharge of a capacitor, where the conductance is inversely proportional to the time scale. A broad Feshbach resonance between the two lowest hyperfine states of ^{6}Li at 834 G allows to tune interparticle interactions to both weakly and strongly repulsive or attractive interacting regimes.

Upon applying a temperature bias to the reservoirs, we observe features of thermoelectricty. In a different measurement, we narrow the channel down to a one-dimensional constriction and measure current induced by applying a particle imbalance between the reservoirs.

Q 4.2 Mon 10:45 DO24 Reuter Saal

Exploring the phase diagram of a strongly interacting 2D Fermi gas — •Martin Ries[1], Mathias Neidig[1], Andre Wenz[1], Puneet Murthy[1], Sebastian Pres[1], Gerhard Zürn[1], Thomas Lompe[2], and Selim Jochim[1] — [1]Physikalisches Institut, Universität Heidelberg, INF 226, 69120 Heidelberg, Germany — [2]Department of Physics, Massachusetts Institute of Technology, Cambridge, MA, USA

In this talk, we present our experiments with a two-dimensional gas of ultracold fermions in the strongly interacting regime.

We prepare a quantum degenerate quasi 2D sample of ^{6}Li atoms in the lowest two hyperfine states. The gas is trapped in a single layer of a standing wave optical dipole trap.

We are able to extract several complementary properties from the sample: the density distribution can be probed by in situ imaging, phase correlations can be extracted from the self interference pattern in short time of flight, and using matter wave focusing [1,2], we can directly access the radial momentum distribution.

For deeply bound molecules, hence in the bosonic limit, we observe a clear bimodal momentum distribution. Additionally, the self interference pattern shows clear signatures of quasi long range phase coherence. We attribute these observations to the emergence of a quasi condensate.

By evaluating our system as a function of interaction strength and temperature, we are thus able to investigate the 2D equivalent of the BEC-BCS crossover.

[1] PRL 100, 090402 (2008) [2] PRL 89, 270404 (2002)

Q 4.3 Mon 11:00 DO24 Reuter Saal

The critical velocity in the BEC-BCS crossover — •Kai Morgener, Niclas Luick, Wolf Weimer, Jonas Siegl, Klaus Hueck, and Henning Moritz — Institut für Laserphysik, Universität Hamburg, D-22761 Hamburg

Ultracold fermionic gases are an ideal model system for the study of quantum many-body phenomena. Of particular interest is superfluidity due to the open questions surrounding high temperature superconductors in solids. One hallmark property of superfluid systems is the critical velocity below which obstacles can move through the fluid without friction.

The broad Feshbach resonance of the fermionic 6Li quantum gases provides the unique possibility to investigate superfluidity over a wide range of interactions. We stir the gas with a red detuned laser beam as a local density perturbation. Above the critical velocity heating can be observed. We present high precision measurements of the critical velocity along the BEC-BCS crossover. Our measurements are in excellent agreement with theoretical predictions which assume that the nature of excitations ranges from Bogoliubov sound waves in the BEC on the repulsive side of the resonance to Cooper-pair breaking for attractive interactions in the BCS regime. The role of vortex excitations is negligible small.

Q 4.4 Mon 11:15 DO24 Reuter Saal

Relaxation dynamics of a Fermi gas in an optical superlattice — •Ameneh Sheikhan[1], Corinna Kollath[1], Johanna Bohn[2,3], Daniel Pertot[2,3], Marco Koschorreck[2,3], Eugenio Cocchi[2,3], Luke Miller[2,3], and Michael Koehl[2,3] — [1]HISKP, University of Bonn, Nussallee 14-16, D-53115 Bonn, Germany — [2]Physikalisches Institut, University of Bonn, Wegelerstrasse 8, 53115 Bonn, Germany — [3]Cavendish Laboratory, University of Cambridge, JJ Thomson Avenue, Cambridge CB30HE, United Kingdom

The question of how a closed quantum system out of equilibrium evolves and relaxes, is still not well understood. A specific setting of coherent quantum dynamics can be provided by quenches when one starts from the ground state of an initial Hamiltonian and suddenly changes the Hamiltonian's parameter. After this change the system is highly excited with respect to the new Hamiltonian and evolves in time.

Here we study a three dimensional Fermi gas initially loaded into a periodic double well potential along one dimension. The superlattice enables us to prepare the initial state with fermions only occupying even wells. Afterwards the superlattice potential is suddeenly removed the time evolution of the local density imbalance between two neighboring wells is probed. The experimental results are compared to the numerical studies based on the exact diagonalization of the Hamiltonian in the continuum.

Q 4.5 Mon 11:30 DO24 Reuter Saal

Relaxation dynamics of a fermionic quantum gas with high spin — •Jasper Simon Krauser[1], Nick Fläschner[1], Klaus Sengstock[1,2], Christoph Becker[1,2], Ulrich Ebling[3], Maciej Lewenstein[3,4], and André Eckhardt[5] — [1]Institut für Laserphysik, Universität Hamburg, Germany — [2]Zentrum für Optische Quantentechnologien, Universität Hamburg, Germany — [3]Institut de Ciències Fotòniques, Castelldefels, Spain — [4]Institució Catalana de Recerca i Estudis Avançats, Barcelona, Spain — [5]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany

The relaxation of a closed quantum system constitutes a fundamental question in many-body physics. We present a detailed study of relaxation dynamics in a fermionic quantum gas of ^{40}K atoms with high spin. The fermions are initially prepared far from equilibrium occupying only a few spin states. This induces a complex relaxation dynamics towards an equal spin population; meanwhile the whole spin system provides a bath for the thermalization for its individual spin subsystems. Our experimental results yield a good agreement with a kinetic Boltzmann equation, derived from a microscopic approach without free parameters. We identify several collisional processes governing the dynamics on fully different time scales and demonstrate the high experimental control by tuning the crucial parameters of the system, e.g. density and magnetic field. Our results open the path to engineer an open system with controllable dissipation into empty subsystems.

Q 4.6 Mon 11:45 DO24 Reuter Saal

Quantum magnetism without lattices in strongly-interacting one-dimensional spinor gases — •Frank Deuretzbacher[1], Daniel Becker[2], Johannes Bjerlin[3], Stephanie Reimann[3], and Luis Santos[1] — [1]Institute for Theoretical Physics, Leibniz University Hanover, Appelstr. 2, DE-30167 Hanover, Germany — [2]Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland — [3]Mathematical Physics, LTH, Lund University, SE-22100 Lund, Sweden

We show that strongly-interacting multicomponent gases in one dimension can be described by an effective spin model. This constitutes a surprisingly simple scenario for the realization of one-dimensional quantum magnetism in cold gases in the absence of an optical lattice. The spin-chain model allows for an intuitive understanding of recent experiments performed in Selim Jochim's group in Heidelberg and for a simple calculation of relevant observables. We analyze the adiabatic preparation of antiferromagnetic and ferromagnetic ground states, and show that many-body spin states may be efficiently probed by means of tunneling experiments. The spin-chain model is valid for more than two components, opening the possibility of realizing SU(N) quantum magnetism in strongly-interacting one-dimensional alkaline-earth or Ytterbium Fermi gases.

Q 4.7 Mon 12:00 DO24 Reuter Saal

Spatially resolved Raman spectroscopy of one-dimensional Fermi gases — •Jan Henning Drewes[1], Eugenio Cocchi[1,2], Luke Miller[1,2], Daniel Pertot[1], Marco Koschorreck[1], and Michael Köhl[1] — [1]Physikalisches Institut, University of Bonn, Wegelerstrasse 8, 53115 Bonn, Germany — [2]Cavendish Laboratory, University of Cambridge, JJ Thomson Avenue, Cambridge CB30HE, United Kingdom

Over the last decade quantum gases in optical lattices have proven to be a versatile tool for quantum simulation. Reducing the dimensions of these systems to one allows to study the famous Luttinger liquid which promises to yield insight into phenomena such as spin-charge separation.

We experimentally study the physics of quasi-one-dimensional fermionic quantum gases by loading a quantum degenerate two component gas of fermionic 40K atoms into a two-dimensional optical lattice geometry.

Here, I will report on our recent work on the characterisation of the system using a combination of high-resolution imaging and spatially resolved two-photon Raman spectroscopy.