A 4: Ultra-cold atoms, ions and BEC I (with Q)

Time: Monday 14:30–16:30 Location: C/HSW

A 4.1 Mon 14:30 C/HSW

Matter wave interference of a chiral superfluid — •Wen-Min Huang[1,2], Thorge Kock[1], Matthias Ölschläger[1], Arne Ewerbeck[1], Andreas Hemmerich[1,2], and Ludwig Mathey[1,2] — [1]Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, Hamburg 22761, Germany

In a recent experiment[1], ultracold atoms were loaded into the second band of an optical lattice, and the resulting chiral superfluid order, that these atoms formed, were revealed by matter wave heterodyning technique: two independent, but coherent, condensates were created, then brought to interference in the time-of-flight expansion. Two classes of interference patterns are observed, and may be attributed to the same or the opposite chiral order spontaneously developed in two independent subsystems. In this work, we construct the interference contrast by computing the convolution of the Green's functions of the two condensates. We confirm that while the same chiral symmetry are developed in the two subsystems, the interference contrast between the two momenta at while the atoms are condensed is correlative. In contrast, if two opposite chiral symmetries are developed, an anti-correlative interference pattern is presented. Our simulations agree with the experimental observation and provide an unambiguous demonstration of two chiral time-reversal symmetry breaking superfluid order. —— [1] T. Kock, M. Ölschläger, A. Ewerbeck, W.-M. Huang, L. Mathey and A. Hemmerich, arXiv:1411.3483

A 4.2 Mon 14:45 C/HSW

Realizing effective state-dependent optical lattices by periodic driving — Gregor Jotzu, Michael Messer, Frederik Görg, Daniel Greif, •Rémi Desbuquois, and Tilman Esslinger — ETH Zurich, Zurich, Switzerland

Ultracold atoms in optical lattices offer the possibility to engineer specific Hamiltonians, with widely tunable properties. For example, the periodic modulation of the lattice potential yields an effective static Hamiltonian. While previous implementations relied on the physical motion of the lattice potential, this effect can also be realized by periodic modulation of a magnetic field gradient. As the coupling of an atom to this magnetic field gradient depends on its internal state, the effective Hamiltonian is state-dependant. For each internal state, the differing band structure can be characterized either by measuring the ballistic expansion of an atomic cloud in the lattice, or by a measurement of the effective mass through dipole oscillations. This method can be used to create novel situations, such as systems where one state is pinned to the lattice, while the other remains itinerant.

A 4.3 Mon 15:00 C/HSW

Saturation absorbtion imaging of dense atom clouds — •Bastian Höltkemeier, Henry Lopez, Julian Glässel, Pascal Weckesser, Stefan Paul, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, INF 226, 69120 Heidelberg

Imaging atomic samples with absorption imaging has become one of the standard techniques in atomic physics. Absorption imaging can be used for a wide range of atomic samples of very different densities. In this talk we will focus on imaging large and dense atom clouds with optical densities of about one hundred. In this case the sample becomes optically thick to the imaging transition which is a common problem of absorption imaging. In order to solve this problem we discuss possible approaches which can be used for such systems. The main idea is to decrease the atoms' absorption cross section and therefore reduce the measured optical thickness. The effective cross section is then characterized by saturated absorption imaging.

A 4.4 Mon 15:15 C/HSW

Goldstone mode in the quench dynamics of an ultracold BCS Fermi gas — •Peter Kettmann[1], Simon Hannibal[1], Mihail Croitoru[2], Alexei Vagov[3], Vollrath Martin Axt[3], and Tilmann Kuhn[1] — [1]Institute of Solid State Theory, University of Münster — [2]Condensed Matter Theory, University of Antwerp — [3]Theoretical Physics III, University of Bayreuth

Ultracold Fermi gases are a convenient testbed for complex interacting Fermi systems like, e.g., superconductors. They are on the one hand easily accessible in experiment. On the other hand they can form not only a BEC but a BCS phase as well. A study of this BCS phase and the crossover to the BEC is expected to give insight into other fields like high temperature superconductivity.

We investigate the BCS phase of an ultracold Fermi gas. In particular we calculate the nonequilibrium dynamics of a confined ^{6}Li gas after a quantum quench, i.e., a sudden change of the BCS coupling strength induced by the abrupt change of an external magnetic field. We find that the excitation leads to a vibration of the cloud with the spectrum containing one dominant low frequency and several higher frequencies. We show that the low frequency corresponds to the Goldstone mode of the order parameter while the higher frequencies result from the amplitude oscillation of the gap, i.e., the Higgs mode.

We study the Goldstone mode over a wide range of parameters. We find that the size-dependent superfluid resonances [1] have a strong impact on the frequency of the Goldstone mode and on its dependence on the size of the cloud. [1] Shanenko et al., PRA 86, 033612 (2012)

A 4.5 Mon 15:30 C/HSW

Anomalously long-range coherence in one dimensional Bose gases far from equilibrium — •Alexander Schnell[1,2], Daniel Vorberg[1], Roland Ketzmerick[1,2], and André Eckardt[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden — [2]Institut für Theoretische Physik, Technische Universität Dresden

As a consequence of the Mermin-Wagner theorem, a one-dimensional Bose gas in equilibrium at finite temperature does not feature Bose condensation in the thermodynamic limit (system size to infinity at constant density). The single-particle correlation function decays exponentially on a finite coherence length ℓ. Bose condensation can, however, occur in a system of finite length L, when for sufficiently large densities n or inverse temperatures β the ratio ℓ/L approaches one.

We investigate the situation where a one-dimensional ideal Bose gas of densisty n in contact with a heat bath of finite inverse temperature β is driven into a non-equilibrium steady state (NESS) by coupling it also to a second, population inverted heat bath described by a negative temperature. We find conditions where the NESS features fragmented Bose condensation into three single-particle modes [1]. Remarkably, this form of non-equilibrium condensation occurs up to system sizes L that can be several orders of magnitude larger than those for which equilibrium Bose condensation occurs for the same β and n.
[1] Vorberg et. al., Phys. Rev. Lett. **111**, 240405 (2013)

A 4.6 Mon 15:45 C/HSW

Fermions in a harmonic trap with spin-imbalanced filling — Denis Morath, Stefan A. Söffing, and •Sebastian Eggert — OPTIMAS und Technische Universität Kaiserslautern

In recent experiments with ultra-cold fermions it was possible to prepare states with imbalanced pseudo-spin fillings, analogous to electrons in quantum dots. This offers the opportunity to make controlled studies on the influence of finite interactions, spin filling and temperature on the density of confined fermions. We now consider the situation in a one-dimensional trap theoretically and with numerical quantum simulations (quantum Monte Carlo and DMRG). Already for three particles in a trap there is a surprising alignment of spin up an down particles with a rather dramatic effect of the temperature. Naively an antiferromagnetic correlation between the spin species should be expected for repulsive interactions, i.e. density maxima of spin-up should correlate in space with spin-down minima and vice versa. However, already very low finite temperatures can induce *ferromagnetic* correlations. Based on the analysis of few-particle situations and symmetry considerations we can also explain the behaviour of many-particle systems.

A 4.7 Mon 16:00 C/HSW

Relaxation Dynamics of an Isolated Large-Spin Fermi Gas Far from Equilibrium — •Ulrich Ebling[1,2], Jasper Simon Krauser[3], Nick Fläschner[3], Klaus Sengstock[3,4], Christoph Becker[3,4], Maciej Lewenstein[2,5], and André Eckardt[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [2]ICFO - Institut de Ciències Fotòniques, Castelldefels, Spain — [3]Institut für Laserphysik, Universität Hamburg, Hamburg, Germany — [4]ZOQ - Zentrum für optische Quantentechnologien, Universität Hamburg, Hamburg, Germany — [5]ICREA - Instituciò Catalana de

Recerca i Estudis Avançats, Barcelona, Spain

A fundamental question in many-body physics is how closed quantum systems reach equilibrium. We address this question experimentally and theoretically in an ultracold large-spin Fermi gas where we find a complex interplay between internal and motional degrees of freedom. The fermions are initially prepared far from equilibrium with only a few spin states occupied. The subsequent dynamics leading to redistribution among all spin states is observed experimentally and simulated theoretically using a kinetic Boltzmann equation with full spin coherence. The latter is derived microscopically and provides good agreement with experimental data without any free parameters. We identify several collisional processes that occur on different time scales. By varying density and magnetic field, we control the relaxation dynamics and are able to continuously tune the character of a subset of spin states from an open to a closed system.

A 4.8 Mon 16:15 C/HSW

High resolution ion microscopy of cold atoms — •Markus Stecker, Hannah Schefzyk, Peter Federsel, Andreas Günther, and József Fortágh — Physikalisches Institut, Universität Tübingen, Germany

We develop a novel quantum gas microscope based on ionization of atoms and high resolution ion optics. The system allows for a magnification up to 1000 and a spatial resolution below the optical diffraction limit. The detection method enables continuous real time observation of trapped quantum gases with single atom sensitivity and high temporal and spatial resolution. In such a system, local statistics like temporal and spatial correlations could be studied as well as global cloud properties and dynamical processes.

We present the ion optics setup and the corresponding simulations, which reveal the principal limits of the system in terms of magnification and resolution. Furthermore, we show the first experimental realization. The current ionization scheme uses a 480nm laser to ionize directly out of a magneto-optically trapped cloud of atoms. In order to experimentally characterize the imaging quality, we imprint test patterns with the ionization laser onto the MOT. This data is used to verify the simulations and find the experimentally achievable resolution limits.