Q 16: Quantum Gases: Interaction Effects I

Time: Tuesday 14:00–16:15 Location: E 001

Group Report Q 16.1 Tu 14:00 E 001

Giant coherence times in trapped atomic gases — Christian Deutsch[1], Fernando Ramirez-Martinez[2], Clement Lacroute[2], Friedemann Reinhard[1], Tobias Schneider[1], Jean-Noel Fuchs[3], Frederic Piechon[3], Franck Laloe[3], Jakob Reichel[1], and •Peter Rosenbusch[2] — [1]LKB, Ecole Normale Supérieure, Paris — [2]LNE-SYRTE, Observatoire de Paris — [3]LPS, Université Paris-Sud, Orsay

We present an atom chip experiment designed to operate a microwave clock using magnetically trapped atoms. The project builds on the demonstration experiment [Phys. Rev. Lett., vol. 92, 203005 (2004)] but aims at an improved clock stability of 10^{-13} at 1 s, 10 times better than commercial clocks. We give results on the contrast of Ramsey fringes recorded in the thermal regime, where atoms can be treated as independent particles following different trajectories. The predicted dephasing time for 10^5 atoms, based on the known collisional shift, the second order Zeeman shift and their partial compensation is around 1.5 s [Appl. Phys. B, vol. 95, 227 (2009)]. Here we present experimental data where the fringe contrast remains bigger than 75% up to 5 s of Ramsey free evolution time, equivalent to a 15 s 1/e-time, which is 10 times longer than predicted. This, to our knowledge is a new record in neutral atom experiments. First simulations indicate that the identical spin rotation effect, known to be at the origin of spin waves [Phys. Rev. Lett., vol. 102, 215301 (2009)], here leads to a synchronisation of the atom phases.

Q 16.2 Tu 14:30 E 001

Atom chip based generation of entanglement for quantum metrology — •Max Fabian Riedel[1,2], Pascal Böhi[1,2], Yun Li[3,4], Theodor Wolfgang Hänsch[1,2], Alice Sinatra[3], and Philipp Treutlein[1,2] — [1]Ludwig-Maximilians-Universität, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [3]Laboratoire Kastler-Brossel, ENS, 75005 Paris, France — [4]State Key Laboratory of Precision Spectroscopy, East China Normal University, Shanghai 200062, China

Entanglement-based technologies, such as quantum information processing, quantum simulations, and quantum metrology have the potential to revolutionize our way of computing and measuring, and help clarify the puzzling concept of entanglement itself. Ultracold atoms on atom chips are attractive for their implementation, as they provide control over quantum systems in compact, robust, and scalable setups. A severe limitation of atom chips, however, is that techniques to control atomic interactions and thus to generate entanglement have not been experimentally available so far.

In this talk we present experiments where we generate multi-particle entanglement on an atom chip by controlling elastic collisional interactions with a state-dependent microwave near-field potential. We employ this technique to generate spin-squeezed states of a two-component Bose-Einstein condensate and show that they are useful for quantum metrology. Our data show good agreement with a dynamical multi-mode simulation and allow us to reconstruct the Wigner function of the spin-squeezed condensate.

Q 16.3 Tu 14:45 E 001

Multi-isotope trapping of metastable neon — •Jan Schütz, Thomas Feldker, Holger John, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

We investigate the interactions of laser cooled metastable neon (Ne*) in the $^3P_2$ state in a magneto-optical trap (MOT) and magnetic trap. Recent modifications of our setup enable us to trap all two-isotope combinations of bosonic ^{20}Ne, bosonic ^{22}Ne, and fermionic ^{21}Ne.

The most remarkable feature of Ne* is its extraordinary high internal energy which exceeds half of its ionization energy. This, on the one hand, leads to extremely high two-body losses due to Penning ionization but, on the other hand, allows for very sensitive detection of ions and metastables using electron multipliers. This serves as a direct probe for inelastic collisions and should enable us to gain a close insight into the inter-isotopic collision processes.

One objective is to determine the inter-isotopic collision cross sections which, if favorable, could open up new possibilities to create quantum degenerate bosonic or fermionic Ne*. Another goal is to create a dense, cold, spin-polarized sample of fermionic ^{21}Ne since reduction of the ion production would present a direct observation of Pauli blocking. We report on the status of the experiment.

Q 16.4 Tu 15:00 E 001

Phase separation in a thermal mixture of ultracold atoms — •Frank Münchow, Florian Baumer, Cristian Bruni, Simon Hübner, and Axel Görlitz — Institut für Experimentalphysik, HHU Düsseldorf, Germany

A fundamental question that arises if two gases of atoms are trapped in the same trap is whether the two species mix or phase separation occurs. Generally, a condition for phase separation in a thermal mixture is that the interspecies interaction energy is extremely large and exceeds the thermal energy. Therefore, interaction-driven phase separation has not been observed in ultracold atom experiments, so far. Here, we report on our recent results on mixtures of ultracold Yb and Rb in a hybrid trap consisting of a bichromatic optical potential superimposed on a magnetic trap. For a specific combination of isotopes, namely ^{174}Yb and ^{87}Rb, we have observed an almost complete spatial separation of thermal clouds of ^{174}Yb and ^{87}Rb at temperatures in the low μK regime. In the particular trapping geometry, the presence of an ultracold ^{87}Rb cloud ($\approx 10^7$ atoms) leads to a strong repulsive interaction potential for the $\approx 10^5$ ^{174}Yb atoms which are repelled from the trap center. The phase separation implies intrinsically large repulsive interspecies interaction for the specific isotopic mixture and indicates an interspecies scattering length greater than $10000\,a_0$.

Q 16.5 Tu 15:15 E 001

Parameterizing the influence of Feshbach resonances for photoassociation and in the context of the Bose-Hubbard model of ultracold atoms in optical lattices. — •Philipp-Immanuel Schneider — AG Moderne Optik, Institut für Physik, Humboldt-Universität zu Berlin, Newtonstraße 15, 12489 Berlin

Ultracold atoms interacting in the presence of a Feshbach resonance (FR) have a vast range of applications from the creation of strong correlations in ultracold gases to the formation of dipolar ultracold molecules. Here we present an extension of the Bose-Hubbard (BH) model for ultracold atoms in optical lattices interacting with large scattering lengths as they appear in FRs. We show by an exact numerical treatment that the BH Hamiltonian can reproduce the two-particle spectrum for arbitrary large scattering lengths only by replacing the original interaction parameter U. The optimal value of this parameter can be well approximated by an analytic expression. Furthermore, we study the enhancement of photoassociation in the presence of an FR. We find that one can describe the transition rate of the complex photoassociation process by only two parameters, the maximal transition rate and the position of vanishing transition rate. It is shown that the latter determines the maximal enhancement of the transition rate.

Q 16.6 Tu 15:30 E 001

Multi-layer stacks of dipolar Bose-Einstein condensates — •Andrej Junginger, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Multi-layer stacks of dipolar Bose-Einstein condensates are investigated variationally using a Gaussian trial wave function for each condensate. The individual condensates arranged in harmonic traps only interact via the long-range dipole-dipole interaction while there is an additional attractive contact interaction present in each condensate.

The stationary states of the stack are calculated minimizing the mean-field energy and the dynamics of the system are obtained applying a time-dependent variational principle. Introducing canonical variables this system is equivalent to a many-body Hamiltonian system with particle interaction. The energy exchange between the condensates in an excited stack is analyzed.

Q 16.7 Tu 15:45 E 001

Far-From-Equilibrium Dynamics of Ultracold Fermi Gases — •Matthias Kronenwett[1], Thomas Gasenzer[1], Michael Foss-Feig[2], and Ana Maria Rey[2] — [1]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg — [2]JILA, University of Colorado, Boulder CO-80309, USA

We study the dynamics of ultracold Fermi gases far from thermal equilibrium. We employ a functional-integral approach based on the Schwinger-Keldysh closed time path integral to derive the two-particle irreducible (2PI) effective action. From this, the two-point correlation functions are determined self-consistently. The action is expanded in inverse powers of N, where N is the number of atomic hyperfine states. The dynamic equations are derived in next-to-leading order of this expansion. This approach reaches far beyond mean-field theory and includes quantum statistical aspects of equilibration dynamics. We present results on the dynamics of a 1D Fermi gas initially prepared far away from equilibrium. We also demonstrate how this formalism is specially suited to describe far-from-equilibrium dynamics in a Kondo lattice of ultracold fermionic alkaline-earth atoms.

Q 16.8 Tu 16:00 E 001

Delocalization of a disordered bosonic system by repulsive interactions — •Benjamin Deissler[1], Matteo Zaccanti[1], Giacomo Roati[1], Chiara D'Errico[1], Marco Fattori[1,2], Michele Modugno[1], Giovanni Modugno[1], and Massimo Inguscio[1] — [1]LENS and Dipartimento di Fisica, Università di Firenze, and CNR-INFM, 50019 Sesto Fiorentino, Italy — [2]Museo Storico della Fisica e Centro Studi e Ricerche 'E. Fermi', 00184 Roma, Italy

Anderson localization of ultracold atoms in disordered optical lattices, i.e. the transition from extended to exponentially localized states, was recently demonstrated for non-interacting samples. With the addition of atomic interactions, such a system becomes more complicated and is more difficult to describe theoretically. The effects of the disorder are expected to be gradually suppressed by repulsive interactions, and the possibility of different quantum phases arises. We employ a Bose-Einstein condensate of potassium, where the interaction can be tuned from negligible to large values via a Feshbach resonance and use a quasi-periodic lattice potential as a model of a controllable disordered system. This allows us to study the interplay of disorder and repulsive interactions in detail. We characterize the entire delocalization crossover through the study of the average local shape of the wavefunction, the spatial correlations, and the phase coherence. Three different regimes are identified and compared with theoretical expectations: an exponentially localized Anderson glass, the formation of locally coherent fragments, as well as a coherent, extended state.