Q 24: Quantum Gases: Mixtures and Spinor Gases

Time: Wednesday 10:30–12:30 Location: E 001

Q 24.1 We 10:30 E 001

Bose-Fermi Mixtures in Optical Lattices at Finite Temperature Beyond the One-Band Approximation — •Matthias Ohliger[1], Marcus Cramer[2], and Jens Eisert[1] — [1]Institute for Physics and Astronomy, University of Potsdam, Potsdam, Germany — [2]Institute for Mathematical Sciences, Imperial College, London, United Kingdom

In this talk we address the question how an admixture of spin-polarized Fermions alter the properties and especially the position of the superfluid transition of Bosons in an optical lattice. Different mechanism have been discussed in the literature focusing eiter on zero-temperature effects like self-trapping or thermal effects.

We have performed both analytic and numerical calculations to simultaneously account for finite temperature and interactions beyond the one-band Bose-Fermi-Hubbard model. We show results corresponding to realistic experimental parameters and discuss the regimes where the different effects are most important and also the interplay between them.

Q 24.2 We 10:45 E 001

Parametric amplification of quantum spin fluctuations in a spinor Bose-Einstein condensate — •Gebremedhn Gebreyesus[1], Philipp Hyllus[2], Frank Deuretzbacher[1], and Luis Santos[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167, Germany — [2]BEC-INFM, Dipartimento di Fisica, Università di Trento, Via Sommarive 14, I-38050 Povo, Italy

In this presentation we analyze the spinor dynamics in spinor condensates (with particular emphasis on the Rb87 F=2 case). Starting from an initial condensate in the Zeeman state m=0, the initial stages of the dynamics are characterized by a correlated pair-creation into m=+1 and -1 which closely resembles parametric amplification in quantum optics. This coherent dynamics is induced by spin-changing collisions, but, as we shall show in detail, the actual amplification gain largely depends on the interplay between these collisions, quadratic Zeeman effect, and external confinement. In particular, the magnetic-field dependence of the amplification (which presents a striking multiresonant character) is shown to map the instability of the corresponding spin excitations. We analyze also in detail the triggering mechanism showing that under proper conditions the systems is basically insensitive against spurious seeding, being purely driven by quantum spin fluctuations. In the last part of this presentation we shall discuss recent results on the number statistics of the parametrically amplified clouds in m=+1 and -1.

Q 24.3 We 11:00 E 001

Excitation modes of a parametric amplifier for matter waves — Carsten Klempt[1], Oliver Topic[1], Garu Gebreyesus[2], •Manuel Scherer[1], Bernd Lücke[1], Frank Deuretzbacher[2], Phillip Hyllus[2], Wolfgang Ertmer[1], Luis Santos[2], and Jan Arlt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Institut für theoretische Physik, Leibniz Universität Hannover

Matter wave optics with ultracold atoms has reached the point where non-classical states can be prepared and their fascinating properties can be explored. In optics, parametric down conversion is routinely used to generate light with squeezed observables as well as highly entangled photon pairs. The applications of these non-classical states range from fundamental tests of quantum mechanics to improved interferometers and quantum computation. Therefore, it is of great interest to realize such non-classical states with matter waves. Bose-Einstein condensates with non-zero spin can provide a mechanism analogous to parametric down conversion, thus enabling the generation of non-classical matter waves. We have observed magnetic field dependent spin resonances where the spin dynamics is dramatically enhanced. On these resonances, a parametric amplification process produces entangled atom pairs in excited spatial modes which are similar to the modes of a classical membrane with fixed boundary conditions. Intriguingly, these spatial modes can carry orbital angular momentum. A first analysis shows that the system may serve as a source of atomic Bell pairs with entangled angular momentum states, possibly allowing for Bell type measurements with neutral atoms.

Q 24.4 We 11:15 E 001

Phase diagram of Bose-Fermi mixtures in the light fermion limit — •Alexander Mering and Michael Fleischhauer — Fachbereich Physik and research center OPTIMAS, Technische Universität Kaiserslautern

We present analytic results for the phase diagram of Bose-Fermi mixtures in the limit of ultralight fermions. Starting from a discussion of the dependence of the Mott insulating phases on the density of fermions we show how the bosonic phase diagram can be understood in terms of a purely bosonic system with underlying complex potential induced by the fermions. Treating the special case of half fermionic filling we show the emergence of a charge density wave phase with a strong interplay between bosons and fermions. In terms of an effective theory we derive the full phase diagram in this case, giving analytic results for all incompressible phases including the CDW phase. Furthermore the existence of regions of coexistence between Mott insulators and CDW is predicted. All analytic results are supported by numerical results obtained by DMRG, showing a good agreement to the analytic predictions.

Q 24.5 We 11:30 E 001

Dynamical Correlations in Spinor-Bose Gases — Jürgen Bosse[1], •Benno Liebchen[1], and Axel Pelster[2,3] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Institut für Physik und Astronomie, Karl-Liebknecht-Str. 24 14476 Potsdam, Germany — [3]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

The dynamical structure factor $S(\mathbf{q},\omega)$ and the response spectrum $G''(\mathbf{q},\omega)$ of both particle and magnetization density have been calculated for trapped ideal $F = 1$ spinor-Bose gases at *finite* temperatures. Such systems with fixed magnetization are known to show two BEC phase transitions [1]. The resulting nonlinear relation between the magnetic field and the magnetization is presented for various temperatures. In the special case of a homogeneous system, earlier results for the *linear* magnetic susceptibility are reproduced [2,3].

[1] T. Isoshima, T. Ohmi, and K. Machida, J. Phys. Soc. J. **69**, 3864 (2000)

[2] J. Bosse, K.N. Pathak, and G.S. Singh, `arXiv:0912.2833`, Physica A **389**, 408 (2010)

[3] J. Bosse, K.N. Pathak, and G.S. Singh, `arXiv:0912.2841`

Q 24.6 We 11:45 E 001

Dipolar effects on the parametric amplification of spinor Bose-Einstein condensates — •Frank Deuretzbacher, Gebremedhn Gebreyesus, and Luis Santos — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167, Germany

In this presentation we analyze the spinor dynamics in spinor Bose-Einstein condensates (with particular emphasis on the Rb87 F=1 case). Starting from an initial condensate in the Zeeman state m=0, the initial stages of the dynamics are characterized by a correlated pair-creation into m=+1 and -1 which closely resembles parametric amplification in quantum optics. This coherent dynamics is induced by spin-changing collisions, which having a very low energy scale associated, are very sensitive to other small energy scales. In particular, as we shall discuss in detail in this presentation, the spinor dynamics is shown to be largely modified by the weak magnetic dipole-dipole interactions. We analyze in detail the dipolar effects (in particular the modification of the parametric amplification dependening on the magnetic-field orientation) and how these effects are extremely sensitive with respect to even rather weak magnetic field gradients in the experiments. In the last part of this presentation, we shall discuss the formation of spatial patterns in the parametrically amplified clouds in m=+1 and -1.

Q 24.7 We 12:00 E 001

Towards the creation of a quantum gas of polar ground state molecules — •Markus Debatin[1], Almar Lercher[1], Bastian Schuster[1], Raffael Rameshan[1], David Baier[1], Francesca Ferlaino[1], Tetsu Takekoshi[1], Rudolf Grimm[1,2], and Hanns-Christoph Naegerl[1] — [1]Institut für Experimentalphysik Univer-

sität Innsbruck — [2]Institut für Quantenoptik und Quanteninformation IQOQI Innsbruck

The creation of quantum gases of deeply-bound ground state molecules, c.f. Danzl et al.[1] and Ni et al. [2], has recently attracted a lot of attention. In our Rb-Cs mixture experiment the focus is on the creation of a bosonic quantum gas of polar ground state RbCs molecules using a stimulated adiabatic Raman transfer (STIRAP) scheme similar to that used in Ref. [1]. Our current goal is the creation of a dual-species BEC as a precursor to molecule production and STIRAP. We are able to create large all-optical BECs for Rb and Cs separately, but comparatively high 3-body interspecies loss rates present a challenge. In the talk, data on 3-body effects is presented and approaches to stabilize the mixture are discussed. After creating a high phase-space density mixture we will create Feshbach molecules and perform high-resolution molecular spectroscopy with the aim to develop a scheme for RbCs ground-state transfer.

[1] J.G. Danzl et al., Science 321, 1062 (2008),
[2] K.-K. Ni et al., Science 322, 231 (2008).

Q 24.8 We 12:15 E 001

Quantum phase diffusion in interacting Bose-Fermi mixtures — •Simon Braun[1], Sebastian Will[1], Thorsten Best[2], Philipp Ronzheimer[1], Michael Schreiber[1], Ulrich Schneider[1], Tim Rom[1], Lucia Hackermüller[1], Kin-Chung Fong[1], Dirk-Sören Lühmann[3], and Immanuel Bloch[1] — [1]Ludwig-Maximilians-Universität München — [2]ALU Freiburg — [3]Universität Hamburg

The system of ultracold bosonic atoms in a 3D optical lattice is commonly described by the Bose-Hubbard model (BHM). While this model only takes into account the lowest Bloch band, theoretical studies indicate that interactions may bring multi-band effects into play.

We have been able to observe and quantify multi-band physics beyond the single-band BHM by studying quantum phase diffusion of a ^{87}Rb BEC in a 3D optical lattice. We observed more than 40 collapses and revivals of the matterwave field, the period of which is determined by the onsite interaction energy. This technique allowed for a precise measurement of interaction energies, being in excellent agreement with theoretical results of a multi-orbital calculation.

In the presence of fermionic ^{40}K atoms, the quantum phase diffusion dynamics show a strong dependence on the interspecies interaction between K and Rb, which can be conveniently tuned via a Feshbach resonance. By driving Raman transitions between Zeeman sublevels we can additionally switch the interspecies interaction almost instantaneously. Our measurements show how interspecies interactions both affect the number statistics in the system and lead to renormalized Hubbard parameters, again revealing multi-band physics in optical lattices.