A 20: Ultra-cold atoms, ions and BEC V (with Q)

Time: Thursday 10:30–13:00 Location: BAR 106

A 20.1 Thu 10:30 BAR 106

Supersolid Phase of Cold Fermionic Polar Molecules in 2D Optical Lattices — •Liang He and Walter Hofstetter — Institut für Theoretische Physik, Johann Wolfgang Goethe–Universität, 60438 Frankfurt/Main, Germany

The recent successful realization of a degenerate quantum gas of fermionic polar molecules of $^{40}K^{87}Rb$ [1] opens the door towards exploring the interesting many-body physics originating from the dipole-dipole interactions in fermionic systems. Here we investigate a system of ultra-cold fermionic polar molecules in a two-dimensional square lattice interacting via both the long-ranged dipole-dipole interaction and the short-ranged on-site attractive interaction. Singlet superfluid, charge density wave, and supersolid phases are found to exist in the system. We map out the zero temperature phase diagram and find that the supersolid phase is considerably stabilized by the dipole-dipole interaction and can thus exist over a large region of filling factors. At finite temperatures, we study the melting of the supersolid with increasing temperature, map out a finite temperature phase diagram of the system at a fixed filling factor, and determine the parameter region where the supersolid phase can be possibly observed in experiments.

[1] K.-K. Ni, S. Ospelkaus, M. H. G. de Miranda, A. Pe'er, B. Neyenhuis, J. J. Zirbel, S. Kotochigova, P. S. Julienne, D. S. Jin, and J. Ye, Science, **322**, 231 (2008).

A 20.2 Thu 10:45 BAR 106

Fermi-Hubbard physics with ultracold fermions in optical lattices — •Daniel Greif, Leticia Tarruell, Thomas Uehlinger, Gregor Jotzu, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, Switzerland

The Fermi-Hubbard Hamiltonian is one of the key models for strongly correlated electrons in solid state systems and incorporates fascinating phenomena such as Mott-insulating behavior or spin ordered phases. Despite intense numerical effort, a number of questions still remains open, in particular on the low temperature phases where spin degrees of freedom start to play a role.

In our experiment we use a two-component Fermi gas loaded into an optical lattice to realize this simple model Hamiltonian. Currently several experiments are reaching out to access the regime of quantum magnetism. We report on recent progress of creation and characterization of low entropy states in the lattice.

A 20.3 Thu 11:00 BAR 106

Generalized Hartree-Fock Theory for Interacting Fermions in Lattices: Numerical Methods — •Christina Kraus and Ignacio Cirac — Max-Planck Institut für Quantenoptik, Garching

We present numerical methods to solve the Generalized Hartree-Fock theory for fermionic systems in lattices, both in thermal equilibrium and out of equilibrium. Specifically, we show how to determine the covariance matrix corresponding to the Fermionic Gaussian state that optimally approximates the quantum state of the fermions. The methods apply to relatively large systems, since their complexity only scales quadratically with the number of lattice sites. Moreover, they are specially suited to describe inhomogenous systems, as those typically found in recent experiments with atoms in optical lattices, at least in the weak interaction regime. As a benchmark, we have applied them to the two-dimensional Hubbard model on a 10x10 lattice with and without an external confinement.

A 20.4 Thu 11:15 BAR 106

Quantum-noise quenching in quantum tweezers — •Stefano Zippilli[1,2,3], Bernd Mohring[4], Eric Lutz[5], Giovanna Morigi[1,2], and Wolfgang Schleich[4] — [1]Departament de Física, Universitat Autònoma de Barcelona, E-08193 Bellaterra, Spain — [2]Theoretische Physik, Universität des Saarlandes, D-66041 Saarbrücken, Germany — [3]Fachbereich Physik and research center OPTIMAS, Technische Universität Kaiserslautern, D-67663 Kaiserslautern, Germany — [4]Institut für Quantenphysik, Universität Ulm, D-89081 Ulm, Germany — [5]Department of Physics, University of Augsburg, D-86135 Augsburg, Germany

The efficiency of extracting single atoms or molecules from an ultracold bosonic reservoir is theoretically investigated for a protocol based on lasers, coupling the hyperfine state in which the atoms form a condensate to another stable state, in which the atom experiences a tight potential in the regime of collisional blockade, the quantum tweezers. The transfer efficiency into the single-atom ground state of the tight trap is fundamentally limited by the collective modes of the condensate, which are thermally and dynamically excited and constitute the ultimate noise sources. This quantum noise can be quenched for sufficiently long laser pulses, thereby achieving high efficiencies, and showing that this protocol can be applied for quantum information processing based on tweezer traps for neutral atoms.

A 20.5 Thu 11:30 BAR 106

Definite angular momentum and fragmentation in 3D attractive BECs — •Marios C. Tsatsos[1], Alexej I. Streltsov[1], Ofir E. Alon[1,2], and Lorenz S. Cederbaum[1] — [1]Theoretische Chemie, Physikalisch-Chemisches Institut, Universität Heidelberg, Im Neuenheimer Feld 229, D-69120 Heidelberg, Germany — [2]Department of Physics, University of Haifa at Oranim, Tivon 36006, Israel

We consider a 3D Bose-Einstein Condensate (BEC), with attractive interparticle interactions, embedded in a harmonic, spherically symmetric trap. This system is metastable only if the total number of bosons N and the interaction strength λ_0 do not exceed some critical values. Otherwise the system collapses. The Gross-Pitaevskii (GP) theory predicts the maximum (critical) number of bosons N_{cr}^{GP} that, for a given λ_0, can be loaded to the ground state of the system, without its collapse. But, what happens to the excited states? To investigate the structure and stability of these states we must go beyond GP theory; the excited states have definite values of angular momentum L, are highly fragmented and can support number of bosons much greater than N_{cr}^{GP}.

A 20.6 Thu 11:45 BAR 106

Continuous Loading of a Conservative Trap from an Atomic Beam — •Markus Falkenau[1], Valentin Volchkov[1], Jahn Rührig[1], Axel Griesmaier[1,2], and Tilman Pfau[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Germany — [2]Niels-Bohr Insitute, Copenhagen, Denmark

We present results on the fast accumulation of ^{52}Cr atoms in a conservative potential from a magnetically guided atomic beam. Without laser cooling on a cycling transition, a single dissipative step realized by optical pumping allows to load atoms at a rate of $2 \cdot 10^7 s^{-1}$ in the trap. Within less than 100 ms we reach the collisionally dense regime, from which we directly produce a Bose-Einstein condensate with subsequent evaporative cooling. This constitutes a new approach to degeneracy where, provided a slow beam of particles can be produced by some means, Bose-Einstein condensation can be reached for species without a cycling transition.

A 20.7 Thu 12:00 BAR 106

Novel magnetic trap design for ultra-cold metastable helium atoms with large optical access — •Franz Sievers, Juliette Simonet, Sanjukta Roy, Jérôme Beugnon, Michèle Leduc, and Claude Cohen-Tannoudji — Laboratoire Kastler Brossel, École Normale Supérieure, 24 rue Lhomond, 75231 Paris, France

We present the design of a modified Cloverleaf-type Ioffe-Pritchard trap for Bose-Einstein condensation of ultra-cold atoms, compatible with in situ loading of the condensed gas into a three-dimensional optical lattice. The coil geometry offers optical access for three independent triplets of orthogonal laser beams that cross in the centre of the trap. Two are used for the magneto-optical trap and the projected three-dimensional optical lattice, respectively. Technical considerations of the trap design, as well as the electric circuitry for fast switching are reviewed. This set-up is intended to operate for metastable helium, but is also of practical interest for experiments with other species.

A 20.8 Thu 12:15 BAR 106

Gauge fields for ultra-cold Ytterbium atoms — •Sebastian Krinner[1,2], Fabrice Gerbier[1], Jerôme Beugnon[1], and Jean Dalibard[1] — [1]Laboratoire Kastler Brossel, 24 rue Lhomond, 75005 Paris, France — [2]Institute for Quantum Electronics, ETH Zürich, Hönggerberg, CH-8093 Zürich, Switzerland

Cold atoms in optical lattices can serve as model systems for condensed matter physics. In our project we plan to investigate the rich physics of fractional quantum Hall phases. I will first briefly explain the core of the planned experiment, i.e. the implementation of a strong U(1)-like gauge field on cold Ytterbium atoms confined in a two-dimensional square lattice.

The second part focuses on the laser cooling of Yb. It consists of Zeeman slowing of an atomic beam using the strong singlet transition at 399nm and subsequent magneto-optical trapping using the green intercombination line at 556nm. Both laser wavelengths are produced via the technique of second-harmonic generation. As a showcase I will treat the generation of the 556nm light relying on intra-cavity frequency doubling of a 2W fiber laser at 1112nm. The output power of 1.2W corresponds to 80% efficiency and suggests an alternative to dye lasers.

A 20.9 Thu 12:30 BAR 106

Radiofrequency spectroscopy of a strongly interacting two-dimensional Fermi gas — •Bernd Fröhlich, Michael Feld, Enrico Vogt, Marco Koschorreck, and Michael Köhl — Cavendish Laboratory, University of Cambridge, JJ Thomson Avenue, Cambridge CB3 0HE

We have realized and studied a strongly interacting two-component atomic Fermi gas confined to two spatial dimensions using an optical lattice. Using radio-frequency spectroscopy we measure the interaction energy of the gas. We find that the strong confinement to two dimensions induces scattering resonances and leads to the existence of confinement-induced molecules which have no counterpart in three dimensions.

A 20.10 Thu 12:45 BAR 106

Large coordination number expansion for a lattice Bose gas — •Patrick Navez[1], Ralf Schützhold[2], and Konstantin Krutitsky[2] — [1]Institut für Theoretische Physik, TU Dresden, D-01062 Dresden, Germany — [2]Fakultät für Physik, Universität Duisburg-Essen, Lotharstrasse 1, D-47057 Duisburg, Germany

We establish a set of hierarchy equations describing the time evolution of the N-points spatial correlation reduced density matrix in a lattice Bose gas. This set of equations is solved through a 1/z expansion where z is the coordination number i.e. number of interaction of a site with its nearest neighbors. The leading order of this expansion corresponds to the time-dependent Gutzwiller mean field approach that is used to describe the Bragg scattering in the superfluid regime. The next order contribution includes the correlations between sites. We illustrate how these correlations appear in the process of a ultra fast sweeping from a deep Mott regime to the superfluid regime.