A 26: Posters: BECs, ultracold gases and plasmas

Zeit: Donnerstag 16:30–18:30 Raum: Poster C3

A 26.1 Do 16:30 Poster C3

Cold collisions of K atoms studied by precision spectroscopy — Stephan Falke[1,2], Matthias Riedmann[1], Jan Friebe[1], Horst Knöckel[1], Eberhard Tiemann[1], and •Christian Lisdat[1,3] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Department of Physics, Yale University, New Haven, U.S.A. — [3]Physikalisch-Technische Bundesanstalt Braunschweig

The interaction in ultracold thermal and quantum degenerate atomic clouds are dominated by binary collisions. Precisely these interactions make ultracold atoms the interesting field of research they are, since they determine BEC properties, produce Feshbach resonances, or allow forming molecules. All these points are closely related to the interaction potential of two colliding atoms. We report our laser-spectroscopic investigation of the least bound levels in the ground state X $^1\Sigma_g^+$ of $^{39}K_2$ undertaken on a molecular beam [1]. We measured in a two-laser lambda scheme energy differences of ground state levels in the order of 1 250 cm^{-1} with a precision better than 5 MHz applying a femtosecond frequency comb and iodine lines for frequency calibration. Precise models of the interaction potentials allow for an accurate description of cold collisions, e.g., Feshbach resonance positions. In a further step of the experiment we will test the precision of the mass-scaling to other isotope combinations based on the Born-Oppenheimer approximation using the isotopomere $^{39}K^{41}K$, which is sufficiently abundant for observation in a molecular beam based on a natural potassium [1].

[1] J. Chem. Phys. **125**, 224303 (2006), Phys. Rev. A **76**, 012724 (2006).

A 26.2 Do 16:30 Poster C3

EIT cooling beyond the Lamb Dicke limit — •Maryam Roghani and Hanspeter Helm — Department of Molecular and Optical Physics, Stefan-Meier-Straße 19, D-79104 Freiburg

Morigi et al have shown, that by applying two laser beams to a trapped atomic sample in a way that EIT(Electromagnetically Induced Transparency) condition is satisfied, there is the a possibility of cooling the sample to the ground state of the trap[1].This scheme proves highly efficient in case of cooling ions in tight traps when the condition of small Lamb-Dicke parameter and the condition of spontaneous emission rate smaller than trap frequency can be met.Transferring this scheme to typical cases of neutral atoms trapped in optical dipole trap environments neither of these conditions can be stringently met. In the neutral atom case typical values of the Lamb-Dicke parameter are in the range of 0.2-1 and spontaneous emission rate is much greater than trap frequency. We explore this situation by developing the Liouville equation for a density matrix describing states of the vibrational and electronic motion of the sample by taking into account the modification of the EIT line-shape due to vibrationally off-diagonal transitions in emission and absorption. [1].F.Schmidt-Kaler, J.Eschner, G.Morigi, C.F.Roos, D.Leibfried, A.Mundt, R.Blatt, Laser cooling with electromagnetically induced transparency:application to trapped samples of ions or neutral atoms, Appl.Phys.B 73,807(2001).

A 26.3 Do 16:30 Poster C3

Observations and Simulation of the evaporation process in an optical dipole trap — •Christoph Käfer[1], Thomas Boll[1], Riad Bourouis[1,2], Jürgen Eurisch[1], and Hanspeter Helm[1] — [1]Department of Molecular and Optical Physics, Stefan-Meier-Str. 19, 79104 Freiburg — [2]Institut für Angewandte Physik, Universität Bonn

We investigate the temporal development of atom number and atom temperature in an optical dipole trap which is established by a focused CO_2 laser. At full power the trap frequencies in radial and longitudinal direction are v_r= 2.4 kHz and v_z= 160 Hz. When forcing the evaporation process by lowering the laser power, these trap frequencies and the elastic scattering rate decrease and spilling of atoms prior to rethermalization is playing an ever more important role as the evaporation process proceeds. Also the effect of gravity becomes a crucial factor at the end of the evaporation process. To our knowledge no published models account for all these parameters, and they cannot quantitatively explain the observations. We present a numerical model which can quantitatively account for all these parameters. In our model, the atoms are distributed according to a chopped Maxwell-Boltzmann distribution, where atoms with a kinetic energies above the potential depth are removed from the sample. After calculating the redistributed kinetic energy of two randomly chosen particles after scattering, the energy distribution of the entire sample can be updated and chopped again. In this fashion natural evaporation and forced evaporation can be traced out numerically. We compare predictions of this recursive model to our experimental result.

A 26.4 Do 16:30 Poster C3

An apparatus for ultracold Fermi gases using sodium and lithium — •Jens Appmeier, Marc Repp, Stefan Weis, Anton Piccardo-Selg, Jan Krieger, Elisabeth Brama, Peter Krüger, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Heidelberg

We report on the setup of an apparatus for cooling fermionic ^{6}Li atoms to quantum degeneracy. As a refrigerant for the fermions, ^{23}Na is used and standard cooling schemes are applied. By tuning the interatomic interactions of ^{6}Li via Feshbach resonances it is possible to study the BEC-BCS crossover. We intend to study this regime in lower dimensions by making use of optical lattices. The current progress of the experimental setup will be reported.

A 26.5 Do 16:30 Poster C3

Stochastic field equations for a finite Bose gas — •Sigmund Heller and Walter T. Strunz — Physikalisches Institut, Universität Freiburg

Based on the P-representation of the grand canonical and, more remarkably, the canonical density operator of a Bose field, we introduce corresponding stochastic field equations. Although strictly valid for non-interacting Bosons, we may include a mean-field interaction to describe the behaviour of weakly interacting Bose gases at finite temperature. The usual ("classical") thermal field state based on the Gross-Pitaevskii energy functional is obtained in the infinite-temperature limit. Nicely, our "quantum" field equations do not suffer from cutoff problems which is reflected by spatial correlations of the driving thermal noise. We present numerical simulations for various applications - mainly in the non-interacting regime.

A 26.6 Do 16:30 Poster C3

Dynamics of a Spinor-BEC in a radio-frequency-dressed magnetic trap — •Stephan Middelkamp[1], Igor Lesanovsky[2], and Peter Schmelcher[1,3] — [1]Theoretische Chemie, Physikalisch-Chemisches Institut, Universität Heidelberg, INF 229, 69120 Heidelberg, Germany — [2]Institut für Theoretische Physik, Universität Innsbruck, Technikerstraße 25, A-6020 Innsbruck, Austria — [3]Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg, Germany

We theoretically investigate the dynamics of a quasi-one-dimensional $F = 1$ Spinor Bose-Einstein Condensates in a magnetic trap. Due to the coupling of the trap to the magnetic quantum number the $m_F = 1$ and $m_F = -1$ components experience inverse trapping potentials, whereas the $m_F = 0$ component experiences no trapping potential at all. We have chosen a double well as trapping potential for the $m_F = 1$ component. Consequently, the $m_F = -1$ component experiences a local potential minimum at the barrier of the double well potential and potential maxima at the position of the wells. In each well resides a BEC of atoms in the $m_F = 1$ state and at the barrier a BEC of atoms in the $m_F = -1$ state. With microwaves one can excite the atoms in the $m_F = -1$ state to the $m_F = 0$ state. Thus eliminating effects of the magnetic trap. Nevertheless, the $m = 0$ component remains trapped due to the interaction with the atoms in the $m_F = 1$ state. The strength of this interaction can be tuned by changing the number of atoms in the $m_F = 1$ state.

A 26.7 Do 16:30 Poster C3

Interaction of Ultra-Cold Atoms with Individual Carbon Nanotubes — •Gabriela Visanescu[1], Philipp Schneeweiss[1], Michael Gierling[1], Hannah Schefzyk[1], Andreas Günther[1], Germán Sinuco[2], Thomas Judd[2], Carsten Weiss[3], Reinhold Walser[3], and József Fortágh[1] — [1]Physikalisches Institut, Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen — [2]School of Physics and Astronomy, University of Nottingham, University Park, Nottingham, NG7 2RD — [3]Institut für Quantenphysik, Universität Ulm, D-89069 Ulm

We designed an atom chip to study the interaction of ultra-cold 87Rb atoms with an individual carbon nanotube (CNT). The chip is loaded from a magnetic trap via adiabatic transfer. Once on the chip, a 4-wire waveguide together with a conveyor belt facilitate moving the atoms to the CNT. Precise control over position and speed allow the study of atom scattering and quantum reflection from the tube.

As outlined in Ref. 1, the interaction will be dominated by the Casimir-Polder-potential between atoms and the CNT. Observing the atomic motion by absorption imaging as well as single atom detection techniques, we will be able to experimentally determine the Casimir-Polder-potential.

[1] R. Fermani, S. Scheel, and P.L. Knight, Phys. Rev. A 75, 062905 (2007)

A 26.8 Do 16:30 Poster C3

Bose-Einstein Condensates in Superconducting Microtraps — •Brian Kasch, Daniel Cano, Helge Hattermann, Reinhold Kleiner, Dieter Kölle, Claus Zimmermann, and József Fortágh — Physikalisches Institut, Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen

We present progress toward producing Bose-Einstein condensation in a superconducting magnetic microtrap. The scientific objective is the coupling of cold atoms to superconducting devices. An experimental system consisting of a BEC apparatus, and a Helium flow cryostat has been set up. A gas of Rb-87 atoms has been loaded into a magneto-optical trap. This cloud will be cooled by forced evaporation, and subsequently translated 5cm by means of optical tweezers to a magnetic microtrap generated on a niobium chip at 4,2 K.

We developed numerical methods for calculating magnetic fields in the vicinity of superconducting surfaces. Inhomogeneous current densities within the superconductor have been calculated using an energy-minimization procedure that relies on the London equations. Corresponding superconducting chips have been produced using optical lithography and lift-off techniques.

In a first experiment, we plan to measure the coherence time of a spin-polarized atomic cloud near a superconducting surface. Theoretical predictions show the spin-flip lifetime should be increased by several orders of magnitude as compared to the normal conducting state of the same wire. The current state of the experiment will be presented.

A 26.9 Do 16:30 Poster C3

An ion in a sea of ultracold atoms — •Stefan Schmid, Sascha Hoinka, Albert Frisch, and Johannes Hecker Denschlag — Universitaet Innsbruck, Technikerstrasse 25 / IV, 6020 Innsbruck

We report on the status of our new hybrid ion/atom trap experiment where a single trapped Ba^+ ion will be immersed into a Bose-Einstein condensate of ^{87}Rb atoms. First experiments will focus on the investigation of the interaction between the ion and the sea of ultracold neutral atoms. We plan to study elastic as well as inelastic scattering processes, e.g. charge transfer and molecule formation. We describe in detail our setup which will feature an optical transport of a Rb BEC into a linear Paul trap, where the Barium ion is stored.

A 26.10 Do 16:30 Poster C3

Multi-channel scattering in cylindrical confining trap — •Shahpoor Saeidian[1], Vladimir Melezhik[2], and Peter Schmelcher[1] — [1]Universität Heidelberg, Heidelberg, Germany — [2]JINR,Dubna,Russian Federation

We suggest a grid method for multi-channel scattering of two particles under a transverse harmonic confinement. With this approach we analyze the transverse excitations of two colliding particles under the action of the confining trap. We consider collisions of two identical as well as distinguishable particles in the harmonic traps with single frequency permitting the center-of-mass (c.m.) separation in both the cases. In the zero-energy limit in single-mode regime we reproduce the known confinement-induced resonances (CIRs) for bosonic, fermionic and mixed collisions. The collisions under the tranverse harmonic confinement then analyzed in the multi-mode regime up to four open transverse channels. Possible applications can include, e.g., atom-atom collisions in atom wave guides and impurity scattering in quantum wires.

A 26.11 Do 16:30 Poster C3

An ultracold Bose gas in an optical dipole trap — •Lena Simon and Walter Strunz — Physikalisches Institut, Hermann-Herder-Str. 3, Universität Freiburg, 79104 Freiburg

Motivated by an experiment in the Helm group at the university of Freiburg, we study an ultracold Bose gas in an optical dipole trap consisting of one single laser beam. An analytical expression for the density of states for the trap potential beyond the usual harmonic approximation is obtained. We are thus able to determine the critical temperature for Bose-Einstein condensation and find that it depends on a cutoff parameter. We discuss these surprising subtleties in some detail. Moreover, we study the dynamics of evaporative cooling and observe a significant deviation from the well-established harmonic approximation.

A 26.12 Do 16:30 Poster C3

A novel atom chip based experiment for studies of Bose-Fermi mixtures in one dimension — •Philipp Wicke and Nicolaas Johannes van Druten — Van der Waals-Zeeman Institute, University of Amsterdam, The Netherlands

One-dimensional (1D) quantum gases offer exciting opportunities to explore many-body physics. A distinguishing feature of quantum physics in 1D is that exactly solvable models are available. Currently we investigate Bose gases in the 1D regime [1]. We plan to extend these studies to Bose-Fermi and Fermi-Fermi mixtures in 1D, and to make use of the many advantages that atom chips offer in this regard: rapid sympathetic cooling of the fermion ^{40}K by the boson ^{87}Rb on an atom chip has already been demonstrated [2], atom chips enable the study of individual realizations of 1D quantum gases [1], and finally they allow the use of versatile radio-frequency dressed potentials [3] that can be both state- and species-selective [4]. The latter should enable tuning the interaction parameters, in order to realize the above-mentioned exactly solvable models in our experiments. Our current design of an apparatus to investigate quantum degenerate mixtures of Rb and K will be presented at the conference. It includes a double chamber vacuum setup and a two-species MOT powered by a system of amplified diode lasers.

[1] van Amerongen et al., arXiv:0709.1899v1 (2007)
[2] Aubin et al., Nature Phys. **2**, 384 (2006)
[3] Hofferberth et al., Nature Phys. **2**, 710-716 (2006)
[4] Extavour et al., in *Atomic Physics 20*, 241-249 (2006)

A 26.13 Do 16:30 Poster C3

Ultracold bosonic and fermionic atoms in optical lattices — •Lucia Hackermueller, Thorsten Best, Ulrich Schneider, Sebastian Will, Dries van Oosten, and Immanuel Bloch — Johannes-Gutenberg-Universitaet Mainz, Staudingerweg 7, 55099 Mainz, Deutschland

The manipulation of ultracold fermionic and bosonic quantum gases in optical lattices permits access to a wide field of exciting experiments ranging from the investigation and simulation of solid state physics to quantum computing and ultracold chemistry.

In our apparatus we sympathetically cool ^{40}K and ^{87}Rb atoms. We use one of our lattice beams as a blue plug in a magnetic quadrupole trap. After precooling to 2μK we transfer our atoms to a crossed optical dipole trap and cool both species to quantum degeneracy. Subsequently we load pure potassium samples or potassium / rubidium mixtures into a blue detuned three dimensional optical lattice. The combination of a red detuned dipole trap with a blue detuned optical lattice enables us to vary the external confinement while leaving the lattice potential unchanged.

This setup allows for the investigation of various interesting experiments like heteronuclear molecules, molecular potassium in optical lattices, in situ cloud sizes of spin polarized potassium or spin mixtures. We report on the latest results from the experiment.

A 26.14 Do 16:30 Poster C3

Magnetic Trapping of metastable Magnesium — •M. Riedmann, J. Friebe, K. Moldenhauer, A. Pape, A. Voskrebenzev, E. M. Rasel, and W. Ertmer — Institute of Quantum Optics, Leibniz University Hannover

Magnesium is one of the few atoms suitable for an neutral atom optical lattice clock. The magic wavelength is predicted between 430 and 470 nm and Mg offers interesting features like a reduced sensitivity to room temperature blackbody radiation, which may limit the accuracy of Sr lattice clocks in the near future. Currently, the high temperatures of more than 3 mK in a MOT based on the strong singlet cooling transition at 285 nm would prevent high loading efficiency into an optical lattice. Therefore, our goal is to produce and cool metastable magnesium, where much lower temperatures are achievable ($T_{recoil} = 5\,\mu K$). In this contribution, we present the production of metastable Magnesium by two-color excitation in the singlet system and further decay to the metastable states $^3P_2$ and $^3P_1$. The metastable atoms are captured in a magnetic trap and detected on the triplet cooling transition at 383 nm. We are able to load more than 10^6 atoms in the long-living $^3P_2$ state into the trap at temperatures below 1 mK. We expect to get much higher atom numbers and lower temperatures in a MOT based on the triplet cooling transition.

A 26.15 Do 16:30 Poster C3

Towards a mesoscopic ensemble of ultracold fermions — •Matthias Kohnen[1], Friedhelm Serwane[1], Timo Ottenstein[1], Thomas Lompe[1], and Selim Jochim[1,2] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Ruprecht-Karls-Universität, Heidelberg

Ensembles consisting of a small number of ultracold fermionic atoms can serve as a model for other finite systems such as electrons in atoms or nuclei in a nucleus. So far experiments studying large fermionic systems have been very succesful in controlling the interparticle interaction by an external magnetic field using a so-called Feshbach resonnance. This allows to turn a degenerate Fermi gas reversibly into a molecular Bose-Einstein condensate. The way to a mesoscopic system would be to prepare an almost pure molecular BEC, convert it into a deeply degenerate Fermi gas and lower the depth of the trapping potential reducing the number of available quantum states which leads to a controlled spilling of atoms from the trap.

On this poster we present our progress in setting up a new apparatus for the preparation of such a mesoscopic system with defined atom number in an optical microtrap. So far, we have realized a magneto-optical trap collecting up to 10^9 ^{6}Li atoms in one second. The next step will be the transfer of the atoms into an optical dipole trap where condensation will be achieved by forced evaporative cooling. This molecular Bose-Einstein condensate will provide excellent starting conditions for our future experiments.

A 26.16 Do 16:30 Poster C3

Dynamics of a low-dimension ultracold Bose gas — •Cédric Bodet and Thomas Gasenzer — Institüt für Theoretishe Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg

The dynamical evolution of a Bose-Einstein condensate trapped in a one-dimensional lattice potential is investigated theoretically in the framework of the Bose-Hubbard model. The emphasis is set on the far-from-equilibrium evolution in a case where the gas is strongly interacting. This is realized by an appropriate choice of the parameters in the Hamiltonian, and by starting with an initial state, where one lattice well contains a Bose-Einstein condensate while all other wells are empty. Oscillations of the condensate as well as non-condensate fractions of the gas between the different sites of the lattice are found to be damped as a consequence of the collisional interactions between the atoms. We approach this problem by numerically solving the Schrödinger equation for this model. We study in detail the particle number fluctuations on-site and between sites in order to investigate the conditions for producing squeezed states in experimentally realistic configurations.

A 26.17 Do 16:30 Poster C3

A frozen Rydberg gas as a model system for quantum critical phenomena — •Peter Kollmann[1], Björn Butscher[1], Hendrik Weimer[2], Ulrich Raitzsch[1], Rolf Heidemann[1], Vera Bendkowsky[1], Robert Löw[1], Hans Peter Büchler[2], and Tilman Pfau[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, D-70550 Stuttgart — [2]Institut für Theoretische Physik III, Universität Stuttgart, Pfaffenwaldring 57, D-70550 Stuttgart

We present our recent experimental results on Rydberg excitation of magnetically trapped Rubidium atoms.

In a thermal cloud of a few μK we observe coherent, collective and strongly blocked excitation induced by the van der Waals interaction among the Rydberg atoms [1]. The observed scaling behaviour can be well understood in the framework of critical phenomenona. The reversibility of the excitation dynamics was measured with an echo type technique [2]. With this experiments we prove the coherence of the excitation and gain insight into the dephasing due to interactions. We further observed a signature of the phase transition to a Bose-Einstein condensate in the fraction of excited Rydberg atoms when cooling the thermal cloud below T_c. The main features of the experimental data are reproduced by a simulation using a superatom model [3].

[1] R. Heidemann et al., Phys. Rev. Lett. 99, 163601 (2007)
[2] U. Raitzsch et al., arXive: quant-phys 0706.2639 (2007)
[3] R. Heidemann et al., arXive: cond-mat 0710.5622 (2007)

A 26.18 Do 16:30 Poster C3

Trapped Rydberg Ions — •Markus Mueller[1], Linmei Liang[1,2], Igor Lesanovsky[1], and Peter Zoller[1] — [1]Institute for Theoretical Physics, University of Innsbruck, and Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, Innsbruck, Austria — [2]Department of Physics, National University of Defense Technology, Changsha 410073, China

We study Rydberg states of ions which are trapped in a linear Paul trap. In such trap the ions are confined by an electric quadrupole field and a ponderomotive force due to an oscillating quadrupole. Using a two-body approach in order to model the Rydberg ions we derive the Hamiltonian for Rydberg excitations in a linear ion crystal. We discuss the creation of strong state-dependent dipole-dipole interaction among the ions using microwave dressing of Rydberg states. This system offers the possibility to study Rydberg excitation dynamics of a mesoscopic ensemble in a well-structured environment and allows the implementation of strongly interacting spin models.

A 26.19 Do 16:30 Poster C3

Ultracold plasma from the gases of light atoms — •Andrey Lyubonko, Amar S. Sil, and JM Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Ultracold neutral plasmas are formed by photoionizing laser cooled atoms near the ionization threshold [1,2]. The electron temperature is from 1-1000K and the ion temperature is around 1K. The fundamental interest in these systems originates in the possibility of creating strongly coupled plasma. We are mainly interested in the theoretical description of dynamics of ultracold metastable Li+ (1s2s 3S) plasma. The special feature of this system is that the ions are in metastable state and can release its internal energy (ΔE = 59eV per ion) due to inelastic collisions. This energy can drastically change the dynamics of the plasma. The important inelastic collisions are superelastic collisions, three-body recombination which leads to Rydberg atoms formation, subsequent excitation, deexcitation and ionization of Rydberg atoms. We tackle this problem by molecular dynamics (MD) technique including inelastic collisions by rates. We will identify the parameter regimes in which such a metastable ultracold plasma can exist.

1.T. C. Killian, Science 316, 705 (2007)
2.T.C. Killian, T. Pattard, T. Pohl, J.M. Rost, Phys.Rep. 449(2007), 77-130

A 26.20 Do 16:30 Poster C3

Excitation of Rydberg atoms in a Bose Einstein Condensate — •Cenap Ates and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden

In an ultracold but non-degenerate gas the dynamics of interacting Rydberg atoms is strongly influenced by the properties (density, spatial structure) of the ground state environment. The macroscopic phase coherence present in a quantum degenerate gas like a BEC, allows for the opposite scenario, i.e. an effect of the Rydberg excitations on the dynamics of the ground state system, due to an additional phase imprinted by the Rydberg impurites onto the condensate wavefunction.

We study the excitation dynamics of the Rydberg atoms and the subsequent time evolution of the BEC by setting up a hierarchy of density matrix equations for the coupled BEC-Rydberg system and treating them self-consistently up to the level of pair correlations of the Rydberg atoms.

A 26.21 Do 16:30 Poster C3

The Subharmonics of Electron Emission from Ultracold Plasmas: Collective Plasma Oscillations vs. Individual Excitation of Rydberg Atoms — •Yurii V. Dumin and Jan M. Rost — MPI for the Physics of Complex Systems, Dresden

One of the most interesting phenomena revealed recently in the study of ultracold plasma clusters is a series of distinctive peaks in the electron emission from an ultracold plasma subjected to external radio waves [R.S. Fletcher, et al., PRL 96, 105003 (2006)]. An evident interpretation of this effect is the excitation of resonant plasma oscillations. This explanation, however, encounters difficulties in the quantitative description of the higher harmonics. The alternative point of view, which will be discussed in our report, is a resonant perturbation of highly excited Rydberg atoms in the plasma, resulting in the escape of the respective Rydberg electrons from the system. The main advantage of this mechanism is an easy generation of the higher harmonics and their robustness with respect to the geometry and size of the cluster.