A 9 Poster I: Ultrakalte Atome und BEC

Zeit: Dienstag 16:30–18:30 Raum: Labsaal

A 9.1 Di 16:30 Labsaal

Thermostatics of ultracold Bose gases in 1D periodic potentials
— •Matthias Rosenkranz, Oliver Zobay, and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt, 64289 Darmstadt

We calculate critical properties of an ideal ultracold Bose gas at the condensation point in a one-dimensional optical lattice and transverse harmonic potential. The limiting cases for weak and strong lattice potentials at low and high condensation temperatures are characterized analytically. Intermediate regimes are investigated numerically on the basis of the exact dispersion relations. We also address changes to the ideal case due to the atomic interactions.

A 9.2 Di 16:30 Labsaal

Rydbergatome als Mittel zur Kontrolle der Elektronentemperatur ultrakalter Plasmen?
— •Thomas Pohl[1] und Thomas Pattard[2] — [1]ITAMP, Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA — [2]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, D-01187 Dresden

Ein neues Feld im Bereich der Plasmaphysik ist die Untersuchung ultrakalter, durch Photoionisation lasergekühlter atomarer Gase erzeugter Plasmen. Eines der Ziele dieser Experimente ist die Erzeugung eines “stark gekoppelten” Plasmas, in dem die elektrostatische Wechselwirkungsenergie über die thermische kinetische Energie der Teilchen dominiert. Intrinsische Heizeffekte führen dazu, dass dieses Regime trotz der extrem niedrigen Anfangstemperaturen zunächst nicht erreicht wird.

Wir diskutieren hier einen Vorschlag [1], die Temperatur der Plasmaelektronen durch Einbringen zusätzlicher Rydbergatome in das Plasma zu kontrollieren. Die Idee besteht hierbei darin, dass die Rydbergatome durch Stöße mit den Plasmaelektronen ionisiert werden und diese dabei kühlen. Ein gewisser Grad an Kontrolle über die Elektronentemperatur kann so bei geeigneter Wahl der Parameter (Hauptquantenzahl, Dichte etc.) in der Tat erreicht werden. Das Ausmaß der erzielbaren Kühlung ist jedoch begrenzt, und es erscheint fraglich, ob das Regime starker Kopplung auf diese Weise erreicht werden kann [2].

[1] N. Vanhaecke, D. Comparat, D.A. Tate, P. Pillet, Phys. Rev. A **71**, 013416 (2005)
[2] T. Pohl, D. Comparat, N. Zahzam, T. Vogt, P. Pillet, T. Pattard, in Vorbereitung für Eur. Phys. J. D

A 9.3 Di 16:30 Labsaal

Manipulating and trapping Rydberg atoms in magnetic quadrupole fields
— •Igor Lesanovsky[1] and Peter Schmelcher[1,2] — [1]Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg, Germany — [2]Theoretische Chemie, Universität Heidelberg, INF 229, 69120 Heidelberg, Germany

We discuss the dynamics of Rydberg atoms being exposed to a magnetic quadrupole field. In contrast to ground state atoms, excited (Rydberg) atoms cannot be considered to be neutral point-like particles which couple only through their magnetic moment to the external field. Instead one has to account for the coupling of the charge and of the magnetic moments of the atomic constituents to the external field [1]. We present a Hamiltonian describing the coupled electronic and center of mass dynamics of alkali atoms in an arbitrarily shaped linear magnetic field configuration. For atoms in Rydberg configuration the underlying Schrödinger equation is solved by employing an adiabatic approach. After having obtained the adiabatic energy surfaces we provide an analysis of the adiabatic center of mass quantum states. We discuss under which circumstances trapped center of mass states are achievable and analyze their lifetimes with respect to radiative decay.

[1] Igor Lesanovsky, Jörg Schmiedmayer, and Peter Schmelcher, J.Phys. B 38 S151 (2005)
[2] Igor Lesanovsky and Peter Schmelcher, Phys. Rev. Lett. 95, 053001 (2005)
[3] Igor Lesanovsky and Peter Schmelcher, Phys. Rev. A 72, 053410 (2005)

A 9.4 Di 16:30 Labsaal

Decay dynamics of a small number of 1D bosons in open potentials
— •Sungyun Kim[1,2], Artem Dudarev[1,2,3], Qian Niu[2], Mark Raizen[2,3], and Joachim Brand[1] — [1]MPI-PKS, Nöthnitzer Str. 38, Dresden 01187 , Germany — [2]Department of Physics, The University of Texas, Austin, TX 78712-1081, USA — [3]CNLD, The University of Texas, Austin, TX 78712-1081, USA

We consider the decay dynamics of bosonic atoms with delta-function interaction in one dimensional potential. We examine two model situations: (i) decay of metastable several-particle states and (ii) dynamics in a well of finite depth with parameters changing in time. We treat the problems perturbatively and fully numerically. In particular we focus on the time dependence of the mean atom number in the traps.

A 9.5 Di 16:30 Labsaal

Dipolblockade in ultrakalten Rydberggasen
— •Cenap Ates[1], Thomas Pohl[2], Thomas Pattard[1] und Jan-Michael Rost[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden — [2]ITAMP, Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, MS14, Cambridge, MA 02138, USA

Mithilfe magneto-optischer Fallen ist es heutzutage möglich atomare Gase in den μ-Kelvin Bereich zu kühlen. Bei diesen Temperaturen spielen binäre Stöße keine dominante Rolle mehr, und es ist möglich quasistatische Wechselwirkungen zwischen den Atomen zu untersuchen. Solche Wechselwirkungen sind insbesondere bei Rydbergatomen aufgrund ihrer riesigen Polarisierbarkeiten besonders stark. Sie können beispielsweise zu einer Anregungsblockade um ein Rydbergatom führen.

Die quantenmechanische Beschreibung dieses wechselwirkenden Vielteilchensystems erweist sich aufgrund der sehr großen Dimension des zugrundeliegenden Hilbertraumes als extrem zeitaufwendig. Basierend auf einer Näherung für die Dynamik eines einzelnen Atoms haben wir eine Methode entwickelt dieses System mit einer klassischen Monte-Carlo Simulation zu behandeln. Sie ist in besonderer Weise dazu geeignet Informationen über die Anregungsstatistik in ultrakalten Rydberggasen zu erhalten. Wir diskutieren den Anwendungsbereich unserer Methode und vergleichen unsere Resultate mit experimentellen Ergebnissen [1,2].

[1] K. Singer *et al.*, PRL **93**, 163001 (2004)
[2] T. Cubel *et al.*, angenommen bei PRL

A 9.6 Di 16:30 Labsaal

Addressing BEC with sculptured wires
— •Leonardo Della Pietra — University Heidelberg, 69120 Heidelberg, Philosophenweg 12

Lithographically patterned wires and electrodes are a common tool for creating and manipulating BEC; current technology limits are on one side the wire quality (definition, crystal structure), affecting the otherwise uniform current flow and giving rise to disorder potentials, and on the other side the resolution, particularly important when considering structures as high as a few μm. These limits can be overcome by sculpturing the wires with focused ion beam (FIB) milling. We present experimental results of a trap made from a step in a wire edge, and measurements with a BEC on a wire polished to reduce fragmentation. The high precision (<20nm) and high aspect ratio (height/width>30) attainable with a FIB enable the creation of specialized current flow patterns and therefore micro-designed magnetic trapping potentials. We give designs for a double barrier, a double well and a lattice, and show how similar structures can be realized engineering electric potentials.

A 9.7 Di 16:30 Labsaal

Fluorescence Atom Camera
— •J. Rottmann, B. Hessmo, and J. Schmiedmayer — Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, D-69120 Heidelberg

Ultra cold atoms can be detected with spatial resolution in time of flight by fluorescence imaging using a light sheet, high numerical aperture light collection and a high sensitivity CCD camera [1]. In this poster we present a detailed analysis of the advantages and limitations of such a *Fluorescence Atom Camera* compared to regular absorption imaging. First steps towards an experimental implementation in the atom chip environment to detect small ensembles of atoms will be discussed. Supported by DFG and the EU AtomChip MC-network.

[1] F. Payr, Diplomarbeit Universität Innsbruck (1999)

A 9.8 Di 16:30 Labsaal

Bose-Einstein Condensation in a far detuned dipole trap — •Riad Bourouis, Ajay Tripathi, Christoph Kaefer, Morten Franz, and Hanspeter Helm — Physikalisches Institut Albert-Ludwigs Universitaet Freiburg

We employ a double-MOT system where atoms are first collected and precooled in 3D-geometry in a high pressure region. From this source region the atoms are efficiently transferred into a conventional MOT inside a UHV chamber with capture rates exceeding 10^8 atoms/s. After a loading time of 1s and a molasses phase of 60 ms about 1% of the atoms are trapped in a tight CO_2 Laser focus (ν_r=2400 Hz, ν_z=150 Hz). Evaporative Cooling is optimized by lowering the dipole trap depth over a 7s period, leading to condensates of typically 30000 atoms at densities exceeding 2 10^{13} atoms/cm^3. We present a detailed characterization of the system and its diagnostic tools.

A 9.9 Di 16:30 Labsaal

Transition from a BEC to a Tonks-Girardeau Gas: An Exact Diagonalization Study — •Frank Deuretzbacher[1], Kai Bongs[2], Klaus Sengstock[2], and Daniela Pfannkuche[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstr. 9, 20355 Hamburg, Germany — [2]Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We study ground state properties of a quasi 1D system consisting of spinless bosons which are confined in a harmonic trap and interact via a repulsive delta potential. Using the exact diagonalization method we analyze various quantities in the weak, intermediate and strong coupling regime. In particular the kinetic and interaction energy show a rich, unexpected behavior which cannot be explained within a mean-field approximation. Correlation effects - induced by the repulsive, short ranged force - start to dominate the system at rather low coupling strengths. It is known that the bosons behave very similar to non-interacting fermions in the strong coupling regime. We show the evolution from a BEC-like density to a density of non-interacting fermions. However, other quantities like the momentum distribution or the mean occupation of the oscillator eigenfunctions do not show fermionic behavior.

A 9.10 Di 16:30 Labsaal

A lithium-MOT target in a reaction microscope — •Jochen Steinmann, Ganjun Zhu, Alexander Dorn, and Joachim Ullrich — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The dynamics of few-particle quantum systems can be studied in detail by experiments on impact ionization of atoms, where the momenta of all fragments are determined simultaneously. For the first time we perform kinematically complete studies of double and triple ionization of lithium by electron impact or intense laser fields. Kinematically complete data of simple atomic systems with structureless final states, for example the extensively studied single- and double-ionization of H and He respectively, are essential for the understanding of such processes and in particular for precise testing of theoretical models. For generation of an ultracold target the widely used supersonic beam technique can hardly be applied in the case of lithium, but a magneto-optical trap (MOT) of lithium atoms with temperatures well below 1 mK is an almost ideal target for high resolution momentum spectroscopy.

This is at present the only experiment combining a reaction microscope (recoil-ion and electron spectrometer) with a MOT. However, the incompatibility of the magnetic fields of the atomic trap and the electron spectrometer and the goal of high event-rates imposes stringent conditions on design and operation of the apparatus.

We present first results on the performance of the setup.

A 9.11 Di 16:30 Labsaal

A toolbox for the theoretical description of ultracold atomic collisions — •Yulian Vanne and Alejandro Saenz — AG Moderne Optik, Institut für Physik, Humboldt-Universität zu Berlin, Hausvogteiplatz 5-7, 10117 Berlin

The theoretical description of collisions between ultracold atoms is very challenging. It starts with the requirement for a very accurate description of the interatomic potential curve which usually needs a combined theoretical and experimental input and continues with the solution of the Schrödinger equation describing scattering processes that occur on these potential curves. In the case of alkali atoms, the number of vibrational states supported by a single potential curve can easily exceed 100, and this leads to a numerically difficult description of scattering processes, especially if short-range interactions are important like in tight traps. Since a number of fascinating experiments in the field of ultracold physics of dilute atomic gases is based on magnetic-field induced Feshbach resonances, their description is also vital. We report on a recently developed program package that allows for very accurate calculations of the potential curves between (effective) one-electron atoms (of the same or different species), the solution of the nuclear-motion problem in these potential curves in the single channel case, and the treatment of the multi-channel case needed for the evaluation of magnetic Feshbach resonances. Examples of the performance of the package are given.

A 9.12 Di 16:30 Labsaal

Bose-Einstein condensate in a double-well potential at finite temperature — •Börge Hemmerling, Rudolf Gati, Timo Ottenstein, Jerome Esteve, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, D-69120 Heidelberg

Here we present the experimental implementation of a single bosonic Josephson junction and discuss our latest results on the influence of thermal effects. The bosonic Josephson junction is realized by splitting a Bose-Einstein condensate with a double-well potential into two localized modes and couple them via tunnelling through the barrier. The potential is generated by the superposition of a dipole trap and a standing light wave and thus allows for a high degree of control over the experimental parameters. Especially the height of the barrier leading to different tunnelling couplings can be accessed directly. Additionally, the temperature of the trapped atoms can be varied over a wide range by holding the sample for different times in the trap. With this bosonic Josephson junction we investigate random fluctuations of the relative phase between the localized modes as a function of the coupling strength and the temperature of the thermal background. The quantitative agreement of our results with a classical model allows for the application of the measurements for thermometry. With this new tool it becomes possible to observe the heating up of a Bose-Einstein condensate in a regime where the standard time-of-flight method fails. These experiments reveal that the heat capacity of the degenerate Bose gas is in agreement with the theoretical prediction confirming the third law of thermodynamics.

A 9.13 Di 16:30 Labsaal

Towards heteronuclear Fermi-Fermi mixtures using a new resonator optical dipole trap — •Andreas Trenkwalder — Institut für Quantenoptik und Quanteninformation, ICT-Gebäude, Technikerstraße 21a, 6020 Innsbruck, Austria

We are setting up an experiment to study ultracold heteronuclear gas mixtures of lithium, potassium and strontium. We will focus on Fermions to study e.g. the BEC-BCS transition. In addition the setup allows mixtures including Bosons, which might for example lead to the condensation of strontium. Future plans include exploration of optical Feshbach resonances in alkaline/alkaline-earth mixtures.

The atoms will be collected in a two species MOT and transferred to an optical dipole trap where they are cooled to BEC. We intend to use Feshbach resonances to enhance the elastic collision rate during evaporative cooling. A new resonator optical dipole trap design enlarges the trapping volume and depth which should result in increased capture of atoms from the MOT. We present a study of the influence of the glass-cell on the performance of the resonator.

A 9.14 Di 16:30 Labsaal

Ultracold Rydberg Atoms in a Structured or Unstructured Environment — •Ivan C. H. Liu and Jan M. Rost — Max-Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, D-01187, Dresden, Germany

We are interested in the traces the Rydberg atoms leave in an ultracold atomic gas. We distinguish the usual disordered gas (unstructured environment) and the ordered case, where Rydberg and ground-state atoms populate an optical lattice (structured environment). In the former case, we determine the optical spectrum and, in the latter, the adiabatic energy levels as a function of the lattice constant [1]. Further more, we will discuss the realizability of the predicted “trilobite” molecules [2], and the signature of such type of interaction in a pressure broadening experiment.

[1] I. C. H. Liu and J. M. Rost, arxiv.org/physics/0512059, (2005).
[2] C. H. Greene et al PRL 85, 2458 (2000).

A 9.15 Di 16:30 Labsaal

Networking surface-electrode ion traps for large-scale QIP* —
•R. Reichle[1], S. Seidelin[1], J. Chiaverini[2], R.B. Blakestad[1], J.J. Bollinger[1], J. Britton[1], R. Epstein[1], D. Hume[1], W.M. Itano[1], J.D. Jost[1], E. Knill[1], C. Langer[1], D. Leibfried[1], R. Ozeri[1], J. Wesenberg[1], and D.J. Wineland[1] — [1]NIST, Time and Frequency Division, Boulder, CO 80305 — [2]Los Alamos National Laboratory, NM 87545

We discuss how surface-electrode ion traps, i.e., planar miniaturized Paul traps where all electrodes reside in a single plane and ions reside above the plane, have many advantages over their multilayer variants for large scale trapped-ion quantum computing. In addition to their relatively simple manufacturing by standard microfabrication techniques, we consider some issues that make them preferable for their use in large scale structures. In the proposed multiplexing versions for large scale ion trap architectures, nodal points are required. These nodes serve as junctions for the ion qubits, to reliably and arbitrarily transfer quantum information from one location to another in the two planar dimensions. We propose optimized geometric layouts for these nodal points that allow for simple concatenation to a multiplexed architecture. High-fidelity simulations show that the proposed layouts are capable of reliably shuttling ion qubits between these elementary units. More explicitly, we identify problems that might arise in the realization of the nodal points and show how they can be eliminated. We provide accurate analytical models for surface-electrode ion traps for characterizing their global behavior, discuss design issues to avoid sites of anti-binding, introduce electrode shapes to smooth the transport characteristics near nodal points, and present ideas to compensate for micromotion in surface-electrode traps. Comparisons between simulations and preliminary experimental data are consistent to within a few percent.
*Supported by DTO and NIST.