A 19: Ultracold atoms III: Manipulation and detection / Rydbergatoms (with Q)

Zeit: Mittwoch 16:30–18:45 Raum: Audi-B

A 19.1 Mi 16:30 Audi-B

Effects of Non-Abelian Gauge Potentials — •Andreas Jacob[1], Luis Santos[1], Michael Merkl[2], Frank Zimmer[2], and Patrik Öhberg[2] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover — [2]SUPA, School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh, United Kingdom

Artificial electromagnetism may be created for neutral atoms, e.g. by rotating the gas. Other forms of inducing artificial electromagnetism are possible, including ways of generating non-Abelian vector potentials. In this talk, we will first discuss simple laser setups that allow the creation of non-Abelian gauge potentials for atoms with a tripod level scheme. We will comment on specific experimental implementations in e.g. ^{4}He* and ^{87}Rb. In particular we will discuss a simple laser arrangement that generates a non-Abelian vector potential proportional to the Pauli matrices. This gauge potential induces a quasi-relativistic physics for cold gases similar to that in graphene, including the possibility of observation of metamaterial phenomena as Veselago lensing. We shall discuss in particular the effects of this gauge potential in the linear and nonlinear atom optics of condensates, including the possibility of creating regions of negative mass in the dispersion relation which allow for bright solitons in the presence of repulsive interactions.

A 19.2 Mi 16:45 Audi-B

State-selective microwave near-field potentials on atom chips — •Pascal Böhi[1,2], Max F. Riedel[1,2], Theodor W. Hänsch[1,2], and Philipp Treutlein[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München

The spectacular experiments with ultracold neutral atoms are intimately connected with the availability of sophisticated techniques for coherent control of internal and motional degrees of freedom of the atoms. For quantum information processing and quantum simulations, for example, tailored potentials are required which control atomic dynamics, but at the same time, control of internal degrees of freedom is needed. Potentials which are in principle arbitrarily configurable can be realized in static magnetic near-field traps on microfabricated 'atom chips'. However, state-selectivity is limited in these potentials.

In this talk we show how we use on-chip microwave near-fields to generate versatile state-selective potentials varying on a μm scale and use these potentials for the state-selective coherent manipulation of Bose-Einstein condensates. We entangle atomic spin and motional state in a controlled and reversible way, as required for a quantum phase gate previously proposed [1]. Our system also constitutes a trapped-atom interferometer with internal-state labeling and is furthermore useful for experiments on squeezing and many-particle entanglement in Bose-Einstein condensates [2].

[1] P. Treutlein et al., Phys. Rev. A 74, 022312 (2006)
[2] Y. Li et al., arXiv:0807.1580 (2008)

A 19.3 Mi 17:00 Audi-B

Light Sheet Fluorescence Imaging of Cold Atoms — •Robert Bücker[1], Aurélien Perrin[1], Stephanie Manz[1], Thomas Betz[1], Christian Koller[1], Wolfgang Rohringer[1], Martin Göbel[1], Jörg Rottmann[2], Thorsten Schumm[1], and Jörg Schmiedmayer[1] — [1]Atominstitut der Österreichischen Universitäten, TU Wien, Stadionallee 2, A-1020 Vienna, Austria — [2]Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, D-69120 Heidelberg, Germany

Fluorescence imaging with illumination by a light sheet is commonly used in optical microscopy of biological specimen. We transfer this approach to detection of ultracold Bosonic gases in an atom chip experiment. During time of flight, the expanding cloud pierces a thin horizontal sheet of near-resonant light. Scattered photons are collected by an imaging objective and detected by an electron-multiplying CCD. This scheme allows for extremely low background and high sensitivity unattainable with conventional methods. By autocorrelation analysis we confirm the efficient detection of single atoms within dilute clouds at a spatial resolution on the order of 10 μm, limited by stochastic motion of the atoms during interaction time. Time-of-flight imaging on a single-atom level paves the way for studying second-order correlations in the various regimes of low-dimensional degenerate Bose gases feasible in our experiment.

A 19.4 Mi 17:15 Audi-B

Quantum resolution limits for imaging Bose gases — •Antonio Negretti[1,2], Carsten Henkel[3], and Klaus Molmer[2] — [1]Institut für Quanteninformationsverarbeitung, Universität Ulm, Albert-Einstein-Allee 11, D-89081 Ulm, Germany — [2]Lundbeck Foundation Theoretical Center for Quantum System Research Department of Physics and Astronomy, University of Aarhus, DK-8000 Aarhus C, Denmark — [3]Universität Potsdam, Institut für Physik und Astronomie, Karl-Liebknecht-Str. 24/25, D-14476 Potsdam, Germany

We present an analysis of the resolution limits for observables contained in the density profiles for an ultracold Bose gas of atoms. Within the Bogoliubov approximation we compute the density-density correlations by including both quantum and thermal fluctuations. These correlations provide a tool to construct the (approximate) joint counting statistics of atoms in an array of pixels covering the gas. As an example of the general theory, we derive the position uncertainty of a dark soliton in a quasi one dimensional Bose gas. The smallest uncertainty scales with the atomic background density, n, as $n^{-3/4}$, beating the classical shot noise limit. Intriguingly, the sensitivity is slightly improved when quantum fluctuations are included.

A 19.5 Mi 17:30 Audi-B

Image formation in scanning electron microscopy of ultracold quantum gases — •Peter Würtz, Tatjana Gericke, Andreas Koglbauer, and Herwig Ott — Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz

We review the image formation and reconstruction of our recently developed scanning electron microscope for ultracold atoms. In our experimental setup, a focussed electron beam with a FWHM of 100 nm ionizes atoms, which are subsequentl y accelerated towards an ion detector. Obtaining images from the time resolved signal of ion detection events involves several post-processing methods to account for effects disturbing the imaging process. For applications with optical la ttices, drifts and fluctuations of the lattice potential have to be determined and compensated for. We discuss differen t imaging modes and interaction mechanisnms and show that the microscope is a very versatile tool for the detection and manipulation of ultracold atoms.

A 19.6 Mi 17:45 Audi-B

Coherent excitation of ultra-long-range Rydberg molecules — •Björn Butscher[1], Vera Bendkowsky[1], Johannes Nipper[1], Jonathan Balewski[1], James Shaffer[1,2], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Deutschland — [2]Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, USA

At ultralow temperatures - in so-called frozen Rydberg gases - the scattering of the Rydberg electron and a nearby polarizable ground state atom can generate an attractive potential due to the negative scattering length which is able to bind the ground state atom to the Rydberg atom at a well localized position within the Rydberg electron wave function. The resulting giant molecules can have an internuclear separation of several thousand Bohr radii, which places them among the largest known molecules to date.

Here we present spectroscopic data on the observation of vibrational ground and first excited state of Rubidium dimers Rb(5S)-Rb(nS). We apply a Born-Oppenheimer model to explain the measured binding energies for principal quantum numbers n between 34 and 40 and extract the s-wave scattering length for electron-Rb(5S) scattering in the relevant low energy regime $E_{\mathrm{kin}} < 100\,\mathrm{meV}$. We also determine the lifetimes and the polarizabilities of these molecules [arXiv:0809.2961].

Additionally, we report on the observation of trimer states, where two ground state atoms are bound by a Rydberg atom.

A 19.7 Mi 18:00 Audi-B

Controlling the pair distribution in an ultracold Rydberg gas — •Christoph S. Hofmann, Thomas Amthor, Christian Giese, Hanna Schempp, Brett DePaola, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg

We show that the pair distribution in an ultracold Rydberg gas can be influenced by means of red or blue detuned Rydberg excitations. To demonstrate this the ionization of the Rydberg gas is used as a sensitive probe [1,2]: For attractive interaction potentials, atoms excited to Rydberg states on the red-detuned wing of the resonance are observed to ionize first, since more atom pairs are prepared at small interatomic distances and hence experience strong attractive forces. This excitation scheme is extended by using Autler-Townes-splittings of up to 150 MHz in order to exploit a wider frequency range for the pair distribution control. This allows to address pairs with a 1.6 times smaller pair distance, yielding an increase of the interaction strength by more than one order of magnitude. A Monte Carlo model for the description of such a system is presented and agrees well with experimental observations. The Autler-Townes-splitting moreover allows for rapid frequency chirps across a resonance without actually tuning any of the excitation laser frequencies.

[1] T. Amthor et al., Phys. Rev. Lett. 98, 023004 (2007)
[2] T. Amthor et al., Phys. Rev. A 76, 054702 (2007)

A 19.8 Mi 18:15 Audi-B

Autler-Townes Splitting in an inverted three-level system using Rydberg gases — •Hanna Schempp, Christian Giese, Sebastian Saliba, Thomas Amthor, Christoph S. Hofmann, Brett DePaola, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg

We investigate coherent excitation phenomena in ultracold Rydberg gases. In a three level Rydberg system Autler-Townes (AT) splitting can be seen by coupling the lower transition and probing the excitation to a Rydberg state [1,2]. The long lifetimes of Rydberg atoms permit us to investigate AT splitting in an inverted Rydberg system, i.e. starting with all atoms in the Rydberg state and stimulating them down to the intermediate state which is split by a strong laser field coupling the intermediate and the ground state. We show the first experimental results and discuss the features of our system.

[1] B. K. Teo et al., Phys. Rev. A 68, 053407 (2003)
[2] J. Deiglmayr et al., Opt. Comm. 264, 293 (2006)

A 19.9 Mi 18:30 Audi-B

Exciton transport in ordered and disordered samples of cold Rydberg atoms — Torsten Scholak, •Thomas Wellens, and Andreas Buchleitner — Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

We study coherent dipolar energy transfer between resonant levels of Rydberg atoms. We determine the transport properties by examining the spectral structure and the associated eigenfunctions. To highlight the impact of disorder on the Rydberg exciton transport, we introduce a disorder parameter allowing us to switch continuously from an ordered to a completely disordered sample of atoms. Special attention is dedicated to the transition from diffusive to non-diffusive transport, as well as to the metamorphosis of the nearest-neighbor level spacing distribution from Wigner to Poisson.