A 40: Poster: Ultra-cold plasmas and Rydberg systems (with Q)

Time: Thursday 16:00–18:30 Location: Empore Lichthof

A 40.1 Thu 16:00 Empore Lichthof

An optically resolvable Schrödinger's cat from Rydberg dressed cold atom clouds — Sebastian Möbius, Michael Genkin, Alexander Eisfeld, •Sebastian Wuester, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Noethnitzer Str. 38, D-01187 Dresden, Germany

In Rydberg dressed ultra-cold gases, ground state atoms inherit properties of a weakly admixed Rydberg state, such as sensitivity to long-range interactions. We show that through hyperfine-state dependent interactions, a pair of atom clouds can evolve into a spin and subsequently into a spatial Schroedinger's cat state: The pair, containing 40 atoms in total, is in a coherent superposition of two configurations, with cloud locations separated by micrometers. The mesoscopic nature of the superposition state can be proven with absorption imaging, while the coherence can be revealed though recombination and interference of the split wave packets.

A 40.2 Thu 16:00 Empore Lichthof

Spin Squeezing in ultracold Strontium lattices — •Laura I.R. Gil[1], Rick Mukherjee[1], Liz Bridge[2], Matthew P.A. Jones[2], and Thomas Pohl[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [2]Department of Physics, Durham University, United Kingdom

Squeezed many-body states of atoms are a valuable resource for high precision frequency metrology and could tremendously boost the performance of atomic lattice clocks. Here, we study the dynamics of Strontium atoms confined in an optical lattice, where strong interactions are induced by exciting one valence electron to a high-lying Rydberg state. Making use of the extra valence electron, we demonstrate how to control the motional dynamics of the atoms and analyze the performance of the proposed setting. Finally, we present a simple protocol to prepare spin squeezed states in such a Strontium-Rydberg clock, and discuss the achievable amount of squeezing for different geometries and experimentally relevant parameters.

A 40.3 Thu 16:00 Empore Lichthof

Equilibration heating of Rydberg atoms — •Yaroslav Lutsyshyn and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

We investigate the equilibration heating in clouds of Rydberg atoms which are interacting with a van der Waals potential. The released energy depends only on the initial and final states, allowing a simple analysis in terms of the excitation parameters and the effective interaction constant. The control of heating is useful both if one wants to increase the motion of the Rydberg atoms, for example to enhance collisional ionization, or, to the opposite, in attempts to achieve an ordered state with an equilibrated or partially equilibrated cloud. Knowing the amount of heating maps the excitation conditions directly to the equilibrium phase diagram of the vdW gas, which we reported previously [1].

[1] O. N. Osychenko, G. E. Astrakharchik, Y. Lutsyshyn, Yu. E. Lozovik, J. Boronat, Phys. Rev. A **84**, 063621, (2011).

A 40.4 Thu 16:00 Empore Lichthof

Line shifts of Rydberg atoms near surfaces due to adsorbate fields — •Florian Karlewski, Markus Mack, Jens Grimmel, Helge Hattermann, Simone Höckh, Florian Jessen, Daniel Cano, and József Fortágh — Physikalisches Institut der Universität Tübingen

Interfacing Rydberg atoms to solid state devices like atom chips is a promising concept for novel quantum systems. However, before attempting to understand and exploit the interactions between solid state quantum circuits and Rydberg atoms, one first needs to investigate the interactions between these atoms and the solid state surface.

The main effect on the Rydberg atoms is a line shift due to the electric field of atoms adsorbed to the surface. We show the accumulation of these adsorbates over time in a cold atom experiment, using electromagnetically induced transparency to detect the line shifts with high accuracy.

In future projects, we plan to study how adsorbates can be reduced, manipulated or avoided.

A 40.5 Thu 16:00 Empore Lichthof

Creation of GHZ-states in optical lattices of alkaline-earth atoms — •Rick Mukherjee, Arnab Das, Frank Pollmann, and Thomas Pohl — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

We present a scheme for the production of many-body GHZ states in an optical lattice of Strontium atoms via optical excitation to strongly interacting atomic states. We identify magic wavelengths that permit strong lattice confinement for both internal states, and yield an effective Ising spin model with controllable external fields. For the considered case, the interactions are attractive such that this system features a quantum phase transition between para- and ferromagnetic phases. We identify suitable field ramps across the transition that permit the controlled creation of GHZ-states for large system sizes and with high fidelity.

A 40.6 Thu 16:00 Empore Lichthof

Microwave Electrometry with Rydberg Atoms in a Vapor Cell using Bright Atomic Resonances — Jonathon A. Sedlacek[2], Harald Kübler[1,2], Renate Daschner[1], Arne Schwettmann[2], •Anita Gaj[1], Robert Löw[1], Tilman Pfau[1], and James P. Shaffer[2] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57 D-70550 Stuttgart, Germany — [2]Homer L. Dodge Department of Physics and Astronomy, The University of Oklahoma, 440 W. Brooks St. Norman, Oklahoma 73019, USA

Quantum based standards of length and time as well as measurements of other useful physical quantities, ex. magnetic fields, are important because quantum systems, like atoms, show clear advantages for providing stable and uniform measurements. We demonstrate a new method for measuring cw microwave electric fields based on quantum interference in a Rubidium atom. Using a bright resonance prepared within an electromagnetically induced transparency window we are able to achieve a sensitivity of $\sim 30\mu\mathrm{Vcm}^{-1}\mathrm{Hz}^{-1/2}$ in a thermal vapor cell[1]. In addition, our approach can be used to detect an arbitrary microwave electric field polarizations and offers a sub-wavelength spatial resolution. The method can serve as a new atom based traceable standard for vector microwave electrometry. The reproducibility, accuracy and stability of using an atom for measuring microwave electric fields promises to advance traceable microwave electrometry to the current levels of magnetometry.

[1] J. A. Sedlacek et al., Nature Physics **8**, 819-824 (2012)

A 40.7 Thu 16:00 Empore Lichthof

Static and dynamical properties of two-dimensional Rydberg lattices — •Sebnem Güneş Söyler[1], Tommaso Macri[1], Thomas Pohl[1], Peter Schauss[2], Marc Cheneau[2], Manuel Endres[2], Takeshi Fukuhara[2], Sebastian Hild[2], Ahmed Omran[2], Christian Gross[2], Stefan Kuhr[2,3], and Immanuel Bloch[2,4] — [1]Max Planck Institut für Physik Komplexer Systeme, Dresden, Germany — [2]Max Planck Institut für Quantenoptik, Garching, Germany — [3]University of Strathclyde, Glasgow, UK — [4]Ludwig Maximilians Universität, München, Germany

Recent experimental efforts to manipulate long range interactions in cold atomic setups offer a unique way to study strongly correlated quantum systems. Among them Rydberg atoms are particularly interesting due to their extremely large dipole moments that result in enormous interactions acting over micrometer distances. We investigate the ground state phase diagram of Rydberg-excited atoms in a two-dimensional optical lattice by large-scale quantum Monte Carlo simulations. In addition, we explore suitable schemes for the dynamical preparation of the resulting quantum phases in the presence of imperfections and de-coherence under realistic experimental conditions.

A 40.8 Thu 16:00 Empore Lichthof

Rydberg Dressing in the Super Atom Picture — •Alexander Krupp, Jonathan Balewski, Anita Gaj, Sebastian Hofferberth, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Germany

Highly excited Rydberg atoms show strong interaction over a mesoscopic range, which can be controlled using external electric and magnetic fields [1]. Such an interaction can block the excitation in the range of the blockade radius around the Rydberg atom. In case of coherently driven samples one can think about one excitation shared by all the atoms within a sphere. These N atoms then effectively behave like one atom driven with a $\sqrt{N}$ enhanced collective Rabi frequency, therefore forming a so called superatom. By exciting a sample of atoms at large detunings from the Rydberg state one can generate a coherent collective state with long lifetime [2], which would allow to observe mechanical effects of the Rydberg-Rydberg interaction potential on the whole sample. By tuning the excitation laser parameters and external fields one can therefore tailor the atomic interaction potential. This ability permits one to achieve interesting and novel many-body phases ranging from superfluid to supersolid crystals. We show that the interaction potential of weakly Rydberg dressed atoms can be understood within the super atom picture. This description allows us to calculate the effect on a BEC under realistic experimental conditions.

[1] J. Nipper et al., *Phys. Rev. X* ***2***, 031011 (2012)
[2] J. Honer et al., *Phys. Rev. Lett.* ***105***, 160404 (2010)

A 40.9 Thu 16:00 Empore Lichthof

Measurement of ion - ion collisions in strongly coupled plasmas — •Georg Bannasch[1], Thomas Pohl[1], Jose Castro[2], Patrick McQuillen[2], and Thomas Killian[2] — [1]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden — [2]Physics & Astronomy Department, Rice University, Houston, USA

Relaxation processes in weakly coupled plasmas are well described within the framework of the famous Spitzer theory [1]. As the theory relies on a Debye screening length λ_D that is much larger than the mean interparticle distance a, the resulting relaxation rates diverge in the strongly coupled domain, where the two length scales can become comparable. Here, we present a joint experimental theoretical study of ion - ion collisions in an ultracold plasma, created at the onset of strong plasma coupling, beyond the validity of the Spitzer theory. Velocity-selective optical pumping combined with fluorescence measurements permits to observe the dynamics of velocity relaxation [2]. We find excellent agreement between measured rates and theoretical results obtained from molecular dynamics simulations as well as from generalized kinetic theory. The presented framework permits direct access to the velocity dependence of the relaxation rate.

[1] Jr. L. Spitzer. Physics of Fully Ionized Gases. Wiley, New York, 1962

[2] G. Bannasch, J. Castro, P. McQuillen, T. Pohl, and T. C. Killian, Phys. Rev. Lett. 109, 185008 (2012)

A 40.10 Thu 16:00 Empore Lichthof

Second-generation apparatus for Ryberg-atoms in an ultracold gas — •Huan Nguyen, Michael Schlagmüller, Thomas Schmid, Robert Löw, Sebastian Hofferberth, and Tilman Pfau — 5. Phys. Institut, Universität Stuttgart

The giant size and large polarizibility of Rydberg-atoms, resulting in strong long-range Rydberg-Rydberg interactions, make them ideal for studying many-body cooperative effects. In particular, the investigation of dense, ultracold Rydberg-gases in a magnetic trap has opened the door to novel effects such as Rydberg-molecules.

Here, we present a new experimental apparatus for the creation and dynamic study of Rydberg-atoms in dense, ultra-cold atomic ensembles. Specific design goals of this new setup are single ion-detection capability, sub-micron optical resolution, and high flexibility in creating both magnetic and optical trapping potentials. We discuss how these different aspects are combined in a single, compact experimental realization.