A 41: Poster: Ultra-cold plasmas and Rydberg systems

Time: Thursday 16:30–19:00 Location: Poster.V

A 41.1 Thu 16:30 Poster.V

A Ramsey interferometer to study Förster induced Rydberg interactions — •Jonathan Balewski, Johannes Nipper, Alexander Krupp, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart

Interacting Rydberg systems show promising prospects in different fields ranging from quantum computing to the simulation of quantum systems. An important ingredient hereof is a strong controllable interaction as it is provided by Stark tuned Förster resonances. Such resonances occur in Rydberg systems by the coupling of degenerate dipole transitions between different atomic states. This leads to an energy transfer between the atoms and to a strong interaction with distinct angular dependence. The sign and strength of this interaction can be controlled by changing the pair state energy levels by applying external electric fields.

We use an interferometric technique based on an optical Ramsey sequence to study such resonances in the $44d_{5/2}$ Rydberg state of ultracold ^{87}Rb atoms. With this phase sensitive method we show that we can switch and tune the interatomic interaction. Extending the scheme using different electric pulse sequences we can additionally probe the coherent coupling of the involved pair states. The coherent nature of the Förster induced interaction is crucial for many of its applications.

Furthermore the system presented here could in principle be used to model Förster induced energy transfer processes which play an important role in biophysics.

A 41.2 Thu 16:30 Poster.V

A new setup for experiments with ultracold Rydberg atoms — •Johannes Deiglmayr, Heiner Sassmannshausen, and Frederic Merkt — LPC, ETH Zuerich, Switzerland

The study of dense samples of ultracold atoms in high Rydberg states has yielded many spectacular results in recent years, such as the observation of exotic dimers with bond-lengths exceeding $1\,\mu$m or the realization of quantum gates based on neutral atoms [1].

Here we present a new setup for high resolution spectroscopy of atomic Rydberg states. Laser-cooled cesium atoms are excited from the $6S_{1/2}$ state to Rydberg states by a UV photon from a pulsed laser. A phase-locked narrowband source of continuous millimeter waves (linewidth <10 kHz) is then used to determine Rydberg-Rydberg transition energies with highest accuracy. First measurements characterizing the performance of our setup are shown.

We also envision the combination of this setup with a chip-based Rydberg decelerator recently developed in our group [2]. Prospects for energy-controlled collisions between Rydberg and ground state atoms are discussed and a new scheme for a single-atom on demand source is presented.

[1] Bendkowsky *et al.*, Nature 458 (2009); Isenhower *et al.*, PRL 104 (2010); Wilk *et al.*, ibid [2] SD Hogan *et al.*, accepted for publication in PRL

A 41.3 Thu 16:30 Poster.V

Second-generation apparatus for Ryberg-atoms in an ultracold gas — •Huan Nguyen, Michael Schlagmüller, Stephan Jennewein, Christoph Tresp, 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.

A 41.4 Thu 16:30 Poster.V

Phase diagram of Rydberg atoms with repulsive van der Waals interaction — •Yaroslav Lutsyshyn and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Germany

Atoms excited to orbitals with high principal quantum number, also known as Rydberg atoms, present rich opportunities for studying strongly correlated quantum many-body effects. Interactions between atoms shift their levels, thus preventing neighboring atoms from being excited simultaneously, an effect called Rydberg blockade. Because of the blockade, excited atoms are spatially correlated and often spaced out to distances where the interaction has the van der Waals C_6/r^6 form. To understand possible ordering and phase transitions in such situations, we consider a phase diagram of particles with a repulsive van der Waals interaction. The system is studied with quantum and classical Monte Carlo methods, and the harmonic theory. With a proper selection of units, the entire phase diagram may be expressed in terms of just the reduced number density and temperature. This allows to compare phase conditions for considerably different interaction constants. Most present experiments are deeply in the “classical” regime of such a phase diagram, where the solidification would happen at temperature $T = 0.22\rho^2 C_6$ (C_6 being the interaction constant, and ρ the number density). At zero temperature, the transition occurs at density $\rho = 3.9(\hbar^2/mC_6)^{3/4}$. The preferred solid phase is fcc. The findings are reported in arXiv:1106.2997 (2011).

A 41.5 Thu 16:30 Poster.V

An electron microscope for the detection and manipulation of Rydberg atoms — •Thomas Niederprüm, Tobias Massimo Weber, Torsten Manthey, Philipp Langer, Vera Guarrera, Giovanni Barontini, and Herwig Ott — TU Kaiserslautern, Germany

In order to control the interactions between ultracold atoms the usage of the strong dipole-dipole coupling between highly excited Rydberg states is very promising. Especially the dressing of Rydberg states can give rise to exotic quantum phases and other phenomena predicted by the Bose-Hubbard-Model. In this poster, we will present a new apparatus for the production, the manipulation and the detection of ultracold Rydberg atoms. A scanning electron microscope inside the vacuum chamber will allow for single Rydberg atom detection with a high spatial resolution.

A 41.6 Thu 16:30 Poster.V

Measurement of ion relaxation in strongly coupled plasmas — •Georg Bannasch[1], Thomas Pohl[1], Jose Castro[2], Patrick McQuillen[2], and Thomas C. 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 plasmas are well described within the framework of the Landau-Spitzer theory as long as the plasma is in a weakly coupled state, for which the Debye screening length is larger than the mean interparticle distance. However, these two length scales become comparable as the plasma approaches the strongly coupled regime, leading to a divergence of the Landau-Spitzer rate. Ultracold plasmas, created at the onset of strong correlations, grant experimental access to the parameter regime beyond the validity of the Landau-Spitzer theory.

Here, we present a joint experimental and theoretical study of ion - ion collisions in such an ultracold plasma. Velocity-selective optical pumping combined with fluorescence measurements allows to observe velocity relaxation on relevant timescales. In addition, we present exhaustive molecular dynamics simulations that yield good agreement with the experiment, and, combined with a statistical description in terms of density- and field-fluctuations, allow to characterize the collision rate from the weakly coupled to the strongly coupled regime.

A 41.7 Thu 16:30 Poster.V

Strong plasma correlations via Rydberg dipole blockade — •Georg Bannasch and Thomas Pohl — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden

One major challenge in ultracold plasmas research is the realization of strong coupling conditions. Since ultracold plasmas are typically created by photoionization of spatially uncorrelated ultracold atoms, the subsequent plasma relaxation leads to heating and, thus, limits the strength of achievable correlations.

Here we propose a double-pulse ionization scheme, consisting of an excitation laser pulse and an additional microwave field. Exploiting the dipole blockade between highly excited Rydberg atoms, this "pumpprobe" type sequence produces strongly correlated ions by reducing disorder-induced heating of the system. On the other hand, the resulting plasma coupling strength allows to easily probe the degree of correlation in the Rydberg blocked atomic system. We thoroughly study the involved steps to discuss the feasibility of our approach and show universal scaling behavior of the achievable plasma coupling strength.

A 41.8 Thu 16:30 Poster.V

Investigation of Rydberg atom interactions by observing electromagnetically induced transparency spectra — •Markus Mack, Florian Karlewski, Helge Hattermann, Peter Federsel, Simone Höckh, Florian Jessen, Daniel Cano, and József Fortágh — Physikalisches Institut, Eberhard-Karls-Universität Tübingen

Rydberg atoms stand out due to their high polarizability which makes them highly sensitive to electric fields and increases many-body interactions.

We determined the binding energy of the 87Rb isotope by extrapolating our recent results for excitation energies of optically accessible Rydberg states.

The combination of measurements of the stark shifts of these Rydberg levels close to a metallic surface and calculated Stark maps provides information concerning the dipole field of any atoms which are adsorbed to the surface.

All Rydberg states and their energy shifts were detected by observing electromagnetically induced transparency.

A 41.9 Thu 16:30 Poster.V

Effects of correlated disorder on optical properties of molecular aggregates — •Sebastian Möbius[1], Sebastiaan M. Vlaming[2], Victor A. Malyshev[2], Jasper Knoester[2], and Alexander Eisfeld[1,3] — [1]Max Planck Intitute for physics of complex systems, Dresden, Germany — [2]Centre for Theoretical Physics and Zernike Institute for Advanced Materials, University of Groningen, Netherlands — [3]Department for Chemistry and Chemical Biology, Harvard University, USA

The dynamical and optical properties of excitons in quantum aggregates are strongly influenced by static disorder, due to inhomogeneities in the environment. This disorder leads to variation of the site energies of the individual monomers, which in turn results in localization of the exciton wavefunctions. In most theoretical studies, an uncorrelated Gaussian static disorder of the site energies has been used, which results in a strong exchange narrowing of the optical absorption upon increasing the interaction between the monomers. Recent results have shown that for certain types of non-Gaussian (Levy-stable) distributions the opposite effect, broadening of the spectrum, can occur. For these type of distributions, only uncorrelated disorder has been studied so far. Using an atomistic model, we show how different types of system-environment interaction lead to various Levy-stable distributions. Within the model, correlations between molecular transition energies can be naturally taken into account. Furthermore, we propose a method to numerically generate correlated Levy-stable distributions.

A 41.10 Thu 16:30 Poster.V

Interplay of conical intersections and entanglement transport in two-dimensional flexible Rydberg aggregates — •Karsten Leonhardt, Sebastian Wüster, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, 01187 Dresden, Germany

Dipole-dipole transfer of electronic excitations on aggregates of atoms or molecules is important in many areas of physics, such as photosynthetic light-harvesting [1] or trapped assemblies of Rydberg atoms. The dipole-dipole interactions can also induce motion of the atoms in the chain [2]. In such a flexible aggregate, ring geometries exhibit conical intersections (CIs) [3] while one-dimensional linear geometries possess entanglement transporting modes [4, 5]. Here we combine both features and study two-dimensional, parallel-chain arrangements of Rydberg atoms. We locate CIs and highlight dynamical scenarios where directed transport is affected by the CIs.

[1] R. van Grondelle and V. I. Novoderezhkin, Phys. Chem. Chem. Phys. **8**, 793 (2006).

[2] C. Ates, A. Eisfeld, and J. M. Rost, New J. Phys. **10**, 045030 (2008).

[3] S. Wüster, A. Eisfeld, and J. M. Rost, Phys. Rev. Lett. **106**, 153002 (2011).

[4] S. Wüster, C. Ates, A. Eisfeld, and J. M. Rost, Phys. Rev. Lett. **105**, 053004 (2010).

[5] S. Möbius, S. Wüster, C. Ates, A. Eisfeld, and J. M. Rost, J. Phys. B: At. Mol. Opt. Phys. **44**, 184011 (2011).

A 41.11 Thu 16:30 Poster.V

Molecular-interaction effects on the dipole blockade in cold Rydberg ensembles — •Weibin Li[1], Thomas Pohl[2], and Jan-Michael Rost[2] — [1]School of Physics and Astronomy, The University of Nottingham, Nottingham NG7 2RD, UK — [2]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

In high density ultracold gases, the interaction between ground state and Rydberg atoms can lead to the formation of ultralong-range molecules upon direct off-resonant photoassociation [1,2,3]. Here, we study resonant excitation in dipole blocked mesoscopic ensembles, in which all but a single excitation is inhibited by the strong Rydberg-Rydberg interaction. We show that the molecular interactions can have considerable effects on the resulting collective Rabi oscillations and investigate corresponding limitations for proposed implementations of quantum information schemes.

[1] V. Bendkowsky et al., Nature 458, 1005 (2009)

[2] V. Bendkowsky et al., Phys. Rev. Lett. 105, 163201 (2010)

[3] W. Li et al., Science 334, 1110 (2011)