A 25: Ultracold Plasmas and Rydberg Systems (with Q)

Time: Wednesday 14:30–16:45 Location: P 104

Group Report A 25.1 Wed 14:30 P 104

Non-equilibrium dynamics of dipolar interacting Rydberg spins — •Adrien Signoles[1], Miguel Ferreira-Cao[1], Asier Pineiro Orioli[2], Renato Ferracini Alves[1], Vladislav Gavryusev[1], Gerhard Zürn[1], Jürgen Berges[2], Shannon Whitlock[1], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Heidelberg, Germany — [2]Institut für Theoretische Physik, Universität Heidelberg, Germany

Rydberg atoms in ultracold gases constitute controllable systems to experimentally study non-equilibrium phenomena, like thermalization of isolated quantum systems or relaxation after quenches. Of specific interest is the possibility to introduce resonant dipolar exchange interactions, providing new opportunities for investigating the dynamics of strongly correlated many-body quantum systems with beyond nearest-neighbour coupling.

We present an experimental realization of a prototypical dipolar spin model by coupling two strongly interacting Rydberg states by a microwave field. At low Rydberg density where interactions are negligible, we show that our system can be mapped into a spin-1/2 model, in which full control and readout are achieved by using arbitrary single-spin rotations. By driving the system out-of-equilibrium for higher densities we report the observation of coherent spin oscillations with interaction-induced damping, which can be described in terms of a dipolar XX-model in effective magnetic fields. The comparison with theoretical calculations allows us to identify the primordial quantum fluctuations as a source of relaxation.

A 25.2 Wed 15:00 P 104

Towards a strongly interacting gas of cold strontium Rydberg atoms — Ingo Nosske[1], Luc Couturier[1], Chang Qiao[1], Fachao Hu[1], •Jan Blume[1,2], Canzhu Tan[1], Peng Chen[1], Yuhai Jiang[1,3], and Matthias Weidemüller[1,2] — [1]University of Science and Technology of China, Shanghai Institute for Advanced Studies, Xiupu Road 99, 201315 Shanghai, China — [2]Physikalisches Institut, Universität Heidelberg, Germany — [3]Shanghai Advanced Research Institute, Chinese Academy of Sciences,

We aim to create a gas of ultracold strontium Rydberg atoms. Our laser cooling strategy, with the goal of reaching temperatures and densities close to quantum degeneracy [1], involves a side-loaded 2D MOT followed by 3D broad-band and narrow-band MOTs. The strontium atoms will be excited to triplet Rydberg states via a narrow singlet-triplet intercombination line.
Here we present our latest experimental progress including the realization of our strontium 2D MOT, as well as a characterization of the locking scheme of our cooling laser which addresses the broad $5s^2\ ^1S_0 - 5s5p\ ^1P_1$ transition of strontium at 461 nm. The locking scheme is based on a commercial wavelength meter (HighFinesse WSU10) with which an absolute frequency stability of a few MHz has been achieved.

[1] Simon Stellmer, Rudolf Grimm, and Florian Schreck. "Production of quantum-degenerate strontium gases." Physical Review A 87.1 (2013): 013611.9.5 571-586 (2014)

A 25.3 Wed 15:15 P 104

Spectroscopy of Rydberg states in ultra cold ytterbium — •Christian Halter, Mustafa Jumaah, Laura Sucke, Tobias Franzen, Bastian Pollklesener, Cristian Bruni, and Axel Görlitz — Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Deutschland

In recent years Rydberg atoms with their special features, like dipole-dipole interaction or van-der-Waals blockade, have become more and more important for quantum optics. Particularly ultra cold Rydberg atoms are of great interest for the investigation of long range interaction. A special feature of ytterbium is that due to its two valance electrons atoms in Rydberg state can be easily manipulated and imaged using optical fields. A first step towards studies of ultra cold ytterbium is to gain precise knowledge on the Rydberg states. Here we present a spectroscopy study of the Rydberg states of ultra cold ytterbium. For the detection of the Rydberg states we are using the induced loss of atoms in a MOT when atoms are excited to a Rydberg state. Using this method we could measure several energy levels of Rydberg states.

A 25.4 Wed 15:30 P 104

Simulating Rydberg dressing of a one-dimensional Bose-Einstein condensate — •Graham Lochead[1,2], Marcin Plodzien[3], Julius de Hond[2], N. J. van Druten[2], and Servaas Kokkelmans[3] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimerfeld 226, 69120 Heidelberg — [2]van der Waals-Zeeman Institute, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands — [3]Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands

Rydberg dressing is the process of weakly admixing strongly interacting Rydberg-character into an otherwise weakly interacting ground state. These systems have the benefit of having strong, controllable, long-range interactions while still maintaining relatively long lifetimes. These properties have lead to many proposals for exotic many-body states/phases. In this talk I will present simulations of the influence of Rydberg dressed interactions on a 1D Bose-Einstein condensate, and show the advantages of 1D geometries over 3D for experimental observation. I will also describe a current experimental setup investigating Rydberg dressing in a 1D BEC.

A 25.5 Wed 15:45 P 104

Photon propagation through dissipative Rydberg medium at large input rates — •Ivan Mirgorodskiy[1], Christoph Braun[1,2], Florian Christaller[1,2], Christoph Tresp[1,2], Asaf Paris-Mandoki[1], and Sebastian Hofferberth[1,2] — [1]5. Phys. Inst. and Center for Integrated Quantum Science and Technology, Stuttgart University, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Department of Physics, Chemistry and Pharmacy, University of Southern Denmark, 5230 Odense M, Denmark

In our experiment we study the propagation of photons through cold atomic ensemble of 87Rb. Coupling photons to a Rydberg state via Electromagnetically Induced Transparency (EIT) leads to excitation of hybrid atom-photon states called Rydberg polaritons. Rydberg polaritons propagate through the atomic medium with vastly reduced speed and therefore strong Rydberg-Rydberg interaction can be mapped onto the photons. Thereby dissipative Rydberg-EIT media reveal a rich physics, understanding of which is of a high necessity.

In this work we investigate the particular case of large input photon rates and study quantum many-body dynamics of a dissipative Rydberg-EIT medium. We discuss effects of polariton propagation resulting in the change of photon transmission through the medium and an effect of "Rydberg pollution" consisting in a drastically increased rate of production of stationary Rydberg excitations inside of the medium.

A 25.6 Wed 16:00 P 104

Rydberg excitation of cold atoms in hollow core fiber — •Mohammad Noaman, Maria Langbecker, Chantal Voss, Maik Selch, Florian Stuhlmann, and Patrick Windpassinger — QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Cold atoms confined inside hollow-core fibers represent a promising candidate to study strongly coupled light-matter systems. Combined with the long range Rydberg interaction which is controlled through an EIT process, a corresponding experimental setup should allow for the generation of a strong and tunable polariton interaction. Due to dipole blockade polaritons are restricted to a quasi one dimensional structure. Using this scheme, novel photonic states, eg crystallization of photons can be observed with possible applications in quantum information and simulation. This talk will review the current status of our experimental setup where laser cooled Rubidium atoms are transported into a hollow-core fiber using optical lattice. We present the first result of Rydberg EIT of cold atoms inside a hollow core fiber and discuss the progress towards physics in a quasi-one-dimensional geometry of Rydberg atoms.

A 25.7 Wed 16:15 P 104

Mixed spin character bound states in ultra-long range giant dipole molecules — •Thomas Stielow, Markus Kurz, and Stefan Scheel — Institut für Physik, Universität Rostock, Albert-Einstein-Str. 23-24, 18059 Rostock

An exotic species of Rydberg atoms in crossed eletric and magnetic fields are so-called giant-dipole atoms [1]. They are characterized by an electron-ionic core separation in the range of several micrometers, leading to huge permanent dipole moments of several hundred thousand Debye. Recently, diatomic molecular states formed by the binding of a giant-dipole atom with a neutral ground-state perturber have been analyzed within the framework of a triplet dominated S-wave Fermi-pseudopotential approach [2]. In this work, we expand this analysis by including both S- and P-wave scattering potentials along with the hyperfine-structure coupling of the ground-state perturber. We discuss the effects of these couplings on the adiabatic molecular potentials. In addition to the Fermi-pseudopotential ansatz we provide a comparative study based on a Green's function approach [3].

[1] Dippel O., Schmelcher P. and Cederbaum L. S., *Phys. Rev. A*, **49** (1994) 4415.

[2] Kurz, M., Mayle, M. and Schmelcher, P., *Europhys. Lett.*, **97** (2012) 43001.

[3] Fey, C., Kurz, M., Schmelcher, P., Rittenhouse, S. T., Sadeghpour, H. R., *New J. Phys.* **17** 055010 (2015).

A 25.8 Wed 16:30 P 104

Strong coupling of a Rydberg super atom to a propagating light mode — •Jan Kumlin[1], Asaf Paris-Mandoki[2], Christoph Braun[2], Christoph Tresp[2], Sebastian Hofferberth[2], and Hans Peter Büchler[1] — [1]Institut für Theoretische Physik III and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Germany — [2]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Germany

Strong coupling of a single atom to a light mode is at the heart of quantum optics. Such systems have so-far been realised experimentally in optical cavities, but recent experimental progress in coupling propagating photons to an atomic cloud with Rydberg states enables the realisation of strong interactions between individual photons in free space and opens up a novel toolbox for quantum optics.

In this talk, we present the exact input-output formalism to describe the phenomenon of collective Rabi oscillations in a single Rydberg two-level superatom coupled to a photon field. The photonic mode defines an effective one-dimensional system, while the large size of the atomic cloud provides a chiral coupling. Using a master equation approach and the quantum regression theorem, we calculate the intensity as well as the second-order correlation function for the outgoing field by numerically solving the quantum master equation. Finally, we compare our findings with recent experimental results.