# Q 43: Ultracold plasmas and Rydberg systems (with A)

Time: Wednesday 16:30–19:00 Location: Empore Lichthof

Q 43.1 Wed 16:30 Empore Lichthof

**Building up a two-species Rydberg experiment with a spatially resolving ion detector** — •Thomas Schmid, Christian Veit, Nicolas Zuber, Robert Löw, and Tilman Pfau — 5th Physical Insitute, University of Suttgart, Stuttgart, Germany

We are building up an experiment for the production of an ultracold mixture of lithium and rubidium gases with the possibility of Rb Rydberg excitation. The machine, to that end, comprises a two-species Zeeman slower [1]. In the science chamber, a high numerical aperture optical lens is incorporated for focused Rydberg excitation. Besides, eight field plates arranged in a clover leaf configuration allow for ultrastable electric field control and field-ionization of the Rydberg atoms. Single ions can be detected temporally and spatially resolved with a delay-line detector [2]. The time resolution is approximately 100 ps, the spatial resolution at the detector is around 100 $\mu$m. The detector can handle single particle rates up to several MHz. In order to get a spatial resolution in the micrometer regime at the position of the ultracold cloud in the centre of the science chamber an ion microscope with a magnification above 100 is planned. It consists of three electrostatic triple-cylinder-lenses and has a total length of about 1.5 m.

[1] G. E. Marti, D. M. Stamper-Kurn et al.; *Phys. Rev. A* **81**, 043424 (2010).
[2] O. Jagutzki, H. Schmidt-Böcking et al.; *Nucl. Instrum. Meth. A* **477**, 244 (2002).

Q 43.2 Wed 16:30 Empore Lichthof

**Correlations and many-body dynamics of Rydberg excitations in the anti-blockade regime** — •Fabian Letscher[1,2], Oliver Thomas[1,2], Thomas Niederprüm[1], Tanita Eichert[1], Michael Fleischhauer[1], and Herwig Ott[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Strasse 47, 67663 Kaiserslautern, Germany

We present experimental and theoretical studies of the many-body dynamics of Rydberg excitations in an optically driven lattice gas in the dissipative anti-blockade regime. Making use of continuous ionization of atoms in a Rydberg state we monitor the time evolution and temporal correlations of Rydberg excitations. We observe large relaxation times (compared to the lifetime of a Rydberg excitation) and strong bunching. To describe the approximate dynamics of the system, we use an efficient many-body rate equation method and compare them with experimental results. Moreover, we construct a simple cluster model which allows a qualitative understanding of the experimental data.

Q 43.3 Wed 16:30 Empore Lichthof

**Storage of coherences and single-photon sources via Rydberg state in thermal vapors** — •Yi-Hsin Chen, Fabian Ripka, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart

Photons are good information carriers, which can be stored and retrieved among different quantum devices. We perform the storage of coherences via a highly excited Rydberg state in thermal vapors. These photonic quantum devices are intrinsically reproducible and scalable, towards the potential application of the photonic-based quantum security communication and information processing. The scheme is based on the combination of four-wave-mixing (FWM) and Rydberg blockade effects in a 220 micrometer thick vapor cell. In the pulsed FWM scheme, we observe coherent dynamics [1] and measure the lifetime of the stored coherence, which is around 1 ns, limited by motional dephasing of the thermal vapors. Moreover, we are going to reduce the excitation volume towards below the Rydberg interaction range by use of high-NA optics and spatial confinement for generating a deterministic single-photon source [2].

[1] Huber et al., PRA 90, 053806 (2014) [2] M. M. Müller et al., PRA 87, 053412 (2013)

Q 43.4 Wed 16:30 Empore Lichthof

**Towards coherence measurements of Rydberg atoms with all-optical detection** — •Lara Torralbo-Campo, Jens Grimmel, Florian Karlewski, Carola Rogulj, and József Fortágh — Physikalisches Institut der Universität Tübingen, Germany

We have developed a non-destructive and time-resolved method to optically detect the population of atoms in a selected Rydberg state as alternative to selective field ionization. This scheme is based on electromagnetically induced transparency (EIT). By monitoring the optical density of the probe laser over time, we can imply the initial population of the Rydberg state. We have tested the new method as proof-of-principle in a cold gas of 87-Rb atoms where lifetimes of Rydberg states under various environment conditions were measured. This method promises also to provide information regarding the initial coherence of the system. We present the ongoing work towards measurements of the coherence in a Rydberg gas.

Q 43.5 Wed 16:30 Empore Lichthof

**Rydberg P-state-molecules** — •Tanita Eichert[1], Philipp Geppert[1], Thomas Niederprüm[1], Oliver Thomas[1,2], Torsten Manthey[1], and Herwig Ott[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Strasse 47, 67663 Kaiserslautern, Germany

We report on the experimental realization of P-state Rydberg-molecules. These molecules are created by photoassociation in a dense sample of ultracold rubidium. High resolution spectroscopy is carried out over a range of more than 10 GHz allowing us to precisely determine the binding energies of molecular states around the 25P state. By characterizing the observed molecular states by their permanent dipole moments and their lifetimes we can distinguish between pure long range Rydberg molecules and bound states in the vicinity of the crossing butterfly state. Rydberg molecules show significantly shortened lifetimes compared to resonant Rydberg excitations caused by the bound ground state atom. Furthermore we demonstrate how the obtained knowledge on the bound states can be used to probe the site occupancy in optical lattices.

Additionally we report on a laser system that will be used to excite Rydberg S- and D-states in ultracold rubidium gases. For this purpose, two external cavity diode lasers for both 420 nm and 1030 nm have been assembled. Due to small linewidths and without the necessity of second harmonic generation, we achieve a high spectroscopic resolution and efficient excitation with increased stability.

Q 43.6 Wed 16:30 Empore Lichthof

**Stable optical lattices for creating and imaging ultracold quantum fluids of potassium** — •Emil Pavlov, Stephan Helmrich, Alda Arias, Tobias Wintermantel, and Shannon Whitlock — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg

Ultracold Rydberg atoms with their long-range interactions offer a controllable environment for realizing synthetic model systems to be studied, e.g. unconventional superfluids and extended Hubbard models. The strength and range of their interactions can be controlled via coherent coupling of the Rydberg states to the ground states (Rydberg dressing). In our experiment we plan to reveal the resulting quantum phases using a quantum gas microscope with single-site resolution. For this purpose we have designed a novel two-dimensional optical lattice induced by three-beam interference, which, when combined with a pancake-shaped trap, provides the necessary two-dimensional geometry. In order to minimize adverse heating effects on the atoms, the whole setup must exhibit high intensity, phase and pointing stability. We will present our evaluation of the lattice stability as well as initial experimental results.

Q 43.7 Wed 16:30 Empore Lichthof

**Measurements and numerical calculations of $^{87}$Rb Rydberg Stark and Zeeman maps** — •Jens Grimmel, Manuel Kaiser, Lara Torralbo-Campo, Markus Mack, Florian Karlewski, and József Fortágh — Physikalisches Institut der Universität Tübingen

Rydberg atoms are extremely sensitive to external electric and magnetic fields and consequently have a rich Stark and Zeeman spectrum. We present measurements and numerical calculations of Stark and Zeeman shifts for Rydberg states of $^{87}$Rb. We have extended our previous calculations [1] to take into account the differential Zeeman shifts as well as the transition strength between all states in the EIT ladder scheme. We have also performed high precision measurements of Zeeman maps in a heated vapour cell with magnetic fields up to 10mT. Recently, we have implemented a new heatable microcell setup for measurements of Stark and Zeeman maps at different temperatures and atomic densities.

[1] J. Grimmel, M. Mack, F. Karlewski, F. Jessen, M. Reinschmidt, N. Sándor and J. Fortágh, N. J. Phys. 17, 053005 (2015).

Q 43.8 Wed 16:30 Empore Lichthof

**Probing electric fields spatially resolved inside hollow core fibers with Rydberg atoms** — •Daniel Weller[1], Georg Epple[1,2], Josephine Gutekunst[1], Christian Veit[1], Tilman Pfau[1], Philip Russel[2], and Robert Löw[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Max Planck Institute for the Science of Light and Department of Physics, University of Erlangen, Günther-Scharowsky-Str. 1, 91058 Erlangen, Germany

The exceptional large polarizability of highly excited Rydberg atoms makes them of great interest for sensitive AC and DC electric field sensors. In addition, long-range interactions between the Rydberg atoms give rise to phenomena such as the Rydberg blockade, enabling the creation of optical nonlinearities at the single photon level. A promising route to technically feasible, miniaturized, room-temperature devices is based on the excitation of Rydberg atoms inside hollow-core photonic crystal fiber (HC-PCF). The confinement of both atoms and light enforces a large inline interaction region, resulting in perfect atom-light coupling. Recently, we demonstrated coherent three-photon excitation to Rydberg states in a cesium vapor confined in both kagome-style HC-PCF and capillaries. Spectroscopic signals exhibiting sub-Doppler features for principal quantum numbers up to $n = 46$ revealed line shifts. To investigate these shifts in detail, two kinds of spatially resolved spectroscopy were implemented: one uses an array of field plates along the fiber, the other relies on higher order modes of the excitation beams, to locally select atoms within the fiber.

Q 43.9 Wed 16:30 Empore Lichthof

**The bound and scattering properties in waveguide around Feshbach resonance** — •gaoren wang[1], panagiotis giannakeas[2], and peter schmelcher[1,3] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Hamburg, Germany — [2]Department of Physics and Astronomy, Purdue University, Indiana, USA — [3]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Hamburg, Germany

The two-body bound and scattering properties in an one-dimensional harmonic waveguide around the free-space magnetic Feshbach resonance are investigated based on the K matrix method. The multichannel characteristics of the interatomic interaction is taken into account, and the free-space phase shift is calculated in the frame work of quantum defect theory. We emphasize the following point: the bound state in the waveguide crosses the ground level of the transversal confinement at the magnetic field where the effective one-dimensional scattering length diverges.

Q 43.10 Wed 16:30 Empore Lichthof

**Flexible Rydberg aggregates** — •Karsten Leonhardt, Sebastian Wüster, and Jan Michael Rost — Max Planck Institute for the Physics of Complex Systems

Rydberg aggregates [1] are assemblies of highly excited atoms, where all atoms experience strong dipole-dipole interactions. Due to their simple structure and strong interactions, it makes them a fertile platform to study the link between motion, energy and entanglement transport. The transport can be almost coherent, since the quantum properties in Rydberg interacting systems are maintained on the relevant time and length scales. Another feature of Rydberg aggregates is that electronic excitation and atomic motion can propagate as a combined pulse, a so called exciton pulse [2-5]. We identified structural elements in flexible Rydberg aggregates [4,5] that significantly affect exciton dynamics, enabling coherent splitting of an exciton pulse, control of its propagation direction and coherence properties. **References**

[1] C. Ates, A. Eisfeld, J. M. Rost, NJP **10**, 045030 (2008).
[2] S. Wüster, C. Ates, A. Eisfeld, J. M. Rost, PRL **105**, 195392 (2010).
[3] S. Möbius, S. Wüster, C. Ates, A. Eisfeld, J. M. Rost, J. Phys. B. **44**, 184011 (2011).
[4] K. Leonhardt, S. Wüster, J. M. Rost, PRL **113**, 223001 (2014).
[5] K. Leonhardt, S. Wüster, J. M. Rost, arXiv:**1511**.06629 (2015).