Q 47: Ultra-cold plasmas and Rydberg systems II (joint session A/Q)

Time: Thursday 14:00–15:45 Location: a320

Invited Talk Q 47.1 Thu 14:00 a320

Anderson localization in a Rydberg composite — •Matthew Eiles, Alexander Eisfeld, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, 38 Noethnitzer Str. Dresden 01187

We demonstrate the localization of a Rydberg electron in a Rydberg composite, a system containing a Rydberg atom coupled to a structured environment of neutral ground state atoms. This localization is caused by weak disorder in the arrangement of the atoms and increases with the number of atoms M and principal quantum number ν. We develop a mapping between the electronic Hamiltonian in the basis of degenerate Rydberg states and a tight-binding Hamiltonian in the so-called "trilobite" basis, and then use this concept to pursue a rigorous limiting procedure to reach the thermodynamic limit in this system, taken as both M and ν become infinite, in order to show that Anderson localization takes place. This system provides avenues to study aspects of Anderson localization under a variety of conditions, e.g. for a wide range of interactions or with correlated/uncorrelated disorder.

Q 47.2 Thu 14:30 a320

Rydberg Dressed Quantum Many-Body Systems — •Nikolaus Lorenz[1], Lorenzo Festa[1], Lea Steinert[1], Philip Osterholz[1], Joop Adema[1], Robin Eberhard[1], and Christian Gross[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching — [2]Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen

Neutral atoms in microtrap arrays brought to interaction by Rydberg coupling offer a novel platform to study quantum magnetism. We have constructed a new experiment with potassium atoms, which aims to induce the magnetic interactions via near-resonant Rydberg coupling, so called Rydberg dressing. Here we report on coherent Rydberg coupling in a two dimensional array of single atoms. We observe fast coherent Rabi oscillations of single atoms as well as of small Rydberg superatoms. Finally we discuss first experiments towards Rydberg dressing induced interactions among atomic ground states.

Q 47.3 Thu 14:45 a320

Extended coherently delocalized states in a frozen Rydberg gas — •Ghassan Abumwis, Matthew T. Eiles, and Alexander Eisfeld — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

The long-range dipole-dipole interaction between excited Rydberg states of atoms can create highly delocalized states due to the exchange of excitation between the atoms. We show that even in a random gas many of the single-exciton eigenstates are surprisingly delocalized, composed of roughly one quarter of the participating atoms. We identify two different types of eigenstates: one which stems from strongly-interacting clusters, resulting in localized states, and one which extends over large delocalized networks of atoms. These two types of states can be excited and distinguished by appropriately tuned microwave pulses, and their relative contributions can be modified by the Rydberg blockade. The presence of these delocalized eigenstates could be relevant to puzzling results in several current experiments.

Q 47.4 Thu 15:00 a320

Characterizing molecular symmetries with quantum gas microscopy — •Simon Hollerith[1], Jun Rui[1], Antonio Rubio-Abadal[1], David Wei[1], Kritsana Srakaew[1], Simon Evered[1], Christian Gross[1,2], and Immanuel Bloch[1,3] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching — [2]Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen — [3]Fakultät für Physik, Ludwig-Maximilians-Universität München, 80799 München

Rydberg macrodimers - molecules consisting of two bound highly excited Rydberg atoms - provide enormous bond lengths even resolvable with optical wavelengths. Here we report on a microscopic study of macrodimers with different molecular symmetries in a gas of ultracold atoms in an optical lattice. The bond length of about 0.7 micrometers matches the diagonal distance of two atoms in the lattice. The geometry of the two-dimensional lattice initially unity filled with ground state atoms allows to control the relative orientation of the molecular axis to an ambient magnetic field and the polarization of the photoassociation light. Using our spatially resolved detection, we detect the associated molecules by correlated atom loss and find the excitation rates to be in agreement with theoretical predictions. Furthermore, we present how the molecular excitation rate can be significantly increased by the use of two color photoassociation. Our results highlight the potential of quantum gas microscopy for molecular physics and show how macrodimers might be used to study many body physics.

Q 47.5 Thu 15:15 a320

energy level statistics in Rydberg Composites — •Andrew Hunter, Matthew Eiles, Alex Eisfeld, and Jan M Rost — Max Planck Institute for the Physics of Complex Systems

Rydberg Composites are a new class of Rydberg matter consisting of a single Rydberg atom interfaced with a dense environment of neutral ground state atoms organized in a lattice [1]. The properties of the Rydberg composite are directly linked to the discrete symmetry of the occupied sites in the lattice with characteristic but unusual footprints of quantum chaos in the energy level statistics of the composite. We have developed techniques to identify these effects and present a systematic study of broken lattice symmetry and the transition to full chaos as atoms are removed from the lattice. We also describe how these statistics change with decreasing lattice constant with a transition to a continuous environment when the Rydberg electron can no longer resolve the lattice spacing.

[1] Hunter A L, Eiles M T, Eisfeld A and Rost J M 2019 arXiv:1909.01097

Q 47.6 Thu 15:30 a320

Stimulated decay and formation of antihydrogen atoms (arXiv:1912.03163) — •Tim Wolz[1], Chloé Malbrunot[1], Lilian Nowak[1], Daniel Comparat[2], and Mélissa Vieille-Grosjean[2] — [1]Physics Department, CERN, Genève 23, 1211, Switzerland — [2]Laboratoire Aimé Cotton, CNRS, Université Paris-Sud, ENS Paris Saclay, Université Paris-Saclay, 91405 Orsay, France

Antihydrogen atoms (Hbar) are routinely formed at the Antiproton Decelerator at CERN in a wide range of Rydberg states. However, precision measurements for stringent tests of the CPT theorem as well as first direct measurements of Earth's gravitational acceleration of antimatter require ground state (GS) atoms. Currently, experiments solely rely on spontaneous decay which so far only allowed for measurements in a neutral atom trap. We report on methods to stimulate the decay of the Rydberg atoms especially in the framework of a beam formation to extract the atoms into a field free region. We propose deexcitation schemes relying on E and B field mixing (applicable to a pulsed charge exchange Hbar production scheme) as well as THz and microwave mixing (applicable to a quasi continuous three body recombination Hbar production scheme). Both methods make use of a (visible) deexcitation laser. We obtain, in either case, close to unity ground state fractions within a few tens of microseconds. Combining such deexcitation methods with a stimulated radiative recombination allows for a direct formation of Hbar atoms in ground state. Finally, we report on first steps toward an experimental implementation of the proposed techniques.