Q 14: Ultracold plasmas and Rydberg systems I (with A)

Time: Monday 17:00–18:45 Location: f303

Q 14.1 Mon 17:00 f303

Rydberg Spectroscopy in a Bose-Einstein Condensate — •Kathrin Sophie Kleinbach[1], Michael Schlagmüller[1], Tara Cubel Liebisch[1], Felix Engel[1], Fabian Böttcher[1], Karl M. Westphal[1], Robert Löw[1], Sebastian Hofferberth[1], Tilman Pfau[1], Jesús Pérez-Ríos[2], and Chris H. Greene[2] — [1]5. Physikalisches Insitut and IQST, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Department of Physics and Astronomy, Purdue University, 47907 West Lafayette, IN, USA

Spectroscopy of a single Rydberg atom excited within a Bose-Einstein condensate is presented. Not only a frequency shift proportional to the density is observed, as discovered by Amaldi and Segre in 1934, but an assymetric broadening, which depends on the principal quantum number n. The line broadening depends on the interaction potential energy curves of the Rydberg electron scatterer with the neutral atom perturber. In Rb there is a shape resonance for the triplet p-wave scattering of e-Rb(5s) at 0.02 eV leading to a potential with a large energy shift, which crosses the lower lying nS, (n-2)D, and (n-1)P states. When a nS +N x 5S1/2 state is photoassociated, neutral atom perturbers near the crossing with the shape resonance potential become relevant, leading to large n-dependent line broadenings. We present a simple microscopic model for the spectroscopic line shape by treating the atoms overlapped with the Rydberg orbit as zero-velocity, independent, point-like particles, with binding energies associated with their ion-neutral separation, and good agreement is found.

Q 14.2 Mon 17:15 f303

Non adiabatic quantum state preparation with Rydberg atoms — •Jiří Minář, Matteo Marcuzzi, Emanuele Levi, and Igor Lesanovsky — School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, United Kingdom

We propose a non-adiabatic protocol to create antiferromagnetic GHZ states in a chain of Rydberg atoms. The proposed implementation relies on the blockade mechanism between atoms in Rydberg states and individual site addressing. The procedure is then generalized in order to create ground states of a many body Rokhsar-Kivelson Hamiltonian, which describes the physics of a one dimensional spin-half chain with repulsive long range interactions. We analyze the performance of the scheme accounting for various effects, such as the interplay between the repulsive interaction strength and the Rabi frequency of the addressing beam, the effect of the tails of the long range interaction or the robustness with respect to the noise in the experimental parameters.

Q 14.3 Mon 17:30 f303

Electron pair formation in He (Cooper pair) — •Hubert Klar — DHBW Lörrach

The empirical shell modell for atoms predicts for two-electron atoms an infinity of high double Rydberg states of the form He(nl,n'l'). A ficticiuos force presented in this conference elsewhere, however, distroys this oversimplified picture. In e-He+(nl) scattering we observe a spontanious time-reversal symmetry breaking. The incoming wavefront is turned towards the top of a potential ridge which leads to an e-e attraction. A Cooper pair is born. After reflection at a centrifugal barrier the outgoing wave diverges from the ridge. Slightly below the threshold for double escape the wave may be reflected at an outer barrier or slightly above threshold the Cooper pair decays immediately. Our quantum mechanical result compares favorably with Wannier's classical ionization theory and with experimental data.

Q 14.4 Mon 17:45 f303

Coherence in a cold atom photon switch — •Weibin Li and Igor Lesanovsky — School of Physics and Astronomy, University of Nottingham, Nottingham, UK

We study coherence in a cold atom single photon switch where the gate photon is stored in a Rydberg spinwave. With a combined field theoretical and quantum jump approach and by employing a simple model description we investigate systematically how the coherence of the Rydberg spinwave is affected by scattering of incoming photons. With large-scale numerical calculations we show how coherence becomes increasingly protected with growing interatomic interaction strength. For the strongly interacting limit we derive analytical expressions for the spinwave fidelity as a function of the optical depth and bandwidth of the incoming photon.

Q 14.5 Mon 18:00 f303

Emergent devil's staircase without particle-hole symmetry in Rydberg quantum gases with competing attractive and repulsive interactions — •Zhihao Lan, Jiří Minář, Emanuele Levi, Weibin Li, and Igor Lesanovsky — School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, UK

The devil's staircase is a fractal structure that characterizes the ground state of one-dimensional classical lattice gases with long-range repulsive convex interactions. Its plateaus mark regions of stability for specific filling fractions which are controlled by a chemical potential. Typically such staircase has an explicit particle-hole symmetry. Here we introduce a quantum spin chain with competing short-range attractive and long-range repulsive interactions, i.e. a non-convex potential. In the classical limit the ground state features generalized Wigner crystals that - depending on the filling fraction - are either composed of dimer particles or dimer holes which results in an emergent complete devil's staircase without explicit particle-hole symmetry of the underlying microscopic model. In our system the particle-hole symmetry is lifted due to the fact that the staircase is controlled through a two-body interaction rather than a one-body chemical potential. The introduction of quantum fluctuations through a transverse field melts the staircase and ultimately makes the system enter a paramagnetic phase. For intermediate transverse field strengths, however, we identify a region, where the density-density correlations suggest the emergence of quasi long-range order. We discuss how this physics can be explored with Rydberg-dressed atoms held in a lattice.

Q 14.6 Mon 18:15 f303

Dynamics of cluster formation and non-equilibrium phases of Rydberg excitations in the anti-blockade regime — •Fabian Letscher[1,2], Thomas Niederprüm[1], Oliver Thomas[1,2], Tanita Eichert[1], Herwig Ott[1], and Michael Fleischhauer[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

Motivated by recent experiments we discuss theoretically the dynamics and temporal correlations of Rydberg excitations in the anti-blockade regime. In this regime spatially extended regions of atoms in the ground state coexist with connected clusters of Rydberg excitations. Measurements performed on an atomic lattice gas show that the non-equilibrium dynamics in the steady state is characterized by strong temporal bunching and large correlation times. The latter arise from two competing intrinsic timescales: In the two-step excitation process, the first Rydberg excitation is highly suppressed, while the second excitation is strongly enhanced. We simulate the dynamics of large lattice systems using a many-body rate equation model which shows good agreement with the experiments. To understand the main features of the two-particle correlations we introduce a simplified cluster model and discuss its many-body dynamics.

Q 14.7 Mon 18:30 f303

Enhancement of a Single-Photon Transistor by Stark-Tuned Förster Resonances — •Christoph Tresp[1], Hannes Gorniaczyk[1], Przemyslaw Bienias[2], Asaf Paris-Mandoki[1], Weibin Li[3], Ivan Mirgorodskiy[1], Christian Zimmer[1], Hans Peter Büchler[2], Igor Lesanovsky[3], and Sebastian Hofferberth[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Germany — [2]Institut für theoretische Physik III, Universität Stuttgart, Germany — [3]School of Physics and Astronomy, University of Nottingham, United Kingdom

We report on the use of Stark-tuned Förster resonances to enhance the gain of a Rydberg mediated single-photon transistor and the non-destructive detection of single Rydberg atoms. We show that our all-optical detection scheme enables high-resolution spectroscopy of Förster resonances, revealing the fine structure splitting of Rydberg states and the splitting of Zeeman-substates. We discuss how excitation hopping between a stored Rydberg excitation and incoming source polaritons can be minimized by choice of the Rydberg states. We then proceed to use a particularly suited two-color resonance to demonstrate scattering of over 100 source photons from a single Rydberg excitation, demonstrating efficient all optical Rydberg detection. Finally, we investigate the Rydberg transistor in coherent operation by reading out the gate photon after scattering source photons. Due to projection of the stored spin wave and phase imprinting, the coherence of the gate excitation is affected by scattered and transmitted source photons.