A 25: Ultra-cold plasmas and Rydberg systems I

Time: Thursday 16:30–18:30 Location: BAR 106

Invited Talk A 25.1 Thu 16:30 BAR 106

Conical intersections in an ultracold gas — •Sebastian Wüster, Alexander Eisfeld, and Jan-Michael Rost — MPIPKS Dresden

We find that energy surfaces of more than two atoms or molecules interacting via transition dipole-dipole potentials generically possess conical intersections (CIs). Typically only few atoms participate strongly in such an intersection. For the fundamental case, a circular trimer, we show how the CI affects adiabatic excitation transport via electronic decoherence or geometric phase interference. These phenomena may be experimentally accessible if the trimer is realized by light alkali atoms in a ring trap, whose interactions are induced by off-resonant dressing with Rydberg states. Such a setup promises a direct probe of the full many-body density dynamics near a CI.

A 25.2 Thu 17:00 BAR 106

Atom-molecule coherence and Ramsey interferometry in ultracold Rydberg gases — •Jonathan Balewski, Björn Butscher, Johannes Nipper, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart

Ultralong-range Rydberg molecules are bound states of a Rydberg atom with ground state atoms [1]. We report on experiments studying the coherence properties of this new class of molecular bond. We demonstrate the coherent transfer of initially free pairs of rubidium ground-state atoms to ultralong-range Rydberg molecules using rotary echo and Ramsey-pulse sequences. The coherent evolution of the molecular system is characterized by measuring the timescales for the energy-conserving dephasing rate, T_2, and for non-energy-conserving decay processes, T_1 [2].

Furthermore, these Ramsey experiments can be viewed as an atom-molecule interferometer where the unbound ground state atoms and the ultalong-range Ryberg molecules form two branches. The relative phase in the arms of such an interferometer can be precisely controlled and varied over a wide range using additional electric field pulses. Besides this proof of principle, this technique provides a phase sensitive tool to measure interactions between Rydberg atoms or molecules.

[1] V. Bendkowsky et al., Nature **458**, 1005 (2009)
[2] B. Butscher et al., Nature Physics, nphys1828 (2010)

A 25.3 Thu 17:15 BAR 106

Many-body spin interactions and the ground state of a dense Rydberg lattice gas — •Igor Lesanovsky — University of Nottingham, School of Physics and Astronomy, University Park, Nottingham NG7 2RD, United Kingdom

We study a one-dimensional atomic lattice gas in which Rydberg states are excited by a laser and whose external dynamics is frozen. We identify a parameter regime in which the Hamiltonian is well-approximated by a spin Hamiltonian with quasi-local many-body interactions and possesses an exact analytic ground state solution. This is due to the fact that for certain parameters the Hamiltonian can be approximately written in a so-called stochastic matrix form. The ground state is then a superposition of all states of the system that are compatible with an interaction induced constraint weighted by a fugacity. We perform a detailed analysis of this state which exhibits a cross-over between a paramagnetic phase with short-ranged correlations and a crystal. Moreover, we discuss its entanglement properties and outline an experimental procedure for achieving a maximally entangled state.

[1] I. Lesanovsky, arXiv:1010.2349 (2010)

A 25.4 Thu 17:30 BAR 106

Creating strongly coupled plasmas via the dipole blockade in ultracold Rydberg gases — •Georg Bannasch and Thomas Pohl — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden

A major challenge in the field of ultracold plasmas is the creation of strongly coupled charges. Since such plasma is typically created by photoionization of spatially uncorrelated ultracold atoms, the subsequent plasma relaxation leads to tremendous heating and, thus, precludes the development of strong correlations.

Here we propose a double-pulse ionization scheme for plasma creation that exploits the dipole blockade between highly excited Rydberg atoms. It is shown that this "pump-probe" type sequence produces strongly correlated ions, which thereby limits subsequent disorder-induced heating. We thoroughly study the involved steps to discuss the feasibility of our approach and give achievable coupling under realistic conditions.

A 25.5 Thu 17:45 BAR 106

Quantum-Spin dynamics with ultracold Rydberg atoms — •Rejish Nath[1], Daniel Charrier[1], Igor Lesanovsky[2], Andreas Läuchli[1], and Thomas Pohl[1] — [1]MaxPlanck Institute for the Physics of Complex Systems, Nöthnitzer strasse 38, D-01187, Dresden, Germany — [2]University of Nottingham, University Park, Nottingham, United Kingdom.

Rydberg atoms are emerging as a promising system to realize spin Hamiltonians with current experimental capabilities. As pointed out previously, groundstate-coupling to one Rydberg state leads to an effective spin-1/2 Ising-type model. Here we discuss an implementation of spin-1 Hamiltonians by exciting two distinct nS Rydberg states. It is shown that this not only increases the spin dimension but results in qualitatively different behavior due to the emergence of a "van der Waals hopping" term. Focussing on experimentally relevant parameters, we will present the resulting phase diagram in several simplifying limits.

A 25.6 Thu 18:00 BAR 106

Excitation and entanglement transport in a flexible rydberg chain — •Sebastian Möbius, Sebastian Wüster, Cenap Ates, Alexander Eisfeld, and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden

In a regular, flexible chain of Rydberg atoms, a single electronic excitation localizes on two atoms that are in closer mutual proximity than all others. We show how the interplay between excitonic and atomic motion causes electronic excitation and diatomic proximity to propagate through the Rydberg chain as a combined pulse. In this manner entanglement is transferred adiabatically along the chain, reminiscent of momentum transfer in Newton's cradle[1].

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

A 25.7 Thu 18:15 BAR 106

Relaxation dynamics of an ultracold Rydberg lattice gas — •Cenap Ates and Igor Lesanovsky — School of Physics and Astronomy, University of Nottingham, NG7 2RD Nottingham, United Kingdom

The discussion about if and how a closed non-equilibrium quantum system relaxes to an equilibrium state compatible with familiar statistical mechanics has gained renewed interest, since experiments are on the horizon that can implement the theoretically studied models with ultracold atomic systems. In this spirit, the long-time dynamics of a coherently driven Rydberg ring was recently studied theoretically. It was shown that for strong Rydberg-Rydberg interactions "classical" observables like the number of excited particles indeed relax towards a state which can be characterized by a thermal distribution [1].

Here we focus on the relaxation process itself. We show that the time it takes to reach the equilibrium state depends non-trivially on the interaction strength. In particular, we demonstrate that the equilibration process dramatically slows down a the point, where the Rydberg blockade sets in.

[1] I. Lesanovsky, B. Olmos and J.P. Garrahan, Phys. Rev. Lett. 105, 100603 (2010)