A 19: Ultra-Cold Plasmas and Rydberg System

Time: Thursday 10:30–12:30 Location: B 302

Invited Talk A 19.1 Th 10:30 B 302

Bound by reflection: Binding mechanisms of ultralong range Rydberg molecules — •Weibin Li — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Quantum reflection, as a pure wave phenomenon, involves the reflection of a particle, which would classically be transmitted. For highly excited atoms it is found that this effect can lead to molecular bound states at extremely long range. Recent experiments have provided evidence for the existence of such ultralong-range molecules, arising entirely from low-energy scattering between a Rydberg electron and a nearby ground state atom. Here, I will report on recent calculations of the molecular structure, that account for such collisions in a non-perturbative way. A broad range of molecular lines are identified, and shown to originate from two different sources: a Rydberg trimer formed in a single-photon association and a series of excited dimer states that arise from, thus far, an unexplored mechanism based on internal quantum reflection at a steep potential drop caused by a shape resonance in electron-atom scattering. The theory shows good agreement with previous experiments and allows to assign the majority of molecular lines observed in recently measured spectra of ultralong-range Rydberg molecules.

A 19.2 Th 11:00 B 302

Thermalization of a strongly interacting 1D Rydberg lattice gas — Beatriz Olmos[1], Markus Müller[2], and •Igor Lesanovsky[3] — [1]Instituto 'Carlos I' de Fisica Teorica y Computacional and Departamento de Fisica Atomica, Molecular y Nuclear, Universidad de Granada, Granada, Spain — [2]Institute for Theoretical Physics, University of Innsbruck, and Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, Innsbruck, Austria — [3]School of Physics and Astronomy, The University of Nottingham, Nottingham, UK

When Rydberg states are excited in a dense atomic gas the mean number of excited atoms reaches a stationary value after an initial transient period. We shed light on the origin of this steady state that emerges from a purely coherent evolution of a closed system. To this end we consider a one-dimensional ring lattice, and employ the perfect blockade model, i.e. the simultaneous excitation of Rydberg atoms occupying neighboring sites is forbidden. We derive an equation of motion which governs the system's evolution in excitation number space. This equation possesses a steady state which is strongly localized. Our findings show that this state is to a good accuracy given by the density matrix of the microcanonical ensemble where the corresponding microstates are approximate zero energy eigenstates of the interaction Hamiltonian. We analyze the statistics of the Rydberg atom number count providing expressions for the number of excited Rydberg atoms and the Mandel Q-parameter in equilibrium.

[1] B. Olmos, M. Müller, I. Lesanovsky, arXiv:0907.4420 (2009)

A 19.3 Th 11:15 B 302

Quantum excitation transport in flexible atomic aggregates — •Sebastian Wüster, Cenap Ates, Alexander Eisfeld, and Jan-Michael Rost — Max-Planck-Institut für Physik Komplexer Systeme, Nöthnitzer Strasse 38, 01187 Dresden

Transfer of electronic excitations on chains of atoms or molecules is important in many areas of physics, such as photosynthetic light-harvesting [1] or assemblies of Rydberg atoms in optical lattices. The electromagnetic interactions responsible for excitation propagation also exert mechanical forces on the chain, inducing motion of the constituents [2]. In such a flexible aggregate, the atomic motion is typically entangled with the state of the electronic excitation.

We consider a linear and a circular arrangement of Rydberg atoms on which a single excitation propagates via dipole-dipole transitions. In the circular scenario, a conical intersection between two Born-Oppenheimer surfaces of the chain's electronic state has a dominating effect on the quantum dynamics. It strongly affects the atomic centre-of-mass motion and thereby decoheres the reduced electronic density matrix. For our investigation we employ both, full quantum mechanical calculations and a mixed quantum-classical surface-hopping method.

[1] R. van Grondelle and V.I. Novoderezhkin, Phys. Chem. Chem. Phys. 8, (2006) 793.

[2] C. Ates, A. Eisfeld and J.M. Rost, New J. Phys. 10 (2008) 045030.

A 19.4 Th 11:30 B 302

Investigating Rydberg-Surface Interactions on an Atom Chip — •Atreju Tauschinsky, Rutger M.T. Thijssen, Shannon Whitlock, N.J. van Druten, H.B. van Linden van den Heuvell, and R.J.C. Spreeuw — Van der Waals-Zeeman Institute, Universiteit van Amsterdam, Amsterdam, The Netherlands

We have prepared an array of ultracold atomic ensembles confined in a 2D-lattice of microtraps on a chip. This system holds great promise as a quantum register, assuming interactions between neighbouring ensembles can be controlled. For this purpose we are studying long-range Rydberg dipole-dipole interactions.

An open question is the influence of nearby surfaces on the properties of Rydberg atoms. We coherently excite interacting Rydberg atoms in an ultracold gas close to the chip and use an electromagnetically induced transparency resonance to probe atom-atom and atom-surface interactions.

Results on the influence of the surface on an ensemble of interacting Rydberg atoms as well as the effects of atom-atom interactions will be presented.

A 19.5 Th 11:45 B 302

High resolution spectra of ultralong-range Rydberg molecules — •Johannes Nipper[1], Vera Bendkowsky[1], Björn Butscher[1], Jonathan Balewski[1], James P. Shaffer[2], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Germany — [2]Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, USA

Ultralong-range Rydberg molecules are bound states of a Rydberg atom with ground state atoms. The binding mechanism relies solely on local Rydberg electron scattering off the perturbing ground state atom, described by a Fermi-like pseudo potential. The bound states show binding length up to 100nm and binding energies of several MHz [1].

We report on experiments showing high resolution spectra of the molecular ground state and vibrationally excited states of the dimers as well as trimer states. The binding energies are reproduced in great precision by a full solution of the electron-atom interaction. While the vibrational ground state is bound by pure s-wave scattering, the binding mechanism for the excited states arises from quantum reflections off a deep potential well due to a p-wave resonance inside the Rydberg electron wavefunction.

Furthermore experiments in electrical fields show a splitting of the molecular line, indication for a rotational substructure of the molecular ground state.

[1] V. Bendkowsky et al., Nature **458**, 1005 (2009)

A 19.6 Th 12:00 B 302

Controlling Interactions and Optical Properties of Cold Rydberg Gases — •Sevilay Sevincli and Thomas Pohl — Max Planck Institute for the Physics of Complex Systems, Noethnitzer Strasse 38, 01187 Dresden, Germany

The high sensitivity of Rydberg atoms to external fields as well as interactions among them leads to strong a enhancement of optical nonlinearities in ultra-cold Rydberg gases. Here we present a many-body density-matrix approach that allows to describe such problems under EIT conditions. We find a strong influence of both the effects of an external electric field as well as strong van der Waals interactions on the optical response of an ultra-cold Rydberg gas, and determine the corresponding optical nonlinearities.

We, moreover, develop a scheme that enables external control of the atom's van der Waals interactions, and even permits to turn them off, while preserving the high polarizability of the Rydberg state. This in turn is shown to yield a greatly enhanced Kerr coefficient under a highly coherent many-body gas dynamics.

A 19.7 Th 12:15 B 302

Controlled qubit rotation using Rydberg level shifts — •Ulrich Krohn, Richard Abel, Christopher Carr, and Charles Adams — Atomic and Molecular Physics, Durham University,

Durham, United Kingdom

We study the transfer of the population between two ground states in ^{87}Rb controlled by an electro-magnetically induced transparency (EIT) resonance. The system used is well described by a four level atom with two ground states coupled by two phase stabilised laser fields [1] to an intermediate state. A Rydberg state is coupled via Ω_r with a detuning δ_r to the intermediate state. With $\Omega_r = 0$ the population is transported from one ground state to the other by means of a π-Raman pulse. This transfer is blocked if $\Omega_r \neq 0$, $\delta_r = 0$ as the two photon resonance is lifted by EIT.

The population transfer can be unblocked by shifting the Rydberg level out of laser resonance using an electric field or the interaction of other Rydberg atoms with the dark state of the EIT resonance [2, 4]. Given a narrow band excitation laser, e.g. [3], this scheme can be used to implement a single site addressability in an optical lattice when replacing the electric field with an electric field gradient.

References

[1] RP Abel, *et al.*, Optics Letters **34**, 3071 (2009)
[2] M Müller, *et al.*, PRL **102**, 170502 (2009)
[3] RP Abel, *et al.*, Appl. Phys. Lett. **94**, 071107 (2009)
[4] JD Pritchard, *et al.*, arXiv:0911.3523v2 (2009)