Q 63: Ultra-cold Plasmas and Rydberg Systems II (joint session A/Q)

Time: Friday 11:00–12:45 Location: F107

Invited Talk Q 63.1 Fri 11:00 F107

Coherent multidimensional spectroscopy of an ultracold gas — •Friedemann Landmesser[1], Tobias Sixt[1], Katrin Dulitz[1,2], Lukas Bruder[1], and Frank Stienkemeier[1] — [1]Institute of Physics, University of Freiburg, Germany — [2]Institut für Ionenphysik und Angewandte Physik, Universität Innsbruck, Austria

Femtosecond coherent multidimensional spectroscopy is demonstrated for an ultracold gas of Li atoms [1]. To this end, Li atoms are cooled in a magneto-optical trap and investigated using a phase-modulation time-domain spectroscopy technique, which is especially beneficial for dilute samples because of its high sensitivity [2]. The technique may offer the possibility to investigate time dependencies on the fs scale and coherent correlations in molecular systems with high frequency and time resolution [3]. Due to its quantum pathway selectivity, the technique is furthermore able to reveal multiphoton processes with specific numbers of interacting particles, as previously demonstrated in multiple quantum coherence experiments of weakly interacting thermal alkali atoms with mean interatomic distances in the micrometer-range [4-7].

[1] F. Landmesser et al., arXiv:2210.03023 (2022).
[2] P. Tekavec et al., J. Chem. Phys. 127, 214307 (2007)
[3] D. M. Jonas, Annu. Rev. Phys. Chem. 54, 425 (2003).
[4] L. Bruder et al., Phys. Rev. A 92, 053412 (2015).
[5] S. Yu et al., Opt. Lett. 44, 2795 (2019).
[6] L. Bruder et al., Phys. Chem. Chem. Phys. 21, 2276 (2019).
[7] B. Ames et al., New J. Phys. 24, 13024 (2022).

Q 63.2 Fri 11:30 F107

Resonance lineshapes in Rydberg atom - ion interactions — •Neethu Abraham and Matthew T Eiles — Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany

Rydberg molecules, ranging from the so-called "trilobite" molecules to Rydberg macrodimers to Rydberg atom-ion molecules, are a stunning highlight of recent experimental progress in ultracold atomic physics. Various factors can contribute to the decay of such molecules, including radiative decay or associative ionization. One non-radiative mechanism is the non-adiabatic coupling between electronic potential energy curves. We investigate this mechanism here in the Rydberg-ion molecule system using the streamlined version of the R-matrix method to compute the resonant line shapes. We provide a detailed analysis of the profiles and widths of these resonances and characterize them using the Fano-Feshbach lineshape. This shows how non-adiabatic coupling shifts the resonance positions away from the binding energies predicted in the Born-Oppenheimer approximation, and indicates the lifetimes of these states with regard to non-adiabatic decay. We explore these resonances over a range of different principal quantum numbers. Such a study can be relevant to the other types of Rydberg molecules as well.

Q 63.3 Fri 11:45 F107

Experimental investigation of multilevel Autler-Townes spectra — •Jana Bender, Patrick Mischke, Tanita Klas, Florian Binoth, Thomas Niederprüm, and Herwig Ott — Department of Physics and Research center OPTIMAS, RPTU Kaiserslautern-Landau

The Autler-Townes splitting in a strongly coupled two-level-system is a well-known effect in atomic physics. However, actual atomic systems seldom are perfect two-level-systems: Both hyperfine structure and magnetic sublevels result in closely spaced multilevel systems where two individual states can be coupled only for distinct combinations of laser polarization and quantum numbers. The coupling lifts degeneracies and mixes the states, resulting in complex spectra deviating from the symmetrical two-level Autler-Townes splitting.

We experimentally investigate these spectra in a thermal cloud of ^{87}Rb atoms by resonantly coupling the $6P3/2, F = 3$ state to a Rydberg state with varying Rabi frequency. We selectively probe the population of the resulting mixed states with a laser of adjustable polarization.

Our experiments confirm that multilevel effects have to be considered in the Autler-Townes regime. As a general rule, the splitting between peaks is not equal to the Rabi frequency if the coupling strength exceeds the energetic distance of adjacent states.

Q 63.4 Fri 12:00 F107

Exploring the Many-Body Dynamics Near a Conical Intersection with Trapped Rydberg Ions — Filippo Gambetta[1,2], Chi Zhang[3], Markus Hennrich[3], Igor Lesanovsky[1,2,4], and •Weibin Li[1,2] — [1]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, United Kingdom — [2]Centre for the Mathematics and Theoretical Physics of Quantum Non-equilibrium Systems, University of Nottingham, Nottingham NG7 2RD, United Kingdom — [3]Department of Physics, Stockholm University, 10691 Stockholm, Sweden — [4]Institut für Theoretische Physik, University of Tübingen, 72076 Tübingen, Germany

Conical intersections between electronic potential energy surfaces are paradigmatic for the study of nonadiabatic processes in the excited states of large molecules. However, since the corresponding dynamics occurs on a femtosecond timescale, their investigation remains challenging and requires ultrafast spectroscopy techniques. We demonstrate that trapped Rydberg ions are a platform to engineer conical intersections and to simulate their ensuing dynamics on larger length scales and timescales of the order of nanometers and microseconds, respectively; all this in a highly controllable system. Here, the shape of the potential energy surfaces and the position of the conical intersection can be tuned thanks to the interplay between the high polarizability and the strong dipolar exchange interactions of Rydberg ions. We study how the presence of a conical intersection affects both the nuclear and electronic dynamics demonstrating, in particular, how it results in the inhibition of the nuclear motion.

Q 63.5 Fri 12:15 F107

Diffusive-like Redistribution in State-changing Collisions between Rydberg Atoms and Ground State Atoms — •Markus Exner, Philipp Geppert, Max Althön, and Herwig Ott — Department of Physics and Research center OPTIMAS, RPTU Kaiserslautern-Landau

We report on inelastic collisions between Rydberg and ground state atoms. Our experiment starts with a cloud of ultracold Rubidium atoms in a crossed dipole trap. Using a three-photon excitation scheme, we photoassociate ultralong-range Rydberg molecules with huge bond lengths . These exotic molecular species are formed by a Rydberg atom and ground state atom, where the binding mechanism originates from scattering interaction between Rydberg electron and the ground state atom. We have observed the decay of these molecules in which the ground state atom tunnels toward the Rydberg core. During this collision a state-change of the Rydberg electron takes place. We found a redistribution of population over a wide range of final states. In addition, a decay into different orbital angular momentum states could be observed. These state-changing collisions can be described as a diffusive-like redistribution at short internuclear distances.

Q 63.6 Fri 12:30 F107

The role of Coulomb anti-blockade in the photoassociation of long-range Rydberg molecules — Michael Peper[1,2], Edward Treu-Painter[1], Martin Trautmann[1], and •Johannes Deiglmayr[1] — [1]Universität Leipzig, Germany — [2]Princeton University, Princeton, USA

We present a new mechanism contributing to the detection of photoassociated long-range Rydberg molecules via pulsed-field ionization: ionic products, created by the decay of a long-range Rydberg molecule, modify the excitation spectrum of surrounding ground-state atoms and facilitate the excitation of further atoms into Rydberg states by the photoassociation light. Such an ion-mediated excitation mechanism has been previously called *Coulomb anti-blockade*. Pulsed-field ionisation typically doesn't discriminate between the ionization of a long-range Rydberg molecule and an isolated Rydberg atom, and thus the number of atomic ions detected by this mechanism is not proportional to the number of long-range Rydberg molecules present in the probe volume. By combining high-resolution UV and RF spectroscopy of a dense, ultracold gas of cesium atoms, theoretical modeling of the molecular level structures of long-range Rydberg molecules bound below $n\,^2P_{3/2}$ Rydberg states of cesium, and a rate model of the photoassociation and decay processes, we unambiguously identify the signatures of this detection mechanism in the photoassociation of

long-range Rydberg molecules bound below atomic asymptotes with | negative Stark shifts.