Q 41: Ultracold Plasmas and Rydberg systems III (joint session A/Q)

Time: Wednesday 14:00–15:45 Location: K 0.011

Q 41.1 Wed 14:00 K 0.011

Van der Waals interaction potential between Rydberg atoms near surfaces — •Johannes Block and Stefan Scheel — Institut für Physik, Universität Rostock, D-18059 Rostock, Germany

Rydberg atoms experience strong van der Waals interactions due to their large transition dipole moments. As these interactions are mediated by photons, they can be altered by dielectric surroundings. As a model system for atoms near a superconducting stripline cavity, we show the effect of a mirror on the van der Waals interaction of Rydberg atoms by direct diagonalization of the interaction Hamiltonian including terms up to electric quadrupole-quadrupole interaction [1,2]. We find that the presence of the mirror strongly modifies the interactions leading to a significant change in the Rydberg blockade [3].

[1] J.S. Cabral *et al.*, J. Phys. B: At. Mol. Opt. Phys. **44**, 184007 (2011).
[2] J. Stanovevic *et al.*, Phys. Rev. A **78**, 082709 (2008).
[3] J. Block and S. Scheel, arXiv:1710.08965

Q 41.2 Wed 14:15 K 0.011

An optogalvanic flux sensor for trace gases — •Johannes Schmidt[1,2,5], Markus Fiedler[1,5], Ralf Albrecht[1,5], Denis Djekic[3,5], Patrick Schalberger[2,5], Holger Baur[2,5], Robert Löw[1,5], Tilman Pfau[1,5], Jens Anders[3,5], Norbert Frühauf[2,5], Edward Grant[4], and Harald Kübler[1,5] — [1]5th Institute of Physics — [2]Institute for Large Area Microelectronics — [3]Institute for Theory of Electrical Engineering — [4]Department of Chemistry, University of British Columbia — [5]University of Stuttgart, Center for Integrated Quantum Science and Technology (IQST)

We demonstrate the applicability of a new kind of gas sensor based on Rydberg excitations. From an arbitrary probe gas the molecule in question is excited to a Rydberg state, by succeeding collisions with all other gas components this molecule gets ionized and the emerging electron and ion can then be measured as a current, which is the clear signature of the presence of this particular molecule. As a first test we excite Alkali Rydberg atoms in an electrically contacted vapor cell [1,2] and demonstrate sensitivities down to 100 ppb on a background of N_2. We investigate different amplification circuits, ranging from solid state devices on the cell to thin film technology based transimpedance amplifiers inside the cell [3]. For a real life application, we employ our gas sensing scheme to the detection of nitric oxide in a background gas at thermal temperatures and atmospheric pressure.

[1] D. Barredo, et al., *Phys. Rev. Lett.* **110**, 123002 (2013)
[2] R. Daschner, et al., *Opt. Lett.* **37**, 2271 (2012)
[3] J. Schmidt, et al., *AMFPD* **24**, 296-298 (2017)

Q 41.3 Wed 14:30 K 0.011

Rydberg molecules for ion-atom scattering in the ultracold regime — •Thomas Schmid[1], Christian Veit[1], Nicolas Zuber[1], Thomas Dieterle[1], Christian Tomschitz[1], Robert Löw[1], Michal Tarana[2], Michal Tomza[3], and Tilman Pfau[1] — [1]5. Physikalisches Institut & Center for Integrated Quantum Science and Technology, Universität Stuttgart, Germany — [2]J. Heyrovskzý Institute of Physical Chemistry of the ASCR, Prague, Czech Republic — [3]Centre of New Technologies & Faculty of Physics, University of Warsaw, Poland

We propose a novel experimental method to extend the investigation of ion-atom collisions from the so far studied cold regime to the unexplored ultracold regime [1]. Key aspect of this method is the use of Rydberg molecules to initialize the ultracold ion-atom scattering event. We exemplify the proposed method with the lithium ion-atom system, for which we present simulations of how the initial Rydberg molecule wavefunction, freed by photoionization, evolves in the presence of the ion-atom scattering potential. We predict bounds for the ion-atom scattering length from *ab initio* calculations of the interaction potential. We demonstrate how the scattering length can be experimentally determined from the scattered wavepacket. Finally, we present our ultracold Rb-Li Rydberg setup containing an ion microscope and a delay-line detector to allow for the temporally and spatially resolved detection of the scattered ion-atom wavepacket.

[1] T. Schmid et al.; *arXiv* 1709.10488 (2017).

Q 41.4 Wed 14:45 K 0.011

Epidemic dynamics in open quantum spin systems — Carlos Perez-Espigares[1], •Matteo Marcuzzi[1], Ricardo Gutierrez[1,2], and Igor Lesanovsky[1] — [1]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, UK — [2]Complex Systems Group, Universidad Rey Juan Carlos, 28933 Móstoles, Madrid, Spain

We derive a simple epidemic spreading process to describe the nonequilibrium dynamics of an open many-body system, motivated by recent experiments realised with strongly-interacting gases of highly-excited (Rydberg) atoms, in which the facilitated excitation of Rydberg states competes with radiative decay in a three-level structure. This is approximately mapped onto a population dynamics model where individuals can be either healthy, infected or immunised, and which displays a continuous phase transition from a regime where the epidemic stops to one where instead it can continue spreading indefinitely. The study of the strongly-dephased (classical) regime displays signatures of this continuous phase transition, whereas a preliminary analysis of the weakly-dephased (quantum) regime suggests a shift to a sequence of discontinuous jumps. We discuss the limitations of our modelling imposed by a more realistic setting of laser-driven Rydberg atoms, with a particular focus on the role of the long-range tails of the interactions.

Q 41.5 Wed 15:00 K 0.011

Multi-excitons in flexible Rydberg aggregates — •Ghassan Abumwis[1,2] and Sebastian Wüster[1,2,3] — [1]mpipks, Dresden, Germany — [2]Bilkent University, Ankara, Turkey — [3]IISER, Bhopal, India

Flexible Rydberg aggregates are ensembles of Rydberg atoms that are allowed to move, they provide a platform to investigate quantum phenomena like energy transport and conical intersections. This can be achieved by doping the aggregate with an excitation, an excited state that is energetically higher but close to the primary Rydberg state, leading to the resonant dipole-dipole interaction becoming dominant. Consequently, the excitation is delocalized throughout the aggregate creating excitons.

We follow up on previous results and add a second excitation to the aggregate. We demonstrate that products of excitons can be used to express biexciton states for a chain with a dislocation at one end, a one-dimensional aggregate with equal spacing between atoms except for the last two. Moreover, we show that non-adiabatic effects can be made prominent in flexible Rydberg chains. Finally, we analyze the interaction between two excitation pulses based on the initial biexciton state and the presence of a dislocation. Our findings further enlarge the pool of Born-Oppenheimer surfaces for quantum transport that can be engineered in flexible Rydberg aggregates.

Q 41.6 Wed 15:15 K 0.011

Experimental realization of an Optical Feshbach resonance using ultra-long range Rydberg molecules — •Oliver Thomas[1,2], Carsten Lippe[1], Tanita Eichert[1], and Herwig Ott[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

Over the last decades Feshbach resonances in ultra cold atomic gases have lead to some of the most important advances in atomic physics. Not only did they enable ground breaking work in the BEC-BCS crossover regime, but they are also a widely used tool for the association of ultra cold molecules. Leading to the observation of the first molecular Bose-Einstein Condensates and the emergence of ultra cold dipolar molecular systems. We show the experimental realization of optical Feshbach resonances using ultra-long range Rydberg molecules and demonstrate their practical use by tuning the revival time of a quantum many-body system quenched into a deep optical lattice. We believe this opens up a complete new field of Feshbach resonances as ultra-long range Rydberg molecules have a plenitude of available resonances for nearly all atomic species.

Q 41.7 Wed 15:30 K 0.011

Pendular states of butterfly Rydberg molecules — •Carsten Lippe[1], Oliver Thomas[1,2], Tanita Eichert[1], and Herwig Ott[1] — [1]Department of Physics and research center OPTIMAS, University of Kaiserslautern — [2]Graduate School Materials Science in Mainz, Staudingerweg 9, 55128 Mainz

Butterfly Rydberg molecules are a special class of Rydberg molecular

states arising from a shape resonance in the p-wave scattering channel of a ground state atom and a Rydberg electron. They owe their name to the shape of the electronic wavefunction which resembles the shape of a butterfly.

We have performed high resolution photoassociation spectroscopy of uv-excited deeply bound butterfly Rydberg molecules of ^{87}Rb. We find states bound up to -50GHz from the $25\mathrm{P}_{1/2}, F = 1$ and $25\mathrm{P}_{1/2}, F = 2$ state, corresponding to bond lengths of $50\,a_0$ to $500\,a_0$.

Due to strong admixture of high angular momentum states the butterfly Rydberg molecules feature giant permanent electric dipole moments of hundreds of Debye which allow us to resolve the rotational structure of the Rydberg molecules and observe pendular states. This enables an unprecedented degree of control over the orientation of dipolar molecules even in weak electric fields.

Furthermore, the identification of different structures of pendular state spectra which can be attributed to different total angular momentum projections helps to map the detected molecular bound states to the corresponding potential energy curves.