Q 32: Ultra-cold plasmas and Rydberg systems (joint session A/Q)

Time: Wednesday 14:00–16:00 Location: S HS 1 Physik

Q 32.1 Wed 14:00 S HS 1 Physik

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

We demonstrate the applicability of a new kind of gas sensor based on Rydberg excitations. From a gas mixture 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 a detection limit of 100 ppb to a background of N_2. For a real life application, we employ our gas sensing scheme to the detection of nitric oxide at thermal temperatures and atmospheric pressure [3]. We are planning to reduce the detection limit to 1 ppb using state of the art cw lasers for the Rydberg excitation of NO. This is a competitive value for applications in breath analysis and environmental sensing.

[1] D. Barredo, et al., *Phys. Rev. Lett.* **110**, 123002 (2013)
[2] J. Schmidt, et al., *SPIE* **10674** (2018)
[3] J. Schmidt, et al., *Appl. Phys. Lett.* **113**, 011113 (2018)

Q 32.2 Wed 14:15 S HS 1 Physik

Alignment of *s*-state Rydberg molecules in magnetic fields — •Frederic Hummel[1], Christian Fey[1], and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We unravel some peculiar properties of ultralong-range Rydberg molecules formed by an *s*-state ^{87}Rb Rydberg atom and a corresponding ground-state atom whose electronic orbitals are spherically symmetric and therefore should not be influenced by the presence of weak magnetic fields. However, the electron-atom interaction, which establishes the molecular bond, is under certain conditions subject to a sizeable spin-orbit coupling and, hence, sensitive to the magnetic field. This mechanism can be harnessed to counterintuitively align the *s*-state molecules with respect to the field axis. We demonstrate this by analyzing the angular-dependent Born-Oppenheimer potential energy surfaces and the supported vibrational molecular states. Our predictions open novel possibilities to access the physics of relativistic electron-atom scattering experimentally.

Q 32.3 Wed 14:30 S HS 1 Physik

Decay dynamics of P-state Rydberg molecules — •Tanita Eichert[1], Carsten Lippe[1], Oliver Thomas[1,2], Thomas Niederprüm[1], and Herwig Ott[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, 67663 Kaiserslautern, Germany

Rydberg molecules are formed when a ground state atom binds into the oscillatory potential resulting from a scattering interaction between this ground state atom and the highly excited electron of a Rydberg atom. The observation of different lifetimes characterizing each molecule gives reason to investigate the dynamics of Rydberg molecules as well as the relation between the lifetime and the bound state in a potential well. We use time-of-flight spectroscopy of different molecular states adiabatically connected to the Rubidium 25P-state to obtain time resolved ion signals representing the molecular decay. We describe the dynamics in a rate model and identify the different decay channels. From this we find that the molecule lifetimes are in addition to the decay processes of the atomic Rydberg state, determined by the tunneling process of the bound ground state atom to smaller internuclear distance. For different molecular states the tunneling rates range between 10kHz to beyond 1MHz. Since in our intuitive expectation the tunneling rate is connected to the binding depth in a potential well, the lifetime is reduced for high lying molecular states and similar to the atomic Rydberg state for molecules deeply bound in the potential well.

Q 32.4 Wed 14:45 S HS 1 Physik

Localization, scarring, and the effects of disorder on Rydberg atoms and other excited systems — •Matthew Eiles, Alexander Eisfeld, and Jan-Michael Rost — Max Planck Institut fur Physik komplexer Systeme

Due to their intrinsic properties, such as a high density of states and strong coupling to external perturbations, excited states of separable quantum systems provide intriguing opportunities with which to explore the relationship between quantum and classical physics and wave function localization. Rydberg atoms are perhaps the most common example of such excited systems in atomic physics, while other excited systems include quantum dots and optical microcavities. These excited states can be strongly modified in the presence of disordered impurities which break the symmetry of the unperturbed Hamiltonian. Two recent examples of this are the "trilobite" state of a Rydberg molecule and the "perturbation-induced scars" recently studied theoretically in 2D potentials [1]. We attempt to understand the commonalities between these systems and provide a framework revealing the classical physics underlying these perturbed quantum excited states. We also explore if this behavior can be connected to Anderson-like localization, drawing on the analogies between the highly excited wave functions in disordered potentials and the properties of electron transport in solids.

[1] P. J. Luukko and J. M. Rost, Phys. Rev. Lett. 119, 203001 (2017)

Q 32.5 Wed 15:00 S HS 1 Physik

High-resolution spectroscopy of ^{39}K atoms and ^{39}K$_2$ long-range Rydberg molecules — •Michael Peper[1], Frédéric Merkt[1], and Johannes Deiglmayr[1,2] — [1]Laboratory of Physical Chemistry, ETH Zurich, Vladimir-Prelog-Weg 2, 8093 Zurich, Switzerland — [2]Felix-Bloch-Institut, Universität Leipzig, Linnéstraße 5, 04103 Leipzig, Germany

The interaction of a Rydberg atom with a ground-state atom can be treated using scattering theory, which predicts oscillatory interaction potentials. These interaction potentials may support bound states of diatomic molecules, called long-range Rydberg molecules [1,2,3].

I will present accurate values for the ionization potential and quantum defects of the *s*, *p*, *d*, *f* and *g* series of ^{39}K, obtained by precision spectroscopy using frequency-comb-referenced ultraviolet and millimeter-wave radiation. The results of the spectroscopy of atomic potassium where used in the theoretical modeling and the first experimental determination of the binding energies of ^{39}K$_2$ long-range Rydberg molecules. These studies reveal a regime with strong hyperfine-induced mixing [3,4].

[1] C. H. Greene, A. S. Dickinson, and H. R. Sadeghpour, Phys. Rev. Lett. 85, 2458 (2000). [2] V. Bendkowsky et al., Nature 458, 1005 (2009). [3] H. Saßmannshausen, F. Merkt, and J. Deiglmayr, Phys. Rev. Lett. 114, 133201 (2015). [4] D. A. Anderson, S. A. Miller, and G. Raithel, Phys. Rev. A 90, 062518 (2014).

Q 32.6 Wed 15:15 S HS 1 Physik

Coupling Rydberg atoms and superconducting coplanar resonators — •Conny Glaser, Manuel Kaiser, Lőrinc Sárkány, Jens Grimmel, Reinhold Kleiner, Dieter Kölle, and József Fortágh — CQ Center for Quantum Science, Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen

The creation of hybrid systems consisting of Rydberg atoms and coplanar superconducting resonators has been proposed to enable efficient state transfer between solid state systems and ultracold atoms. Due to the large dipole moment of Rydberg atoms, the coupling strength to the cavity is expected to be much larger than for ground state atoms. At the same time, Rydberg states are strongly affected by any detrimental fields, such as the electric field of adsorbates on the chip-surface, which lead to spatially inhomogeneous energy shifts. We aim to transfer population between neighbouring Rydberg states using the microwave field of a driven coplanar waveguide resonator on a superconducting atom chip. The state transfer in the presence of adsorbate fields is detected via selective field ionisation. Ultimately, this method

may aid in the observation of Rabi oscillations between neighbouring Rydberg states.

Q 32.7 Wed 15:30 S HS 1 Physik

Experimental realization of a symmetry protected topological phase of interacting bosons with Rydberg atoms — Sylvain de Léséleuc[1], Vincent Lienhard[1], Pascal Scholl[1], Daniel Barredo[1], •Sebastian Weber[2], Nicolai Lang[2], Hans Peter Büchler[2], Thierry Lahaye[1], and Antoine Browaeys[1] — [1]Laboratoire Charles Fabry, Institut d'Optique Graduate School, CNRS, Université Paris-Saclay, France — [2]Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, University of Stuttgart, Germany

The paradigm of Landau symmetry breaking has proven very successful for characterizing phases of matter. However, not all phases follow this paradigm: some of them are characterized in the framework of topological phases, which is a powerful concept to characterize ground states of quantum many-body systems. While a few topological phases appear in condensed matter systems (such as quantum Hall states), a current challenge is the implementation and study of such phases in artificial matter. Here, we report the experimental realization of a symmetry protected topological phase of interacting bosons in a one-dimensional lattice, and demonstrate a robust ground state degeneracy attributed to protected edge states. The setup is based on atoms trapped in an array of optical tweezers and excited into Rydberg levels, which gives rise to hard-core bosons with an effective hopping by dipolar exchange interaction.

Q 32.8 Wed 15:45 S HS 1 Physik

Quantum gas microscopy of Rydberg macrodimers — •Simon Hollerith[1], Jun Rui[1], Johannes Zeiher[3], Antonio Rubio-Abadal[1], Valentin Walther[2], Thomas Pohl[2], Dan M. Stamper-Kurn[3], Immanuel Bloch[1,4], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]Department of Physics and Astronomy, Aarhus University, DK 8000 Aarhus C, Denmark — [3]Department of Physics, University of California, Berkeley, CA 94720, USA — [4]Fakultät für Physik, Ludwig-Maximilians-Universität München, 80799 München, Germany

Rydberg macrodimers - molecules consisting of two bound highly-excited Rydberg atoms - provide enormous bond lengths even resolvable with optical wavelengths. Here we report on the microscopic observation, characterization and control over the formation of such Rydberg macrodimers in a gas of ultracold atoms in an optical lattice. The huge size of about 0.7 micrometers matches the diagonal distance of two atoms in the lattice. Starting from a two-dimensional array of one atom per site, the discrete spatial density provided by atoms in their motional ground state combined with a narrow-linewidth ultraviolet laser enables the resolved two-photon photoassociation of more than 50 theoretically predicted vibrational states. Using our spatially resolved detection, we observe the macrodimers by correlated atom loss and demonstrate control of the molecular alignment by the vibrational state and the polarization of the excitation light. Our results allow for a detailed test of Rydberg interactions and establish quantum gas microscopy as a powerful tool for quantum chemistry.