A 27: Ultra-cold Plasmas and Rydberg Systems I (joint session A/Q)

Time: Thursday 11:00–12:45 Location: HS PC

Invited Talk A 27.1 Thu 11:00 HS PC

High precision spectroscopy of trilobite Rydberg molecular series — •Richard Blättner[1], Markus Exner[1], Rohan Srikumar[2], Matt Eiles[3], Peter Schmelcher[2], and Herwig Ott[1] — [1]RPTU Kaiserslautern-Landau — [2]Zentrum für Optische Quantentechnologien, Universität Hamburg — [3]Max Planck Institut für Physik komplexer Systeme

Trilobite Rydberg molecules consist of a highly excited Rydberg atom and a perturber atom in the electronic ground state. The underlying binding mechanism is based on the scattering interaction between the Rydberg electron and the perturber. These molecules exhibit extreme properties: their dipole moments are in the kilo-Debye range, and their molecular lifetimes may exceed the lifetimes of the close by atomic Rydberg states. We use three-photon photoassociation and a reaction microscope to perform momentum-resolved spectroscopy on trilobite ^{87}Rb Rydberg molecules for principal quantum numbers $n = 22, 24, 25, 26, 27$. The large binding energies and the high spectroscopic resolution of 10^{-4} allow us to benchmark theoretical models. Previous models relied on exact diagonalization, which suffered from basis-dependent convergence problems. Using a recent basis-independent theoretical method based on Green's functions, which accounts for all relevant spin interactions, we fit the measured spectra. This enables a new estimate of the involved low-energy scattering lengths. However, with the precision of our experiment, we encounter conceptual issues, suggesting that the fundamental modeling of the molecular Hamiltonian has reached the limits of its predictive power.

A 27.2 Thu 11:30 HS PC

Impact of micromotion on the excitation of Rydberg states of ions in a Paul trap — Wilson Santana Martins[1], •Joseph William Peter Wilkinson[1], Markus Hennrich[2], and Igor Lesanovsky[1,3] — [1]Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany — [2]Department of Physics, Stockholm University, SE-106 91 Stockholm, Sweden — [3]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, United Kingdom

Trapped ions are among the most advanced platforms for quantum simulation and computation. Their capabilities can be further enhanced by making use of electronically highly excited Rydberg states. So far, most experimental and theoretical studies focus on the Rydberg excitation of ions in Paul traps. These generate confinement by a combination of static and oscillating electric fields, which need to be carefully aligned to minimize micromotion. In this talk, we briefly discuss the results in Ref. [1], which aim to understand the impact of micromotion on the Rydberg excitation spectrum when the symmetry axes of the electric fields do not coincide. This is important in the case of field misalignment and is inevitable for Rydberg excitations in 2D and 3D ion crystals. We developed a model describing a trapped Rydberg ion, which we solved using Floquet and perturbation theory. We calculated the excitation spectra and analyzed in which parameter regimes energetically isolated Rydberg lines persist, which are an important requirement for conducting coherent manipulations.

[1] W. S. Martins et al., arXiv:2410.24047 (2024)

A 27.3 Thu 11:45 HS PC

Resonant stroboscopic Rydberg dressing: electron-motion coupling and multi-body interactions — •Chris Nill[1,2], Sylvain de Léséleuc[3,4], Christian Gross[5], and Igor Lesanovsky[1] — [1]Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany — [2]Institute for Applied Physics, University of Bonn, Wegelerstraße 8, 53115 Bonn, Germany — [3]Institute for Molecular Science, National Institutes of Natural Sciences, 444-8585 Okazaki, Japan — [4]RIKEN Center for Quantum Computing (RQC), 351-0198 Wako, Japan — [5]Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany

Rydberg dressing traditionally refers to a technique where interactions between cold atoms are imprinted through the far off-resonant continuous-wave excitation of high-lying Rydberg states. Dipolar interactions between these electronic states are then translated into effective interactions among ground state atoms. Motivated by recent experiments, we investigate two dressing protocols, in which Rydberg atoms are resonantly excited in a stroboscopic fashion [1]. The first one is non-adiabatic, meaning Rydberg states are excited by fast pulses. In this case, mechanical forces among Rydberg atoms result in electron-motion coupling, which generates effective multi-body interactions. In the second, adiabatic protocol, Rydberg states are excited by smoothly varying laser pulses. We show that also in this protocol, substantial multi-body interactions emerge.

[1] C. Nill et al., arXiv:2411.10090 (2024).

A 27.4 Thu 12:00 HS PC

A Floquet-Rydberg quantum simulator for confinement in $\mathbb{Z}_2$ gauge theories — •Enrico Domanti[1,2,3], Dario Zappalà[3,4], Alejandro Bermudez[5], and Luigi Amico[1,2,3] — [1]Technology Innovation Institute, Abu Dhabi, United Arab Emirates — [2]University of Catania, Catania, Italy — [3]INFN-Sezione di Catania, Catania, Italy — [4]Centro Siciliano di Fisica Nucleare e Struttura della Materia, Catania, Italy — [5]Instituto de Fisica Teorica, UAM-CSIC, Madrid, Spain

Recent advances in the field of quantum technologies have opened up the road for the realization of small- scale quantum simulators of lattice gauge theories which, among other goals, aim at improving our understanding on the non-perturbative mechanisms underlying the confinement of quarks. In this work, considering periodically-driven arrays of Rydberg atoms in a tweezer ladder geometry, we devise a scalable Floquet scheme for the quantum simulation of the real-time dynamics in a $\mathbb{Z}_2$ LGT, in which hardcore bosons / spinless fermions are coupled to dynamical gauge fields. Resorting to an external magnetic field to tune the angular dependence of the Rydberg dipolar interactions, and by a suitable tuning of the driving parameters, we manage to suppress the main gauge-violating terms and show that an observation of gauge-invariant confinement dynamics in the Floquet-Rydberg setup is at reach of current experimental techniques. Depending on the lattice size, we present a thorough numerical test of the validity of this scheme using either exact diagonalization or matrix-product-state algorithms for the periodically-modulated real-time dynamics.

A 27.5 Thu 12:15 HS PC

Chirality Signatures in Atomic Rydberg States – Experimental State Preparation — •Stefan Aull[1], Steffen Giesen[2], Miles DeWitt[1], Moritz Göb[1], Peter Zahariev[1,3], Robert Berger[2], and Kilian Singer[1] — [1]Experimental Physics 1, Institute of Physics, University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Berger Group, Institute of Chemistry, University of Marburg, Hans-Meerwein-Str. 4. 35043 Marburg, Germany — [3]Institute of Solid State Physics, Bulgarian Academy of Sciences, 72, Tzarigradsko Chaussee, 1784 Sofia, Bulgaria

A protocol for the preparation of chiral orbital Rydberg states in atoms is presented. It has been shown theoretically that using a suitable superposition of hydrogen wave functions, it is possible to construct a state with chiral signature, e.g. in the probability density or probability current density [1]. Circular Rydberg states can be generated and subsequently manipulated with tailored RF pulses under the influence of electric and magnetic fields, so that the desired chiral superposition of hydrogen-like states with corresponding phases can be prepared. The results are intended to be used for chiral discrimination [2] of molecules. The experimental progress is presented. This contribution is a continuation of the submission "Chirality Signatures in Atomic Rydberg States – Conditions and Symmetry Considerations".

[1] A. F. Ordonez and O. Smirnova, Phys. Rev. A, 99, 4, 43416 (2019).
[2] S. Y. Buhmann et al., New J. Phys., 23, 8, 8 (2021).

A 27.6 Thu 12:30 HS PC

Chirality Signatures in Atomic Rydberg States – Conditions and Symmetry Considerations — •Steffen M. Giesen[1], Stefan Aull[2], Miles Dewitt[2], Moritz Göb[2], Peter Zahariev[2], Kilian Singer[2], and Robert Berger[1] — [1]Chemistry Department, Philipps-Universität Marburg, Hans-Meerwein-Str. 4. 35043 Marburg — [2]Experimental Physics 1, Institute of Physics, University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

Chirality in the electronic structure of bound systems is regularly associated with the three-dimensional spatial distribution of nuclei in molecules. But also in atomic systems, states with chiral signatures can be formed as superpositions of the achiral eigenstates of hydrogenic

systems, either due to parity-violating effects [1] or through careful state preparation [2].

We use linear combinations of hydrogenic functions as model systems to identify the conditions for the quantum numbers and relative phases that lead to chirality in such a superposition. Moreover, we show which minimal selection of states enable which diverse chiral signatures and report simple rules for the composition of states with specific chiral signatures. Our model system most naturally applies to Rydberg states, especially in atoms, but can also further the understanding of chirality in molecules and chiral potentials. This topic is continued in the submission "Chirality Signatures in Atomic Rydberg States – Experimental State Preparation".

[1] I. B. Zel'Dovich, Sov. Phys. JETP, 6, 1958, 1184.

[2] A. F. Ordonez and O. Smirnova, Phys. Rev. A, 99, 2019, 043416.