Q 61: Ultra-cold Plasmas and Rydberg Systems II (joint session A/Q)

Time: Thursday 14:30–15:45 Location: HS PC

Q 61.1 Thu 14:30 HS PC

Lamb-Dicke Dynamics of Rydberg Atoms in Optical Tweezers — •Aslam Parvej[1,2], Lia Kley[1,2], and Ludwig Mathey[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]Institut für Quantenphysik, Universität Hamburg, 22761 Hamburg, Germany

Neutral Rydberg atoms trapped in optical tweezer arrays provide a platform for quantum simulators and computation. In this study, we investigate the dynamics of the Lamb-Dicke-coupled internal states of the atoms, which form the logical qubits, in conjunction with the motion of the optical tweezers across different parameter regimes. In this setup, the logical qubit is coupled to a laser with a Rabi frequency, while each atom is also harmonically trapped with a trap frequency. The impact of coherent motion of the optical tweezers on collective non-equilibrium dynamics of the Rydberg atom is explored for varying Lamb-Dicke parameters and resonant Rabi frequencies.

Q 61.2 Thu 14:45 HS PC

Calculating Rydberg interactions with pairinteraction-next — •Johannes Mögerle[1], Frederic Hummel[2], Henri Menke[3], and Sebastian Weber[1] — [1]Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, University of Stuttgart, Germany — [2]Atom Computing, Inc., Berkeley, California — [3]Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

Rydberg atoms are utilized in a variety of experimental applications, including quantum simulations, ultracold chemistry, and quantum information. Their strong and highly tunable interactions via external fields and their inter-atomic distance vector make them a powerful platform for these applications. Many of these experiments are conducted with such high precision that perturbative calculations of the interaction potentials are insufficient, and exact calculations are needed.

In this talk, we present a new version of the pairinteraction software, a tool for calculating the interaction potentials between two Rydberg atoms in arbitrary fields, as well as interesting properties like dipole matrix elements and effective Hamiltonians. The updated pairinteraction version now includes simulations of alkaline earth atoms, described by multichannel quantum defect theory (MQDT), leading to larger Hilbert spaces. These calculations are now feasible due to the improved performance of the C++ backend. Additionally, the new version features a Python package that abstracts the C++ backend, providing users with a high-level and easy-to-use Python interface.

Q 61.3 Thu 15:00 HS PC

Functional Rydberg Complexes in the VdW Model — •Simon Fell — ITP 3 - Uni Stuttgart

We consider the construction of functional Hilbert spaces characterized by local constraints as the low-energy sector of a microscopic system of Rydberg atoms. The construction of such Hilbert spaces provides a path towards the realization of quantum phases with topological order or geometric programming in the NISQ era. We consider realistic, algebraic decaying Van der Waals (VdW) interactions and compare with previous studies performed within the PXP blockade approximation. We present tools to tackle the residual interactions and introduce a versatile set of efficient elementary building blocks to implement the constraints, both in two and in three dimensions. We illustrate the limitations imposed by the VdW interactions on lattice realizations of string-net Hilbert spaces with loop degrees of freedom on the Rydberg platform.

Q 61.4 Thu 15:15 HS PC

Nonlinear effects on the transport of fractional charges in quantum wires — •Flavia Braga Ramos[1], Rodrigo Gonçalves Pereira[2], Sebastian Eggert[1], and Imke Schneider[1] — [1]Physics Department and Research Center OPTIMAS, University of Kaiserslautern-Landau, Kaiserslautern, Germany — [2]International Institute of Physics and Departamento de Física Teórica e Experimental, Universidade Federal do Rio Grande do Norte, Natal, Brazil

We investigate the transport properties of one-dimensional systems beyond linear response, focusing on the fractionalization of propagating charges. Starting from a right-moving unit charge, we predict its evolution into at least three distinct stable parts: a fractionally charged particle with freeparticle dynamics, a left-moving signal, and a right-moving low-energy excitation, which can carry positive or negative charge depending on the interaction strength and energy regime. Our findings provide deep insights into the universal correlated nature of these emergent particles and pave the way for out-of-equilibrium transport measurements, offering a direct method to extract the interaction parameters governing correlations in the system.

Q 61.5 Thu 15:30 HS PC

Ground State Cooling of a Single Beryllium Ion in a Superconducting Paul Trap — •Stepan Kokh, Vera M. Schäfer, Elwin A. Dijck, Christian Warnecke, José R. Crespo López-Urrutia, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg

Spectroscopy of ions and atoms for generalized King Plot analysis allows for the search of new physics, such as unknown particles or forces, using one of the most precisely measurable quantities, the transition frequency of an atom. Employing highly charged ions (HCI) greatly increases the number of available transitions through the different charge states [1]. This method requires high precision. Therefore, suppression of external perturbations is essential. Our superconducting Paul trap shields external fields by 57 dB, a level comparable to dedicated magnetically shielded rooms [2]. However, the current setup limits our secular frequencies due to thermal effects in the Paul trap resonator. Therefore, we operate only in an intermediate Lamb-Dicke regime at $\eta = 0.84$. We demonstrate how we nevertheless achieve ground-state cooling of a single beryllium ion with 80 % ground-state population in the given setup as a first step towards quantum logic spectroscopy of HCI.

[1] Nils-Holger Rehbehn, et al., Phys. Rev. Lett. 131, 161803 (2023)
[2] Elwin A. Dijck, et al., Rev. Sci. Instrum. 94, 083203 (2023)