# Q 67: Rydberg Systems (joint session Q/A)

Time: Friday 10:30–11:45 Location: Q-H14

Q 67.1 Fri 10:30 Q-H14

**Trapped Rydberg Ions in Motional States for Quantum Computation and Sensing** — •Jonas Vogel[1], Alexander Schulze-Makuch[1], Marie Niederländer[1], Bastien Gely[2], Arezoo Mokhberi[1], and Ferdinand Schmidt-Kaler[1,3] — [1]QUANTUM, Institut für Physik, Universität Mainz, D-55128 Mainz, Germany — [2]ENS Paris-Saclay, 91190 Gif-sur-Yvette, France — [3]Helmholtz-Institut Mainz, D-55128 Mainz, Germany

Cold and controlled atoms and ions are currently of great interest for applications in quantum information processing, simulation and sensing. Excitation of trapped ions to their Rydberg states offers a unique opportunity for combining advantages of precisely controllable trapped-ion qubits with long-range and tunable Rydberg interactions [1]. Intrinsically large polarizabilities of Rydberg states result in enhanced electric field sensitivity to generate entanglement in sub-$\mu$s timescales [2]. Here, we present two-photon spectroscopy on high lying Rydberg states of $^{40}Ca^{+}$ ions for precise determination of the second ionization energy as well as principal quantum number scaling for blackbody induced ionization and depopulation rates [3]. We introduce a model to simulate the transition lineshape and study phonon number induced frequency shifts. Finally, we excite large coherent states of motion to extract the Rydberg state polarizability, a prerequisite for using Rydberg ions as electric field sensors.

[1] Mokhberi et al., Adv. At., Mol., Opt. Phys. Ch.4, 69 (2020)
[2] Vogel et al., Phys. Rev. Lett. 123, 153603 (2019)
[3] Andrijauskas et al., Phys. Rev. Lett. 127, 203001 (2021)

Q 67.2 Fri 10:45 Q-H14

**Structure and dynamics of cesium long-range Rydberg molecules** — •Michael Peper, Ali-Dzhan Ali, Martin Trautmann, and Johannes Deiglmayr — Leipzig University, Department of Physics and Geosciences, 04103 Leipzig, Germany

Long-range Rydberg molecules (LRMs) are exotic bound states of a Rydberg atom and a ground-state atom within its orbit. Because their structure is very sensitive to the elastic electron–ground-state-atom scattering phase shifts, precision measurements and accurate theoretical modelling may provide a unique possibility to test quantum scattering theories for such systems at extremely low collision energies [1]. A detailed understanding of the structure of LRMs is also a prerequisite for the proposed creation of ultracold neutral plasmas with equal-mass charges via photoassociation (PA) and stimulated charge-transfer of LRMs [2,3].

In this talk I will present recent results on the modelling of experimental PA spectra using an accurate Hamiltonian [4] and optimized scattering phase shifts. I will discuss in detail the characterization of molecular decay processes and the role of Stark-facilitated excitation of Rydberg atoms at molecular PA resonances.

[1] M. Peper, J. Deiglmayr, Phys. Rev. Lett. 126, 013001 (2021) [2] M. Peper, J. Deiglmayr, J. Phys. B 53, 064001 (2020) [3] F. Hummel *et al.*, New J. Phys. 22, 063060 (2020) [4] M. Eiles, C. Greene, Phys. Rev. A 95, 042515 (2017)

Q 67.3 Fri 11:00 Q-H14

**Hamiltonian Engineering of a many-body Rydberg-spin system** — •Sebastian Geier[1], Nithiwadee Thaicharoen[1,2], Clément Hainaut[1,3], Titus Franz[1], Andre Salzinger[1], Annika Tebben[1], David Grimshandl[1], Gerhard Zürn[1], Matthias Weidemüller[1], Pascal Scholl[4], Hannah J. Williams[4], Guillaume Bornet[4], Loic Henriet[5], Adrien Signoles[5], Florian Wallner[4], Daniel Barredo[4], Thierry Lahaye[4], and Antoine Browaeys[4] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Physikalisches Institut, Im Neuenheimer Feld 226 — [3]Université Lille, CNRS, UMR 8523 -PhLAM- Physique des Lasers, Atomes et Molécules, Lille, France — [4]Université Paris-Saclay, Institut d'Optique Graduate School, CNRS, Laboratoire Charles Fabry, 91127 Palaiseau Cedex, France — [5]Pasqal, 2 avenue Augustin Fresnel, 91120 Palaiseau, France

Using time-periodic driving, we present how a naturally given many-body Hamiltonian of a quantum system can be transformed into an effective target Hamiltonian. We demonstrate such Floquet engineering with a Rydberg-spin system in different spatial geometries. Applying a sequence of spin manipulations, we change the interaction parameters of the effective XYZ Hamiltonian. In a 3D disordered configuration with hundreds of spins, we explore the conservation laws associated to engineered symmetries. In complementary experiments, we apply the engineering to a 1D array of ordered atoms and benchmark the technique for the case of two atoms. Furthermore, we explore the transport behavior of a domain wall state for tunable XXZ Hamiltonians.

Q 67.4 Fri 11:15 Q-H14

**Controlled Dephasing and Unequal Time Correlations in Rydberg Qubits** — •Andre Salzinger[1], Kevin T. Geier[2,3], Titus Franz[1], Sebastian Geier[1], Nithiwadee Thaicharoen[4], Annika Tebben[1], Clément Hainaut[5], Robert Ott[3], Martin Gärttner[1], Gerhard Zürn[1], Philipp Hauke[2], and Matthias Weidemüller[1] — [1]Physikalisches Institut Heidelberg — [2]University of Trento — [3]Institut für Theoretische Physik Heidelberg — [4]Chiang Mai University — [5]Université Lille

Engineering open system dynamics relies on restricted degrees of freedom of a larger system. Equivalently, master equations can be derived by averaging over realisations of stochastic processes. We present experimental results for qubit rotations subjected to random phase walks, which are sampled from 1D Brownian motion. The observed realisation average follows a Lindblad description with decay parameter $\gamma$ given by the variance of sampled phase walks. We use this controlled dephasing in a linear-response scheme to extract the unequal-time anticommutator in an ensemble of driven two-level systems by coupling to an ancilla level. This acts as a first benchmark for future measurements in many-body systems far from equilibrium, where unequal-time commutator and anticommutor probe fluctuation-dissipation relations.

Q 67.5 Fri 11:30 Q-H14

**Quantum transport enabled by non-adiabatic transitions** — Ajith Ramachandran[1], Alexander Eisfeld[2], •Sebastian Wüster[1], and Jan-Michael Rost[2] — [1]Indian Institute of Science Education and Research, Bhopal — [2]Max Planck Institute for the Physics of Complex Systems, Dresden

Quantum transport of charge or energy in networks with discrete sites is a core feature of diverse prospective quantum technologies, from molecular electronics over excited atoms to photonic metamaterials. In many of these examples, transport can be affected by motion of the sites or coupling to phonons.

The Born-Oppenheimer surfaces of the hybrid Rydberg chain with side-unit (Fano-Anderson chain), are shown to inherit characteristics from both constituents: A dense exciton band from the regular chain with added avoided crossings or conical intersections. Using time dependent quantum wave packets, we demonstrate that these features enable a setting in which only a mobile, symmetric side unit permits quantum transport on the regular chain, while transport is blocked without motion or for a distorted side unit [1]. This provides an example for functional synthetic Born-Oppenheimer surfaces with possible uses for temperature sensing in molecular electronics, through the sensitive linkage between molecular motion and quantum transport [2].

[1] A. Ramachandran, A. Eisfeld, S. Wüster, J. M. Rost; ArXiv (2022).
[2] A. Ramachandran, M. Genkin, A. Sharma, A. Eisfeld, S. Wüster, J. M. Rost; PRA 104 (2021) 042219.