Q 56: Ultra-cold plasmas and Rydberg systems III (joint session A/Q)

Time: Friday 11:00–13:00 Location: b305

Invited Talk Q 56.1 Fri 11:00 b305
Coherent facilitation dynamics in Rydberg atomic lattice quantum simulators — •Paolo Pietro Mazza[1], Richard Schmidt[2,3], and Igor Lesanovsky[1,4] — [1]Institute of Theoretical physics, University of Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany — [2]Max-Planck-Institute of Quantum Optics, Hans-Kopfermann-Strasse, 1, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 München, Germany — [4]School of Physics and Astronomy and Centre for the Mathematics and Theoretical Physics of Quantum Non-Equilibrium Systems, The University of Nottingham, Nottingham, NG7 2RD, United Kingdom

The possibility to precisely control many-body systems at the quantum level has opened the era of quantum simulators. Rydberg atoms held in optical tweezer arrays represent currently one of the most advanced simulator platforms. They are particularly suited for the implementation and study of strongly interacting spin systems. In this talk I will present results on the coherent many-body dynamics in the so-called *facilitation regime*. The focus of my talk is on the understanding of the interplay between Rydberg excitations and lattice vibrations. Using both analytical arguments and numerical simulations, I will show how vibrations of the atoms around their local equilibrium positions can alter the dispersion relation of spin excitations or even leads to their spatial localization.

Q 56.2 Fri 11:30 b305
Entanglement and Critical Dynamics in $(1+1)D$ (Rydberg) Quantum Cellular Automata — •Edward Gillman[1], Federico Carollo[1,2], and Igor Lesanovsky[1,2] — [1]School of Physics and Astronomy,University of Nottingham, Nottingham, NG7 2RD, United Kingdom — [2]Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany

The study of non-equilibrium phase transitions in dissipative quantum many-body systems presents a significant challenge [1,2]. One open problem relates to the relevance of quantum correlations, and particularly entanglement, on critical physics. Recently, quantum cellular automata (QCA) * realisable in quantum simulators based on Rydberg atoms * have been shown to constitute an ideal platform for investigating such questions. In this talk we present a framework for analysing QCA with absorbing states based on projected entangled pairs states. This permits the study and quantification of the effect of entanglement on non-equilibrium dynamics and critical behaviour.

[1] F. Carollo, E. Gillman, H. Weimer, and I. Lesanovsky, Phys. Rev. Lett. 123, 100604 (2019). [2] E. Gillman, F. Carollo, and I. Lesanovsky, New Journal of Physics 21, 093064 (2019).

Q 56.3 Fri 11:45 b305
Fermi surface deformation and pairing of Rydberg-dressed fermions — •Yijia Zhou[1] and Weibin Li[1,2] — [1]School of Physics and Astronomy, University of Nottingham, University Park, Nottingham, NG7 2RD, UK — [2]Centre for the Theoretical Physics and Mathematics of Quantum Non-equilibrium Systems, University of Nottingham, Nottingham, NG7 2RD, UK

Anisotropic long-range interactions in cold Fermi gas have attracted broad interest in studying exotic many-body physics. Previous theories and experiments on magnetic dipolar atoms have revealed distorted Fermi surface, directional zero sound, anisotropic Cooper pair and Wigner crystallisation, etc. In this work, we study the laser dressing of fermions to Rydberg p-states and d-states. Due to the higher angular momentum, the Rydberg-dressed interaction is anisotropic and long-ranged. By controlling the strength and length of the interaction, the anisotropicity is enhanced in a controlled fashion. Focusing on a single component fermion gas, we show that the strong anisotropic interaction alters the many-body ground state, such that the Fermi surface is deformed. When two fermions with opposite momentum are paired through the long-range interaction, they exhibit interesting anisotropic features. We study dependences of the anisotropic physics of the fermion gas on the laser parameter, Rydberg state, and density of atoms.

Q 56.4 Fri 12:00 b305
Precision Spectroscopy of Negative-Ion Resonances in Ultralong-Range Rydberg Molecules — •Thomas Dieterle[1], Felix Engel[1], Frederic Hummel[2], Christian Fey[4], Peter Schmelcher[2,3], Robert Löw[1], Tilman Pfau[1], and Florian Meinert[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart — [2]Zentrum für optische Quantentechnologien, Fachbereich Physik, Universität Hamburg — [3]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg — [4]Max-Planck-Institute of Quantum Optics, Garching

Negative ions constitute remarkable objects that, in contrast to their neutral relatives, are very weakly bound and typically feature only few bound states. Moreover, the level structure of negative ions near the electron detachment limit also dictates the low-energy scattering of an electron with the parent neutral atom.

Here, we demonstrate how ultralong-range Rydberg molecules (ULRM) can be used as an atomic-scale system to precisely probe details of the underlying near-threshold anion states. For the first time, we present measurements of the so-far unobserved fine structure of the $^3\mathrm{P}_J$ triplet of Rb^-. In addition, these measurements allow us to extract s- and p-wave scattering lengths with unprecedented precision and determine the positions of the p-wave shape resonances associated with the $^3\mathrm{P}_J$ fine-structure triplet of Rb^-.

Q 56.5 Fri 12:15 b305
Engineering non-binary Rydberg interactions via electron-phonon coupling — •Filippo Maria Gambetta[1,2], Weibin Li[1,2], Ferdinand Schmidt-Kaler[3,4], and Igor Lesanovsky[1,2] — [1]School of Physics and Astronomy, University of Nottingham, Nottingham, United Kingdom — [2]Centre for the Mathematics and Theoretical Physics of Quantum Non-equilibrium Systems, University of Nottingham, Nottingham, United Kingdom — [3]QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, Mainz, Germany — [4]Helmholtz-Institut Mainz, Mainz, Germany

Coupling electronic and vibrational degrees of freedom of Rydberg atoms held in optical tweezer arrays offers a flexible mechanism for creating and controlling atom-atom interactions. In our work, we demonstrate that the state-dependent coupling between Rydberg atoms and local oscillator modes gives rise to two- and three-body interactions which are controllable through the strength of the local confinement. This approach even permits the cancellation of two-body terms such that three-body interactions become dominant. We analyze the structure of these interactions on two-dimensional bipartite lattice geometries and explore the impact of three-body interactions on system ground state on a square lattice. Our work shows a highly versatile handle for engineering multi-body interactions of quantum many-body systems in most recent manifestations on Rydberg lattice quantum simulators.

Reference: F. M. Gambetta, W. Li, F. Schmidt-Kaler, I. Lesanovsky, arXiv:1907.11664

Q 56.6 Fri 12:30 b305
Engineering Rydberg-spin Hamiltonian using microwave pulse sequences — •Sebastian Geier[1], Nithiwadee Thaicharoen[1], Clement Hainaut[1], Titus Franz[1], Andre Salzinger[1], Annika Tebben[1], Carlos Brandl[1], David Grimshandl[1], Gerhard Zürn[1], and Matthias Weidemüller[1,2] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

We present engineering of general classes of spin Hamiltonians differing from the underlying Rydberg interaction Hamiltonian to experimentally study quantum spin models in an isolated environment. A system of Rydberg atoms in two distinct Rydberg states, interacting via Van der Waals or dipolar interaction, can already be mapped onto a spin system with a Heisenberg XX- and XXZ-Hamiltonian. In order to obtain access to more general classes of XYZ-Hamiltonians, we dynamically engineer terms in the given interaction Hamiltonian using global microwave pulses which couple the two different Rydberg states. With a sequence widely used in nuclear magnetic resonance that is called WAHUHA sequence, we show the ability to transform a system with XX-like interactions into an isotropic XXX-model. Magnetization measurements reveal that this sequence can be used to preserve the magnetization of any arbitrary initial state even if it is far-from-equilibrium. By modifying the delay time between the pulses we implement XXZ-models with different anisotropies and observe their relaxation dynamics.

Q 56.7 Fri 12:45 b305

An optogalvanic flux sensor for trace gases — •Fabian Munkes[1,2], Patrick Kaspar[1,2], Yannick Schellander[1,2], Johannes Schmidt[1,2,4], Denis Djekic[2,3], Patrick Schalberger[2,4], Holger Baur[2,4], Robert Löw[1,2], Tilman Pfau[1,2], Jens Anders[2,3], Norbert Frühauf[2,4], Edward Grant[5], and Harald Kübler[1,2] — [1]5. Physikalisches Institut — [2]Center for Integrated Quantum Science and Technology — [3]Institut für Intelligente Sensorik und Elektrotechnik — [4]Institut für Großflächige Mikroelektronik — [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 becomes ionized and the emerging electron can 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 show first results of cw spectroscopy of the $\mathrm{A}\,{}^2\Sigma^+ \leftarrow \mathrm{X}\,{}^2\Pi_{1/2}$ transition in NO.

[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)