A 1: Cold atoms I - Rydbergs (joint session A/Q)

Time: Monday 10:30–12:00 Location: K 0.011

A 1.1 Mon 10:30 K 0.011

Probing many-body dynamics on a 51-atom quantum simulator — •Ahmed Omran[1], Hannes Bernien[1], Alexander Keesling[1], Harry Levine[1], Sylvain Schwartz[1,2], Hannes Pichler[3,1], Soonwon Choi[1], Markus Greiner[1], Vladan Vuletic[2], and Mikhail D. Lukin[1] — [1]Department of Physics, Harvard University, Cambridge, MA 02138, USA — [2]Department of Physics and Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA — [3]Institute for Theoretical Atomic Molecular and Optical Physics, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA

The realization and control of large-scale quantum systems is an exciting frontier of modern physical science. Using a novel cold atom platform, we trap single neutral atoms in an array of optical tweezers, and use real-time feedback to prepare defect-free chains of tens of atoms in one dimension with a high fidelity and repetition rate [1]. Excitation of the atoms to Rydberg states enables strong and tunable van der Waals interactions over long distances, which allows for engineering an Ising-type Hamiltonian with non-trivial spatial correlations between Rydberg atoms.

The flexibility and controllability of our platform enables us to perform powerful simulations of quantum many-body systems in and out of equilibrium and shed light on the quantum dynamics around different phase transitions and following sudden quantum quenches [2].

[1] M. Endres et al., Science 354, 1024-1027 (2016)

[2] H. Bernien et al., Nature 551, 579-584 (2017)

A 1.2 Mon 10:45 K 0.011

Spin-Interaction Effects for Ultralong-range Rydberg Molecules in a Magnetic Field — •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 investigate the fine and spin structure of ultralong-range Rydberg molecules exposed to a homogeneous magnetic field. Each molecule consists of a ^{87}Rb Rydberg atom whose outer electron interacts via spin-dependent s- and p-wave scattering with a polarizable ^{87}Rb ground state atom. Our model includes also the hyperfine structure of the ground state atom as well as spin-orbit couplings of the Rydberg and ground state atom. We focus on d-Rydberg states and principal quantum numbers n in the vicinity of 40. The electronic structure and vibrational states are determined in the framework of the Born-Oppenheimer approximation for varying field strengths ranging from a few up to hundred Gauß. The results show that the interplay between the scattering interactions and the spin couplings gives rise to a large variety of molecular states in different spin configurations as well as in different spatial arrangements that can be tuned by the magnetic field. We quantify the impact of spin couplings by comparing the extended theory to a spin-independent model.

A 1.3 Mon 11:00 K 0.011

Coupling Rydberg atoms and superconducting resonators — •Helge Hattermann, Li Yuan Ley, Conny Glaser, Daniel Bothner, Benedikt Ferdinand, Lörinc Sárkány, Reinhold Kleiner, Dieter Koelle, and József Fortágh — CQ Center for Quantum Science, Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen

We report on the the coupling between ultracold ^{87}Rb Rydberg atoms and a driven coplanar waveguide resonator on a superconducting atom chip. The superconducting cavity at 20.5 GHz is near-resonant to the transition frequency between Rydberg states. Driven transitions are detected by state selective field ionization of the Rydberg states.

Close to the chip, Rydberg states are strongly affected by the electric field of adsorbates on the chip, leading to spatially inhomogeneous energy shifts.

Coupling Rydberg atoms to coplanar superconducting resonators has been proposed for efficient state transfer between solid state systems and ultracold atoms, the generation of an atomic quantum memory and the implementation of novel quantum gates [1].

[1] L. Sárkány et al., Phys. Rev. A 92, 030303 (2015).

A 1.4 Mon 11:15 K 0.011

Non-equilibrium criticality in driven Rydberg gases — •Graham Lochead[1,2], Stephan Helmrich[1], Alda Arias[1,2], Henrik Hirzler[1], Tobias Wintermantel[1,2], Michael Buchhold[3], Sebastian Diehl[4], and Shannon Whitlock[1,2] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg — [2]Institut de Physique et de Chimie des Matériaux de Strasbourg (IPCMS), University of Strasbourg, France 67200 — [3]California Institute of Technology, 1200 E California Boulevard, CA 91125, Pasadena, U.S. — [4]Institut für Theoretische Physik, Universität zu Köln, D-50937 Cologne

We study the dynamics of well controlled systems of ultracold atoms excited to long-range interacting Rydberg states by an off-resonant laser field. Starting from an initial seed excitation, there is a characteristic distance at which the interaction energy precisely matches the laser detuning, thus facilitating further excitations. This interplay between coherent driving, dissipation and long-range interactions can lead to rich many body dynamics, including self similar evolution and scale invariant behavior. We present experiments on the temporal evolution of the system as a function of the amplitude of the driving field and investigate possible links to paradigmatic non-equilibrium universality classes such as directed percolation and self-organized criticality. This opens a new route to explore non-equilibrium critical phenomena in three-dimensions, and in settings where quantum and classical fluctuations can compete on an equal footing.

A 1.5 Mon 11:30 K 0.011

Accurate Rydberg quantum simulations of spin-1/2 models — •Sebastian Weber[1], Sylvain de Léséleuc[2], Vincent Lienhard[2], Daniel Barredo[2], Thierry Lahaye[2], Antoine Browaeys[2], and Hans Peter Büchler[1] — [1]Institute for Theoretical Physics III, University of Stuttgart, Germany — [2]Laboratoire Charles Fabry, Institut d'Optique, CNRS, Université Paris-Saclay, France

Using non-perturbative calculations of the interaction potentials between two Rydberg atoms taking into account both electric and magnetic fields, we can simulate a broad range of two-atom Rydberg systems. Benchmarks against varied experimental data show an excellent agreement between the simulations and experiments. We apply our simulation procedure to investigate under which experimental conditions spin-1/2 models can be accurately simulated using Rydberg atoms. More specifically, we determine experimental parameters for which a system of atoms that are laser driven to $nD_{3/2}$ Rydberg states and interacting via the van der Waals interaction can be mapped accurately to an Ising-like spin-1/2 model, despite the large number of Rydberg levels involved. Our investigations show the importance of a careful selection of experimental parameters in order not to break the Rydberg blockade mechanism which underlies the mapping. By selecting appropriate parameters, even in a large system of 49 Rydberg atoms, an excellent agreement is achieved between the measured time evolution and the numerically calculated dynamics of the Ising-like spin-1/2 model. This result opens exciting prospects for the realization of high-fidelity quantum simulators of spin Hamiltonians.

A 1.6 Mon 11:45 K 0.011

The impact of ionization laser polarization on spatio-temporal distribution of photoelectrons from Cs atoms in a MOT — •Olena Fedchenko[1], Sergey Chernov[1], Melissa Vielle-Grosjean[2], Gerd Schönhense[1], and Daniel Comparat[2] — [1]Institut für Physik, JGU Mainz, Germany — [2]University Paris-Sud, Orsay, France

We present results of investigation of the properties of a monochromatic photoelectron source based on near threshold photoionization of cold Cs atoms in MOT by time-of-flight momentum microscopy [1]. A 3D-stack of experimental results was obtained under absence of magnetic field. For this purpose a scheme with switched trapping B-field was used in the DC-MOT: 5 ms to load the MOT and 4 ms for excitation (@1470 nm, 1 ms exposition). Measurements were done for different linear polarizations of the ionizing Ti-sapphire fs-laser. Study of near-threshold photoionization with different gradients of the extracting electric field showed that the difference between signals with s- and p-polarization of the ionization light was due to real dichroism and partly due to contribution of field ionization of Rydberg states.

Variation of the bandwidth of the Ti-sapphire laser revealed that in case of broad bandwidth several photoionization paths took place simultaneously. Namely, excitation of Rydberg atoms had place in the combination with subsequent field ionization and photoionization from higher states. To study the energy and time spread of photoelectrons, an accelerator with homogeneous pulsed electric field is proposed.

[1] O. Fedchenko et al., Appl. Phys. Lett, 111, 021104 (2017).