A 32: Rydberg gasses I

Time: Friday 11:00–13:00 Location: HS 20

A 32.1 Fri 11:00 HS 20

Rydberg blockade of excitons in Cu_2O — •Julian Heckötter[1], Marcel Freitag[1], Marc Assmann[1], Tomasz Kazimierczuk[2], Dietmar Fröhlich[1], and Manfred Bayer[1] — [1]Experimentelle Physik 2, TU Dortmund, Dortmund, Germany — [2]Institute of Experimental Physics, University of Warsaw, Warsaw, Poland

In this work we report on absorption measurements on Rydberg-Excitons [1] in Cu_2O with quantum numbers up to $n = 25$. In Cu_2O, excitonic states with an odd angular momentum quantum number, such as P- and F-excitons, are dipole allowed. We study the interaction between P-envelope states of high principal quantum numbers. For non-degenerate states the concept of the Rydberg blockade mechanism [2] is introduced to explain the decrease in absorption for increasing laser powers. We find a scaling of the blockade efficiency as n^{10} in accordance with theory [1].

In recent two-color pump-probe experiments we used two narrow bandwidth dye lasers to investigate the interaction between degenerate states. For high pump powers, we find a decrease in absorption at the resonances of high n but also an enhancement in between. Here, the blockade efficiency shows a n^8 scaling behaviour. In addition, for lower n states, the reduction of absorption is overlayed by an initial increase of the oscillator strengths.

[1] T. Kazimierczuk et al., Nature **514**, (2014), p. 343
[2] E. Urban et. al, Nature Physics **5**, (2009)

A 32.2 Fri 11:15 HS 20

Collective holonomic phase gate by Rydberg-dressed photon blockade — •Felix Motzoi and Klaus Molmer — Aarhus University

We present a scheme for applying a phase gate on an array of neutral atoms, conditioned on all of them being in the same ground state. The gate consist of a geometric phase using the ancillary degrees of freedom given by a cavity and second ensemble of neutral atoms of a different species, via an EIT mechanism to blockade or allow photons to enter the system. All operations are dark with respect to the atoms, of both the quantum register and ancillary species, with far-detuned Rydberg dressing avoiding almost any Rydberg population. This allows for a gate error that scales nearly independently of the total number of quantum registers.

A 32.3 Fri 11:30 HS 20

High-fidelity Rydberg-blockade entangling gate using shaped, analytic pulses — •Lukas Theis[1], Felix Motzoi[1], Frank Wilhelm[1], and Mark Saffman[2] — [1]Theoretical Physics, Saarland University, 66123 Saarbrücken, Germany — [2]Department of Physics, University of Wisconsin-Madison, Wisconsin, USA

We show that the use of shaped pulses improves the fidelity of a Rydberg-blockade two-qubit entangling gate by several orders of magnitude compared to previous protocols based on square pulses or optimal control pulses. Using analytical derivative removal by adiabatic gate (DRAG) pulses that reduce excitation of primary leakage states and an analytical method of finding the optimal Rydberg blockade, we generate Bell states with a fidelity of $F > 0.9999$ in a 300 K environment for a gate time of only 50 ns, which is an order of magnitude faster than previous protocols. These results establish the potential of neutral atom qubits with Rydberg-blockade gates for scalable quantum computation.

A 32.4 Fri 11:45 HS 20

Topological ordering and entanglement of Rydberg atoms in the presence of decoherence — •Durga Bhaktavatsala Rao Dasari[1] and Klaus Moelmer[2] — [1]3. Physikalisches Institut, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany. — [2]Department of Physics and Astronomy, Aarhus University, Ny Munkegade 120, DK-8000, Aarhus C, Denmark.

We investigate the role of topology and decoherence for generating robust many body entanglement in a Rydberg atomic system. Such decoherence assisted entanglement results only when the atoms are arranged on graph like structures with a preferred connectivity. Further, lattice structures that have maximum nearest neighbors of 2 in 1D, 4 in 2D and 6 in 3D always lead to such entanglement. Any defect arrangement that does not satisfy these geometrical constraints can destroy both entanglement and purity in the entire network. We further show how the topologically ordered state of Rydberg atoms can lead to deterministic single photon emission without the requirement for the global Rydberg blockade.

A 32.5 Fri 12:00 HS 20

Stability and instabilities of bosonic crystalline quantum phases of Rydberg dressed lattice gases — •Andreas Geissler[1], Mathieu Barbier[1], Ulf Bissbort[2], Yongqiang Li[3], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Goethe Universität Frankfurt am Main, Germany — [2]Engineering Product Development, SUTD, Singapore — [3]Department of Physics, NUDT, China

Recent experiments have shown the feasibility of Rydberg dressing [1], even in a lattice system [2], thus paving the way towards realizing exotic states of matter in ultracold gases. While our latest results have shown a rich diversity of crystalline and supersolid quantum phases in bosonic lattice systems [3], induced by the strong correlations due to Rydberg dressing, a better understanding of crystallisation is still required. We therefore analyse the instabilities due to quasiparticle excitations, which we determine from linearised Gutzwiller equations. Furthermore, we simulate the dissipative dynamics induced by the finite lifetime of Rydberg states and decoherence effects inherent to these driven systems. The Lindblad master equation is solved within a Gutzwiller mean-field description, which also allows for itinerant dynamics. We thus show the existence of exotic ordered steady states after various parameter sweeps, as well as the stability of these states.

[1] Y.-Y. Jau et al., Nat. Phys. 12, 71-74 (2016)
[2] J. Zeiher et al., arXiv:1602.06313
[3] A. Geißler et al., arXiv:1509.06292

A 32.6 Fri 12:15 HS 20

Reservoir engineering using Rydberg atoms — David W. Schönleber, Christopher D. B. Bentley, and •Alexander Eisfeld — Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden

We apply reservoir engineering to construct a thermal environment with controllable temperature in an ultracold atomic Rydberg system [1]. A Boltzmann distribution of the system's eigenstates is produced by optically driving a small environment of ultracold atoms, which is coupled to a photonic continuum through spontaneous emission. This technique provides a useful tool for quantum simulation of both equilibrium dynamics and dynamics coupled to a thermal environment. Additionally, we demonstrate that pure eigenstates, such as Bell states, can be prepared in the Rydberg atomic system using this method.

[1] D. W. Schönleber et al., arXiv:1611.02914 (2016)

A 32.7 Fri 12:30 HS 20

Bistability vs. Metastability in Driven Dissipative Rydberg Gases — •Oliver Thomas[1,2], Fabian Letscher[1,2], Thomas Niederprüm[1], Michael Fleischhauer[1], and Herwig Ott[1] — [1]Department of Physics and research center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Strasse 47, 67663 Kaiserslautern, Germany

We investigate the possibility of a bistable phase in an open many-body system. To this end we discuss the microscopic dynamics of a continuously off-resonantly driven Rydberg lattice gas in the regime of strong decoherence. Our experimental results reveal a prolongation of the temporal correlations exceeding the lifetime of a single Rydberg excitation and show strong evidence for the formation of finite-sized Rydberg excitation clusters in the steady state. We simulate the dynamics of the system using a simplified and a full many-body rate-equation model. The results are compatible with the formation of metastable states associated with a bimodal counting distribution as well as dynamic hysteresis. Yet, a scaling analysis reveals, that the correlation times remain finite for all relevant system parameters, which suggests a formation of many small Rydberg clusters and finite correlation lengths of Rydberg excitations. These results constitute strong evidence against the presence of a global bistable phase previously suggested to exist in this system.

A 32.8 Fri 12:45 HS 20

Coherent many-body dynamics in Rydberg-dressed spin chains — •Simon Hollerith[1], Johannes Zeiher[1], Antonio Rubio-Abadal[1], Jae-yooni Choi[1], Rick van Bijnen[3], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München, Schellingstraße 4, 80799 München, — [3]Institut für Quantenoptik und Quanteninformation, Technikerstr. 21a, 6020 Innsbruck, Austria

Off-resonant optical coupling of a ground state atom to a Rydberg state, so called "Rydberg-dressing", has been proposed as a versatile method to implement various long-range interacting spin models with ultracold atoms. In our experiment, we realize Rydberg-dressing to implement an Ising spin system, starting with an atomic Mott insulator of Rubidium-87 in an optical lattice with a single atom per site. Using a single photon uv-transition, we couple off-resonantly to a Rydberg p-state. First interferometric experiments in a two-dimensional sample showed the versatility of Rydberg dressing for control of the interactions, however collective loss processes reduced the lifetime of the system. Here, we present results of Rydberg-dressing in a 1d spin chain with long-range Ising interactions. Contrary to the 2d case, the collective loss can be avoided and lifetimes get close to the values expected in an ideal two-level system. We substantiate the improved lifetimes by showing coherent collapse and revival dynamics in the 1d chain. Our results pave the way to study novel symmetry protected topological phases in periodically driven 1d spin chains.