A 21: Ultra-cold plasmas and Rydberg systems II (with Q)

Time: Wednesday 11:00–12:45 Location: C/kHS

A 21.1 Wed 11:00 C/kHS

Bistability in a dissipative Rydberg lattice model — •Dominik Linzner, Michael Höning, and Michael Fleischhauer — Fachbereich Physik and Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

We study bistability in chains of atoms off-resonantly excited to strongly interacting Rydberg states. A novel approach enables simulation of system sizes substantially beyond previous investigations [1] by adapting established numeric methods based on matrix product states to dissipative systems. Whereas simulation of the dissipation free limit is infeasible using such methods, we show that the presence of dissipation renders the approach efficient.

The model gives unique insight into the emergence of bistability and the formation of aggregates in off-resonantly driven Rydberg systems. We quantitatively study the critical behavior of the size of aggregates and its relation to the overall time scale of relaxation. Based on this analysis we discuss the emergence of bimodal probability distributions for the number of excitations in extended systems and clarify the significance of earlier results obtained with a mean field ansatz.

[1] C. Ates et al., Phys. Rev. A, 85, 043620 (2012)

A 21.2 Wed 11:15 C/kHS

Imaging of Microwave Fields with sub-100 μm Resolution in Vapor Cells — •Andrew Horsley, Guan-Xiang Du, and Philipp Treutlein — University of Basel, Switzerland

Microwave devices form an essential part of modern technology, finding application, e.g., in telecommunications and scientific instrumentation. We have developed a technique for imaging microwave magnetic fields using alkali vapor cells, detecting microwaves through Rabi oscillations driven on atomic hyperfine transitions. This could prove transformative in the design, characterisation, and debugging of microwave devices, as there are currently no established microwave imaging techniques. We present results from a new imaging system which provides spatial resolutions of $40-100\,\mu$m, an order of magnitude improvement from our previous proof-of-principle setup. More importantly, our vapor cell allows imaging of fields as close as $150\,\mu$m above structures, through the use of extremely thin external cell walls. This is crucial in allowing us to take practical advantage of our high spatial resolution, as feature sizes in near-fields are on the order of the distance from their source. We demonstrate our system through the imaging of microwave fields above a selection of microwave devices.

Our spatial resolution and approach distance are now sufficient for characterising a range of real world devices at fixed frequencies. However, the development of a broadband imaging technique is essential for wider applications. We also present progress on a frequency-tunable setup, allowing us to image microwaves at any frequency, from sub-GHz to 10s of GHz.

A 21.3 Wed 11:30 C/kHS

Rydberg atoms in hollow-core photonic crystal fibres — •Georg Epple[1,2], Christian Veit[1], Kathrin Kleinbach[1], Tijmen Euser[2], Tilman Pfau[1], Philip Russell[2], and Robert Löw[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany — [2]Max Planck Institute for the Science of Light and Department of Physics, University of Erlangen-Nürnberg, Günther-Scharowsky-Str. 1, 91058 Erlangen, Germany

The exceptionally large polarizability of highly excited Rydberg atoms uniquely enables long-range interactions between atoms, giving rise to phenomena such as the Rydberg blockade. This makes them of great interest as sensitive electric field sensors or for creating optical nonlinearities at the single photon level. A promising route to technically feasible, miniaturized, room-temperature devices is the excitation of Rydberg atoms inside hollow-core photonic crystal fiber (HC-PCF). The confinement of both atoms and light in the hollow core results in perfect atom-light coupling. Recently we demonstrated coherent three-photon excitation to Rydberg states in a caesium vapour confined in both kagomé-style HC-PCFs and capillaries with various core diameters. Spectroscopic signals exhibiting sub-Doppler features were detected for principal quantum numbers up to n = 46. Our studies revealed that the frequencies of the absorption peaks measured in HC-PCF differed from those measured in a reference cell, suggesting interactions between the atoms and the core-walls. Our current goal is to better understand these line-shifts and to get insight into caesium diffusion in the fibres.

A 21.4 Wed 11:45 C/kHS

Effects of anisotropic dipole-dipole interactions on 3D flexible Rydberg aggegrates. — •Karsten Leonhardt, Sebastian Wüster, and Jan Michael Rost — Max Planck Institute for the Physics of Complex Systems

Exciton pulses transport excitation and entanglement adiabatically through flexible Rydberg aggregates [1], assemblies of highly excited light atoms, which are set into directed motion by resonant dipole-dipole interaction [1-4]. In the systems studied so far, the dipole-dipole interaction among the Rydberg atoms was completely isotropic, either enforced by geometry [2-4] or by external fields [5]. Here, we present the dynamics of exciton pulses, taking into account the spatial dependence of the dipole-dipole interaction. We also include fine-structure splitting into our model, which is relevant for Rb experiments.

References

[1] C. Ates, A. Eisfeld, J. M. Rost, *New. J. Phys.* **10**, 045030 (2008).
[2] S. Wüster, C. Ates, A. Eisfeld, J. M. Rost, *Phys. Rev. Lett.* **105**, 195392 (2010).
[3] S. Möbius, S. Wüster, C. Ates, A. Eisfeld, J. M. Rost, *J. Phys. B.* **44**, 184011 (2011).
[4] S. Wüster, A. Eisfeld, J. M. Rost, *Phys. Rev. Lett.* **106**, 153002 (2011).
[5] K. Leonhardt, S. Wüster, J. M. Rost, *Phys. Rev. Lett.* **113**, 223001 (2014).

A 21.5 Wed 12:00 C/kHS

Probing mechanical oscillators with excited atoms — •Adrián Sanz Mora, Alexander Eisfeld, Sebastian Wüster, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, 01187 Dresden, Germany

We investigate the use of electronically excited atoms to control the motion of nano-mechanical oscillators. A setup that exploits the optical response of a three-level ultracold atomic gas can serve as a means to drive the motion of a classically oscillating nano-mirror via electromagnetic radiation. The probe- and control beams that electromagnetically induce transparency (EIT) [1] in the gas, interact also with the vibrating mirror via radiation pressure forces. The control light field is phase-modulated by the mirror vibrations, thus altering the transparency of the atoms with respect to the probe light and leading to the generation of probe light sidebands. The frequency mismatch between the light fields and the atomic resonances can then be adjusted to either cool down or amplify the mirror motion. In another setup, by using highly excited Rydberg states of a beam of atoms one can realize protocols for quantum state reconstruction of mechanical motion [2] thanks to the extreme sensitivity of such atomic states to external perturbers.

[1] M. Fleischhauer, A. Imamoglu, J. P. Marangos, Rev. Mod. Phys. 77, 633 (2005).
[2] M. R. Vanner, I. Pikovski, M. S. Kim, http://arxiv.org/abs/1406.1013 (2014).

A 21.6 Wed 12:15 C/kHS

Modelling spin systems using arrays of single Rydberg atoms — •Henning Labuhn, Sylvain Ravets, Daniel Barredo, Thierry Lahaye, and Antoine Browaeys — Laboratoire Charles Fabry, UMR 8501, Institut d'Optique, CNRS, Univ Paris Sud 11, 2 avenue Augustin Fresnel, 91127 Palaiseau cedex, France

I will present the latest results of our experiment, where we trap single atoms in variable 2D arrays of optical tweezers [1]. By optically coupling the atoms to Rydberg states, i.e. electronic states with a high principle quantum number n, we can engineer strong interactions between the trapped atoms. We then use a microwave field to drive transitions in the Rydberg manifold. Applying such a transition locally on one atom allows us to investigate the coherent propagation of this excitation, which can be fully described by a XY spin Hamiltonian, in the atomic array [2]. The results suggest that arrays of Rydberg atoms are ideally suited to large scale, high-fidelity quantum simulation of spin dynamics.

[1] F. Nogrette, H. Labuhn, S. Ravets, D. Barredo, L. Béguin, A. Vernier, T. Lahaye and A. Browaeys, "Single-Atom Trapping in Holographic 2D Arrays of Microtraps with Arbitrary Geometries", Phys. Rev. **X** 4, 021034 (2014)
[2] D. Barredo, H. Labuhn, S. Ravets, T. Lahaye, A. Browaeys, C. S. Adams, "Coherent Excitation Transfer in a "Spin Chain" of Three Rydberg Atoms", arXiv:1408.1055

A 21.7 Wed 12:30 C/kHS

Photonic phase gates in multi-level Rydberg EIT media — •Callum Murray and Thomas Pohl — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

The interaction of Rydberg polaritons under conditions of electromagnetically induced transparency (EIT) represents a promising route towards realizing a photonic phase gate. The basic principle exploits the establishment of a locally refractive medium for a polariton in response to the conditional presence of another in its vicinity, allowing for the accumulation of a relative phase shift. However, previous studies have shown that high gate fidelities require such large atomic densities that ground state interactions would begin to manifest, bringing with it additional undesired decoherence effects. We report on recent progress in alleviating this issue by considering a modified EIT setting involving an auxiliary ground state. We show that this gives rise to a slowly propagating bright state polariton in response to Rydberg interactions that, in contrast to ladder excitation schemes, enables high fidelity phase gates at moderate densities.