A 43: Ultracold Plasmas and Rydberg Systems IV (with Q)

Time: Friday 14:30–16:00 Location: P/H2

A 43.1 Fri 14:30 P/H2

Controlled interactions between optical photons stored as Rydberg polaritons — •Hannes Busche, Simon W. Ball, Teodora Ilieva, Paul Huillery, Daniel Maxwell, David Paredes-Barato, David J. Szwer, Matthew P. A. Jones, and Charles S. Adams — Joint Quantum Centre (JQC) Durham-Newcastle, Department of Physics, Durham University, South Road, Durham, DH1 3LE, United Kingdom

We are using electromagnetically induced transparency to store photons as Rydberg excitations in a cold atom cloud in order to map their strong and long-ranged dipolar interactions onto the optical field and introduce effective interactions at the single photon level. The application of an external microwave field [1] allows control of the interaction strength, manifesting itself in a modification of the retrieved photon statistics [2].

Recently, we completed a new experimental apparatus that will give us the ability to store single photons in individually addressable sites. In this setup, we aim to study interactions between stored photons in spatially separated channels and explore applications such as the implementation of a universal quantum gate for photonic qubits [3].

[1] D. Maxwell et al., Phys. Rev. Lett. 110, 103001 (2013).
[2] D. Maxwell et al., Phys. Rev. A 89, 043782 (2014).
[3] D. Paredes Barato and C. S. Adams, Phys. Rev. Lett. 112, 040501 (2014).

A 43.2 Fri 14:45 P/H2

Two-photon bound states of Rydberg polaritons — •Matthias Moos, Razmik Unanyan, and Michael Fleischhauer — Fachbereich Physik und Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

We consider the propagation of photons in a medium of Rydberg atoms. Under conditions of electromagnetically induced transparency the photons form strongly interacting massive particles, termed Rydberg polaritons. Recent experiments have realized strong interactions between Rydberg polaritons and shown photon blockade as well as bunching phenomena [1],[2]. We consider an off-resonant coupling of the Rydberg polaritons to the medium. We derive a one-dimensional effective Hamiltonian and find parameter regimes where bound states can be excited near the threshold of the scattering continuum. Using numerical wave-function simulations we show that bound states can be created in a pulsed experiment and analyze their properties and time-evolution inside the medium.

[1] Peyronel et al. Nature 488, 57 (2012)
[2] Firstenberg et al. Nature 502, 71 (2013)

A 43.3 Fri 15:00 P/H2

Dipolar Dephasing of Rydberg D-state Polaritons — •Christoph Tresp[1], Przemyslaw Bienias[2], Sebastian Weber[2], Hannes Gorniaczyk[1], Ivan Mirgorodskiy[1], and Sebastian Hofferberth[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]3. Institut für theoretische Physik, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

We report on our current experiments investigating photon propagation through a cold Rubidium sample, by coupling the ground state to a long lived Rydberg D-state via electromagnetically-induced transparency (EIT). In addition to the strong nonlinearities known from similar experiments carried out with Rydberg S-states, we observe a decay of transmission over time. The rate of this decay strongly depends on the number of photons send into the medium. We attribute this effect to induced dipolar dephasing of Rydberg polaritons, which occurs for nonzero interaction angles of Rydberg pair-states and leads to stationary Rydberg excitations. For further understanding, we model our system by numerically solving the polariton propagation through our system, taking the full interaction problem into account.

A 43.4 Fri 15:15 P/H2

Photon interactions in a laser-driven Rydberg gas — •Dario Jukić, Fabian Maucher, and Thomas Pohl — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden

Electromagnetically induced transparency (EIT) in a system of interacting Rydberg atoms provides a unique platform to explore strong and nonlocal optical nonlinearities, both in the classical and quantum regime. We present our recent progress in understanding the nature of effective photon interactions in such a medium. In the limit of large photon numbers and moderate nonlinearities we discuss the applicability of a mean-field approach for the light field, which is shown to permit an analytical treatment of its propagation dynamics. In the opposite limit, strong correlation effects start to play a dominant role and are explored within few-body quantum calculations. Experimental signatures for the found interaction effects will also be discussed.

A 43.5 Fri 15:30 P/H2

Single-Photon Transistor Based on Rydberg Blockade — •Daniel Tiarks, Simon Baur, Katharina Schneider, Stephan Dürr, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Garching, Deutschland

An all-optical transistor is a device in which a gate light pulse switches the transmission of a target light pulse with a gain above unity. The gain quantifies the change of the transmitted target photon number per incoming gate photon. In Refs. [1,2], we study the quantum limit of one incoming gate photon and observe a gain of 20. The gate pulse is stored as a Rydberg excitation in an ultracold gas. The transmission of the subsequent target pulse is suppressed by Rydberg blockade which is enhanced by a Förster resonance. The detected target photons reveal in a single shot with a fidelity above 0.86 whether a Rydberg excitation was created during the gate pulse. The gain offers the possibility to distribute the transistor output to the inputs of many transistors, thus making complex computational tasks possible.

[1] D. Tiarks et al. PRL 113, 053602 (2014); see also H. Gorniaczyk et al. PRL 113, 053601 (2014).
[2] S. Baur et al. PRL 112, 073901 (2014).

A 43.6 Fri 15:45 P/H2

Single-Photon Transistor Mediated by Interstate Rydberg Interactions — •Hannes Gorniaczyk[1], Christoph Tresp[1], Ivan Mirgorodskiy[1], Johannes Schmidt[1], Helmut Fedder[2], and Sebastian Hofferberth[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Germany — [2]3. Physikalisches Institut, Universität Stuttgart, Germany

We present the realization of an all-optical transistor by mapping gate and source photons into strongly interacting Rydberg excitations with different principal quantum numbers in an ultracold atomic ensemble. A switch contrast of 40% is obtained for a coherent gate input with mean photon number one. We show that over 60 source photons can be attenuated with a single gate photon demonstrating a high-gain optical transistor. We use this optical transistor for the nondestructive detection of a single Rydberg atom with a fidelity of 79%. The read-out of gate photons marks a crucial step for the implementation of quantum information protocols. For this reason, we study the coherence of gate photon spin waves in the context of source-gate interaction.