Non-destructive detection of ensembles of Rydberg atoms with microwave cavity transmission measurements

Sébastien Garcia[1], Mathias Stammeier[1], Johannes Deiglmayr[2], Frédéric Merkt[2], Andreas Wallraff[1]

[1] Department of Physics, ETH Zürich, CH-8093 Zürich, Switzerland
[2] Laboratorium für Physikalische Chemie, ETH Zürich, CH-8093, Zürich, Switzerland

Cavity quantum electrodynamics (QED) provides a powerful tool to realize quantum non-demolition measurements of either part of the system, emitter or photon, by observing the effect of the interaction on the other part. Such ideal projective measurements allow to detect, to prepare and to manipulate quantum states in a controlled and coherent manner. They are used with atomic or solid-state emitters in the optical or microwave domain. So far, Rydberg atoms in cavity QED systems have mainly been used to measure or create quantum states of light. Using a microwave cavity to determine the state of a single Rydberg atom or an ensemble thereof is less explored and constitutes a step towards the application of the long coherence time of Rydberg atoms as quantum memories for microwave-based quantum information processing. In our experiment, transmitting a weak probe tone through a 3D microwave cavity allows us to measure the dispersive shift induced by an ensemble of helium Rydberg atoms [1]. The system is quantitatively described by the dispersive Tavis-Cummings hamiltonian. We consistently observe maximal collective coupling strengths above 1 MHz with up to 3300 Rydberg atoms. We also determine the scaling of the collective dispersive shift with the atom-cavity detuning and the number of Rydberg atoms. The latter provides a non-destructive measurement of the number of Rydberg atoms (cf. Figure 1). We discuss the extension of this technique to non-demolition measurements of the pseudo-spin polarization of an ensemble of Rydberg atoms used as microwave frequency qubits.

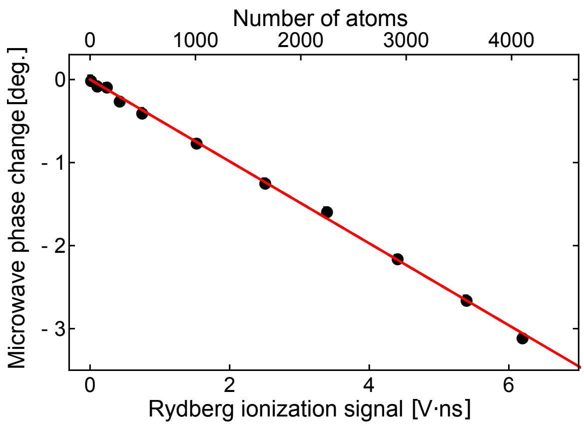

Figure 1. Phase change of the microwave probe as function of detected signal from ionization of Rydberg atoms : both detections signals are here proportional to the atom number, which is scaled on top axis from phase change and known atom-cavity coupling and detuning.

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