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Rydberg quantum optics in ultracold atomic gases

Mapping the strong interaction between Rydberg excitations in ultracold atomic ensembles onto single photons enables the realization of optical nonlinearities which can modify light on the level of individual photons. In our group, we explore this novel approach to realizing effective photon-photon interaction in multiple experiment setups and following two complementary approaches employing Rydberg polaritons and superatoms.

We here present our recent work on a single Rydberg superatom, an optical medium smaller than a single Rydberg blockade volume, strongly coupled to a few-photon probe field. Due to the strong coupling and the large number of atoms in the blockade volume we achieve coherent interaction even if the probe contains only few photons. With the superatom we can study the dynamics of a single two level system strongly coupled to a quantized propagating light field in free space, enabling for example the investigation of intrinsic three photon correlations mediated by a single quantum emitter. We also discuss our experimental progress towards the formation of multiple superatoms coupled to a single probe-mode.

Further we discuss our development of a new experiment designed to study the interactions between a large number of Rydberg polaritons simultaneously propagating through a medium with extremely high atomic density. Our new setup employs for the first time ultracold Ytterbium, an alkaline-earth-like element, for Rydberg quantum optics experiments. We discuss details of our experimental implementation and report on the progress towards observation of few-photon nonlinearities in Yb.

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