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## Free-space QED with Rydberg superatoms

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. This approach forms the basis of a growing Rydberg quantum optics toolbox, which already contains photonic logic building-blocks such as single-photon sources, switches, transistors, and photonic two-qubit gates.

For an optical medium smaller than a single Rydberg blockade volume, a large number of individual atoms behave as a single Rydberg “superatom” which can be efficiently coupled to few-photon probe pulses. The strongly enhanced collective coupling and the highly directed collective emission of this system realizes an analogue to waveguide-QED systems, which enables the study of coherent emitter-photon interaction in free-space [1]. In this talk, we present our recent investigation of intrinsic three-photon correlations mediated by a single superatom [2]. We also present our steps towards the formation of multiple superatoms coupled to a single probe-mode to realize a cascaded system of quantum emitters.

[1] A. Paris-Mandoki, C. Braun, J. Kumlin, C. Tresp, I. Mirgorodskiy, F. Christaller, H. P. Büchler, and S. Hofferberth, *Phys. Rev. X* 7, 41010 (2017)

[2] N. Stiesdal, J. Kumlin, K. Kleinbeck, P. Lunt, C. Braun, A. Paris-Mandoki, C. Tresp, H. P. Büchler, and S. Hofferberth, *Phys. Rev. Lett.* 121, 103601 (2018)

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