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Coupling, controlling, and processing non-transversal photons with a single atom

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I will report on recent experimental investigations of the interaction between single rubidium atoms and light that is confined by continuous total internal reflection in a whispering-gallery-mode (WGM) bottle microresonator. These resonators offer the advantage of very long photon lifetimes in conjunction with near lossless in- and out-coupling of light via tapered fiber couplers. We discovered that the non-transversal polarization of WGMs fundamentally alters the physics of light-matter interaction [1]. Taking advantage of this effect, we recently demonstrated switching of signals between two distinct optical fibers controlled by a single atom [2]. Owing to the excellent optical properties of our bottle microresonator, the scheme yields high switching fidelities and low losses. Furthermore, we exploited the strong birefringence of the bottle microresonator and implemented a single-atom-controlled polarization flip of the light that is guided through the coupling fiber [3]. And finally, we made use of the strong nonlinear response of the atom-resonator system and experimentally realized an optical Kerr nonlinearity at the level of single photon [3]. Analyzing the transmitted light, we observe a nonlinear phase shift of π between the cases of one and of two photons passing the resonator. This phase shift leads to entanglement between previously independent fiber-guided photons, which we verify by performing a full quantum state tomography of the transmitted two-photon state.

[1] C. Junge et al., Phys. Rev. Lett. **110**, 213604 (2013).
[2] D. O'Shea et al., Phys. Rev. Lett. **111**, 193601 (2013).
[3] J. Volz et al., submitted (2013).