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Strong photon-photon interaction in a coupled quantum dot- photonic crystal nanocavity[1]

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Quantum dots (QDs) in photonic crystal nanocavities are interesting both as a testbed for fundamental cavity quantum electrodynamics (QED) experiments, as well as a platform for classical and quantum information processing. In addition to providing a scalable, on-chip, semiconductor platform, this system also enables very large dipole-field interaction strengths, as a result of the field localization inside of sub-cubic wavelength volumes (vacuum Rabi frequency is in the range of 10's of GHz). We have demonstrated controlled amplitude and phase modulation between two continuous wave (CW) optical beams at the single photon level (power less than a photon per cavity photon lifetime) interacting via a strongly coupled quantum dot - photonic crystal cavity system, and have subsequently extended this experiment to weak time-varying control field and a CW signal field. Recently, we have performed all-optical switching at the single photon level between two pulsed, resonant optical beams (with 40ps pulses and 80MHz repetition rate). In this experiment, we have measured transmission through the strongly coupled QD-cavity system as a function of delay between the two pulses, and have demonstrated a 22% increase in the transmission at zero delay. The increase in the transmission is a result of the saturation of the strongly coupled QD-cavity system. We have also studied the effects of the photon blockade and photon induced tunneling which result from the anharmonicity of the ladder of dressed states in a strongly coupled QD-nanocavity system. These effects lead to dramatic changes in the transmitted photon statistics, which can be varied from sub-Poissonian to super-Poissonian, and can be employed to generate nonclassical states of light (such as Fock or NOON states) with high efficiency.

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