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Quantum state detection and state preparation based on cavity-enhanced nonlinear interaction of atoms with single photon

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Our ability to engineer quantum states of light and matter has significantly advanced over the past two decades, resulting in the production of both Gaussian and non-Gaussian optical states. The resulting tailored quantum states enable quantum technologies such as quantum optical communication, quantum sensing as well as quantum photonic computation. The strong nonlinear light-atom interaction is the key to deterministic quantum state preparation and quantum photonic processing. One route to enhancing the usually weak nonlinear light-atom interactions is to approach the regime of cavity quantum electrodynamics (cQED) interaction by means of high finesse optical resonators. I present results from the MIT experiment of large conditional cross-phase modulation between a signal photon, stored inside an atomic quantum memory, and a control photon that traverses a high-finesse optical cavity containing the atomic memory. I also present a scheme to probabilistically change the amplitude and phase of a signal photon qubit to, in principle, arbitrary values by postselection on a control photon that has interacted with that state. Notably, small changes of the control photon polarization measurement basis by few degrees can substantially change the amplitude and phase of the signal state. Finally, I present our ongoing effort at Purdue to realize similar peculiar quantum phenomena at the single photon level on chip scale photonic systems.