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Strong Interactions of Photon Pairs in Cavity QED[1]

H.J. KIMBLE, California Institute of Technology

The charge and spin degrees of freedom of massive particles have relatively large long-range interactions, which enable nonlinear coupling between pairs of atoms, ions, electrons, and diverse quasi-particles. By contrast, photons have vanishingly small cross-sections for direct coupling. Instead, photon interactions must be mediated by a material system. Even then,typical materials produce photon-photon couplings that are orders of magnitude too small for nontrivial dynamics with individual photon pairs. The leading exception to this state of affairs is cavity quantum electrodynamics (cQED), where strong interactions between light and matter at the single-photon level have enabled a wide set of scientific advances [1]. My presentation will describe two experiments in the Caltech Quantum Optics Group where strong interactions of photon pairs have been observed. The work in Ref. [2] provided the initial realization of photon blockade for an atomic system by using a Fabry-Perot cavity containing one atom strongly coupled to the cavity field. The underlying blockade mechanism was the quantum anharmonicity of the ladder of energy levels for the composite atom-cavity system. Beyond this *structural* effect, a new *dynamical* mechanism was identified in Ref. [3] for which photon transport is regulated by the conditional state of one intracavity atom, leading to an efficient mechanism that is insensitive to many experimental imperfections and which achieves high efficiency for single-photon transport. The experiment utilized the interaction of an atom with the fields of a microtoroidal resonator [4]. Regulation was achieved by way of an interference effect involving the directly transmitted optical field, the intracavity field in the absence of the atom, and the polarization field radiated by the atom, with the requisite nonlinearity provided by the quantum character of the emission from one atom.

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