Correlated quantum photon states generated by vacuum fields

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This talk is to explore various techniques to manipulate populations in quantum systems by applying tailored optical pulses included even vacuum fields. The techniques are based on interactions between adiabaticaly changing quantum fields with the quantum systems. The obtained results will be beneficial to the fields of atomic and molecular physics, quantum electronics, and nonlinear physics. In particular, these new techniques will be important for developing quantum sensors, quantum information systems. The quantum fields created and emitted can be used for quantum communications.

Propagation of quantum field interacting with single two-level or three-level atoms has been studied. Using the Gaussian quantum mode functions, we calculate evolution of the quantum state that includes atomic and field variable. We demonstrated the phase acquired by the single photon propagation [1,2] that can be of great importance for long quantum communications. The results can be used for controlling quantum field propagation, and for design of optical elements such as a quantum prism and a quantum lens.

We consider a Lambda-type three-level atom in a QED cavity. One atomic transition is driven by a classical field and the other transition is driven by the “vacuum” field. The vacuum field can be strongly modified by the cavity, and in particular, the “vacuum” field can have a chirped frequency modulation that it can be a part of adiabatic rapid passage together with classical drive field. The action of the classical and “vacuum” or quantum field can result in the generation of the quantum fields with controllable parameters. Such QED cavity can be used to generate strongly correlated quantum fields that can be of interest for quantum sensing, spectroscopy at the single photon level, quantum teleportation, and other applications for quantum information.

[1] Yuri Rostovtsev, Jacob Emerick, Anil Patnaik, “The refractive index of a single atom experienced by a single photon”, Results in Optics, 2023. DOI: 10.1016/j.rio.2023.100568

[2] https://sciencefeatured.com/2024/01/24/light-particle-meets-atom-revolutionizes-communication/