Simulation and design of a superconducting qubit for the quantum wave mixing experiment

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With the advances of superconducting qubit technology, it became possible to in- vestigate different quantum optical effects on artificial atoms. One of such fundamental nonlinear parametric phenomena is wave mixing. Thus, mixing of two coherent waves with frequencies $\omega_0 \pm \delta\omega$ in a nonlinear medium gives rise to many new modes at frequencies $\omega_0 \pm (2n+1)\delta\omega$, where $n = 0, 1, 2, \ldots$. In two studies [1, 2], the wave mixing effect was studied for the case when the medium is reduced to a single superconducting qubit strongly coupled to the continuum of modes in the coplanar waveguide. The discrete spectrum was observed and was shown to be a consequence of stationary emission from an artificial atom. Besides, quantum wave mixing of coherent microwave pulses was demonstrated, in which the order of multi-photon scattering was controlled by a level structure of qubit or a qutrit.

Further study of quantum wave mixing implies the characterization of scattering spec- tra when the initial microwave pulses are not coherent states of light. We have designed an experimental setup and the topology of a chip for such experiment. Finally, we calcu- lated all the necessary parameters of the essential elements on the chip. This setup will be used further for investigation of wave mixing effects with superconducting qubits in a waveguide.

We propose to use a single-photon source to generate superposed states of the vacuum and single photon. The single-photon source [3, 4] is based on a single qubit asymmetrically coupled to two half-spaces. An additional qubit, henceforth a mixing atom, is used as a scatterer to observe the effect of mixing between classical and quantum state of light.

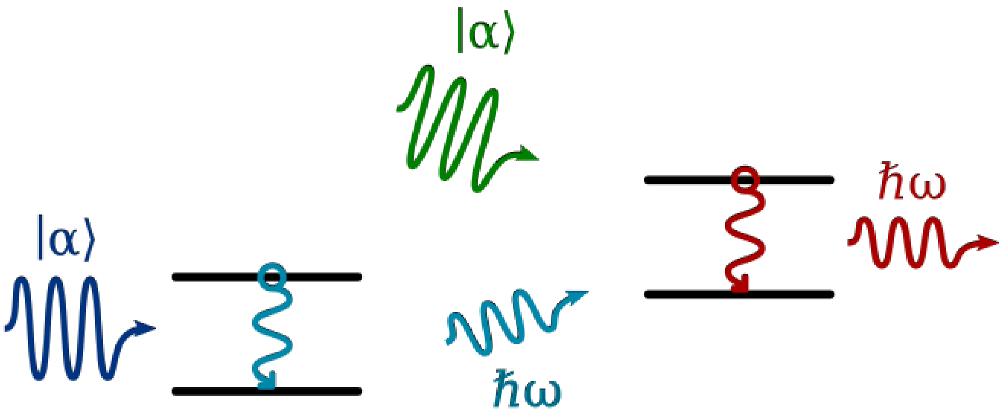

Figure 1: Mixing of coherent pulses with single photons on an artificial atom.

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