Single-atom microwave laser based on transmon

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Superconducting artificial atoms, aside from their practical applications, are a useful tool in exploring fundamental phenomena of quantum optics. For example, a transmon may be used to realise a single-atom laser; in this work, we present a blueprint for such a device.

The essential concept of any laser is the population inversion. To achieve population inversion in a transmon, one can employ using two-photon excitation of the level f (see fig. 1). However, for the population of level e to be significantly larger than of level g, an increased f-e dissipation is required. To enhance the rate of this process, we propose to couple the transmon to an auxiliary resonator with a small quality factor, which is in resonance with the e-f transition. Our numerical simulations show that such approach indeed allows achieving significant population inversion.

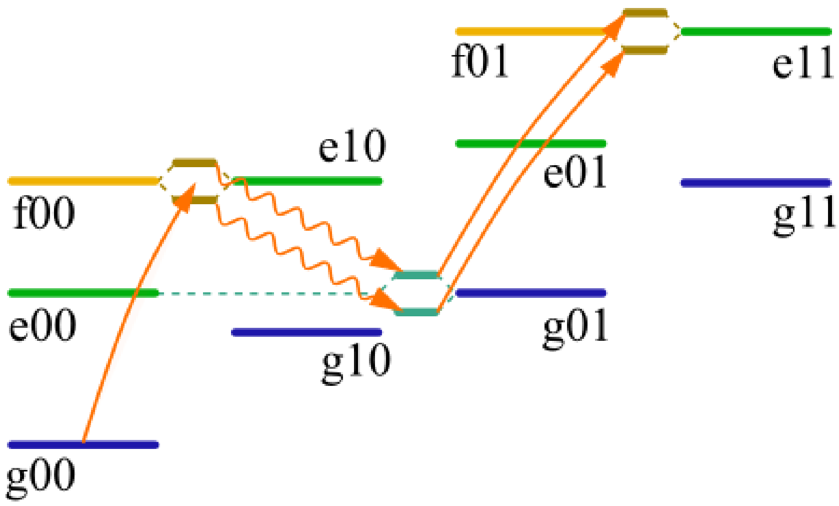

Figure 1: Energy levels of the transmon laser. The letter is transmon level, the first number is the number of photons in the auxiliary resonator, the second number — in the reservoir (e.g. g10 means that there is 1 photon in the auxiliary resonator and 0 — in the reservoir)

Next, as in a standard laser, we additionally couple the transmon to a high-quality cavity resonant with its g-e transition. However, one needs to account for modifications in the level structure caused by the strong coupling to both resonators (see fig. 1). These level splittings should be explicitly considered while choosing the resonance conditions to achieve a large number of photons.

In our simulation, we could pump more that 20 photons in the cavity which corresponds to −140 dBm of emitted power.