Single-photon microwave switch with a recoverable control photon

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Abstract: A single-photon signal can be controlled by another single photon, thus enabling the realization of a low-power single-photon microwave switch. We study such device in an open-system fashion, and optimize it by maximizing its efficiency.

We study the switching behavior of a device [1] composed of a two-level system coupled to a single-mode resonator via a Jaynes-Cummings (JC) interaction. Because of the anharmonicity of the JC energy levels, it is possible to exploit a single photon to control the absorption of another single photon by the resonator, simply by matching the photons carrier frequencies with the proper frequencies related to the transitions between different JC energy levels. Under that condition, if both the traveling photons reach the device, they are absorbed by the joint JC system (switch-ON case); the signal photon is then released, while the control one is blocked by an additional filtering cavity. On the contrary, if only the signal photon is sent towards the switch, it is reflected back (switch-OFF case). To describe the switch we take advantage of the SLH framework [2, 3], a quantum open-systems formalism which allows to model a complex quantum system by decomposing it into modular elements, as well by considering a broad variety of physical features (such as the the photon wavepackets and the interactions between the itinerant fields and the localized systems). We compute the expectation of the output field number operator $\hat{b}^{\dagger}_{out}(t)\hat{b}_{out}(t)$ that can be defined within the input-output theory [4], on which the SLH framework is based. The quantity $\phi(t)=\langle\hat{b}^{\dagger}_{out}(t)\hat{b}_{out}(t)\rangle$ is a photon flux, and its integral over time,

$$\Phi(t)=\int_0^t \phi(t')dt' \quad (1)$$

represents the average number of photons escaping from the device from time 0 to time t. We then optimize the physical parameters involved in the model, by adopting the integrated photon flux (1) as a figure of merit. An efficient switch maximizes indeed the integrated flux in presence of both the signal (s) and the control (c) photon, $\Phi^{(s,c)}(t)$, while minimizes the same quantity if only one photon is present, $\Phi^{(s)}(t)$ [or $\Phi^{(c)}(t)$], as depicted in Fig.1. Finally, we find that time-dependent couplings between the itinerant fields and the localized systems, *γ(t)*, can increase the switch efficiency if properly engineered. Furthermore, a real-time control on the coupling parameters makes the recovering of the control photon feasible, since it can be absorbed, stored and then released from the device by appropriately turning the interactions on or off.

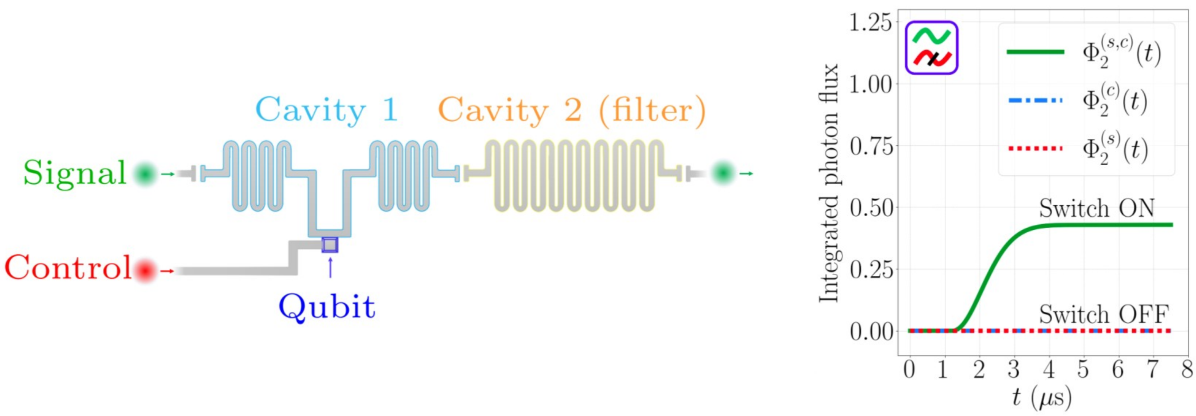

Fig. 1 The device scheme and the switching efficiency, represented by the integrated photon flux (1).

References

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