Shortcuts to Adiabaticity for Fast Qubit Readout and Quantum Gate in Circuit Quantum Electrodynamics

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Superconducting quantum circuits (SC) and circuit quantum electrodynamics (cQED) have become promising quantum platforms for quantum information processing to implement quantum algorithms. It also has been suitable for quantum simulation and, lately, provided strong evidence of computational advantages over its classical counterpart.

Based on the renewed interest in the shortcut-to-adiabaticity techniques [1] in quantum control, we propose how to engineer longitudinal coupling to accelerate the measurement of a qubit longitudinally coupled to a cavity. We compare different modulations, designed from inverse engineering, counter-diabatic driving, and genetic algorithm, for achieving optimally large values of the signal-to-noise ratio (SNR) at a nanosecond scale. We demonstrate that our protocols outperform the usual periodic modulations on pointer state separation and SNR as well [2].

In addition, this allows us to suppress the unwanted transitions in the time-evolution operator such that the system dynamics resemble a controlled-phase gate acting in the qubit subspace at the nanosecond scale [3]. The reduced gating time mitigates the detrimental effect produced by the loss mechanisms in all the parties.

Finally, we show a possible implementation considering state-of-the-art circuit quantum electrodynamics architecture, see Figs. 1 and 2.

References

[1] D. Guéry-Odelin, A. Ruschhaupt, A. Kiely, E. Torrontegui, S. Martínez-Garaot, and J. G. Muga, Rev. Mod. Phys. 91, 045001 (2019).
[2] F. A. Cárdenas-López and Xi Chen, Phys. Rev. Appl. 18, 034010 (2022).
[3] Jia-Xin Li, F. A. Cárdenas-López, and Xi Chen, Front. Quantum. Sci. Technol., submitted.

Figures

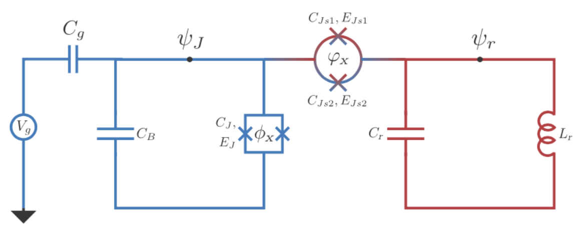

Figure 1: Schematic illustration of the experimental proposal for qubit readout: a transmon qubit formed by a capacitor C_B parallel-connected to a tunable inductor is biased by a gate voltage V_g through a gate capacitor Cg. The two-level system is coupled to an LC resonator of capacitance C_r and inductance L_r via an asymmetric SQUID threaded by an external magnetic flux φ_x. Furthermore, we describe the circuit in terms of their flux nodes ψ_J and ψ_r.

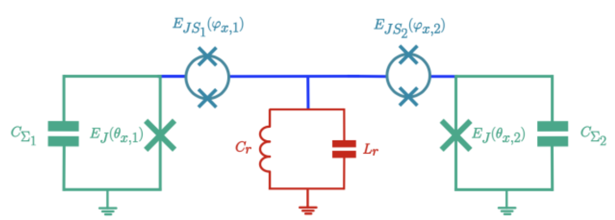

Figure 2: Schematic illustration of the experimental proposal for a controlled-phase gate: two transmon circuits formed by a capacitor $C_{\Sigma l}$ parallel connected to a tunable Josephson junction E_J $(\theta_{x,l})$ coupled to a LC resonator of capacitance C_r and inductance L_r via a SQUID threaded by an external magnetic flux $\varphi_{x,l}$.