Optimal Control for Open Quantum System in Circuit Quantum Electrodynamics

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We propose a quantum optimal control framework based on the Pontryagin Maximum Principle to design energy- and time-efficient pulses for open quantum systems. By formulating the Langevin equation of a dissipa- tive LC circuit, see Fig. 1(a), as a linear control problem, we derive optimized pulses with exponential scaling in energy cost, outperforming conventional shortcut-to-adiabaticity methods such as counter-diabatic driving. When applied to a resonator dispersively coupled to a qubit, see Fig. 1(b), these optimized pulses achieve an excellent signal-to-noise ratio (as shown in Fig. 2) comparable to longitudinal coupling schemes across varying critical photon numbers. Our results provide a significant step toward efficient control in dissipative open systems and improved qubit readout in circuit quantum electrodynamics.

References

[1] Mo Zhou, F. A. Cardenas-Lopez, D. Sugny, and Xi Chen, Optimal Control for Open Quantum System in Circuit Quantum Electrodynamics, arXiv:2412.20149.

Figures

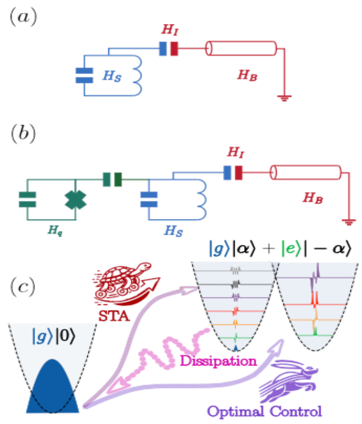

Figure 1: (a) Schematic illustration of driven open quantum system, a LC resonator of frequency ωr is coupled to a transmission line res- onator mimicking the electronic reservoir. (b) Representation of the cavity-qubit system. (c) Illustration of the optimal control and STA protocols: starting from an eigenstate of the harmonic oscillator, we transfer this state non-adiabatically to a high-fidelity final coherent state.

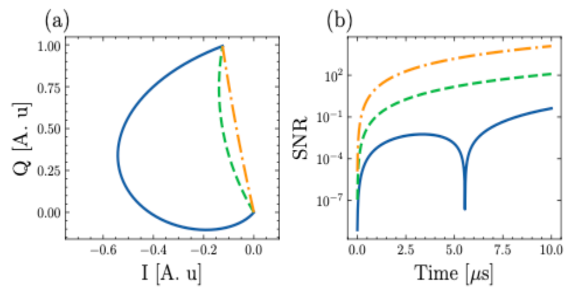

Figure 2: (a) The evolution in the normalized IQ plane for a qubit-cavity system initialized in the state $|0, g\rangle$ with an initial $\langle N(0)\rangle = 0$. (b) SNR versus measurement time for the same critical photon number, with $\varphi = 0$. Here the critical photon numbers: $n_{crit} = 1$ (solid blue), $n_{crit} = 10$ (green dashed), and $n_{crit} = 100$ (orange dot-dashed) are chosen, corresponding to different final $\langle N(t_f)\rangle$. Parameters are listed in the main text.