**High-fidelity and robust quantum gates for superconducting qubits and semiconductor spin qubits**

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To realize practical quantum computation, the ability to precisely control qubit systems is a prerequisite. To increase the reliable circuit depth on noisy intermediate-scale quantum (NISQ) computing devices, or achieve the ultimate goal of error-corrected fault-tolerant quantum computation, constructing high-fidelity and robust quantum gates to meet the stringent computing requirements (beyond the fault-tolerant error threshold) is an important and timely issue. We apply the robust control method [1,2] to construct smooth optimal control pulses to enhance the gate fidelity and enlarge the robust window against noises and system parameter uncertainties for superconducting transmon qubits and semiconductor silicon-based quantum-dot electron spin qubits.

The two-qubit CZ gate infidelity of the directly-coupled superconducting transmon qubits with characterized noises of the fast dephasing $T\_{ϕ,1}$ contributed from the energy relaxation $T\_{1} $ and from white noise potentially due to the room temperature control electronics (RTCE), and of the slow dephasing $T\_{ϕ,2}$ contributed from the flux noise (1/*f* noise) from the experiment [3] can be suppressed to $\~4.7×10^{-4}$, limited by the energy relaxation time $T\_{1}=30 μs$. If $T\_{1}$ is increased to $360 μs$ [4], the infidelity can be further reduced to $≲10^{-4}$.

 The two-qubit CNOT gate infidelity of the silicon-based quantum-dot spin qubits considering the dephasing noise and the control pulse uncertainty can still be suppressed to $≲10^{-4}$. The effect of the spin relaxation time $T\_{1}$ in the spin-qubit system does not contribute appreciably to the gate infidelity as compared to the spin dephasing time $T\_{2}^{⋆}$ since $T\_{1}$ is usually two or three orders of magnitude larger than $T\_{2}^{⋆}$. We also demonstrate a high-fidelity (infidelity $≲10^{-4}$) three-qubit Toffoli gate robust against the dephasing noise (the dominant error contribution due to the longer gate time of the Toffoli gate).

References:

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