Investigating Entanglement Rates of Coupled Superconducting Qubits

J. Howard¹, K. Clark¹, C. Haack¹, J. Long², M. Bao², R. Zhao², T. Zhao², D. Pappas², Z. Gong¹, M. Singh¹

¹Department of Physics, Colorado School of Mines, Golden, CO, 80401, USA
²National Institute of Standards and Technology, Boulder, CO, 80305, USA

Overview

Quantum entanglement, the operation by which multiple qubits enter a non-separable quantum state, is the defining operation that distinguishes quantum from classical computation. Due to finite coherence windows in which to perform operations, the maximum rate at which entanglement can be generated is an important metric. Theoretical predictions from Dr. Gong’s group show that this rate can be boosted via coupling to a third ancillary qubit. The goal of this work is to experimentally demonstrate this increase in the entanglement speed limit on a superconducting qubit platform.

Theory

Current work focuses on demonstrating an entangling speed limit for reaching the Bell state |01⟩ → |11⟩ (for two σ_x-σ_y-coupled qubits) and determining these ratios closer to unity, with theory efforts focusing on developing a means to account for this drive coupling in the speed limit prediction. Because the dipole ratios (r₁, r₂) in the “Devices” section) are not both unity, there exists drive coupling in addition to the σ_x-σ_y interaction that affect the entangling speed limit. Future experimental efforts will focus on bringing these ratios closer to unity, with theory efforts focusing on developing a means to account for this drive coupling in the speed limit prediction.

Device

The two-qubit coupled concentric transmon system currently being measured (see “Devices” section) has the following Hamiltonian:

\[ H = \frac{g_2}{4} |0⟩⟨0| + \frac{r_1 r_2}{4} |0⟩⟨0| + \frac{r_1 r_2}{4} |1⟩⟨1| + \frac{r_2}{4} |1⟩⟨1| \]

(1)

with \( g_2 = 9.75 MHz \), \( r_1 = 1.14 \), \( r_2 = 0.77 \) and Rabi strengths \( \Omega_{[1]}(x,y) \) determined by our optimized drive pulses.

Experiment

The numerically-optimized pulses intended to generate the target Bell state are shown in figure 3. These will be followed by tomographic sequences and projective readout.

Future Work

- Because the dipole ratios (r₁, r₂ in the “Devices” section) are not both unity, there exists drive coupling in addition to the \( \sigma_x \sigma_y \) interaction that affect the entangling speed limit. Future experimental efforts will focus on bringing these ratios closer to unity, with theory efforts focusing on developing a means to account for this drive coupling in the speed limit prediction.
- Upon successfully generating a fidelity curve for the two qubit system that matches the theoretical speed limit predictions work will begin on designing a three-qubit system to demonstrate the predicted speedup.

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