Generating highly entangled states and synthetic gauge fields on a superconducting processor

Ilan T. Rosen[1*], Cora Barrett[1], Patrick M. Harrington[1], Max Hays[1], Amir H. Karamlou[1], Sarah Muschinske[1], Jeffery A. Grover[1], William D. Oliver[1]

[1]*Massachusetts Institute of Technology, Cambridge, Massachusetts, USA*
*itrosen@mit.edu

Recently, the application of transmon arrays as analog quantum simulators has received growing interest. Here, photonic excitations in the array behave as strongly interacting particles according to the Bose-Hubbard model. Work in this area has centered around one- and quasi-one-dimensional dynamics problems [1-6].

We study a two-dimensional, 4-by-4 square array of tunable transmon superconducting qubits with capacitive coupling between nearest neighbors. Rather than preparing a definite state, we simultaneously drive all lattice sites, generating highly entangled many-body states [7]. We extract the entanglement entropy of the states, observing volume-law entanglement scaling for states at the center of the energy spectrum and a crossover to the onset of area-law scaling near its edges [8].

Second, we discuss the emulation of magnetic fields in the superconducting processor. Magnetic fields are a central ingredient in many Hamiltonians of interest. Here, we introduce a scheme to generate synthetic magnetic fields by parametrically modulating the transmon qubits [9]. We verify key signatures of the field's presence, including the Aharonov-Bohm effect, gauge invariance, and the Faraday effect.

References

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Figures

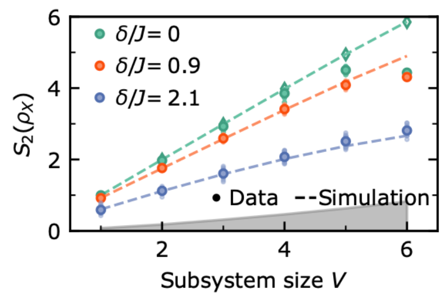

Figure 1: The second Renyi entropy, as extracted from full state tomography of subsystems, versus subsystem volume. Entropies of superposition states with three different energies are shown.

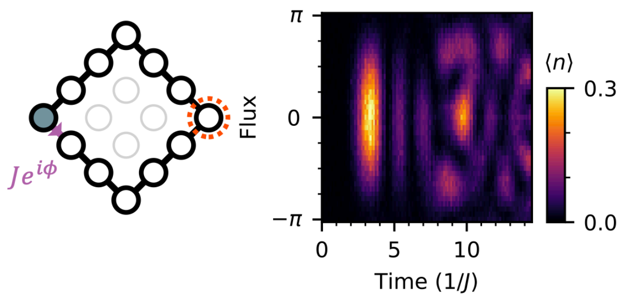

Figure 2: Aharonov-Bohm interference in a 12-site ring. A photon is prepared on one corner of the ring (teal). The population at the opposing corner (orange circle) is measured as a function of time and synthetic magnetic flux.