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Realization of Simple Quantum Algorithms with Circuit Quantum Electrodynamics[1]

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Superconducting circuits have made considerable progress in the requirements of quantum coherence, universal gate operations and qubit readout necessary to realize a quantum computer. However, simultaneously meeting these requirements makes the solid-state realization of few-qubit processors, as previously implemented in nuclear magnetic resonance, ion-trap and optical systems, an exciting challenge. We present the realization of a two-qubit superconducting processor based on circuit quantum electrodynamics (cQED), and report progress by the Yale cQED team towards a four-qubit upgrade. The architecture employs a microwave transmission-line cavity as a quantum bus coupling multiple transmon qubits. Unitary control is achieved by concatenation of high-fidelity single-qubit rotations induced via resonant microwave tones, and multi-qubit adiabatic phase gates realized by local flux control of qubit frequencies. Qubit readout uses the cavity as a quadratic detector, such that a single, calibrated measurement channel gives direct access to multi-qubit correlations. We present generation of Bell states; entanglement quantification by strong violation of Clauser-Horne-Shimony-Holt inequalities; and implementations of the Grover search and Deutsch-Jozsa algorithms. We report experimental progress in extending adiabatic phase gates and joint readout to four qubits, and improving qubit coherence on the road to realizing more complex quantum algorithms. Research done in collaboration with J. M. Chow, J. M. Gambetta, Lev S. Bishop, B. R. Johnson, D. I. Schuster, A. Nunnenkamp, J. Majer, A. Blais, L. Frunzio, M. H. Devoret, S. M. Girvin, and R. J. Schoelkopf.

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