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Towards Quantum Information Processing with Superconducting Circuits[1]

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In the dozen years since the initial demonstrations that superconducting circuits based on Josephson junctions could be considered as qubits, there has been remarkable progress in the field. Several different "species" of these artificial atoms have been designed and tested, and coherence times have increased by more than 1,000, or a factor of 10 every three years. While real devices are still far from satisfying all the DiVincenzo criteria with fidelities that would meet the error correction threshold, one can nonetheless perform preparation, control, quantum logic, and measurement on multiple superconducting qubits, all with surprisingly high purity and precision given that these are man-made, solid-state systems. In recent years we have seen the preparation of highly-entangled multi-qubit states that violate the Bell and Mermin inequalities, as well as the demonstration of single quantum algorithms, which all benefit from the strong coupling, addressability, and all-electronic control that is possible with these systems. Many experiments employ the concept of a "quantum bus," where qubits couple via superconducting transmission lines that form high-quality resonant cavities. A spinoff of this work is the advent of quantum optics on a chip: microwaves are photons too! The combination of qubits coupled to cavities has allowed the preparation and detection of single gigahertz photons, as well as other highly non-classical states of microwave light. Great progress has also been made in quantum measurement, and other Josephson circuits are now delivering amplifiers that operate at or beyond the Heisenberg limit. In this talk I will attempt to give an overview of some of the key concepts, some experimental highlights from recent years, and point out some possible directions for the future in this field.

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