Quantum light:
Synthesis of complex microwave photon states with superconducting qubits

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Josephson qubits are one of the most promising approaches for solid-state quantum information processing. I will discuss recent experiments at UC Santa Barbara that demonstrate our ability to synthesize complex quantum states of microwave photons in superconducting resonators using phase qubits. I will review experiments that generate photon number (Fock) states up to 12 photons, as well as a protocol for arbitrary states and their measurement via Wigner tomography. The violation of Bell's inequality has also been demonstrated along with a closure of the measurement loophole. I will also discuss a recent experiment that shows complex entanglement of microwave photons in a pair of superconducting resonators. We use as a benchmark the generation of NOON states, with N photons in one resonator and 0 in the other, superposed with the state with the occupation numbers reversed. The resonator states are analyzed using bipartite Wigner tomography, which is required to distinguish entanglement from an ensemble of mixed states. These experiments have led to the development of a new RezQu architecture that utilizes memory resonators for each qubit and a common coupling bus. With experimental demonstration of Bell-state memory, CNOT gates, C-phase gates for the quantum Fourier transform, and Toeffoli gates, we believe it is possible to operate 9 to 17 mode quantum processors in the immediate future.