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Coherent manipulation of quantum information using two Josephson phase qubits coupled to a resonant cavity

MIKA SILLANPAA, National Institute of Standards and Technology

We have taken the first step towards the implementation of circuit quantum-electro dynamics (QED) quantum information processing with Josephson phase qubits. We have observed for the first time a coherent interaction between two phase qubits and an LC cavity formed by a 7 mm long coplanar waveguide resonant at 9 GHz. When either qubit is resonant with the cavity, we observe the vacuum Rabi splitting of the qubit's spectral line. In a time-domain measurement, we observe coherent vacuum Rabi oscillations between either qubit and the oscillator. Using controllable shift pulses, we have shown coherent transfer of a arbitrary quantum state. We first prepare the first qubit in a superposition state, then this state is transferred to the resonant cavity and then after a short time, we transfer this state into the final qubit. These experiments show that quantum information can be coherently stored and transferred between superconducting quantum bits using a resonant cavity. This opens up new possibilities for performing circuit QED and studying quantum information science.