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Coherent Dynamics of a flux-qubit coupled to a harmonic oscillator

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Superconducting circuits containing Josephson junctions are promising candidates for the implementation of solid-state quantum bits or qubits. Complex single-qubit operations have already been reported, as well as the realization of a two-qubit gate. Coupling a qubit to a harmonic oscillator is interesting from a fundamental point of view to generate and study non-classical states of the oscillator, and is relevant in quantum information as well, since coupling many qubits via a harmonic oscillator has been proposed. The strong coupling between a charge qubit and a superconducting coplanar waveguide resonator has recently been observed [1]. Here we present measurements demonstrating the coupling of a flux-qubit to the plasma mode of the DC Squid which at the same time is used to measure the qubit state [2]. This coupling is manifested by the appearance of two side-band resonances around the bare qubit peak. By performing two-pulse experiments, we show that these additional resonances are indeed excitations of the coupled system. We also observe Rabi oscillations between the coupled |qubit,Squid> states, thus demonstrating entanglement between the states of two superconducting circuits. We use the qubit to measure intrinsic properties of the plasma mode : temperature, relaxation time. Conversely, we also measure the qubit state via the plasma mode. We finally investigate the influence of the qubit-plasma mode coupling on the qubit quantum coherence. These results indicate that complex manipulation of entangled states similar to cavity quantum electrodynamics or trapped-ions experiments is within reach with superconducting circuits. [1] A. Wallraff et al., Nature **431**, 162 (2004) [2] I. Chiorescu et al., Nature **431**, 159 (2004) .