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Continuous High-Fidelity Monitoring of a Superconducting Qubit: From Quantum Jumps to Feedback[1]

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Great advances have been made in superconducting qubit technology since the first demonstration of coherent oscillations more than 10 years ago. Continuous, high-fidelity monitoring of the qubit state, however, has remained an elusive target. We demonstrate this functionality by using a wide-bandwidth superconducting parametric amplifier operating near the quantum noise limit to read out the state of a transmon qubit coupled to a linear resonant cavity. Depending on the qubit-cavity detuning and the cavity photon occupation, two different measurement regimes can be accessed. In the strong measurement regime, the qubit states are fully resolved in a time much shorter than T_1. This permits the observation of quantum jumps between qubit states in real time, and enables the study of the quantum Zeno effect and measurement non-idealities. In the weak measurement regime, information is extracted slowly and the measurement is no longer projective on short time scales. However, the measurement record is still highly correlated with the qubit dynamics and can be used to steer the qubit state using feedback. We demonstrate this idea by phase-locking Rabi oscillations to a classical reference. This allows the oscillations to persist indefinitely, albeit with a reduced amplitude indicative of the efficiency of the feedback protocol.

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