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Novel approaches to high fidelity qubit state measurement in circuit quantum electrodynamics

ERAN GINOSSAR, Yale University

Qubit state measurement ('readout') in solid state systems is an open problem, which is currently the subject of intensive experimental and theoretical research. Achieving high fidelity in a single-shot measurement is an interesting quantum control problem, as well as an important component for the successful implementation of quantum information protocols. For superconducting qubits we can distinguish between linear dispersive and nonlinear methods, the latter relying on the bistability of a nonlinear resonator. In the context of circuit quantum electrodynamics, the transmon qubit is strongly coupled to a linear resonator and described by a generalized Jaynes-Cummings model (JCM) with external drive and dissipation. Recent novel approaches to achieve high-fidelity readout in the dispersive regime rely on the intrinsic nonlinearity of the JCM and its ultimate linearity in the high excitation regime. In the degenerate regime we rely on the photon blockade and precise transient dynamics of the system. This regime presents a theoretical challenge and the driven damped JCM model exhibits a dynamical phase transition. Another proposed approach extends the Josephson Bifurcation Amplifier and employs the dynamical effects of frequency chirping of the drive on the coupled qubit-resonator system. We will discuss the physics of these different regimes and describe the readout schemes which have been demonstrated by recent experiments and quantum simulations, as well as the role of quantum fluctuations and optimal control.