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Nonlinear Dispersive Measurement with Superconducting Circuits

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Superconducting circuit elements can be used to form high quality factor harmonic and anharmonic oscillators. When coupled to a pseudospin system, these oscillators can be used for quantum state measurement. In the dispersive limit, the oscillator resonant frequency depends on the spin state. The case of a linear transmission line resonator coupled to a superconducting qubit was demonstrated by R. Schoelkopf and co-workers [1]. We will describe quantum measurement performed using a nonlinear resonator consisting of a Josephson tunnel junction shunted with a reactive impedance. As the Josephson oscillator is excited with an increasing number of photons, its resonant frequency progressively decreases. Under appropriate bias conditions, it is also possible to access a bifurcation where two dynamical states exist. We will show that with a nonlinear Josephson oscillator, it is possible to realize both analog and digital quantum state measurement with variable gain. We will discuss two protocols for accessing the nonlinear response of the junction, amplitude modulation and frequency modulation, and describe in detail two applications—superconducting qubit readout and high speed magnetometry of single molecule magnets.

[1] A. Wallraff et al, *Physical Review Letters* **95**, 060501 (2005).