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Josephson Parametric Amplifiers: Theory and Application

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Measurement of signals consisting of small numbers of microwave photons per unit bandwidth requires multiple amplification stages so the signal can be efficiently detected by room temperature electronics. However, even the lowest-noise commercially available microwave amplifiers add the equivalent of tens of photons of noise, making them insufficient for the amplification of single- or sub-photon signals. Recent interest in measuring photon-level signals from superconducting circuits has motivated the intensive development of Josephson parametric amplifiers (JPAs). Consisting of Josephson junctions shunted by a capacitor to form a nonlinear resonator, a typical JPA provides large gain (~20 dB) with nearly quantum-limited noise performance over instantaneous bandwidths of many MHz (depending on frequency band) that can be tuned over an octave. These devices have enabled a variety of experiments with superconducting qubits, including high-fidelity readout, quantum feedback, and observation of individual quantum trajectories. They also provide a valuable tool for the field of microwave quantum optics through their ability to generate squeezed states of the EM field. In this talk, I will discuss the operating principle and design considerations of a JPA circuit, their typical usage in qubit measurement, and their potential application to the detection of dark matter.

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