Field-Programmable Josephson Amplifier

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Superconducting parametric amplifiers provide high gain and near quantum-limited noise performance that enable high fidelity state readout of superconducting quantum bits (qubits). In Josephson parametric amplifiers, gain is obtained by modulating a nonlinear inductive element (such as a DC-SQUID) with a strong microwave pump, so that energy is converted from the pump to a signal and idler waves. Due to their purely reactive nature, parametric amplifiers have low dissipation and can operate close to sensitive superconducting quantum circuits. Moreover, by driving multiple parametric pumps, a parametric amplifier can be turned into a nonreciprocal 2-port device, thus eliminating the need for lossy ferrite circulators. As a result, we can couple the amplifier directly to the qubit readout cavity and improve readout fidelity.

In this talk we are going to discuss a new type of Josephson parametric device, called the FPJA (Field-Programmable Josephson Amplifier). The FPJA consists of 3 resonant modes that can be parametrically coupled in any arbitrary configuration via a single flux-driven DC-SQUID. We are going to discuss three different modes of operation: microwave circulation, phase-preserving amplification and phase-sensitive amplification. Each configuration can be activated on demand by selecting an appropriate set of microwave drives, demonstrating more than 30dB of reverse isolation, 20dB of gain and one photon of added noise in phase preserving amplification mode. We will also discuss a directional and phase-sensitive operating mode with noise temperature below the standard quantum limit. Based on a gradiometric superconducting quantum-interference device with Nb/Al-AlOx/Nb Josephson junctions, the FPJA is furthermore first-order insensitive to flux noise and can be operated without magnetic shielding at low temperature. Owing to its flexible design and compatibility with existing superconducting fabrication techniques, the FPJA offers a straightforward route toward on-chip integration with superconducting quantum circuits.