DOCTORAL DEFENSE

Creating Directional Quantum-Limited Amplification Using Multiple Parametric Drives

Tzu-Chiao Chien

Friday, May 15, 2020
3:00PM

Zoom ID: 851 642 532
Non-department members:
Contact Graduate Administrator at **pagrad@pitt.edu** for access

Research Advisor:
Dr. Michael Hatridge

Abstract: One of the primary requirements for superconducting quantum information processors is high-fidelity, quantum non-demolition qubit readout. In superconducting circuits, we perform measurements with quantum-limited microwave amplifiers. These amplifiers are based on microwave cavities and powered by Josephson-junction based nonlinearities, which we drive to parametrically modulate the circuit and generate gain. However, cavity-based amplifiers generally suffer from a fixed gain-bandwidth product, a limited dynamic range, and the absence of directionality, and so they must be operated with external lossy microwave commercial components such as circulators.

Many of these limitations can be circumvented by combining multiple parametric processes in a few-mode device, in particular by combining parametric drives which produce gain and those which produce gainless photon conversion. By combining balanced gain and conversion processes between a pair of modes, we have demonstrated transmission-only, phase-sensitive, gain-bandwidth-free amplification. We have also used measurements of transmon qubits with this mode of amplification to demonstrate its practical utility. More, by combining multiple instances of imbalanced gain and conversion processes among three modes, we have realized devices with non-reciprocal, transmission-only amplification, matched ports, and a large, gain-independent bandwidth.

One of the biggest challenges in tuning multiple parametric processes is both inherent and dynamically-generated higher order nonlinearities in the device, which shift mode frequencies and parametric coupling strengths with pump power, preventing accurate balancing of the parametric processes. These can be controlled through engineering the Hamiltonian of the nonlinear element, in this thesis either a linearly-shunted Josephson Ring Modulator or SNAIL (Superconducting Nonlinear Asymmetric Inductive eLements), which for certain applied flux values can minimize or even change the sign of higher-order even nonlinearities. More, we have explored a range of circuit parameters, allow us to also control the relative size of odd-order nonlinearities. We have developed a series of prototypes which implement these concepts, and have achieved both high-dynamic range singly pumped amplifiers, and a promising platform for multi-parametric devices. We conclude by presenting recent progress towards implementing multiple parametric schemes that generates a practical directional amplifier, and discuss the remaining obstacles to truly ideal parametric amplifiers.