Reciprocal and Nonreciprocal Amplification at the Quantum Level

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Preserving the quantum coherence of signals is of paramount importance for components utilized in quantum information processing, quantum computation and quantum measurement setups. In recent years a tremendous progress has been made in the development of quantum-limited components, such as reciprocal and nonreciprocal amplifiers, circulators and isolators. A promising way to design these devices is based on parametric modulation of coupled modes, where the required mode-mixing processes are realized by utilizing Josphson junction-based tunable couplers or via coupling to mechanical degrees of freedom. All designs come with their unique challenges, such as higher-order nonlinearities – limiting the dynamical range, or high thermal occupations – leading to noise contamination of the signal. In addition, standard cavity-based parametric amplifiers suffer from a fixed gain-bandwidth product.

In this talk we present possible ways to face these challenges, complemented with an introduction of the basic concept on how to engineer nonreciprocal interactions and devices based on balancing a coherent interaction with the corresponding dissipative interaction. Furthermore, we present possible implementations in superconducting circuit and optomechanical architectures and discuss routes for optimizing the design of microwave circuits enabling nonreciprocal and reciprocal amplification at the quantum limit.