Contribution ID: **3** Type: **not specified**

Quantum limited superconducting resonator amplifiers for high frequency Axion dark matter search

Monday, 1 December 2025 10:30 (20 minutes)

Superconducting Parametric Amplifiers (SPAs) have seen great interest in recent years due to their high gain and quantum limited noise performance. Among these amplifiers, resonant SPAs have been widely developed for experiments where ultra low-noise narrow-band amplification is of interest, such as the search for Axion dark matter in particle physics and the detection of spectroscopic lines in astrophysics, while also finding applications in quantum computing. This work presents an amplifier based on a Complementary Split Ring Resonator (CSRR), patterned on a NbTi coated sapphire substrate embedded within a waveguide, designed to work at a set of four narrow frequency bands throughout Ka band (26-40 GHz) using the kinetic inductance of the superconducting film. The S-parameters measured at 400 mK, using a sorption cooler, show the four resonances between 23.3 and 26.3 GHz at 1 GHz spacing, with a maximum transmission on resonance of -1 dB. Four-wave mixing has been observed with each resonance and a maximum signal gain of 30 dB has been measured, corresponding to 29 dB of insertion gain. The noise performance of the amplifier has been measured, showing an added noise of 1.2 half quanta at 400 mK. These results motivate the implementation of such amplifiers in future high frequency Axion dark matter experiments, where system noise has a direct impact on the parameter space explored within a given time.

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Session Classification: Morning Session 1