Observation of positive gain by a combination of quasiparticle SIS up and down frequency converters

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Abstract— Heterodyne instruments have recently attained quantum-limited low-noise performance, particularly in radio astronomy, but it is difficult to develop large heterodyne arrays. In the realization of the heterodyne array, the reduction of power dissipation for semiconductor-based amplifiers remains a major challenge. Alternatively, superconducting parametric amplifiers still seem to have several barriers to application, especially in terms of operating temperature. Here, we show a novel concept of microwave amplification based on up and down frequency-conversion processes using quasiparticle superconductor-insulator-superconductor (SIS) tunnel junctions. The SIS up- and down-converters were connected in cascade and driven by a local oscillator (LO) power supply. In this case, input and output microwave signal frequencies become identical, and the input microwave power can be amplified with bilateral conversion gains.

We demonstrate positive gain using a proof-of-concept test module, which operates with a power dissipation of several μW at a bath temperature of 4 K. The test module used in this experiment is an existing heterodyne mixer block and two SIS converter chips at a radio frequency (RF) band of 100 GHz developed for the four beam receiver system on the 45-m telescope (FOREST). The operation temperature is high compared to those of a superconducting Josephson amplifier and kinetic inductance travelling wave amplifier with a typical operating temperature of several hundred milli-Kelvins. The result indicates that the configuration potentially works as a low-noise and low-power-consumption microwave amplifier at an operating temperature of 4 K with Nb-based SIS junctions.

At the conference, we will present the detailed configuration, and describe measurement and analysis results.