# Noise temperature and *S*-parameter measurements of an SIS-based microwave amplifier

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***Abstract*—In this presentation, we report on characterization of a superconducting microwave amplifier based on superconductor-insulator-superconductor (SIS) mixers, that has comparable performance with conventional cryogenic low-noise amplifiers based on semiconductor devices.**

***Keywords—SIS mixer, superconducting amplifier, low noise, microwave***

## I. INTRODUCTION

We have studied a novel low-noise and wideband microwave amplifier operating at a physical temperature of 4 K and a low-power consumption of a few microwatts [1, 2]. The amplifier uses two quasiparticle superconductor-insulator-superconductor (SIS) mixers connected as frequency up- and down-converters in cascade. Since the input and output microwave frequencies can be the same by injecting an identical local oscillator (LO) power at a millimeter wavelength into each mixer, it is possible for this amplifier configuration to have positive gain in total utilizing the bilateral gains in their frequency up and down conversion processes. Our primary target of this study here is to demonstrate the superior performance comparable with conventional cryogenic low-noise amplifiers based on semiconductor devices such as a high electron mobility transistor or heterojunction bipolar transistor.

In this study, we have configured this amplifier using two heterodyne SIS mixer modules as frequency up- and down-converters at W-band (75-110 GHz) developed for the four-beam receiver system on the 45-m telescope (FOREST) [3] and inserting a W-band cryogenic waveguide isolator (2.54 mm x 1.27 mm) between these SIS mixers (see Fig. 1). The W-band cryogenic isolator, produced by Micro Harmonics inc., has an insertion loss less than 1 dB and isolation more than 25 dB across the 75-110 GHz at cryogenic temperature. It minimizes deterioration of amplifier gain and noise temperature and can independently operates the SIS mixers in terms of impedance at the up-converted frequencies. For the independent controllability of LO powers into each SIS mixer, W-band waveguide attenuators have been inserted in the respective LO paths at room temperature. In addition, another simulation indicates that phase rotation of the up-converted signals between the SIS mixers and relative phase difference between two LO powers at the SIS mixers are critical for the amplifier gain. Therefore, a W-band waveguide phase shifter was inserted into one of the LO branches. For the noise temperature measurement setup, we inserted a 20 dB attenuator at the input of this amplifier to avoid the gain saturation and a different low-noise amplifier which covers 0.5-8.0 GHz at the output of the SIS down converter.

The measurement result showed 6 dB gain and 12 K noise temperature up to 5 GHz in typical at an LO frequency of 87.4 GHz. This result is quite comparable with the cryogenic low-noise amplifier based on semiconductor transistors. We also plan to measure *S*-parameters of the amplifier at the microwave frequencies using a vector network analyzer. In this symposium, we will present the detailed characterization, analysis results, and future prospective of this low noise amplifier.

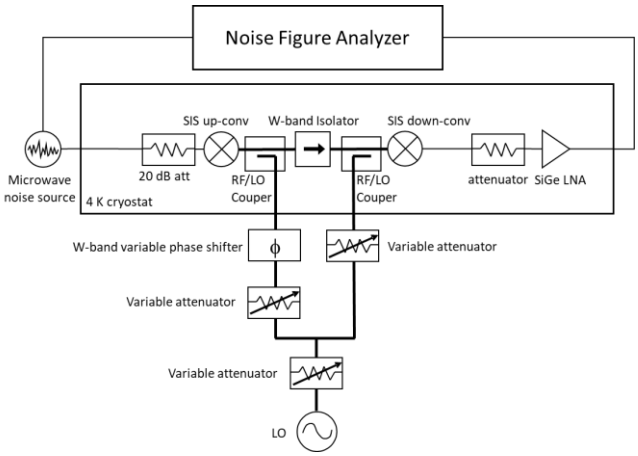


Fig. 1. Schematic of noise temperature measurement setup for the SIS-based amplifier.

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## REFERENCES

[1] T. Kojima et al., "Microwave amplification based on quasiparticle SIS up and down frequency converters," AIP Advances 8, 025206, 2018

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[2] Y. Uzawa et al, "An SIS-mixer-based amplifier for multi-pixel heterodyne receivers", *Proc. SPIE*, Dec. 2020.
[3] T. Minamidani, et al., "Development of the new multi-beam 100 GHz band SIS receiver FOREST for the Nobeyama 45-m Telescope," *Proc*. of SPIE, vol. 9914, 99141Z, 2016.

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