Characterization System for SIS Frequency Converters based on Scalar Mixer Calibration Technique

Takafumi Kojima[1], Yoshinori Uzawa[1], and Wenlei Shan[1], Yuto Kozuki[2]

It is well known that a quasiparticle superconductor-insulator-superconductor (SIS) tunnel junction potentially allows positive conversion gain in the down-conversion process from millimeter wave to microwave. In recent, it was found that the tunnel junction could also have positive up-conversion gain from microwave to millimeter-wave [1]. Utilizing this bilateral gain in the SIS up- and down-conversion processes, we demonstrated a microwave amplification with low power consumption in several micro-watts using a proof-of-concept test module. The module uses SIS up- and down-converters which were connected in cascade and driven by an identical local oscillator (LO) power. The superconducting microwave amplifier based on this concept is promising for future radio astronomical heterodyne instruments such as a large scale multi-beam receiver at (sub-)millimeter wavelengths [3], but it has not been studied well so far.

In order to design the amplifier with low noise and high gain, it is important to characterize both the SIS converters in radio frequency (RF) and intermediate frequency (IF). However, in general, the evaluation of cryogenic devices based on a module approach has been carried out at millimeter-wave and even microwave frequencies. In this case, the measured conversion gain and impedance are affected by interconnections and interfaces of the package, e.g. connectors, bonding wires and transmission line. This requires correction of the measured values to extract device parameters, which causes uncertainties.

We have established a characterization system for an SIS up- and down-converter using a 4-K cryogenic probe station in combination with a vector network analyzer up to 50 GHz (Fig.1). The characterization system allows us to directly measure mixer conversion gain and reflection coefficients at RF and IF. It consists of a high pass filter with f_{cutoff} of 26 GHz and a low pass filter with f_{cutoff} of 21.5 GHz to divide the RF and IF signals, and a broadband 20-dB coupler for LO power injection. The LO chain uses a microwave synthesizer and a frequency doubler within an output frequency of 26.5-40 GHz. A DC bias voltage to the SIS junction is applied via a bias tee. A vector network analyzer (N5225B PNA, 10 MHz-50 GHz) produced by Keysight technology was used to measure the frequency conversion properties.

For accurate characterization of conversion properties, a scaler mixer calibration technique was employed. An SIS device sample based on Nb/Al/AlO_x/Nb junctions with a diameter of 0.8 μm and critical current density of approximately 5.5 kA/cm^2 was used for the verification of the measurement technique.

In the conference, the characterization method and measurement example of the SIS converter will be presented.

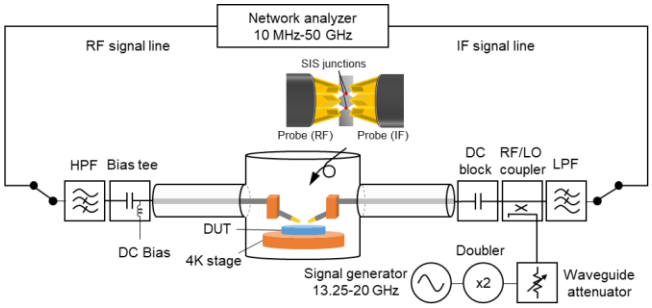

Fig. 1. Schematic of the on-wafer characterization system for an up- and down-converter.

ACKNOWLEDGEMENT

This work was supported by JSPS KAKENHI under Grant JP19H02205 and Grant JP18H03881.

REFERENCES

[1] Y. Uzawa, T. Kojima, W. Shan, A. Gonzalez, M. Kroug, “Investigation of SIS Up-Converters for Use in Multi-pixel Receivers,” Journal of Low Temperature Physics, Vol. 193, pp 512–517, Nov. 2018.

[2] T. Kojima, Y. Uzawa, W. Shan, “Microwave amplification based on quasiparticle SIS up and down frequency converters,” AIP Advances 8, 025206, 2018.

[3] W. Shan, S. Ezaki, K. Kaneko, A. Miyachi, T. Kojima and Y. Uzawa, "Experimental Study of a Planar-Integrated Dual-Polarization Balanced SIS Mixer," in IEEE Transactions on Terahertz Science and Technology, vol. 9, no. 6, pp. 549-556, Nov. 2019.

[1] National Astronomical Observatory of Japan, Mitaka, Tokyo, Japan.
[2] The University of Elector-communications, Chofu, Tokyo, Japan

NOTES: