Performance of the SIS terahertz photon detector

Hajime Ezawa[1,2], Hiroshi Matsuo[1,2], Masahiro Ukibe[3], Go Fujii[3], and Shigetomo Shiki[3]

We are developing a fast terahertz photon detector. Fast photon detector may be one of the key technologies for future terahertz instruments, which may resolve each photons to realize high sensitivity. In addition, fast photon detectors may be used to study the photon statistics, which may act as a precise measure to determine the physical properties of the radiation.

Among various technologies to detect terahertz radiation, SIS junction (or STJ) is a good candidate as a device to realize a fast photon detector, which should be as fast as 1 GHz. We have developed an SIS junction of Nb/Al/AlOx/Al/Nb which exhibits a leakage current as low as 1 pA at a cryogenic temperature of T <0.7 K [1]. The junction was 3 μm x 3 μm in size, with critical current density of J_c=300 A/cm^2. The junction is developed using the CRAVITY facility at AIST [2]. The junction has been integrated into an antenna coupled SIS detector. The design of the detector is discussed in [1]: A twin-slot antenna connects to the SIS through a coplanar waveguide. The SIS forms a parallel connected twin junction (PCTJ) [3], which is tuned to our target frequency of 500 GHz. The low critical current density will result in a relatively narrow RF bandwidth (4 GHz for our case). The current detector is aimed for laboratory experiments where the background radiation dominates, therefore the narrow bandwidth is preferred.

Recently, we evaluated the performance of the detector. The leakage current was measured at bias voltage of 600 μV to confirm the low leakage feature of 1-2 pA. The optical performance was also evaluated: The SIS detector was irradiated with a blackbody source to evaluate the photocurrent. The measurement was done at cryogenic temperature of 0.4 K, with the SIS detector mounted on a silicon hyper-hemispherical lens. The spectral response was investigated with a Fourier Transform Spectrometer. The results clearly show that the detector is sensitive to terahertz photons, however the performances were slightly shifted from the designed values. The optical efficiency was derived to be low, which may have caused by the degraded spectral performance, or transmission properties due to the detector design.

Based on the results, we are now in the course to revise the detector design: The detector fabrication parameters are investigated to realize a better spectral performance. The geometrical design of the detector is studied to improve the transmission efficiency from the antenna to the detector, and to realize a stable fast readout. The performances of the detectors with the revised design are being studied, which includes the optical response of the detectors with improved fabrication parameters. The design and performance of the SIS photon detectors, and their improvement studies will be discussed in the presentation.

References

[1] H. Ezawa, H. Matsuo, M. Ukibe, G. Fujii, S. Shiki, “Studies on Terahertz Photon Counting Detectors with Low-Leakage SIS Junctions”, J. Low Temp. Phys. 194, 426-432, 2019, DOI: 10.1007/s10909-019-02149-y.

[2] M. Ukibe, S. Shiki, Y. Kitajima, M. Ohkubo, “Soft X-ray Detection Performance of Superconducting Tunnel junction Arrays with Asymmetric Tunnel Junction Layer Structure”, Jpn. J. Appl. Phys. 51, 010115, 2012, DOI: 10.1143/JJAP.51.010115.

[3] T. Noguchi, S-C. Shi, J. Inatani, “Parallel Connected Twin SIS Junctions for Millimeter and Submillimeter Wave Mixers: Analysis and Experimental Verification”, IEICE Trans. Electron. E78-C, 481-489, 1995.

[1] National Astronomical Observatory of Japan, Tokyo 181-8588, Japan.
[2] Department of Astronomical Science, The Graduate University for Advanced Studies, SOKENDAI, Tokyo 181-8588, Japan.
[3] National Institute of Advanced Industrial Science and Technology, Tsukuba, Ibaraki 385-8568, Japan.

NOTES: