SIS Photon Detectors for Terahertz Astronomy

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Abstract— Demands of high sensitivity detectors for astronomy and astrophysics are increasing. Observation technologies have advanced extremely in the past decades; large ground base observatory ALMA exhibited a very high resolution and high sensitivity capability at millimeter and submillimeter wavelengths. On the other hand, for space born terahertz missions, photon counting detectors are advantageous to realize high sensitivity and high dynamic range observations. Fast photon counters may significantly improve the capability of future intensity interferometers, aiming for ultra-high resolution imaging.

Considering the observation from space, photon rate from a 1 Jy source, such as stars or active galactic nuclei, is estimated to be in the order of 100 M photons/sec, when observed at a frequency of 1 THz and a bandwidth of 100 GHz with a 10 m telescope. To resolve these photons individually, the detector is to respond as fast as 1 GHz with NEP $< 3\times10^{-17}$ W/$\sqrt{}$Hz. We are considering that an SIS junction operated in a photon-assisted tunneling mode may fulfill this requirement, when its leakage current is as low as 1 pA. Our development is undergoing with the CRAVITY facility in AIST. The basic design of our SIS junction consists of thin layers of Nb/Al/AlOx/Al/Nb. As a first step we are developing an SIS junction to demonstrate the fast photon counting capability in lab experiments. For this purpose we utilize a detector with a relatively narrow bandwidth. So far we have successfully fabricated a junction of 3 μm x 3 μm with the leakage current of 1 pA below 0.7 K. The current density was 200 A/cm^2, which leads to the bandwidth of a few GHz. This satisfies our requirement for lab experiments, while developments towards wider bandwidth are necessary to realize future space borne astronomical instruments.

Based on this achievement, we are now designing to integrate this junction into an SIS photon detector. Twin slot antenna optimized for terahertz waves connects to the detector via a coplanar wave guide, where the detector is designed as a parallel connected twin junction (PCTJ). The signal is fed to the readout circuit through a choke filter, similar to conventional SIS mixers. We are considering a GaAs-JFET or a Junction-PHEMT for the first stage FET, followed by a SiGe cryogenic amplifier at 4 K. The development and performance of the SIS junction, as well as the basic design of the detector and its readout circuit will be discussed in the presentation.