# SIS JUNCTION AS A DIRECT DETECTOR AT 850 μm WAVELENGTH

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## ABSTRACT

We have demonstrated the feasibility of a broad band SIS direct detector with a bandwidth up to 70 GHz around 330 GHz. The SIS detector responsivity approaches the quantum limit. The optical noise of 13 mK√s measured with the new direct detector receiver is close to the noise of bolometer receiver developed for radioastronomy at the same wavelength. The SIS direct detector works at 4.5 K instead 0.1-0.3 K required for bolometer receiver.

## INTRODUCTION

The cryogenics of a spacecraft submillimeter detector is important for lifetime of the instrument and the duration of a space telescope mission. The basic solution for the 850 μm wavelength channel of the FIRST mission is the 0.1 K He3 cooled semiconductor bolometers.

The direct detection of radiation at millimeter and submillimeter wavelengths via quantum assisted tunneling in a quasiparticle tunnel junction gives an attractive alternative to detection using low-temperature bolometers. A possibility to use a Superconductor - Insulator - Superconductor (SIS) junction as a low noise detector in radioastronomy was discussed since mid-eighties [1].

Only a few experiments have been dedicated to the direct detection in SIS junctions of the mm [2] and submm [3] radiation. Apparently the noise achieved with SIS detectors does not allow one to built an instrument competitive with broad band bolometer receivers used in radioastronomy. Recently we presented a SIS direct detector receiver [4] at $\lambda \approx 850$ μm with the optical noise only 4 - 5 time larger than with a bolometer detector [5]. Below we describe the experiment with SIS detector achieving the same noise as bolometer receiver. The detector with a Nb/AlOx/Nb junction works at 4.5 K instead 100-300 mK required for bolometer.

## SIS DETECTOR

The SIS detector comprises a Nb circuit printed on a 0.1 mm thick quartz substrate with two SIS junctions and a detector block. The sketch of the waveguide detector block is presented in the figure 1. It is a single backshort block with a reduced height 0.78×0.1 mm waveguide. The transition to the 0.78×0.39 mm waveguide is prepared according to [6]. The printed circuit of the mixer is optimized for the individual junction normal resistance of about 25 Ohm and $R_N \omega C \approx 6$.

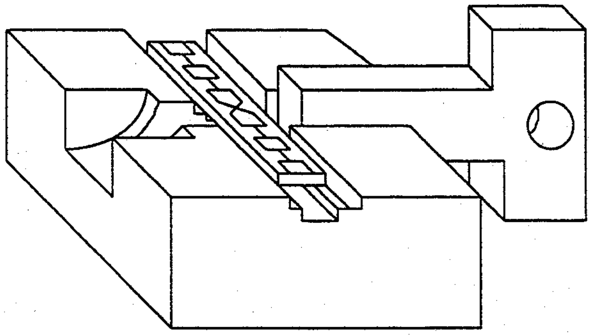

Figure 1. A half of the SIS detector block, the backshort and a quartz substrate with the SIS junctions.

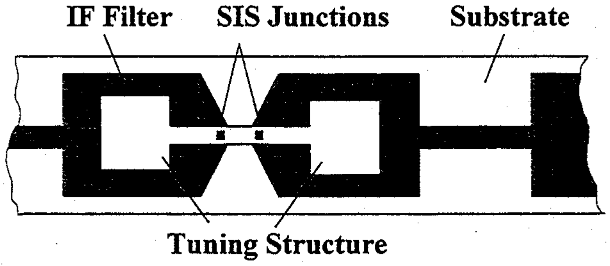

Figure 2. The SIS junctions with individual tuning structure. An L-C microstrip circuit is used to compensate for the junction capacity.

We developed a matching circuit and optimized the SIS detector circuit with the aim to get about 100 GHz effective band of detector operation around 340 GHz [7]. Out of this band the intrinsic capacitance of the junction provides a good rejection of the signal without additional filters normally used with bolometer detectors.

Two Nb-Aloxide-Nb SIS junctions 0.9 μm² each with a normal resistance of 30 Ohm are connected in series in the detector circuit. The leacage current at 4 mV is 2.8 μA. The inductive microstrip LC tuning circuit is connected to each of the junctions as a part of interconnection layer in the junction fabrication process (Figure 2). The microstrip is 27 μm long and 4 μm wide. The dielectric layer is in $SiO_2$ 200 nm thick. The DC block capacitance is about 0.4 pF.

## EXPERIMENT

The SIS detector responsivity is measured in experiment with a shopper switching the beam of the detector between two black bodies at the different temperatures - an ambient temperature load and a nitrogen cooled load. The variation of the source temperature in this experiment is about 215 K. The switching frequency is 10 Hz. A Ithaco lock-in amplifier is used for the measurement of detected current and of the rms of current fluctuations (optical noise). The optical noise comprises the contributions of the detector, amplifier, receiver optics and parasitics. The optical noise is measured only with the ambient temperature load in front of receiver to avoid the instabilities of nitrogen cooled load.

The same installation is used for detection of a weak monochromatic signal at 330 GHz. In this experiment the detector beam is switched between the ambient temperature black body and a 330 GHz signal source with the power of about 2 $10^{-10}$ W. The position of the backshort in detector block is adjusted with the aim to get the best responsivity around 330 GHz.

The measured variation of SIS junction current versus bias voltage is presented in Figure 3. The quantum step produced by the 330 GHz signal is presented by a dashed line with + points and the step produced by the broad band black body radiation is presented by a solid line with the ◊ points. The amplitude of the 330 GHz signal is adjusted to get the same maximum detected current of 61 nA as in experiment with the black body.

The measured detected current corresponds to effective bandwidth of the detector of about 70 GHz taking into account the 17 % loss in the detector optics. This band is close to the model prediction and is largely sufficient for the application in radioastronomy. The optical noise of 13 mK√s measured with the new direct detector receiver is close to 15 mK√s noise of the bolometer receiver developed for radioastronomy at the same wavelength [4]. The SIS direct detector works at 4.5 K instead 0.1-0.3 K required for bolometer receiver.

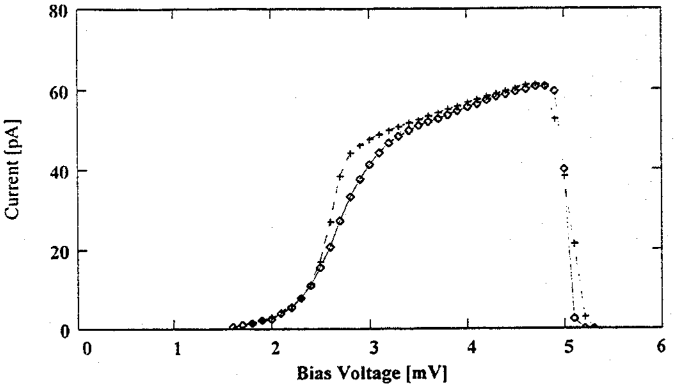

Figure 3. The measured current variation versus bias voltage for a two Nb-Al oxide-Nb junction array. The quantum step with 330 GHz signal (dashed line with +) and with black body radiation (solid line with ◊).

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