A 100 GHz SIS QUASIPARTICLE MIXER WITH 10 dB COUPLED GAIN

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Abstract

We have tested a superconducting quasiparticle mixer for 85–110 GHz which gives much larger coupled gain than has been previously observed. When operated with a negative dynamic resistance of about 2000 Ω, the maximum coupled gain was G_M(DSB)= 12.5 ± 0.5 dB [G_M(SSB)= 9.5 ± 2.5 dB]. The associated mixer noise temperature was 15.9 K (DSB). Large gain was also observed with large positive dynamic resistance, giving the lowest mixer noise temperature of 12.4 K (DSB).

Introduction

Unlike classical resistive mixers which always have gain less than unity, large gain is predicted in superconductor-insulator-superconductor (SIS) quasiparticle mixers [1]. Experimental SSB gains larger than unity have been observed only in SIS mixers with low IF frequencies of 25–50 MHz [2,3]. We have tested a practical broad band (85–110 GHz) SIS mixer with a 1.5 GHz IF which shows very large gain.

Experimental results

Our mixer shows stable operation with large gain in two regimes: 1) for positive dynamic resistance from a few hundred ohms to infinity, and 2) for negative dynamic resistance of about 1000–2000 Ω. The lowest mixer noise temperature of T_M(DSB)= 12.4 ± 1.5 K was obtained with a gain of 7.9 dB (DSB) for a positive dynamic resistance nearly matched to the load resistance of about 500 Ω. For a negative dynamic resistance, coupled gain larger than unity was observed from 85 to 108 GHz, as is shown in Fig. 1. The highest coupled gain measured was G_M(DSB)= 12.5±0.5 dB (9.5±2.5 dB SSB) at 95.4 GHz. The associated mixer noise temperature was 15.9 K (DSB). The I-V curve which gave the highest gain is shown in Fig. 2.

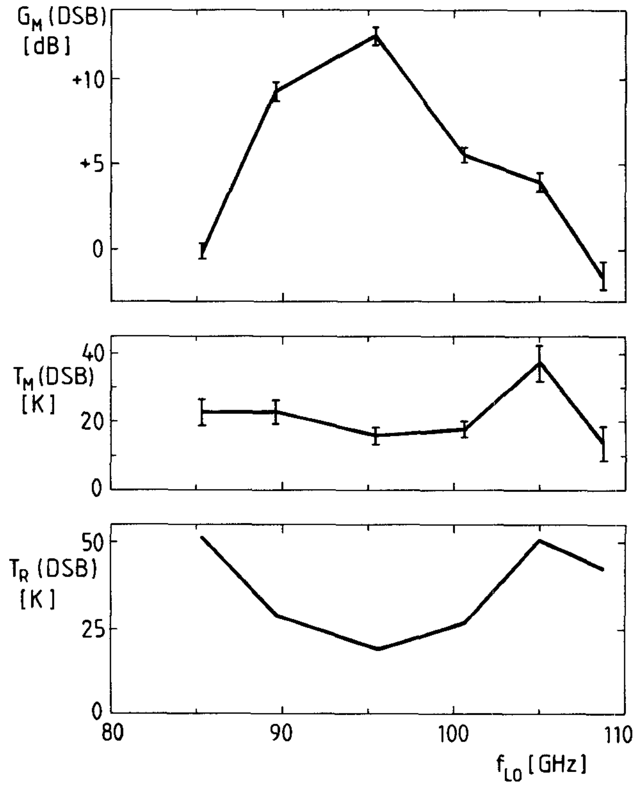

Figure 1. Coupled gain and noise temperature of the mixer and noise temperature of the mixer test receiver versus LO frequency.

Theoretically, a parallel resonant circuit including a negative conductance is stable when the net conductance is positive. This condition was fulfilled in the output circuit of our mixer. Strong oscillations in the IF band were observed when the negative dynamic resistance was low. In some cases the measurement of the dynamic resistance of the bias point was ambiguous, because structure in the middle of the step was observed.

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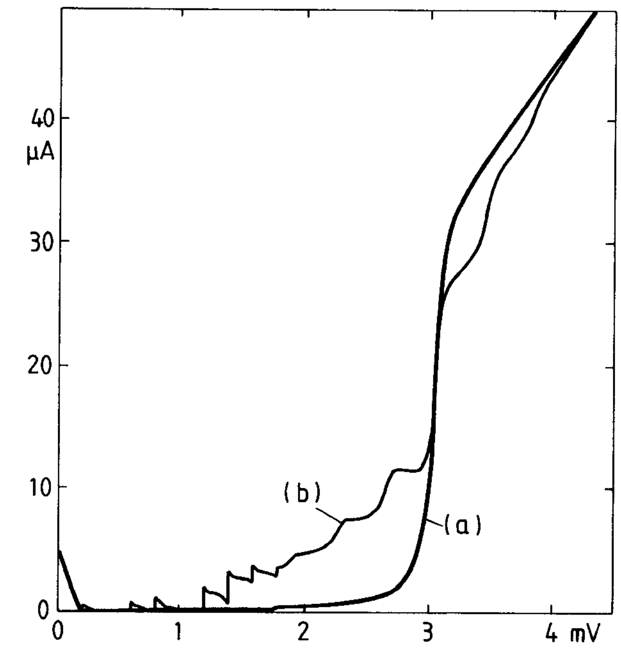
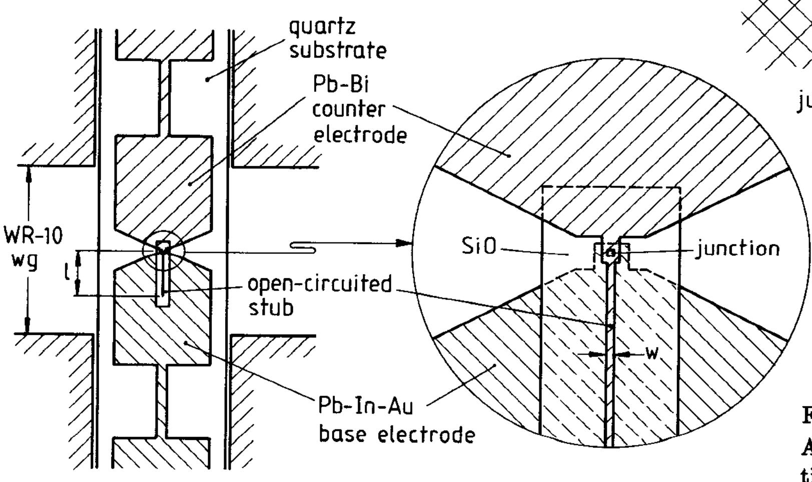


Figure 2. I-V characteristic of the $2 \times 2\ \mu m^2$ Pb-alloy junction at 1.3 K. (a) Unpumped, (b) pumped with LO power of 3.5 nW at 95.4 GHz with optimum tuning.

Mixer design

The mixer mount used for these measurements has a full height WR-10 waveguide channel and a single mechanical tuning element. A broad band RF match to a single $2 \times 2\ \mu m^2$ Pb-alloy junction is obtained from 85 to 110 GHz by using the reactances of the RF filter and of the integrated open-circuited microstrip stub [4] shown in Fig. 3. The microstrip stub was 0.35 mm long and 3 μm wide. It had a phase velocity of 0.3 c and a characteristic impedance of 16 Ω. The mixer mount and tests with several other types of Pb-alloy junctions are described elsewhere [5].



(a)

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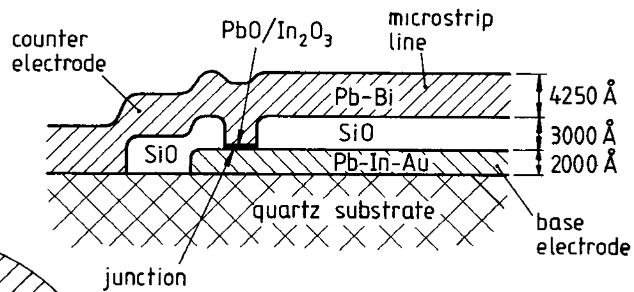

(b)

Figure 3.
A detail of (a) the mixer mount and (b) the junction with an integrated superconducting microstrip stub.