Noise and Mixing in Aluminum Based Sub-Micron Hot-Electron Bolometers

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Previous work with superconducting hot-electron bolometer (HEB) mixers has shown that the primary source of noise in well optimized Nb devices is thermal fluctuation noise [1]. Our results for microwave mixing in sub-micron long diffusion-cooled thin film superconducting aluminum HEB structures (T_c ~ 1.7K-2.4K) in the bath temperature range of T=0.25-1.6K [2] show that is possible to operate the mixer, with good conversion efficiency and intermediate frequency bandwidth, in a region where the thermal fluctuation noise is very small. In these devices, the resistive transition, R *vs.* T, is very broad. At T/T_c ~ 0.3 we still observe a resistance that is consistent with ~0.2 μm of the total microbridge length being resistive [3]. At T=0.25K (T/T_c ~ 0.1) in zero magnetic field, the banks of the HEB are superconducting. By applying a magnetic field H‡0.03T, the banks can be driven normal, in which case we again observe that about 0.2 m of the 0.6 micron bridge is resistive. Thermal fluctuation noise is largest near the onset of T_c ¯ 2.5 K for that sample. The best mode of heterodyne mixing in our devices was observed at low bias voltages ~0.2mV.

If the Al HEB with normal banks is modeled as a N-S-N structure with near ideal transparency, then charge-imbalance arguments [4] can be invoked to explain the behavior of the resistive transition near T_c. Noticeable fractions of the microbridge edges should be resistive since the characteristic charge-imbalance diffusion length is non-negligible compared with the microbridge length L. The diffusion length is $\Lambda_{Q*}(T)=(D\tau_{Q*}(T))^{1/2}$ [5]. The charge-imbalance relaxation time τ_{Q*} is estimated from reported values of the inelastic scattering time τ_i at the Fermi energy [6], and the diffusion constant D is measured from H_{c2}. However, far below T_c charge-imbalance effects should not be significant, and Andreev transfer of pairs should dominate. The resistance of the N-S boundaries should be negligibly small. At T=0.25K, the quasiparticle population which can be injected into the superconductor is exponentially small. Yet we observe a large series resistance at 0.25 K in a magnetic field H‡0.03T. Thus, the physical model for the resistance is not complete for the low temperature / low voltage regime, even though excellent heterodyne performance is observed there and diffusion cooling appears to be operative.

We discuss possible mechanisms to account for the measured device resistance as a function of temperature, and how they effect the mixing mechanism and output noise within the context of a diffusion cooling model.

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