

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

A.Verevkin, I.Siddiqi, and D.E. Prober

Department of Applied Physics, Yale University, New Haven, CT 06520-8284

A.Skalare, B.S.Karasik, W.R.McGrath, P.M.Echternach, and H.G.LeDuc

Center for Space Microelectronics Technology, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109-8099

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 ($T_c \sim 1.7\text{K}-2.4\text{K}$) in the bath temperature range of $T=0.25-1.6\text{K}$ [2] show that it 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 $T/T_c \sim 0.3$ we still observe a resistance that is consistent with $\sim 0.2 \mu\text{m}$ of the total microbridge length being resistive [3]. At $T=0.25\text{K}$ ($T/T_c \sim 0.1$) in zero magnetic field, the banks of the HEB are superconducting. By applying a magnetic field $H \pm 0.03\text{T}$, the banks can be driven normal, in which case we again observe that about $0.2 \mu\text{m}$ of the $0.6 \mu\text{m}$ bridge is resistive. Thermal fluctuation noise is largest near the onset of $T_c \sim 2.5 \text{K}$ for that sample. The best mode of heterodyne mixing in our devices was observed at low bias voltages $\sim 0.2\text{mV}$.

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 $T=0.25\text{K}$, the quasiparticle population which can be injected into the superconductor is exponentially small. Yet we observe a large series resistance at 0.25K in a magnetic field $H \pm 0.03\text{T}$. 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.

1. Burke et al., Appl. Phys. Lett. **72**, 1516 (1998); B.S. Karasik, and A.I. Elantiev, Appl. Phys. Lett. **68**, 853 (1996).
2. I.Siddiqi et al., Proceedings 11th Int'l Symp. Space THz Tech., Ann Arbor, MI, (2000).
3. P.M.Echternach et al., Proceedings 10th Int'l Symp. Space THz Tech., Charlottesville, VA, 261(1999).
4. J.R.Waldram, Proc.R.Soc.Lond.A **345**, 231(1975); S.N.Artemenko, and A.F.Volkov, Sov.Phys.JETP **45**, 533(1977); G.E. Blonder et al., Phys. Rev. B **25**, 4515 (1982)
5. D.W. Floet et al., Appl. Phys. Lett. **73**, 2826 (1998); M. Stuiyinga et al., JLTP **53**, 633 (1983)
6. P.Santhanam and D.E.Prober, Phys.Rev.B **29**, 3733(1984); T.M. Klapwijk et al, Phys. Rev. B **33**, 1474 (1986); J.M. Gordon and A.M. Goldman, Phys. Rev. B **34**, 1500 (1986); E.M. Gershenzon et al., Solid State Com. **75**, 639 (1990).