Low-Noise and Wideband Hot-Electron Superconductive Mixers at THz Frequencies

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Superconductive hot-electron bolometer (HEB) mixers have been built and tested in the frequency range from 1.1 THz to 2.5 THz. The mixer device is a 0.15-0.3 μm microbridge made from a 10 nm thick Nb film. This device employs diffusion as a cooling mechanism for hot electrons. The HEB device is combined with a planar antenna on a Si or quartz substrate lens in a quasioptical mixer configuration. The double sideband noise temperature was measured to be ≤3000 K at 2.5 THz and the mixer IF bandwidth is expected to be at least 10 GHz for a 0.1 μm long device. The large IF bandwidth allows for spectroscopy using FIR lasers or fixed tuned multipliers as LO sources. The local oscillator (LO) power dissipated in the HEB microbridge was 20-100 nW. The HEB mixer is a primary candidate for ground based, airborne and spaceborne heterodyne instruments at THz frequencies. HEB receivers are planned for use on the NASA Stratospheric Observatory for Infrared Astronomy (SOFIA) and the ESA Far Infrared and Submillimeter Space Telescope (FIRST). The performance of our HEB receivers at THz frequencies will be discussed.

The distinctions in ultimate performance of phonon-cooled and diffusion-cooled HEB mixers will be discussed. We will show that the temperature independent bandwidth in a diffusion-cooled HEB mixer allows for more flexibility in the mixer design. There is a wide choice of materials suitable for a diffusion-cooled HEB device and optimization of the mixer for particular applications. The practical need for a low local oscillator (LO) power requirement can be more easily met in diffusion-cooled devices by selection of a material with lower critical temperature and low density of electron states. In contrast, the parameters in the NbN-based phonon-cooled mixer cannot be widely varied because of the high resistivity and high transition temperature of the material and the necessity of using ultrathin films. Given the limited availability of LO power from compact solid-state sources at frequencies above 1 THz, a diffusion-cooled mixer based on aluminum, for example, is a very attractive choice for low-background radioastronomy applications.

Atmospheric heterodyne remote-sensing applications at THz frequencies currently employ Schottky-diode based receivers. A $YBa_2Cu_3O_{7-\delta}$ (YBCO) HEB mixer is a strong candidate for use in this application, due to its predicted lower noise and lower LO power requirement. The device would be a submicron bridge made from a 10 nm thick film on a high thermal conductance substrate. The mixer performance expected for this device is analyzed in the framework of a two-temperature model which includes heating both of the electrons and the lattice. Also, the contribution of phonon-diffusion from the film through the substrate and from the film to the normal metal contacts is evaluated. The intrinsic conversion efficiency and the noise temperature have been calculated as functions of the device size, LO power, and bath temperature. Assuming thermal fluctuations and Johnson noise to be the main sources of noise, a minimum single sideband (SSB) mixer noise temperature of ≅ 2000 K is predicted. The intrinsic conversion loss at an IF of 2.5 GHz can be less than 10 dB or better and the required local oscillator power dissipation is ~ 1–10 μW. The progress on fabrication and RF tests of the high-T_c HEB mixer will be reported.

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