IF Impedance and Mixer Gain of Hot-Electron Bolometers and the Perrin-Vanneste Two Temperature Model

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We have measured the frequency dependent IF impedance and mixer conversion gain of a small area NbN hot-electron bolometer (HEB). The device used is a twin slot antenna coupled NbN HEB mixer with a bridge area of 1 x 0.15 mm, and a critical temperature of 8.3K. In the experiment the local oscillator (LO) frequency was 1.300 THz, and the intermediate frequency (IF) 0.05-10 GHz. We find that the measured data can be described in a self consistent manner with a thin film model presented by Nebosis, Semenov, Gousev, and Renk, that is based on the two temperature electron-phonon heat balance equations of Perrin-Vanneste. From these results the thermal time constant, governing the gain bandwidth of HEB mixers, is observed to not only be a function of the electron-phonon scattering time and phonon escape time, but also a function of electron temperature. The latter is due to the temperature dependence of the electron and phonon specific heat. Because hot electron bolometers nominally operate at, or slightly above, the critical temperature (T_c) of the superconducting film, where local resistivity as a function of electron temperature is largest, it follows that the critical temperature of the film plays an important role in determining the HEB mixer gain bandwidth. For an NbN based hot electron bolometer, the maximum predicted gain bandwidth is approximately 5.5 GHz, given a film thickness of 3.5 nm and a T_c=12K.

Both the measured impedance and calibrated mixer gain data are used to determine (fit) values for t_{eph}, t_{esc}, and c_e/c_{ph} in the NSGR model. We demonstrate that in this way the model provides a self consistent set of parameter values. Results agree well with literature, and provide an excellent agreement between model and measurement, inclusive of electro-thermal feedback modulations.

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