Lumped-element Model Analysis for THz HEB Mixer Based on Sputtered MgB_2 Thin Films

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***Abstract*—We experimentally and theoretically investigate the mixer properties of THz hot-electron bolometer (HEB) mixer based on sputtered MgB_2 thin (7 nm) films. By simultaneously measuring the U-factor and the Y-factor of the device, we measure the voltage bias dependence of the conversion gain, output noise temperature, and the mixer input noise temperature. The great uniformity of the sputtered MgB_2 film allows us to apply the lumped-element bolometric model that describes the mixer characteristics surprisingly well. The measured double-sideband (DSB) receiver noise temperature after correcting for optical loss is ~2,000 K at 2.52 THz at 5 K, with a -3dB intermediate frequency (IF) bandwidth of ~3 GHz and a required local-oscillator (LO) power of ~ 2 μW.**

***Keywords*—THz heterodyne receiver, MgB_2 THz hot-electron bolometer**

I. Introduction

While the superconducting Hot-Electron Bolometer (HEB) mixer has been around for more than three decades, there is still a poor understanding why the noise temperature in practical mixers is still far from the quantum limit, partially due to the lack of the adequate model applicable to non-uniform HEB devices. If the device is uniform, however, a relatively simple lumped-element bolometric model [1, 2] can be applied to describe the mixer characteristics, which is important for understanding the mixer performance and giving a guidance on how to optimize the material and device parameters for better performance.

THz HEB mixers based on magnesium diboride (MgB_2) films have recently become an attractive option due to their higher critical temperature and short electron-phonon interaction time, useful for high temperature operation above 20 K and a wide -3dB intermediate frequency (IF) bandwidth ~ 10 GHz. Recently, we began employing sputtered MgB_2 thin films for the fabrication of HEB mixers. The great uniformity of these films allows us to fabricate small (0.75 μm (L) × 2 μm (W)) devices with reproducible characteristics and to apply the lumped-element model [1,2] that describes the mixer parameters well. Below, we present a set of experimental data and an analysis showing what can be learned about the HEB mixer when a detailed model is available.

II. Results

By simultaneously measuring the U-factor and the Y-factor, we investigated the voltage bias dependence of the conversion gain, output noise temperature, and the mixer input noise temperature of the MgB_2 HEB device (Fig. 1). The lumped-element model analysis using the experimental current-voltage (IV) characteristics and the temperature dependence of the device resistance (Fig. 1(a)) reproduces the bias dependence of the conversion gain, output noise temperature, and mixer input noise temperature reasonably well (Fig. 1(b-d)).

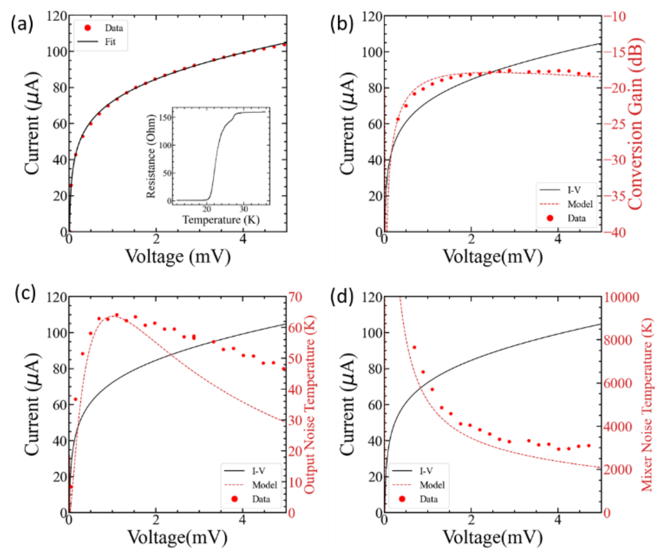

Fig. 1. Lumped-element model analysis results for THz HEB mixer based on sputtered MgB_2 thin films. (a) current-voltage (IV) characteristics when the device is pumped with a local-oscillator (LO) power at 2.52 THz at 5 K. The inset shows the temperature dependence of the device resistance. (b-d) bias dependence of conversion gain (b), output noise temperature (c), and mixer input noise temperature (d). Red dots indicate the experimental data, and the red dashed lines show the modelling results.

References

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