Characterisation and Modeling of MgB_2 HEBs IF impedance

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I. INTRODUCTION

The Terahertz region of the electromagnetic spectrum which offers many molecular and atomic emission is of particular interest for astrophysics [1]. In order to explore the THz frequency band low noise heterodyne receiver are required. Hot electron bolometers (HEB) are the most sensitive THz mixers for frequencies above 1 THz offering a gain bandwidth (GBW) as wide as 4 GHz [2]. HEBs made from NbN films were successfully used in many radio astronomical projects [2, 3]. For NbN films the technological limitations have been already achieved therefore new superconductor material is required in order to fulfill the demand for wider GBW. The high critical temperature (Tc) and the short electron-phonon interaction time ($\tau_{e\text{-}ph}$) make magnesium diboride (MgB_2) a very promising material for low noise and wider GBW THz heterodyne receivers [4, 5].

The gain variations across the band is another important problem for astronomical receivers [6]. Gain ripples originated from mismatch between the THz mixer and the low noise amplifier (LNA) are very difficult to process imposing limitations for the final receiver sensitivity. Therefore the microwave impedance of the HEB at the IF frequencies has to be measured.

II. EXPERIMENTAL AND RESULTS

For the impedance measurements the MgB_2 HEBs were mounted in a detector block which has an SMA connector at the IF terminal. The detector was placed on the cold plate of the liquid helium cryostat and connected to the 4.2 K semi rigid coaxial cable. The Vector Network analyzer was connected to the cryostat using a room temperature K cable. An accurate cryogenic impedance measurement in a coaxial environment requires a non-trivial calibration procedure. In this work we propose a non-destructive calibration technique which uses only two cooling cycles and the HEB as calibration standards. The short and load standards were realized using the device in the superconducting and in the normal state, respectively. For the open standard a broken device was used. The “new” standards allowed us to recalibrate the VNA at cryogenic temperature.

Employing the technique described above the S_{11} of several MgB_2 HEBs at different I-V and bias voltages were measured. Fig.1 shows the real and imaginary part of the impedance measured across the frequency range of 0.1 to 10 GHz for a HEB made from 20 nm MgB_2 film. The measured impedance was fitted using the HEB lumped model (solid red line). According the lumped model the real part of the impedance (Re[*Z*]) approaches the dV/dI and the dc resistance for lower and higher frequencies, respectively while the impedance imaginary part is capacitive for the entire frequency range. Similar behavior is observed in Fig. 1. From the linear fit of the I-V curve (not shown here) around the bias point (V=46.8mV; I=0.8mA) the dV/dI was extrapolated to be 173 Ohm showing a one to one correspondence with the Re[*Z*] for frequency up to 500 MHz. The dc resistance was 58 Ohm hence a bit lower than the Re[*Z*] at 10 GHz.

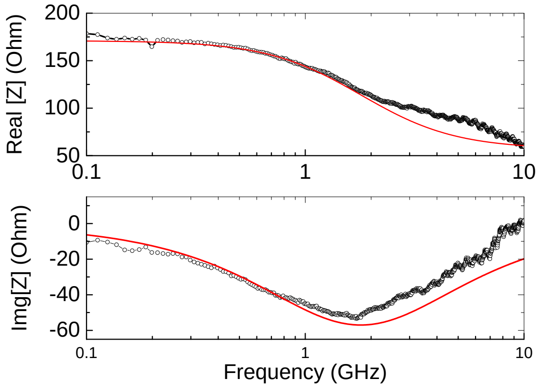

Fig 1: Real and imaginary part of the impedance for MgB_2 HEB. The symbols are measured data and the solid read line is the fitting using HEB standard model.

III. CONCLUSIONS

The method adopted here allows to measure quite accurately the HEB impedance employing just one cooling. By knowing the HEB IF impedance a coupling matching network can be designed for a possible packaged receiver.

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