Towards the heterodyne receiver for balloons and SmallSats above 2 THz

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***Abstract*— We demonstrate a broadband THz heterodyne receiver for astrophysics using Hot-Electron Bolometer (HEB) mixers based on high-T_C superconducting MgB_2 and Quantum Cascade Laser (QCL) as local oscillator (LO). This detector will advance the SOA by allowing an operation at elevated temperature (~20 K) and providing the intermediate frequency (IF) bandwidth of about 10 GHz. Such a bandwidth is required for high-resolution spectroscopy of interstellar molecular clouds at frequencies 3-5 THz and is not currently available in NbN based HEB mixers. A lab receiver system is being developed to prototype the payload for application on balloons and SmallSats.**

Keywords—hot-electron bolometer, quantum cascade laser, MgB_2, THz heterodyne receiver

I. Introduction

Terahertz (THz) heterodyne receivers play a critical role in astrophysical studies of star- and planet-formation, and the overall structure and lifecycle of the interstellar medium. Along with the most studied [CII] line at 1.9 THz, [OI] (4.74 THz), HD (2.68 THz), [NII] (1.46 THz, 2.46 THz), [NIII] (5.23 THz), and [OIII] (3.39 THz , 5.79 THz) lines are of great importance. Observations in the THz remain challenging due to the lack of well-developed technologies in the THz frequency range, the need for cryogenically cooled superconducting detectors, and the need for doing measurements from space or suborbital platforms.

II. MgB_2 HEB Mixer

Quasioptical mixer devices were made from 10-nm thin MgB_2 films grown on C-terminated face of 6H-SiC using HPCVD process. The HEB device is a 2μm (W) × 5μm (L) bridge made using ion milling and integrated with log-spiral planar antenna for coupling to the THz radiation. The critical temperature of the HEB devices was $T_C \approx$ 34-36 K.

The high critical current density $j_C > 10^7$ A/cm^2 @ 4.2 K indicated the film quality and uniformity. This value is higher than in our previous films prepared by a combination of the HPCVD and ion mill processes [1]. We also found a clear correlation between the mixer performance and the degree of granularity of the MgB_2 films traceable via the bias dependence of the output mixer noise.

III. THz Quantum Cascade VECSEL

THz quantum-cascade vertical-external-cavity surface-emitting-lasers (QC-VECSEL) were developed recently with the goal of achieving high-power, tunable sources with nearly Gaussian beam. A laterally extended emitting metasurface allows the beam to be minimally distorted by the diffraction. An external cavity allows continuous tuning over the fractional bandwidth ~ 20% around 3.4 THz. Such a device operated in a LN_2 cooled cryostat (77K) was used as local oscillator. Similar devices at 2.7 THz and 4.7 THz have been fabricated and will be employed in the THz breadboard receiver system being constructed at JPL.

IV. THz Heterodyne Receiver

Currently, we have characterized a number of MgB_2 HEB mixers using the 3.4 THz QCL, the 600 GHz Schottky-diode frequency multiplier source, and several discrete frequency lines in the 1.9-4.3 THz range of the far-IR molecular gas laser. The best data are shown in Fig. 1 along with the data for other JPL THz receivers.

The near temperature independent (up to ≈ 20K) sensitivity of the MgB_2 HEB mixer is an important factor enabling applications on small spaceborne platforms where SWaP limits are tight. The MgB_2 mixer and the QC-VECSEL make a pair of novel components, very promising for future THz instruments.

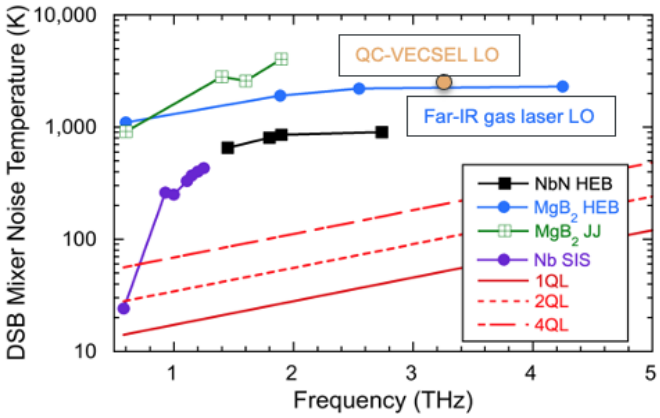

Fig. 1. JPL THz heterodyne receiver data to date. 0.6 THz, 1.9 THz, and 4.3 THz data points for MgB_2 HEBs are from the devices described in [1].

References

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