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Highly Sensitive and Compact THz heterodyne receiver based on HEB and QCL at 2.7 THz

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Abstract— **We present the development of a highly sensitive and compact HEB/QCL heterodyne detection system. The HEB mixer is a NbN nano-bridge mounted in an integrated lens-antenna configuration. The local oscillator is a low power consumption and low beam divergence 3rd order distributed feedback quantum cascade laser with single mode emission at the target frequency of 2.7 THz. A new quasi-optical coupling scheme between the mixer and the local oscillator has been developed that allows the removal of the beam splitter and therefore a better transmission of the RF signal and a more compact detection system. The lowest uncorrected double side band receiver noise temperature of this system is about 880 K.**

I. INTRODUCTION

HIGHLY sensitive heterodyne receivers at THz frequencies are of particular interest for astronomical observations since they are able to detect week emissions of molecular and atomic lines of multiple species and to provide important information about the cosmic background, the formation of stars and galaxies.

Superconducting Hot Electron Bolometer (HEB) mixers are currently the most sensitive solution for operating frequencies beyond 1.4 THz and QCL (quantum cascade laser) sources offer a great potential as local oscillators for heterodyne detections in the THz range.

We have undertaken the development of custom-tailored QCLs operating around 2.7 THz and experimented with **an original quasi-optical coupling scheme** to couple the LO power to the HEB. **An uncorrected double side band receiver noise temperature of 880 K at 2.7 THz has been obtained, confirming the potential of this concept for future space missions.**

II. RESULTS

We have designed and fabricated 3rd order DFB lasers [1] with the target single mode emission around 90 cm^{-1} (2.7 THz). Both pulsed and continuous wave (CW) laser operation was achieved. Lasing was observed up to 90 K in pulsed operation, with a typical single-mode laser spectrum at the target frequency [2]. The operating currents are in the 30-50 mA range and the power dissipation is <200 mW, thus enabling a compact integration of these devices with our HEB heterodyne mixer in the same cryostat.

The HEB mixer consists of a superconducting NbN nano-bridge connected to a gold log spiral planar antenna on a silicon substrate [3]. The ultra-thin NbN film with a thickness of 5 nm was provided by the Russian company SCONTEL. The device is mounted on the flat side of an extended hemispherical high resistivity silicon lens to increase the directivity of the antenna in the dielectric side.

We have developed a new quasi-optical coupling system (Fig.1) in order to increase the compactness of the HEB/QCL based receiver. The coupling onto the HEB of the RF signal to be detected is made through the extended hemispherical lens with an anti-reflection coating. The 3rd order DFB QCL, our LO, is instead directly coupled, from the flat side of the lens, to the HEB's planar antenna via a dielectric hollow wave guide. This original optical arrangement permits to forgo the beam splitter usually used to overlay the RF and LO signals on the HEB. The IF output signal is amplified then recorded by a sub-mm wave range power-meter.

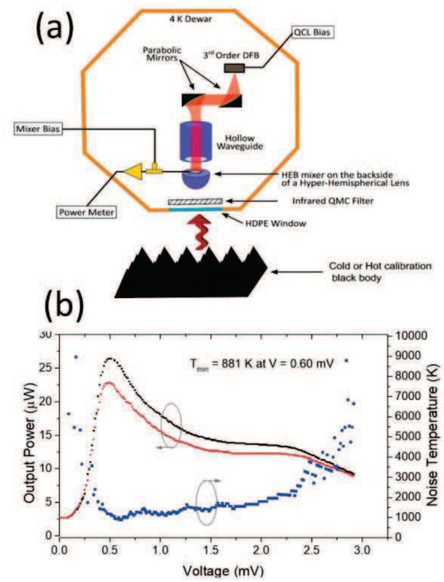

Figure 1 *– (a) Experimental setup for heterodyne measurements with the new quasi-optical coupling scheme between HEB and QCL. (b) IF output power as a function of the HEB bias voltage (black and red dots) and the corresponding receiver noise temperature TREC (blue dots) measured with the Y-factor method.*

We have obtained the lowest noise temperature of 880 K at 2.7 THz for a HEB's bias voltage around 0.6 mV (Fig. 2b), thus confirming the potential for ultra-high sensitive heterodyne detection of this scheme. This receiver concept has allowed us to maximize the transmission of the RF signal and to increase the receiver compactness while providing excellent detection sensitivity. We believe its high potential for future space missions where high sensitivity and compactness are crucial.

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