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Operation of a Monolithic Planar Schottky Receiver Using a THz Quantum Cascade Laser

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***Abstract*—This paper presents heterodyne mixer measurements at 2.9 THz using quantum cascade lasers (QCLs) as sources. The linewidth of the laser was explored by biasing it to run in dual mode operation and observing the linewidth of the beat note. In addition the frequency of the QCL is determined by beating it against a deuterated methanol line from a molecular gas laser.**

I. Introduction

Terahertz heterodyne receivers using Schottky diode mixers are desirable because they require no cryogenic cooling, have intermediate frequency (IF) bandwidths $\geq$ 20 GHz, and can deliver usefully low noise performance. However, to minimize noise temperature, Schottky receivers in the THz range require at least several milliwatts of local oscillator (LO) power. For this reason, the most common THz LO source for Schottky receivers is the molecular gas laser. Of clear interest is the possibility of replacing the molecular gas laser with a solid-state THz LO source capable of pumping a Schottky mixer. To date the only solid-state source capable of producing >1 mW of continuous wave power above ~ 2 THz is the quantum cascade laser (QCL). THz QCLs have been shown to work as LO sources for superconducting HEB mixers [1], which require significantly less LO power than Schottky mixers. Frequency down-conversion has also been accomplished using two QCL lines and a point-contact Schottky diode. [2]

II. Mixer Details

We have investigated the operation of a monolithic planar Schottky diode receiver using a THz QCL. The Schottky mixer consists of a Ti/Pt/Au anode contacting a GaAs membrane and is packaged into a waveguide block with a horn antenna. The details of the receiver are described in Refs. [3] and [4] . At 2.5 THz the noise temperature of the fully packaged receiver was measured to be 11,000 K using a standard 300 K / 77 K Y-factor measurement and approximately 5 mW of LO power from a methanol line from a molecular gas laser. The design of the antenna and receiver block was optimized for 2.5 THz, but good responsivity and measurable noise temperature were obtained up to 3.1 THz.

III. THz Mixer Measurements

Using the 2.9 THz deuterated methanol line from a molecular gas laser as the LO, the receiver showed noise temperature

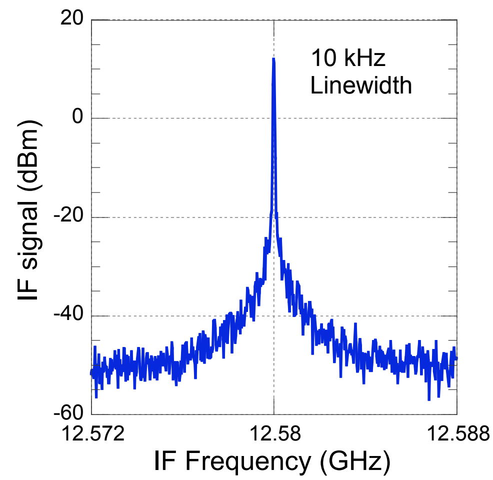

Fig. 1. Beat note of from output of a Fabry-Perot THz QCL laser biased to obtain two laser modes. A linewidth of less than 10 kHz was observed for the beat note from the free running laser.

$\sim$ 20,000 K using 6 mW of LO power in a standard Y-factor measurement. This receiver has been operated with both a 2.92 THz plasmon-guided QCL and a 2.97 THz distributed-Bragg-reflector (DBR) QCL. In both cases, the QCLs coupled insufficient LO power to the receiver to observe a measurable difference between 300 K and 77 K thermal load signals in a Y-factor measurement. However, difference-frequency generation by both dual-mode mixing and mixing against known molecular laser lines have been measured using these QCLs. When the 2.92 THz QCL was driven past a threshold bias, its output split into two Fabry-Perot modes that generated a 12.8 GHz IF signal in the receiver as seen in Fig. 1. The width of this difference-frequency signal indicated that the linewidth of the free-running QCL was $\leq$ 10 kHz. Differential frequency stability between these modes was observed to be very good, but no information was obtained about common-mode or absolute frequency stability in this measurement. In addition, the frequencies of both QCLs were accurately determined via difference frequency generation against standard 2.907 and 2.95 THz deuterated methanol molecular gas lines. The 2.97 THz DBR QCL always showed single-mode behavior, while the 2.92 THz QCL, in pulsed operation, showed single mode behavior at low powers and a complicated set of distinct lines spaced a few MHz apart when run above a certain power as shown in Figs. 2 and 3 respectively. The complicated IF spectra of Fig. 3 were usually observed right after the laser was turned on and had not yet heated up to a stable running temperature. After $\sim$ 1 min. of operation, the average power level dropped to a steady state (presumably after the device temperature stabilized) and the IF spectrum simplified to a single line.

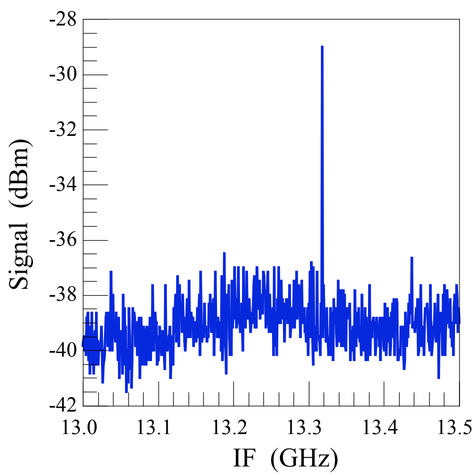

Fig. 2. Beat note of from free running Fabry-Perot laser running single mode against 2.9072 THz deuterated methanol line.

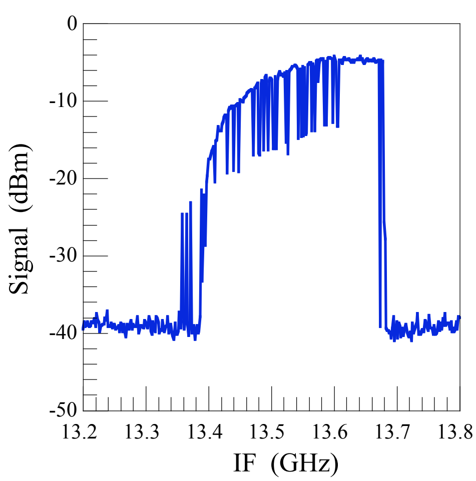

Fig. 3. Beat note of from free running Fabry-Perot laser running against 2.9072 THz deuterated methanol line with laser running at high power with multiple modes

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References

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