Demonstration of a TACIT Heterodyne Detector at 2.5 THz

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The field of THz mixers for astrophysics is dominated by superconducting hot-electron bolometers (HEBs), whereas Schottky-diode mixers have been the only devices suitable for planetary instruments. The Schottky mixers operate at ambient temperature, which is a great advantage for planetary applications, but are much less sensitive than the state-of-the art HEBs and require a 10^3 higher local oscillator (LO) power. Here, we have demonstrated a novel THz mixer which offers the best of both worlds: it operates at ~ 60 K (accessible by passive cooling on space), requires ~ μW LO power, and has a potential to be as sensitive as the HEB mixer [1].

Our THz device – the Tunable Antenna-Coupled Intersubband Transition (TACIT) mixer – is essentially an HEB based on a 2-dimentional electron gas (2DEG) in an GaAs/AlGaAs quantum well (QW). HEB mixers based on a high-mobility 2DEG have been investigated since 1990 [2]. In two-terminal versions of these 2DEG HEB mixers, the RF and LO electric fields are oriented along the 2DEG plane and the radiation couples to the 2DEG directly, by means of Drude conductivity. Since the kinetic inductance of high-mobility electrons is large, this results in large conversion losses, placing a practical upper frequency limit on such mixers to be 500 GHz [3]. The TACIT mixer functions as a four-terminal HEB (Fig. 1a). Electrons in a 2DEG are efficiently heated by the THz RF and LO electric fields oriented perpendicularly to the plane of the 2DEG to couple resonantly to an intersubband transition, overcoming the conversion losses associated with the two-terminal 2DEG HEB mixers. The gates used to apply the THz field can also be used to electrically tune the intersubband transition frequency and impedance. The intermediate frequency (IF) response is coupled out through source and drain (Fig. 1a).

We have fabricated TACIT mixers using a flip-chip process in which lithography is performed on both sides of a sub-micron thick membrane (Fig. 1b). The wafers from which these mixers were made contain a 40 nm QW, in which the intersubband absorption frequency, in the absence of voltages applied to both gates, is near 2.5 THz. The 2DEG in this wafer has a mobility that exceeds 10^7 cm^2/V-s at 2 K, and is strongly temperature-dependent above that temperature ($1/R \cdot dR/dT \approx 0.02$ K^{-1} at 50-77 K).

Direct detection measurements in response to monochromatic radiation show that the responsivity is sensitive to applied gate voltages at temperatures between 20 and 90 K. At 60 K, the peak responsivity is tunable between at least 2.52 THz and 3.11 THz with gate voltages, consistent with expectations for a 40 nm GaAs QW. Mixing of two monochromatic signals near 2.5 THz was also observed at 60 K (Fig 1c). By tuning the difference between those signals, the IF bandwidth was measured to be 6 GHz. The demonstration of THz mixing in a TACIT device lays a strong foundation for future development of this technology.

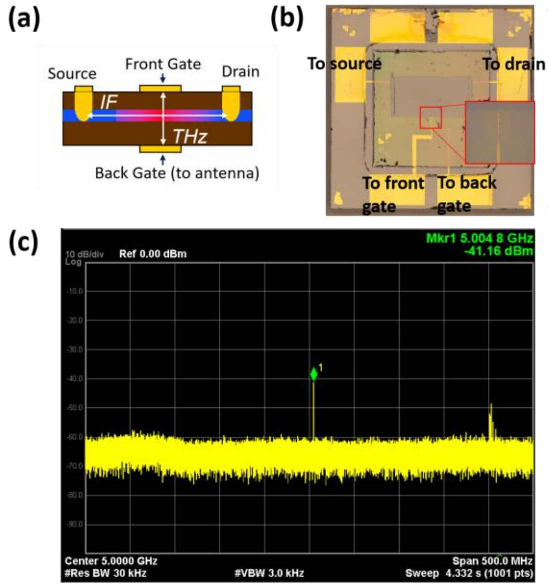

Fig. 1. 2.5 THz TACIT mixer. (a) schematic of four-terminal TACIT mixer, (b) fabricated TACIT mixer (c) IF response at differential frequency of 5 GHz between two sources emitting near 2.5 THz, observed at 60 K.

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