Design Study for Optimal Performance of Tunable Antenna-Coupled Intersubband Terahertz (TACIT) Mixer

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Tunable Antenna-Coupled Intersubband Terahertz (TACIT) mixer is a new type of hot-electron bolometer mixer based on high-mobility 2-dimensional electron gas (2DEG) in a GaAs/AlGaAs quantum well that uses intersubband transition for efficient absorption of THz radiation [1, 2]. TACIT mixers operate at relatively high temperatures (50–70 K), and are predicted to offer low single-sideband (SSB) noise temperature (~1,000 K), a wide intermediate frequency (IF) bandwidth (~10 GHz), and low required local-oscillator (LO) power (< 1μW) along with in-situ tunability in the detection frequency (2–5 THz) [3]. These mixer characteristics potentially make TACIT mixers an attractive mixer technology for high-resolution, multi-pixel THz heterodyne instruments particularly for planetary applications.

A TACIT mixer is a four-terminal device in which two ohmic contacts (source and drain; see Fig. 1. (a)) are used to read out the IF response due to the change of the device resistance caused by THz radiation, and top and bottom gates are used to couple THz radiation into the active region of the device (see Fig. 1. (b)). A planar THz antenna integrated in the top and bottom gate metallization orients THz fields perpendicular to the 2DEG plane at the active region, in which THz energy is resonantly absorbed by the 2DEG through an intersubband transition. The excited electrons quickly thermalize and heat up the active region, resulting in a fast bolometric response in the device resistance. The top and the bottom gates can also electrically tune the intersubband absorption frequency (via the dc Stark effect) as well as the device impedance seen by the THz antenna.

In our recent work [2], we have successfully fabricated a prototype TACIT mixer for 2.5 THz using a flip-chip technique to perform lithography on both sides of a sub-micron thick quantum well membrane, and have observed tunability in the detection frequency (2.5–3.1 THz) and THz mixing at 60 K with an IF bandwidth exceeding 6 GHz. However, the antenna structure and the 2DEG mesa geometry of the prototype device were not designed for optimal mixer performance, and thus the noise temperature, the conversion gain, and the required LO power could not be characterized in the current prototype device.

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To achieve optimal mixer performance of a TACIT mixer, a new design and fabrication effort is under way. In this work, we theoretically or experimentally investigate all design parameters of a TACIT mixer including the 2DEG mesa geometry and antenna design and evaluate how they affect the mixer performance. Details on the design and estimated mixer characteristics will be provided in the presentation.

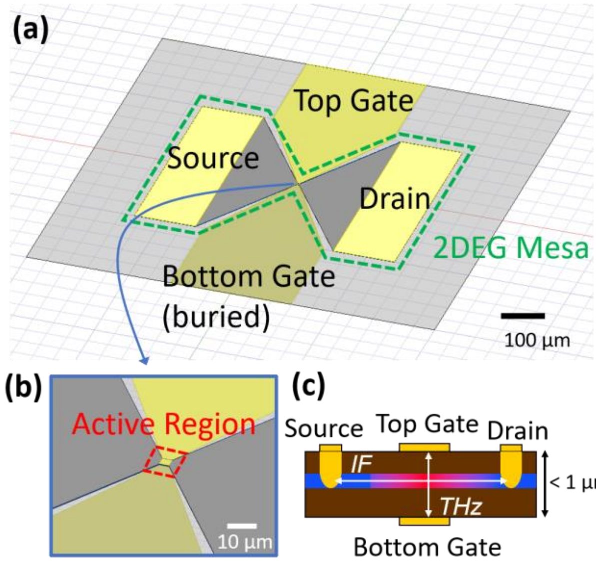

Fig. 1. TACIT mixer integrated with a bow-tie antenna for optimal mixer performance (a) layout for a TACIT mixer showing 2DEG mesa (outlined by green dashed lines) and a bow-tie antenna integrated in top and bottom gates, (b) active region of a TACIT mixer, (c) vertical schematic of a TACIT mixer.

References

[1] M. S. Sherwin, "Tunable Antenna-Coupled Intersubband Terahertz (TACIT) Detector," US Patent 5,914,497, Jun. 22, 1999.

[2] C. Yoo et al, "Demonstration of a Tunable Antenna-Coupled Intersubband Terahertz (TACIT) Mixer." *Appl. Phys. Lett* (in-press)

[3] M. S. Sherwin et al, "Tunable Antenna Coupled Intersubband Terahertz (TACIT) Mixers: The Quantum Limit Without the Quantum Liquid," *Proc. Far-IR, Sub-mm and mm Detector Technology Workshop*, 2002.

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