A Tunable Antenna-coupled Intersubband Terahertz Detector

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Abstract— We are developing a 2.5 THz electrically tunable heterodyne detector for molecular line spectroscopy, operating at 50 K to 70 K. Named as Tunable Antenna-Coupled Intersubband Terahertz (TACIT) detectors, the detectors promise noise performance <10 times the quantum limit at frequencies above 1 THz while operating at temperatures accessible with passive cooling to 50-60 K in space. The detection frequency of a TACIT device can be electrically tuned in the THz frequency during a mission, adding the flexibility to search for a range of species with spectral signatures in different frequency bands. Compared to Schottky-diode mixers, TACIT mixers would require much smaller local oscillator (LO) power (~ μW) which enable operation in the 1-5 THz range where powerful LO sources are not readily available.

The TACIT detector can be approximated as a hot-electron bolometer based on the intersubband transition of two-dimensional electron gas (2DEG) in a 40 nm GaAs/AlGaAs quantum well (QW) heterostructure. The detector is fabricated from a high mobility (>10^6 cm^2/V-s at 4 K) 2DEG where the device resistance is highly sensitive to temperature in the temperature range between 50K and 70K. The designed TACIT detector is a 4-terminal device with source, drain, top gate and back gate where the source and the drain are Ohmic contacts to the 2DEG and the top and the bottom gates are used to tune the resonant frequency of the intersubband transition of the 2DEG. Indium Bonding And Stop Etch (IBASE) method is designed to process the backside of the device where a planar antenna structure will be deposited to efficiently couple the THz radiation to the active region of the device. When THz radiation near the resonant frequency of the intersubband transition impinges on the device, electrons in the 2DEG are excited to the next subband, leading to an increase in the electron temperature. In the presence of a local oscillator signal, the intermediate frequency (IF) signal can be detected between the source and the drain.

Currently, we have optimized the quantum well structure to have electron density of ~10^{11} cm^{-2} and high electron mobility of 10^6 cm^2/V-s at 4 K. Our preliminary devices retain the required electron density and high mobility throughout all the microfabrication steps up to the IBASE step. Our initial trial with the IBASE step show that a smaller sample size (~ 3 mm by 3 mm) and fewer number of bonding pads (~3) would be beneficial for the process. Optical measurements of the test structure using a 2.5 THz source show the tunability of the response by varying the gate voltage.

We will report the results of characterization of complete TACIT devices during the meeting.