Frequency Agile Heterodyne Detector for Submillimeter Spectroscopy of Planets and Comets

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We are developing a novel heterodyne detector called a Tunable Antenna-Coupled Intersubband Terahertz (TACIT) detector, a four-terminal semiconductor device that has numerous advantages over current state-of-the-art Schottky and superconducting mixers. This detector absorbs radiation via micro-antennas which are ohmically contacted to a front and back gate biased two dimensional electron gas (2DEG) quantum well structure engineered from high mobility (>10^6 cm^2/Vs) GaAs. The photons are initially absorbed in a resonant intersubband transition of a 2DEG, which then creates a population of hot electrons that changes its resistance. The resonant frequency of the intersubband transition is electrically tunable in the 1-5 THz range, and the mixing mechanism should allow low-noise near-quantum limited operation up to a 70 K bath temperature. Because of the low density of electrons in the mixer volume, the TACIT mixer requires just a few μW of Local Oscillator (LO) power. Additionally, the technology is compatible with proven technology used to generate LO power at THz frequencies (in contrast to the > 1mW required to pump Schottky mixers). The low LO power requirement further translates into the possibility of deploying array receivers. Thus the advantages of the TACIT mixer over existing mixer technologies are as follows:

(1) Low noise operation at bath temperatures achievable using passive radiative cooling in space (50-70K).
(2) Very low LO power requirements compatible with solid-state sources with flight heritage (μW).
(3) Planar structure allows for simple and straightforward implementation of array receivers.

This mixer is ideal for long-duration planetary, astrophysics and Earth science missions, as they do not require active cooling like superconducting devices. Preliminary devices have demonstrated some salient properties of the device, in particular, by using high mobility (>10^6 cm^2/Vs) GaAs 2DEG antenna-coupled devices we have shown the key principles of electrical tuning and enhanced resonant absorption of THz radiation. This ability to electrically tune the resonant frequency over a wide range is what sets this detector apart from previous 2DEG mixers. We are currently optimizing the design as well as producing test structures to assess the performance of the antenna and the influence of the back gate.