Plasmonic Detection of Wide Band Modulated THz Radiations in GaAs Technology

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***Abstract*—A fully integrated THz detection system consisting of an on chip dipole antenna, a plasmonic detector, and a wide band amplifier in $130\ nm$ AlGaAs/InGaAs pHEMT technology is reported. The fabricated chip achieves an absolute responsivity of $3\ V/W$, while maintaining a $50\ dB$ signal to noise ratio (SNR) over a modulation bandwidth of $8.5\ GHz$ at $\sim 0.3\ THz$.**

I. Introduction

PLASMONIC field effect transistor (FET) based detection has shown a great potential for detecting modulated THz signals for low ($< 1\ kHz$) and high modulation bandwidths [1]–[4]. Such advances in THz detection combined with possible THz generation in standard technologies using foundry services are expected to generate low cost, mass produced THz cameras, spectrometers, extreme bandwidth communication systems that would widely impact the biomedical, information technology, and security markets. This paper presents the design and measured performance of an on chip antenna-coupled plasmonic detector-amplifier system for wide band modulated THz detection.

II. Design of THz Detector-Amplifier Chain

The THz detection chain is formed of an antenna, a plasma-wave FET detector and a wide bandwidth amplifier as shown in Fig. 1(a). The chip is fabricated in Triquint TQP13 technology with unity gain frequency (f_T) of $95\ GHz$. The technology features two gold metal layers - one local and one air-bridge. The two metal layers are merged to realize the on chip dipole antenna whereas the $85\ \mu m$ GaAs substrate works as the dielectric medium. A back metal plane has also been included to minimize the high dielectric loss in GaAs substrate with a dielectric constant (ε_r) of 12.9 [5]. The designed antenna is simulated in 3D EM simulator HFSS and the simulated return loss shows a bandwidth of $13\ GHz$ (Fig. 2(a)) with a directivity and efficiency of $3.8\ dB$ and 40% respectively.

The plasmonic detector is realized using two depletion mode pHEMT devices with a gate width of $10\ \mu m$ and a length of $130\ nm$. The minimum length is chosen to minimize the parasitic loss beyond the effective length (L_{eff}) [2]. The low modulation frequency characterization results for the dipole antenna coupled differential HEMT have been reported in [1]. Given the square law behavior of the plasmonic detection, the output signals at the drains of the two detectors have the same polarity, hence, the drain terminals are tied together and connected to the wide band amplifier.

The designed amplifier consists of two gain stages followed by a buffer. The stages are ac coupled and the dc bias tee is designed using an on chip metal-insulator-metal (MIM) capacitor ($1\ pF$) and Epi resistors ($2\ k\Omega$). Each stage employs shunt peaking through the resistor-inductor connected at the drains of transistors $m_1 - m_3$ as shown in Fig. 1(a). The use of shunt peaking extends the bandwidth of the common source amplifier stage. Simulation results show a bandwidth of $9\ GHz$ with a $19\ dB$ gain and $94\ mW$ dc power consumption (Fig. 2(b)).

III. Measurement Results

The proposed detector-amplifier chain is characterized for a sinusoidally modulated $295\ GHz$ carrier signal with a

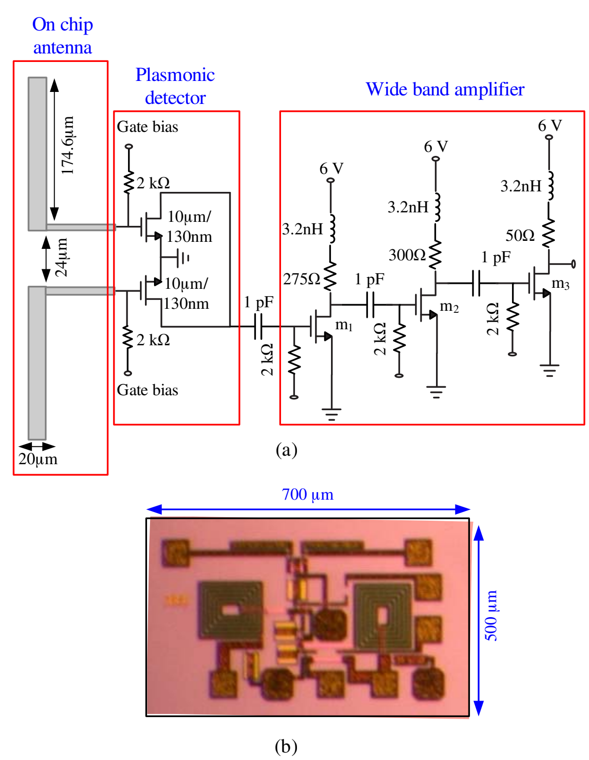

Fig. 1. On chip dipole antenna coupled plasmonic detector followed by wide band amplification, (a) system block diagram, and (b) die micrograph.

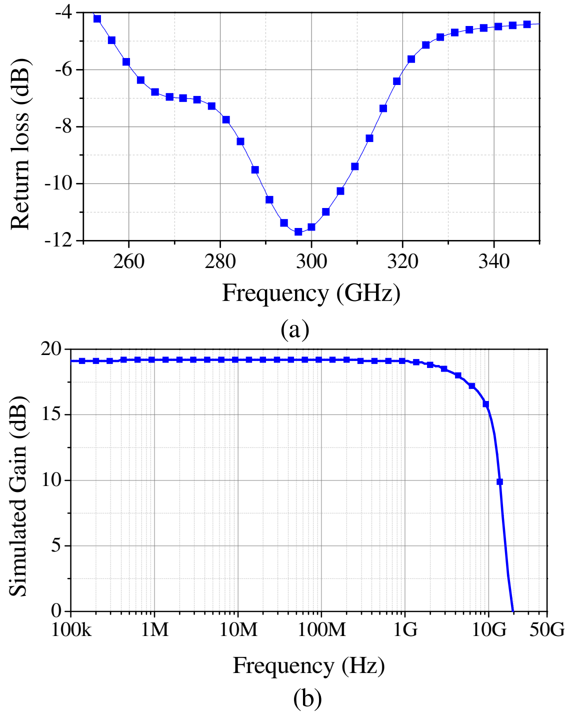

Fig. 2. Simulation results (a) antenna return loss, (b) amplifier gain and bandwidth.

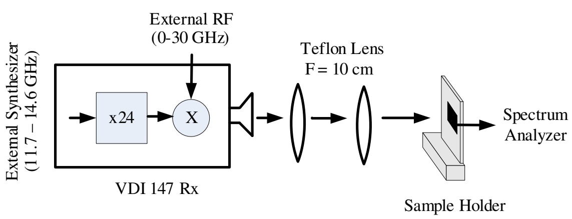

Fig. 3. High modulation frequency characterization setup.

modulation bandwidth up to 20 GHz. The measurement setup includes a VDI multiplier-mixer chain (VDI 147 Rx) followed by two teflon lenses to collimate and focus the radiation on the detector chip. The incoming radiated power measured at the incident plane is 20 μW. The chip is wire-bonded to a printed circuit board (PCB) and then mounted on a XYZ translational stage. The output of the on chip amplifier is then recorded using a spectrum analyzer. The measurement setup is shown in Fig. 3.

The detector operates in an *open drain* mode (no drain current) at a gate bias of $0.1\ V$. The *absolute responsivity* (R_v) is defined as the ratio of the voltage response over the incoming radiation power and is measured as 3 V/W for the sinusoidally modulated THz radiation at 295 GHz. The response shows a 3 dB bandwidth of 8.5 GHz as shown in (Fig. 4). The system achieves a SNR of $> 50\ dB$ over the entire bandwidth in a non-shielded environment.

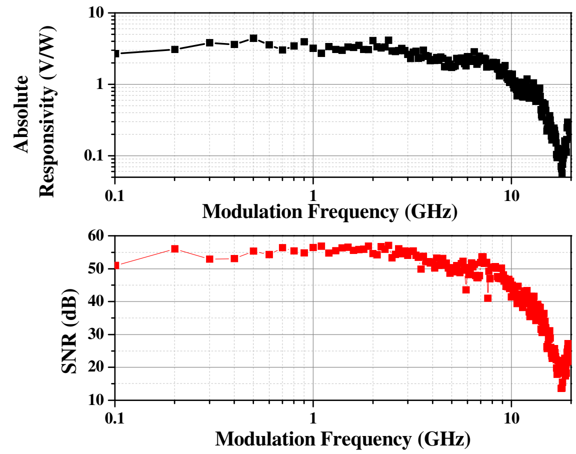

Fig. 4. Measured absolute responsivity and SNR vs. frequency

IV. Conclusion

The presented chip successfully detects modulated THz signal at $\sim 0.3\ THz$ for a modulation bandwidth upto 8.5 GHz with absolute responsivity and SNR of 3 V/W and 50 dB respectively. The fully integrated detector system shows comparable response to recently reported GaAs detectors using off the shelf antenna and amplifier [3] while providing higher modulation bandwidth. The proposed system can provide a compact, efficient solution to short range THz communication applications.

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