High Performance Graphene-Based CW THz Photoconductive Detector

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***Abstract*—New CW THz detectors based on graphene nanoelectrodes photomixer are completely investigated. The graphene nanoelectrodes are placed on low-temperature-grown (LTG) GaAs as photoconductive material. Due to the high transparency and high conductivity of graphene, increasing carrier densities were obtained which leads to the high performance detection of THz induced photocurrent being one order of magnitude higher than for conventional metallic interdigitated photomixer. The THz measurement was performed in the range of 50 GHz to 1.1 THz.**

I. INTRODUCTION

GRAPHENE has driven significant attention scientifically and practically for the development of optoelectronic devices. The unique properties of graphene such as the gapless electronic structure, high optical transmittance, high intrinsic mobility, among many others, make it attractive as transparent conductive electrodes for many applications [1]. In particular, THz photomixers using graphene nanoelectrodes rather than metal electrodes have shown great performance enhancement as THz emitters [2-7]. The important advantage of these THz photomixers is that they can also be used as THz detectors. In homodyne systems, the same optical beat signal, which was previously used to generate THz waves by applying a bias field, is also used to create free carriers that are separated by the THz bias field, as shown in Fig. 1. The generated photocurrent is proportional to the product of the optical beat signal and the THz field [8]. The detected photocurrent is given as,

$$I_{det} = V_{THz} G \tag{1}$$

where V_{THz} is the THz field induced voltage, G is the device photoconductance, A is the electrodes area, L is the electron travailing path length from one electrode to another.

$$G = \frac{A}{L}\sigma \tag{2}$$

where $\sigma = e\mu_c n_c$ is the conductivity, e is the electron charge, μ_c is the carrier mobility, and n_c is the carrier density. This leads to the detailed formula for the detected photocurrent:

$$I_{det} = V_{THz}\frac{A}{L}e\mu_c n_c \tag{3}$$

The use of graphene as transparent electrode increases the number of the generated photocarriers and increases the detected photocurrent.

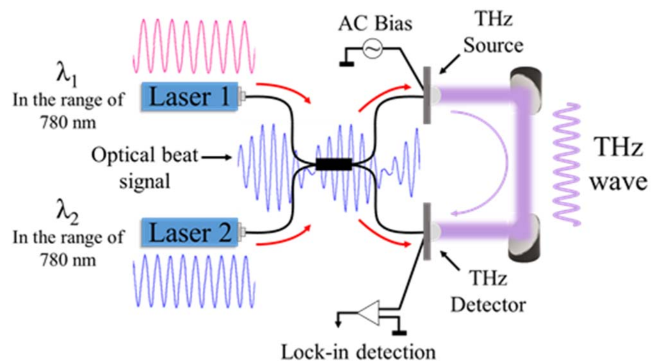

Fig. 1. Coherent detection diagram for the CW-THz system.

II. RESULTS AND DISCUSSION

The 6-8 layers CVD-grown Trivial Transfer Graphene (obtained from ACS Material LLC.), was transferred onto LTG-GaAs substrate. A spiral antenna with 10 μm separation between the antenna contacts with multilayer graphene (MLG) as nanoelectrodes was fabricated. The configuration of the interdigitated fingers of the MLG was formed using a standard optical lithography process, where the finger width was 0.5 μm, the spacing gap between the fingers 1.5 μm, and the finger length 9 μm, as shown in Fig. 2 (a). The photomixer device with MLG nanoelectrodes was capsulated by 150 nm SiNx to isolate the graphene nanoelectrodes from the environmental contamination. For comparison with a conventional interdigitated photo-mixer with gold electrodes, the same interdigitated electrodes configuration was used to fabricate a photomixer with gold electrodes, see Fig. 2 (b). Both devices were characterized as detectors using two detuned distributed feedback diode lasers (DFB-LDs) (λ = 780 nm) in a homodyne detection system. The total optical power of 29 mW and 27.5 mW were used to illuminate the active area of the emitter and the detector photomixers, respectively. The radiation range of the THz beam was tuned by varying the frequency difference between the two detuned DFB-LDs. A scanning range of the THz radiation from 50 GHz to 1.9 THz was obtained.

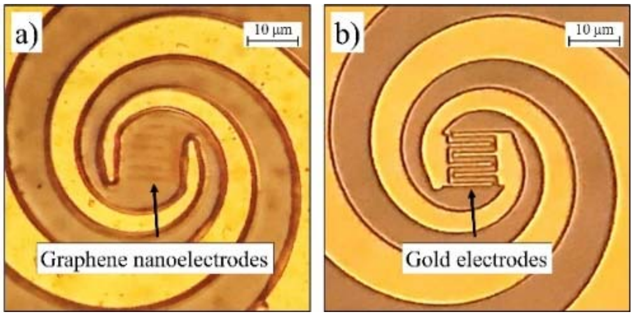

Fig. 2. Spiral photomixer with six-finger interdigitated a) graphene nanoelectrodes and b) gold electrodes.

Figure 3 shows the envelope of the detected THz photocurrent for the photomixer with graphene nanoelectrodes and in comparison with the reference data obtained using the conventional photomixer with gold electrodes. It is clear that the photomixer with graphene nanoelectrodes shows one order of magnitude higher detected photocurrent compared to the detected photocurrent by the photomixer with gold electrodes. Additionally, the photomixer with graphene nanoelectrodes was able to detect the THz beam up to 1.1 THz, which is detected twice the spectral range of the detected THz beam by the photomixer with gold electrodes, up to 600 GHz. This enhancement in the device performance is attributed to the high conductivity and high transparency of graphene, which allows almost all of the light beam to propagate through the nanoelectrode material and increase the number of carriers that are used to modulate the THz biasing field.

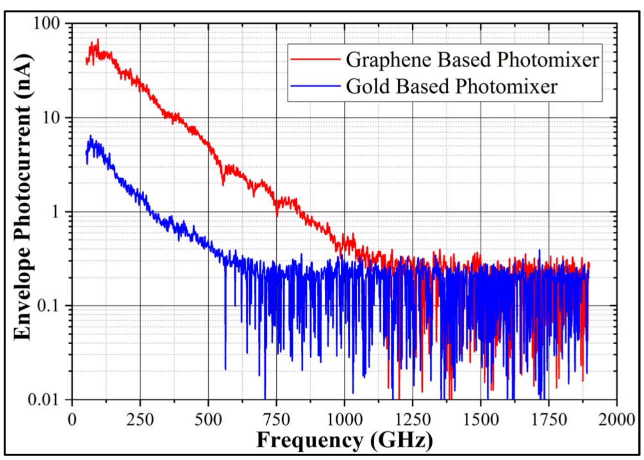

Fig. 3. Comparison of the envelope of the obtained photocurrent of photomixer with interdigitated graphene nanoelectrodes and the photomixer with interdigitated gold electrodes.

III. Summary

Room temperature coherent detection of CW THz radiation was demonstrated for the first time using photomixers with graphene nanoelectrodes. The photomixer fabricated on LTG-GaAs as photoconductive material. Due to the high conductivity and high transparency of the graphene, the increased number of the carriers results in a detected photocurrent which is about one order of magnitude higher than that of the conventional interdigitated photomixer. This offers a path to produce highly responsive devices for THz applications.

IV. Acknowledgment

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