Tunable Wideband Terahertz Absorber

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***Abstract*—Recent works have demonstrated the possibility to develop tunable terahertz devices based on two-dimensional semiconductor materials. Many of these materials, including graphene, have exceptional optical and electronic properties. The modified thickness of graphene increases the efficiency of its interaction with radiation. A broadband tunable terahertz absorber is proposed in this work. It consists of metasurface with cross-shaped multi-layered graphene resonators and works in reflection mode. This device possesses good tunable absorption over the range of 0.4-0.8 THz and can be easily fabricated. Dynamical tuning of absorption band is achieved by external infrared optical pumping with different intensities. This multi-layered graphene-based absorber has high potential for various applications in terahertz science and technology.**

***Index Terms*—Graphene, metasurface, optical tuning, terahertz absorber**

I. INTRODUCTION

GRAPHENE devices, including absorbers, have recently earned the attention of researchers, especially in the terahertz (THz) frequency range [1-2]. In comparison with conventional THz absorbers, graphene-based ones allow to dynamically control the resonant frequency and absorption value due to the graphene adjustable electronic transport properties. Moreover, graphene can interact with radiation in wide range of wavelengths, so using this material, the THz radiation intensity can be controlled by optical pumping with high operation frequency in all-optical mode. Most of existing graphene/metasurface-based THz absorbers usually have low and narrowband absorption in the THz frequency range due to the weak light-matter interaction in graphene monolayer and its resonant nature. To realize wideband absorption, multi-resonance and multi-layering approaches are utilized, but they are difficult in practical implementation [3]. In this work, optically tunable wideband THz absorber based on 80-layered structured graphene is proposed: it has good absorption over 0.4-0.8 THz and can be easily fabricated.

II. CONDUCTIVITY MEASUREMENTS AND STRUCTURAL DESIGN

The samples were produced by our partners from University of Exeter (Opto-Electronics Systems Laboratory) using chemical vapor deposition method [4]. The measurements of optical properties of 80-layered graphene (80LG) were performed under infrared excitation using THz time-domain spectroscopy (at room temperature). The scheme of corresponding setup is depicted in Fig. 1. To obtain complex conductivity dispersions, the effective medium model and the thin-film approximation [5] were used (the wavelength of radiation is much more than thickness of 80LG).

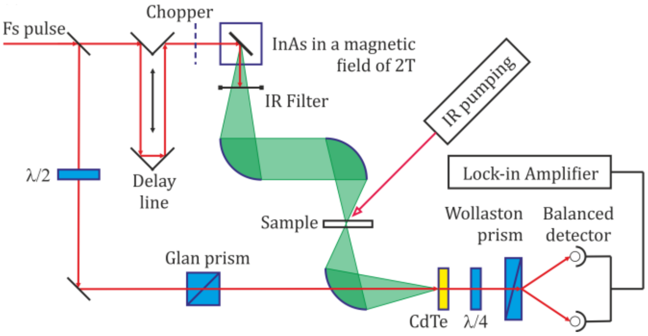

Fig. 1. Scheme of the experimental setup.

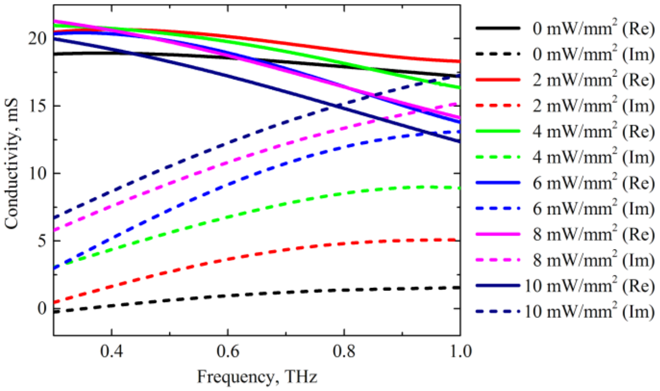

Fig. 2. Complex sheet conductivity of 80LG on TPX substrate under 980 nm optical pumping of different intensities.

The data obtained were used in electromagnetic simulations (using CST Microwave Studio package). The optimized unit cell geometry of absorber metasurface under development is shown in Fig. 3. This structure consists of cross-shaped 80LG resonators, 0.5 μm thick aluminum film (with conductivity $\sigma=3.56\times10^7$ S/m) and 80 μm thick dielectric (with permittivity $\varepsilon=2.1$) spacer between them (made from TPX material, transparent in the studied frequency range). The boundary conditions are periodical along x- and y-axis, and the THz radiation propagates along z-axis from the graphene-coated side. THz wave reflects from the aluminum film, so interaction efficiency is increased, and device works in the reflection

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(absorption) mode. The parameters of absorber are controlled by external optical pumping with wavelength of 980 nm and intensity in the range from 0 to 10 mW/mm^2. The geometrical dimensions (Fig. 3) are the next: K=20 µm, L=175 µm, G=200 µm, h=80 µm, and c=0.5 µm.

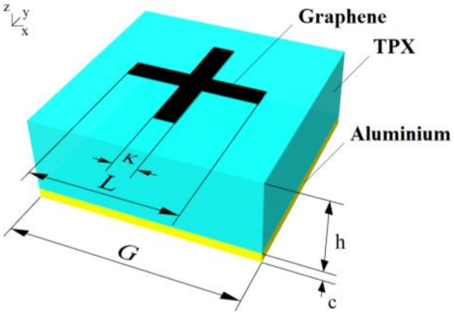

Fig. 3. Unit cell geometry of absorber.

III. RESULTS

The absorption spectra of designed device are shown in Fig. 4. It can be seen that there is a significant influence of external optical pumping on the absorption coefficient from 0.3 THz to 1.0 THz.

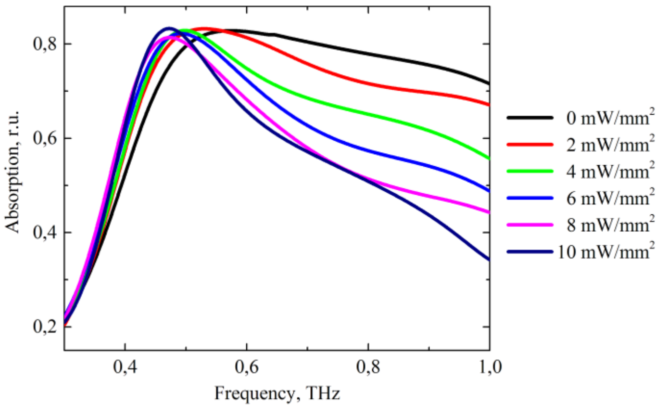

Fig. 4. Absorption spectra of 80LG-based THz absorber under different optical pumping intensities.

The proposed structure works in broadband mode, and the degree of tunability depends on the frequency of THz radiation. At 0.5-1.0 THz, as the intensity of the optical pumping increases, the absorption of the structure decreases (due to photogeneration of charge carriers in 80LG). The greatest amplitude of absorption tuning is observed at frequencies near 0.9-1.0 THz (in the studied range). It should be mentioned that at some frequency point (0.5 THz) the absorption coefficient almost does not depend on the pumping intensity. The position of such frequency point depends on the geometry of the metasurface unit cell.

IV. CONCLUSION

An optically tunable broadband THz absorber based on multi-layered graphene metasurface was designed and numerically simulated on the basis of data obtained experimentally for 80LG. Despite the ordered structure, this device operates efficiently in broadband mode. The ultrafast electronic properties of graphene allow to realize high-speed modulation of amplitude of THz wave which interacts with absorber. The usage of optical pumping method avoids the application of an electrode system and makes the absorber to work in all-optical mode. Moreover, this method allows to achieve the working frequency of the device, unattainable in the electronic control circuit. Graphene is resistant to atmospheric influences and easily can be manufactured. It was shown that the efficiency of the absorption modulation depends on the frequency of THz radiation, while the absorption spectra of the structure are determined by its geometric parameters. Relatively weak optical pumping source can be used to control the absorber state. The proposed absorber can be used in many promising THz applications such as biosensing, imaging and wireless communications (in transparency windows of the atmosphere).

V. FUTURE PLANS

This study allows to make a conclusion about the possibility of multilayer graphene application in various fields of THz science and technology in conjunction with the method of ultrafast optical tuning. The MTT-S Pregraduate award has given me access to the large field of discovery going on in THz technologies. It was the first award I won, and I decided to continue my work at the next stage of study – in graduate school in the field of Radiophysics. In addition to Optics, I chose this direction in order to expand my knowledge and acquire new skills in the field of THz radiation control devices. I plan to create the experimental versions of devices under development. I am grateful for the support from MTT-S and I look forward to attending a conference organized with assistance of this community.

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