Tunable Terahertz Radiation from Graphene Surface Plasmon Polaritons Excited by Parallel Moving Electron Beam

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***Abstract*—We propose a novel kind of terahertz radiation source utilizing grapheme surface plasmon polaritons (GSPPs) excited by parallel moving electron beam. Theoretical analyses show that terahertz radiation can generate from graphene sheet on a periodic grating structure. The intensity of the radiation are greatly enhanced due to GSPPs and the frequency of the radiation can be widely tuned by both of the electron beam energy and chemical potential of graphene. The experiment based on this mechanism are in progress.**

I. INTRODUCTION

Recently, the development of terahertz sources is still an emergent problem in THz science and technology. Many publications focus on the novel methods and mechanism to generate the terahertz waves. Among them, some investigations demonstrate that the combination of electronics, photonics and nanotechnology is a good promising way for the THz generation.

We present our new method to combine electronic and photonic to generate THz electromagnetic waves. We utilize free electron beam to excite surface plasmon polaritons on graphene and transform them through a grating substrate into radiation waves. The schematic diagram and dispersion curves of GSPPs on periodic structure are shown in Figure 1.

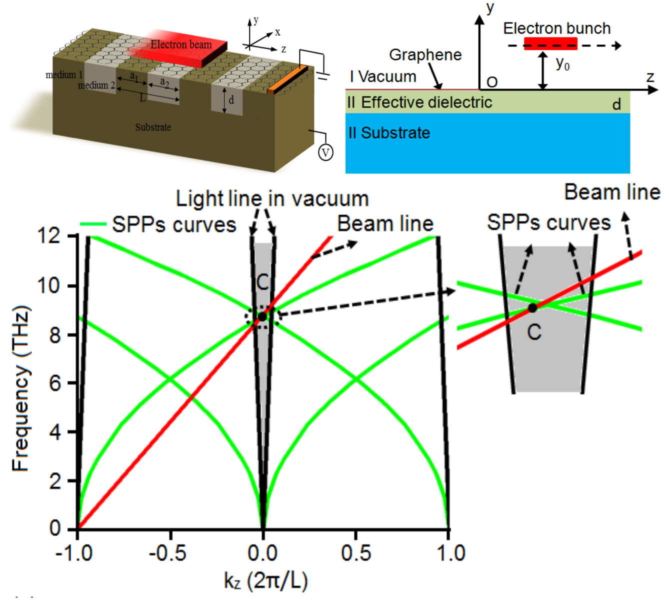

Fig. 1. Schematic diagram of GSPPs radiation from graphene layer on periodic grating substrate excited by electron beam. And Brillouin diagram of dispersion curves of GSPPs and electron beam line.

The dispersion equation of this structure is as follow:

$$\frac{\varepsilon_{eff}k_3+\varepsilon_s k_2}{\varepsilon_{eff}k_3-\varepsilon_s k_2}e^{-2jk_2d}=\frac{\varepsilon_{eff}k_0k_1-\eta_0\sigma_g k_1k_2-k_0k_2}{\varepsilon_{eff}k_0k_1+\eta_0\sigma_g k_1k_2+k_0k_2}$$

where, $k_1=\sqrt{k_0^2-k_z^2}$, $k_2=\sqrt{\varepsilon_{eff}k_0^2-k_z^2}$, $k_3=\sqrt{\varepsilon_s k_0^2-k_z^2}$, $\varepsilon_{eff}=\varepsilon_s(1-r)+\varepsilon_2 r, r=a_2/L$, η_0 is the wave impendence in vacuum.

The dispersion curves of GSPPs are shown in Fig.1 as green lines. The electron beam line is drawn as red line in Fig.1. Due to periodical structure, the dispersion curves and electron beam lines are expanded into space harmonics. The intersection of electron beam line and dispersion curve of GSPPs is working point as point C. That means the SPPs at this point can be excited by electron beam. SPPs can be transformed into radiation wave when the working point lies in the gray region. As shown in Fig1. SPPs at about 8.3THz are excited and radiated.

II. RESULTS

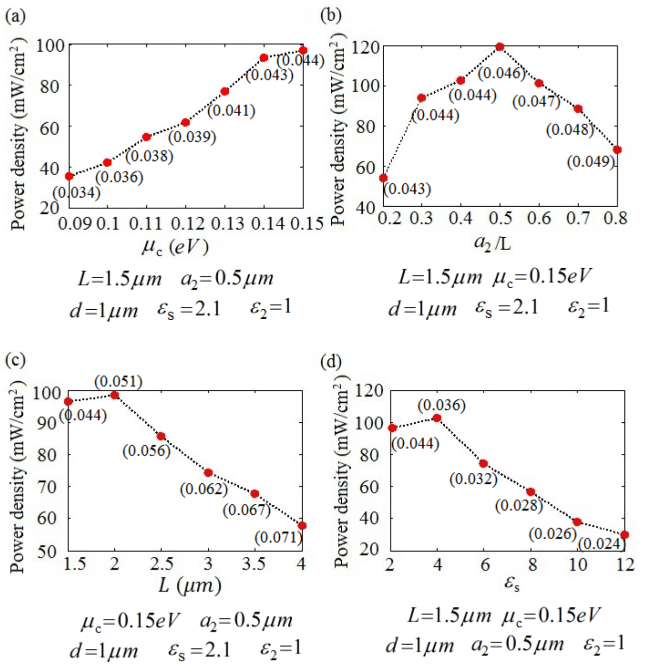

Fig. 2. The dependence of the radiation frequency on various different parameters

The theoretical analysis and numerical calculation show that in a monolayer graphene SPPs can be excited by a uniformly moving parallel electron beam, and SPPs in graphene with a micro-meter slits array loading can be transformed into coherent terahertz radiation with intensity enhancement. The radiation frequencies of the THz radiation are determined by the working points, the intersection points of the graphene dispersion curves with the electron beam lines.

THz radiation power and frequency adjusted by the parameters of period, dielectric of substrate, chemical potential of graphene and electron beam energy are theoretically calculated as shown in Fig.2. The numerical calculations based on the theoretical analysis demonstrate that THz radiation is strongly enhanced by GSPPs and radiation frequency covers almost the whole THz frequency regime.

The experiment is in progress as shown in Fig.3.

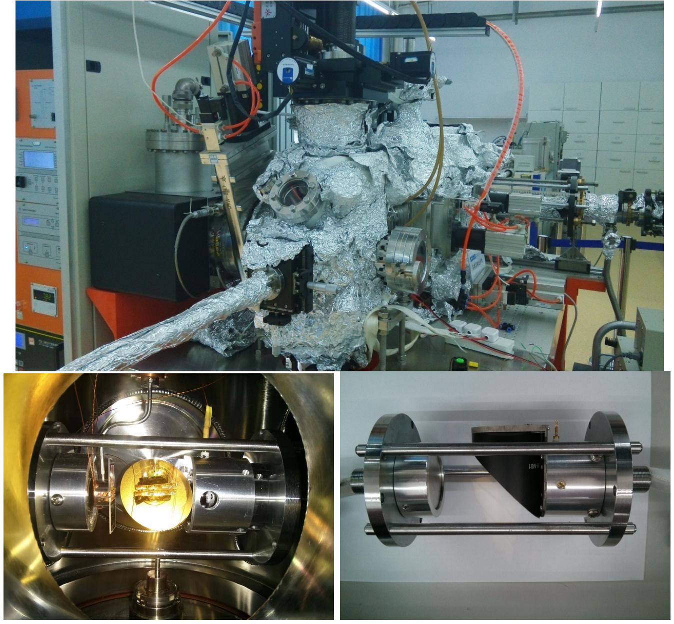

Fig. 3. Experimental setup

III. SUMMARY

We propose a new kind of terahertz radiation source which utilizes GSPPs excited by parallel moving electron beam to enhance output power. This source is a miniature THz source working at room temperature with widely tunability.

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