Optimized Nonlinear THz response of Graphene in a Parallel-Plate Waveguide

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Abstract

Several experimental and theoretical groups have examined third-harmonic generation from graphene at terahertz frequencies. Almost all have employed a configuration where the field is normally incident on the graphene [1]. However, we have found that due to the increase in interaction time, a much higher power conversion efficiency can be achieved when the graphene is inside of a parallel-plate waveguide as shown in Fig. 1 [2]. For low input fields, there is generally good phase matching in the waveguide between the pump field in the TE1 mode at ω and third harmonic field in the TE3 mode. However, when the pump field amplitude increases, the phase matching degrades, due to self- and cross-phase modulation. To overcome this, we consider the waveguide shown in Fig. 1 where there are two different dielectric materials in the waveguide: cyclic polyolefin (n_1= 1.53) and phenol-formaldehyde resin (n_2 = 1.70) [3]. Using a coupled-mode theory including all propagating lossy modes, we calculate the power efficiency for third harmonic generation. In Fig. 2, we plot the power efficiency for a 2.0 THz incident field as a function of the thickness of the cyclic polyolefin layers for different input field amplitudes, for a plate separation of b = 70 μm and Fermi energy of E_F = 20 meV. We find that, by tuning the layer thickness to improve phase matching, the power efficiency can be improved by more than a factor of two. For example, for an input field of 15 kV/cm, the efficiency can be increased from 33% to 68%. This shows the promise of this approach to harmonic generation from graphene.

References

[1] P. Bowlan, *et al.*, Phys. Rev. B 89, (2014) 041408.
[2] P. Navaeipour, I. Al-Naib, M. Dignam, Phys. Rev A, 97 (2017) 013847.
[3] P. Cunninghan, *et al.*, J. App. Phys, 109 (2011) 043505.

Figures

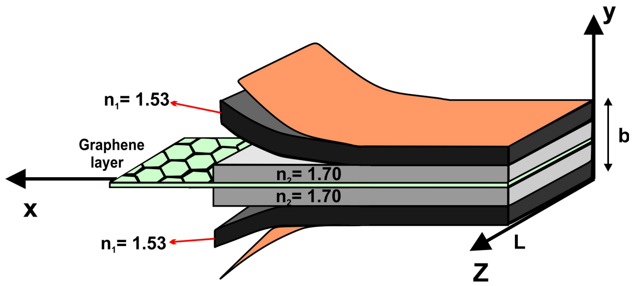

Figure 1: Metallic parallel-plate waveguide with graphene at the center of the waveguide between two different dielectric layers.

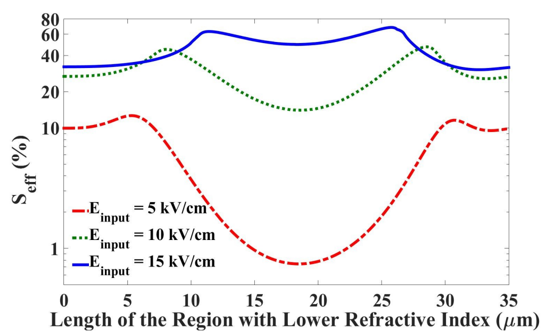

Figure 2: Power efficiency as a function of cyclic polyolefin layer thickness for b = 70 μm and E_F = 20 meV for different input fields.