Supplemental Document

Journal of the Optical Society of America B

OPTICAL PHYSICS

Dual-channel graphene-based optical metasurface switch at telecommunication wavelengths: supplement

RASHMI KUMARI,[1,*] SHUBHANSHI SHARMA,[1,2] SHAILENDRA KUMAR VARSHNEY,[2] AND BASUDEV LAHIRI[1]

[1] *Nano Bio Photonics Group, Advance Photonics Laboratory, Department of Electronics and Electrical Communication Engineering, IIT Kharagpur, West Bengal 721302, India*
[2] *Fiber Optics, Nano & Quantum Photonics (FONQP) Group, Advance Photonics Laboratory, Department of Electronics and Electrical Communication Engineering, IIT Kharagpur, West Bengal 721302, India*
[*] *rashmi.k@iitkgp.ac.in*

Supplement DOI: https://doi.org/10.6084/m9.figshare.22087490

Parent Article DOI: https://doi.org/10.1364/JOSAB.482687

Dual-Channel Graphene-Based Selective Switch at Telecommunication Wavelengths: supplemental document

1: Real and Imaginary part of Interband and Intraband Conductivity

Graphene's total conductivity consists of both interband and intraband conductivity. Here, the carrier relaxation time is assumed to be τ= 0.5 ps. At low wavelengths, the carrier has high energy to transit between the valence and conduction bands, so interband absorption is dominant. Whereas at high wavelengths, carriers don't have enough energy to transit from the valence band to the conduction band, so they transit in different energy levels of the valence band. Thus, intraband conductivity is dominant in that region. Here, we have plotted both the real and imaginary part of the conductivity at a Fermi potential of E_f = 0.4 eV. At the incident frequency ω corresponding to $E_f = \hbar\omega/2$ graphene's interband conductivity drastically reduces to zero, and the absorption is blocked by the graphene surface, making the incident light pass through the device.

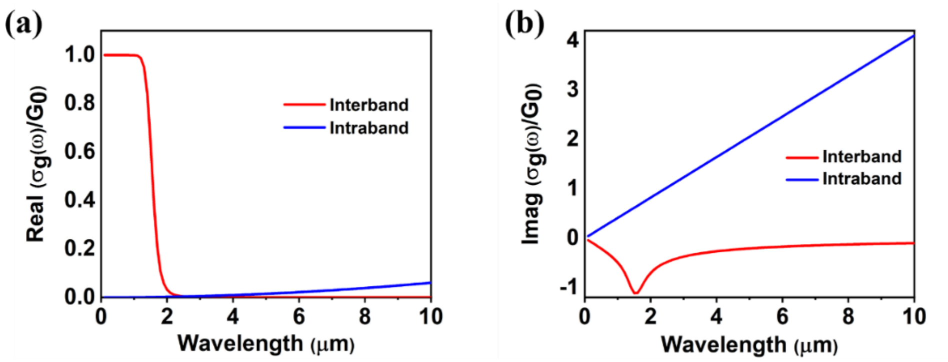

Fig S1: (a) Real and (b) Imaginary part of graphene's interband and intraband conductivity

2: Total conductivity and permittivity

Graphene's imaginary permittivity is related to the real part of the total conductivity (as given by equation 2 of the main text). At low wavelengths, when real conductivity is large, the imaginary permittivity is also large, responsible for the high absorption due to the graphene surface.

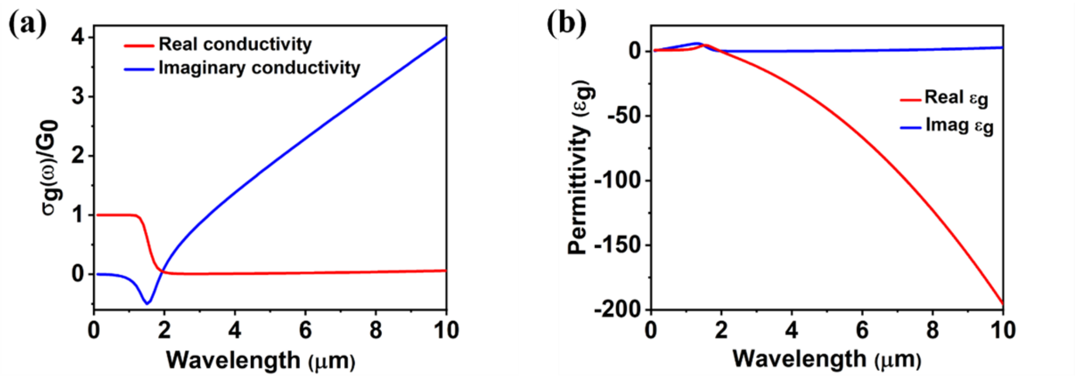

Fig. S2: Real and Imaginary part of (a) total conductivity normalized with static conductivity G_0 (b) Permittivity

3. Magnified view of a variation of Imaginary effective refractive index and group index with Fermi level of graphene sheet placed beneath G1

With the increasing graphene's Fermi potential, its absorption decreases due to the decrease in conductivity. This decreasing absorption decreases the imaginary part of the effective refractive index at both the resonant wavelengths. At 1.53 μm, this decrease in absorption occurs at a very low Fermi potential of 0.06 eV as the silicon nano bars in G1 are completely embedded in a silica environment. The electromagnetic radiation confined in the G1 pair finds it easy to move toward the G2 pair. Thus, a very low potential is needed for the transmission of light. Also, a large group index is achieved at a low potential.

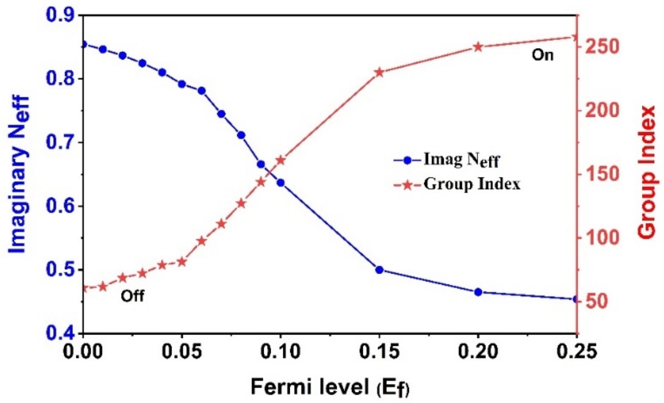

Fig. S3: Imaginary effective refractive index and group index as a function of Fermi level E_f at resonance wavelength of 1.53 μm.

4. Coupling of the confinement in G1 and G2 at 1.53 μm and 1.57 μm to show the reciprocal coupling

The confinement in G1 at 1.53 μm is mainly around the nano bars in G1, as the resonator is placed in the homogenous medium. The magnetic field distribution is also mainly concentrated around G1 and couples very less in G2 as shown in Fig S4(a). Whereas, confinement in G2 at 1.57 μm also penetrates to G1 as the resonator G2 is placed in non-homogenous medium and the magnetic field distribution lines also couples with G1 as shown in Fig S4(b). The Weak coupling in G1 is responsible for the decreased N_{eff} and the strong coupling in G2 is responsible for increased substrate losses and increased value of N_{eff}.

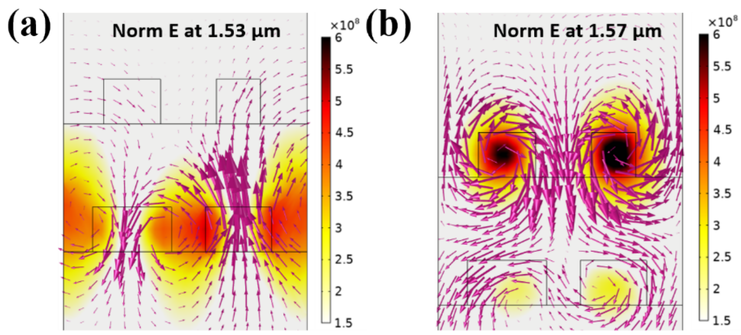

Fig. S4: Normalized Electric field plots with magnetic field lines at the resonance wavelength of (a) 1.53 μm and (b) 1.57 μm

5. Biasing mechanism for the device

We have biased the dual channel switch by adding another graphene layer in between the two graphene layers as shown in the mauscript. The Fermi potential of graphene is set at E_f=0.9 eV that can be achieved during fabrication process. Now, the Fermi potential required for the resonances to be in ON state changes to 0.6 eV. The spectrum of four possible states is as shown in Fig. S5.

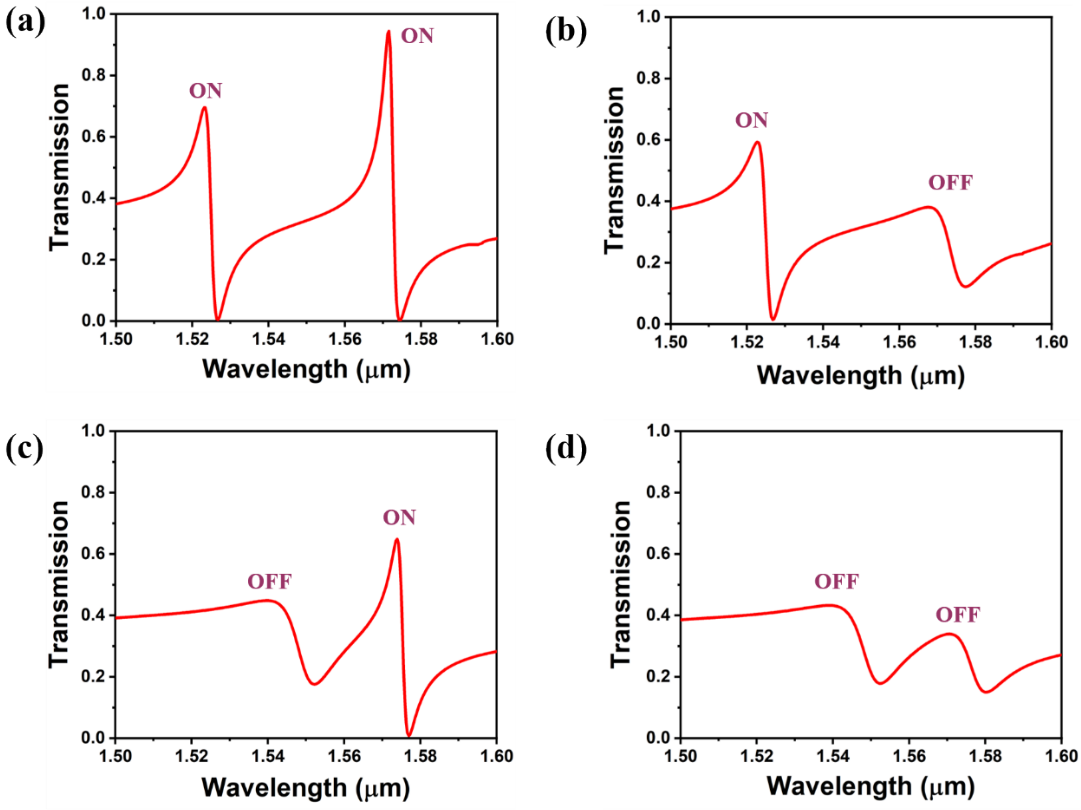

Fig S5. Four states of the dual channel optical switch with proper biasing for (a) ON-ON (b) ON-OFF (c) OFF-ON (d) OFF-OFF states. Where ON state is with E_f = 0.6 eV and OFF state with E_f = 0 eV.