Goos-Hänchen shifts due to graphene when intraband conductivity dominates

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A light beam impinging on a plane dielectric interface exhibits spatial and angular shifts due to its finite beam width. The lateral displacement of beam, known as the Goos-Hänchen shift [1], was originated from the dispersion of the reflection coefficients shown by Artmann in 1948 [2] and relies on the polarization of the incident beam [3]. The dimensionless spatial (ΔGH) and angular (ΘGH) Goos-Hänchen shifts are expressed as:

$$\Delta_{GH} = \omega_p Im\left(\frac{\partial ln r_p}{\partial\theta}\right) + \omega_s Im\left(\frac{\partial ln r_s}{\partial\theta}\right) \quad (1)$$

$$-\Theta_{GH} = \omega_p Re\left(\frac{\partial ln r_p}{\partial\theta}\right) + \omega_s Re\left(\frac{\partial ln r_s}{\partial\theta}\right) \quad (2)$$

where $\omega_p = \frac{R_{p/s}^2 a_{p/s}^2}{R_p^2 a_p^2 + R_s^2 a_s^2}$ ($a_{p/s}$ are the electric field components), and $r_{p/s}$ is the Fresnel coefficient for the interface formed by two dielectric surface with permittivity constants ϵ_1 and ϵ_2 separated by graphene layer. To physically measure the beam shift, we consider both spatial and angular factor:

$$k_0 \Gamma_X = \Delta_{GH} + (z/L)\ \Theta_{GH} \quad (3)$$

where $k_0 = 2\pi/\lambda$, z is the propagation distance, and L is the Rayleigh length.

The GH shifts depend on the reflection coefficients, which in turn depend on the conductivity of the material interface. In the case of a monolayer graphene, its intraband conductivity dominates at room temperature, $\sigma = (2ie^2\ E_F)/(\pi\hbar\ (\omega + \ i/\tau))$. It can be seen that the conductivity of a monolayer graphene at intraband transitions is sensitive on the Fermi level and on the wavelength of the incident beam and thus may offer better control of light impinging on it. In this paper, we investigate reflection, the simplest interaction of light on such surface, by looking at its effect on the Goos-Hänchen (GH) shift experienced by the incident light. We determine the dependence of GH shifts on the Fermi level when the wavelength of the incident beam is at the THz range. We calculated that both spatial and angular GH shifts are present.

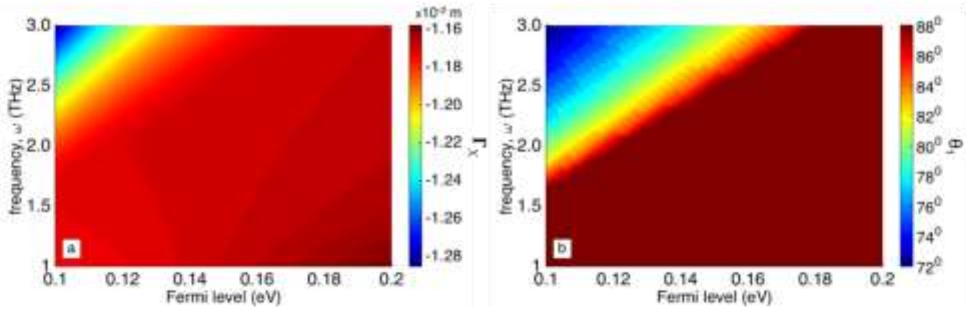

Figure 2. Colormaps of (a) Maximum physical GH shifts as a function of Fermi level and incident frequency and (b) the corresponding incident angles for each maximum physical beamshift. We have calculated a physical beamshift of up to -13 mm.

We see that at higher frequencies, the amount of beam shift decreases with the Fermi level and at lower frequencies, the shift becomes proportional to the Fermi level. Upon obtaining the measurable shifts, the angular GH shift dominates the spatial GH shift given appropriate experimental parameters. Our results may pave the way for this material's use in optoelectronics devices and applications.

Acknowledgments:
We would like to acknowledge the support of the UP OVPAA 2015-06, UP ECWRG 2016-02-27, and PCIEERD of the Department of Science and Technology of the Republic of the Philippines.

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