Fabry-Perot enhanced Faraday rotation in graphene

UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES
Département de physique de la matière condensée

Nicolas Ubrig[1], Iris Crassee[1], Julien Levallois[1], Ievgeniia Nedoliuk[1], Felix Fromm[2], Michl Kaiser[2], Thomas Seyller[2], Alexey B. Kuzmenko[1]

[1]Département de Physique de la matière condensée (DPMC), University of Geneva, Switzerland

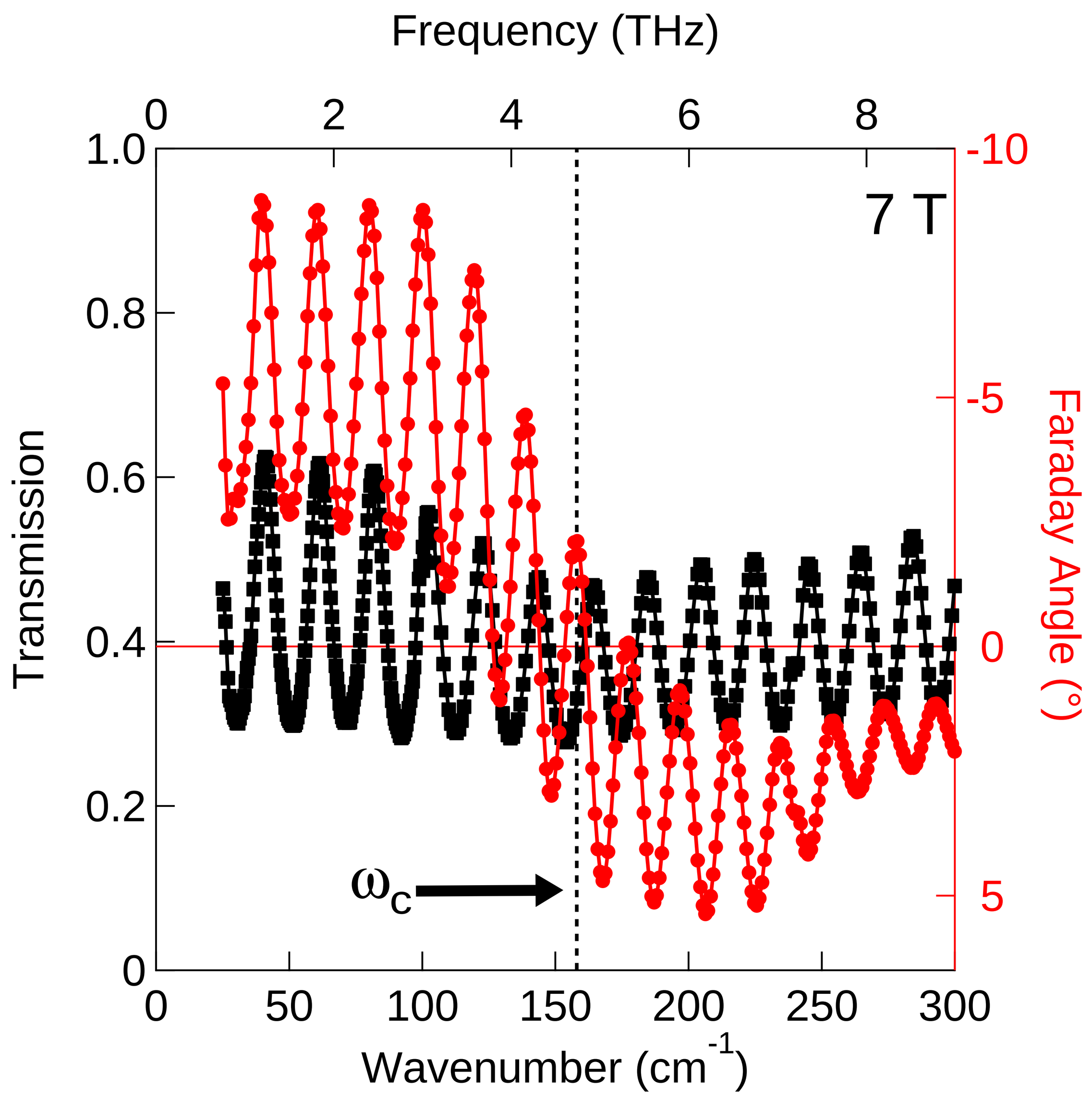
[2]Lehrstuhl für Technische Physik, Universität Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen, Germany

FNSNF Swiss National Science Foundation
MaNEP SWITZERLAND

Introduction

We demonstrate that giant Faraday rotation in graphene in the terahertz range due to the cyclotron resonance is further increased by the constructive Fabry-Perot interference in the supporting substrate. Simultaneously, an enhanced total transmission is achieved, making this effect doubly advantageous for graphene-based magneto-optical applications. As an example, we present high-resolution far-infrared spectra of epitaxial multilayer graphene grown on the C-face of 6H-SiC, where the Faraday rotation up to 0.15 radians (9°) is attained. Further, we discuss other ways to increase the Faraday rotation using the principle of the optical cavity and make a link to other propositions[1].

Experimental results



- Magneto-transmission and Faraday rotation measurements
- 1cm^{-1} and 2cm^{-1} resolution respectively
- Fabry-Perot fringes accurately resolved
- Faraday Rotation of 9°
- Even bigger rotation angle than reported in reference [2]
- The maxima of the transmission and the absolute value of the Faraday rotation virtually coincide, except in the spectral region close to the resonance
- Cyclotron resonance ω_c =156cm^{-1} from the highly doped bottom layers, Negative slope of Faraday rotation means n-type doping

Fresnel equations

We model the experimental spectra, by treating all graphene layers as a thin film with the total conductivity $\sigma_\pm$ (i.e. right/left circular polarized light) and taking into account the multiple internal reflections in the substrate.

Substrate $n_s \approx 3.1$

$$r_{\mathrm{v},\pm} = \frac{1 - n_s - Z_0\sigma_\pm}{1 + n_s + Z_0\sigma_\pm}$$

$$t_{\mathrm{v},\pm} = \frac{2}{1 + n_s + Z_0\sigma_\pm}$$

$$\sigma_\pm(\omega) = \frac{2D}{\pi}\frac{i}{\omega \mp \omega_c + i\gamma} + \sigma_b$$

Graphene on top of the substrate

$$t_\pm = 4n\tau_s \cdot \left[(n+1)^2 - (n-1)^2\tau_s^2 + Z_0\sigma_\pm\left(n + 1 + (n-1)\tau_s^2\right)\right]^{-1}$$

Graphene on both sides of the substrate

$$t_\pm = 4n\tau_s \cdot \left[(n+1)^2 - (n-1)^2\tau_s^2 + 2Z_0\sigma_\pm\left(n+1+(n-1)\tau_s\right)^2 + Z_0^2\sigma_\pm^2(1-\tau_s^2)\right]^{-1}$$

Graphene in the middle of the substrate

$$t_\pm = 4n\tau_s \cdot \left[((n+1)^2 - (n-1)^2\tau_s^2 + \frac{Z_0\sigma_\pm}{2n}\left(n+1+(n-1)\tau_s\right)^2\right]^{-1}$$

Graphene on top of the substrate, constructive interference, $\tau_s = \pm 1$

$$t_{\mathrm{constr},\pm} = \tau_s\left(1 + \frac{Z_0\sigma_\pm}{2}\right)^{-1}$$

Graphene on both sides of the substrate, $\tau_s = \pm 1$

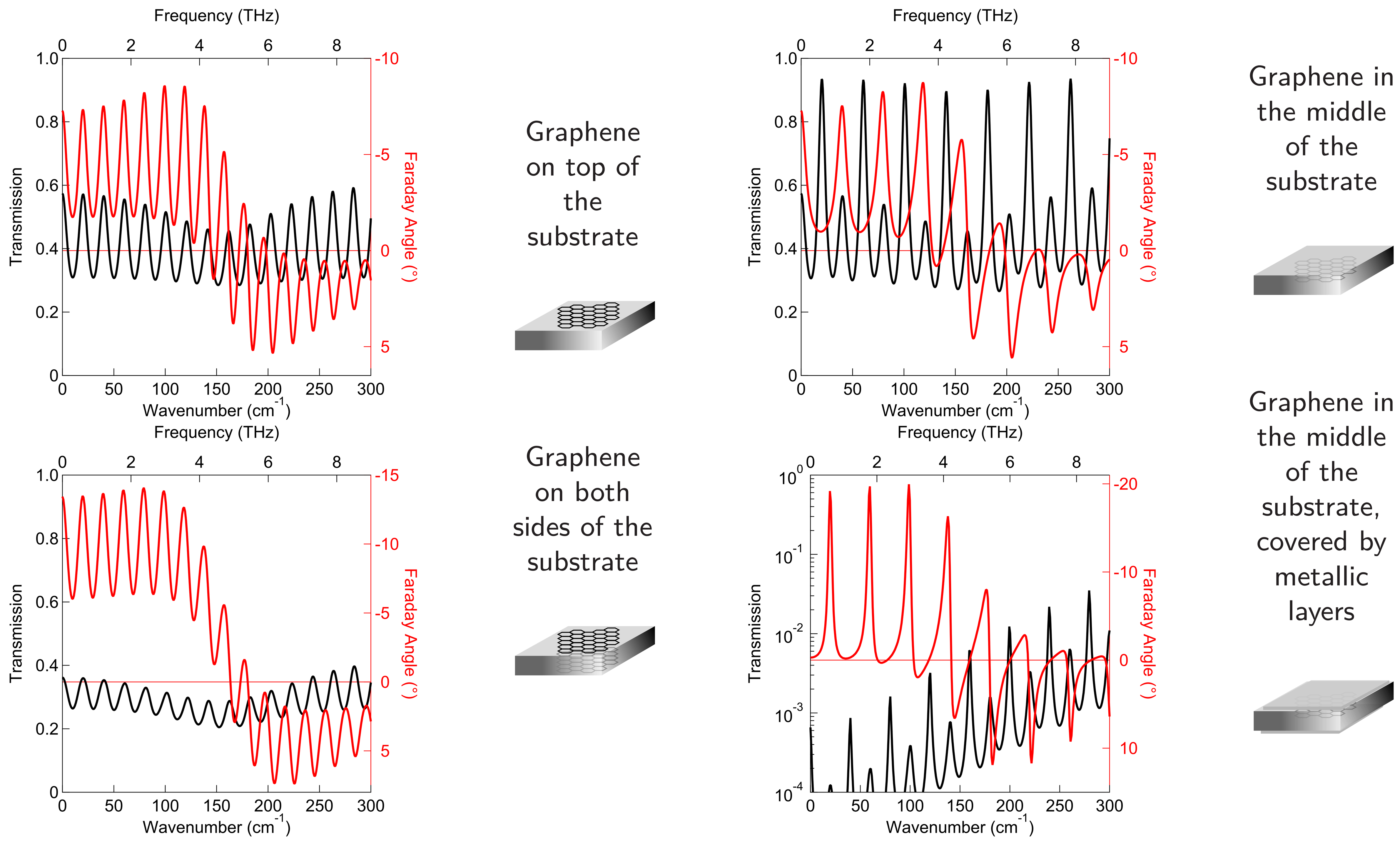
$$t_{\mathrm{constr},\pm} = \tau_s\left(1 + Z_0\sigma_\pm\right)^{-1}$$

Graphene in the middle of the substrate, $\tau_s = -1$

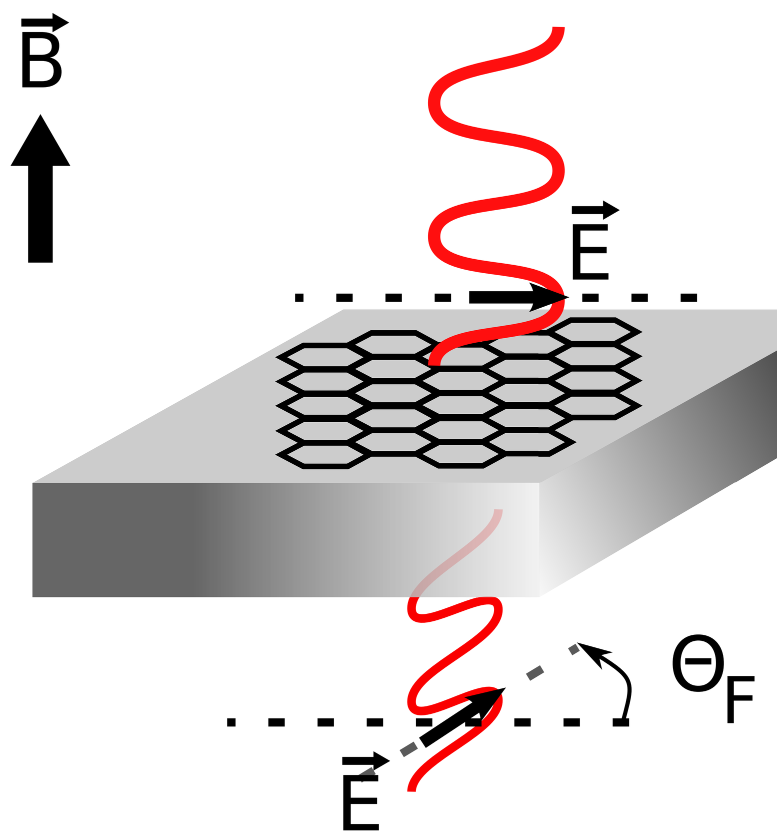
$$t_{\mathrm{constr},\pm} = \tau_s(1 + Z_0\sigma_\pm/2n^2)^{-1}$$

$\tau_s = +1$ like graphene on top

Simulation



Faraday Rotation



$$T = \frac{|t_-|^2 + |t_+|^2}{2}$$

$$\theta_F = \frac{1}{2}\arg\left(\frac{t_-}{t_+}\right)$$

Conclusion

We report the enhancement of the Faraday rotation in graphene due to the constructive Fabry-Perot interference in the substrate as compared to the case when the interference is not resolved. We show that under these conditions the total transmission of the system is also increased. Our calculations suggest that in order to increase the rotation even further, one can either cover both sides of the substrate with graphene or to use the substrate as a high-finesse optical cavity by coating a metal film on it. Although the transmission strongly decreases in the latter case, the maximum achievable rotation is much higher than in low finesse cavity.

References

[1] A. Ferreira *et al.* Physical Review B 84, 235410 (2011)

[2] I.Crassee *et al.* *Nat. Phys.*, **7**, 48 (2011)