Nonlinear Electrodynamic Response of Graphene: a Nonperturbative Quasiclassical Approach and the Influence of Substrates

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We report on our new results in the theory of nonlinear electrodynamic response of graphene. In Ref. [1] we study the third harmonic generation from graphene lying on different substrates, consisting of a dielectric (dispersionless or polar), metalized or non-metalized on the back side. We show that the third harmonic intensity emitted from graphene lying on a substrate, can be increased by orders of magnitude as compared to the isolated graphene, due the LO-phonon resonances in a polar dielectric or due to the interference effects in the dielectric substrates metalized on the back side. In some frequency intervals, the presence of the polar dielectric substrate compensates the strongly decreasing with ω frequency dependence of the third-order conductivity of isolated graphene making the response almost frequency independent, see Figure 1.

In Ref. [2] we develop a non-perturbative quasi-classical ($\hbar\omega<2E_F$, E_F is a Fermi energy) theory of the nonlinear electrodynamic response of graphene. We investigate the saturable absorption and higher harmonics generation effects, as well as the transmission, reflection and absorption of radiation incident on the graphene layer, as a function of the frequency and power of the incident radiation and of the ratio of the radiative (Γ) to scattering ($\gamma=1/\tau$) damping rates, see Figure 2.

References

[1] N.A.Savostianova and S.A.Mikhailov, arXiv:1608.05975

[2] S.A.Mikhailov, arXiv:1608.00877

Figures

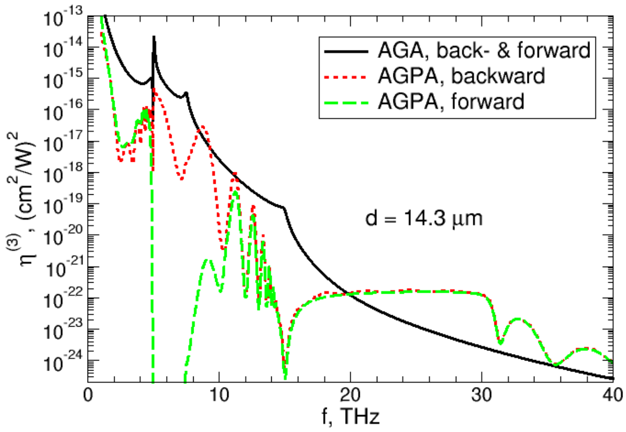

Figure 1: The 3rd harmonic upconversion efficiency $\eta^{(3)}=I_{3\omega}/(I_\omega)^3$ in a AGPA structure (Air – Graphene – Polar dielectric – Air), as a function of frequency. The polar dielectric thickness is d=14.3 μm, TO and LO phonon frequencies are 15 and 30 THz respectively; the electron density in graphene is 7×10^{10} cm^{-2}.

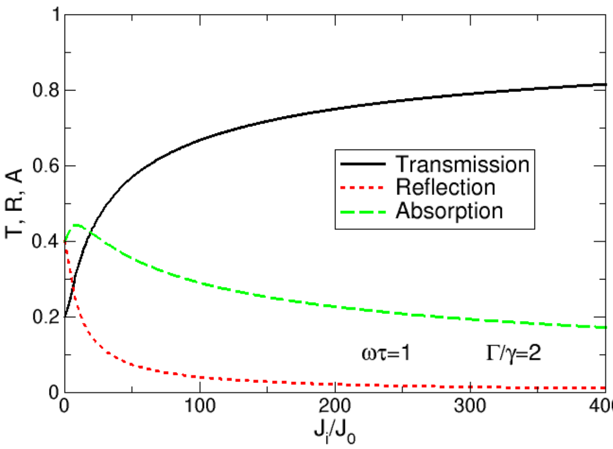

Figure 2: The transmission, reflection and absorption coefficients of graphene as a function of the incident wave intensity, at $\omega\tau=1$

and $\Gamma/\gamma=2$. The perturbative approach corresponds to $J_i/J_0<1$.