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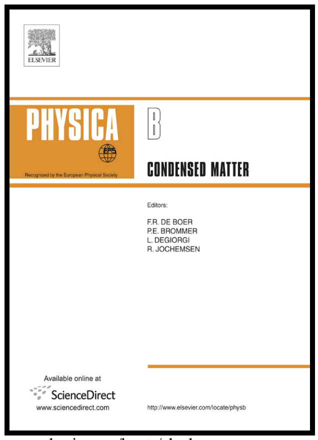

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A theory for non-degenerate four-wave mixing in doped graphene

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Abstract

We present a theoretical study of the nonlinear optical (NLO) response of doped graphene to two coherent laser beams, of frequencies ω_1 and ω_2, resulting in the generation of radiation at frequency $\omega_\sigma = 2\omega_1 - \omega_2$. The two main ingredients of the developed theory are the interplay of interband and intraband electron motion, induced by the incident light waves, and the finite lifetime of excited electronic states, caused by electron scattering. Adopting a tight-binding approximation for the π-electronic band structure of graphene and the Genkin-Mednis formalism of the nonlinear conductivity theory of semiconductors, we calculate the third-order NLO susceptibility $\chi^{(3)}(-\omega_\sigma; \omega_1, \omega_1, -\omega_2)$ responsible for the non-degenerate four-wave mixing process under consideration. Our calculations show the resonant enhancement of the $|\chi^{(3)}|$ (up to a value of 2.8×10^{-7} esu) when the frequencies ω_1 and ω_2 of the input beams are matched to provide a resonance for the output photon energy $\hbar\omega_\sigma$ with an effective optical gap of $2E_{\rm F}$ in the π-electronic band structure of doped graphene ($E_{\rm F}$ is the Fermi energy of charge carriers in the graphene, tunable by an external gate voltage). The results obtained may be of practical interest for generating mid-infrared radiation from doped graphene pumped with two near-infrared laser beams.

Keywords: Doped graphene, Nonlinear optical response, Four-wave mixing

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