Enhanced Kerr nonlinearity due to double dark resonances in a quantized four-level graphene nanostructure under external magnetic field

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Many proposals have been suggested for achieving giant Kerr nonlinearity in different medium [1,2]. In this study we propose a new model for achieving giant Kerr nonlinearity in a single layer of graphene nanostructure. The properties of electron near the Dirac points make it possible for interacting by electromagnetical fields [3]. The nonlinear optical features of graphene nanostructure in the presence of strong magnetic field have been discussed very recently in four-wave mixing [4]. To the best of our knowledge, the giant Kerr nonlinearity of graphene with zero linear and nonlinear absorption has not been reported theoretically or experimentally. The enhanced Kerr nonlinearity with zero linear absorption is very interested in nonlinear optics and quantum information science. Here, we proposed a new model based on double dark resonance for enhancing the Kerr nonlinearity in a graphene nanostructure under external magnetic field.

1. Model and Equations

The considered single layer of graphene system under external magnetic field is presented in fig. 1. After solving the density matrix elements of the system, the linear and nonlinear susceptibility of the medium can be obtained [1, 2].

$$\chi^{(1)} = \frac{2N|\mu_{14}|^2}{\varepsilon_r \hbar \Omega_p} \rho_{41}^{(1)}, \qquad (1)$$

$$\chi^{(3)} = \frac{2N|\mu_{14}|^4}{3\varepsilon_r \hbar^3 \Omega_p^3} \rho_{41}^{(3)}, \qquad (2)$$

Where, N and ε_r are the sheet electron density of graphene and the substrate dielectric constant, respectively. The $\rho_{41}^{(1)}$ and $\rho_{41}^{(3)}$ denotes the linear and nonlinear terms of density matrix elements.

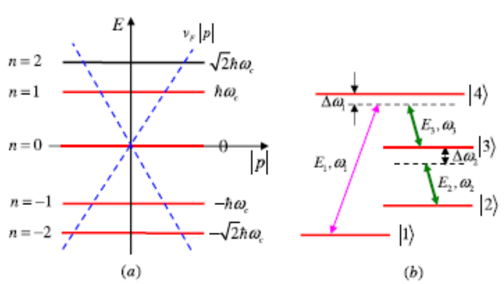

Fig. 1: (a) Landau levels of graphene in the absence of external magnetic field (a) and presence of external magnetic field (b).

2. Results

The linear absorption and Kerr nonlinearity of probe pulse propagated in a graphene system versus elliptical parameter θ is shown in fig. 2. It can be seen that the linear absorption (solid line) is vanished at some values of elliptical parameter θ. In this case, the Kerr nonlinearity (dashed line) reaches to the maximum value with zero linear absorption. The enhanced Kerr nonlinearity with zero linear absorption is favoraitable in nonlinear optics.

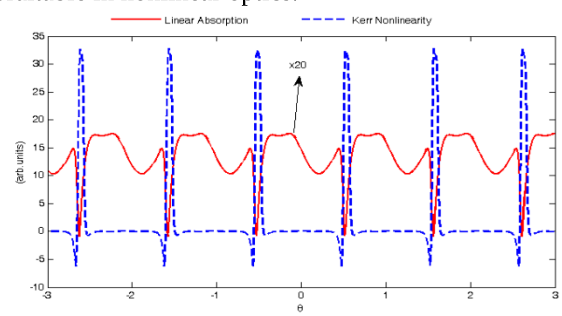

Fig. 2: Linear absorption (solid line) and Kerr nonlinearity versus elliptical parameter θ.

In fig. 3, we display the behaviors linear susceptibility and nonlinear susceptibility versus probe field detuning.

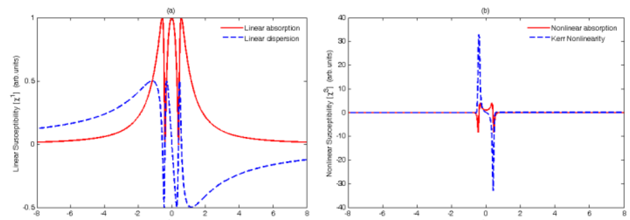

Fig. 3: (a) Linear susceptibility and (b) nonlinear susceptibility versus probe field detuning.

We find that for $\theta = \pi/4$, the giant Kerr nonlinearity is obtained with zero linear absorption a nonlinear amplification

Ref

[1] Y. Niu, S. Gong, Phys. Rev. A 73 053811 (2006)
[2] H. R. Hamedi, Phys. Rev. A 91 053823 (2015)
[3] M. Tokman, et al, Phys. Rev. Lett 110 077404 (2013)
[4] C. Ding, et al, Phs. Rev. A 90 043819 (2014)