Quantum Dynamical Simulation of Photo-Induced Graphene Switch

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INTRODUCTION

The long-continued advance of the performance of information processing technologies has been based on miniaturization of electronic components. Fundamental limits imposed by the laws of physics, however, threaten to halt the continued miniaturization, clouding the future of silicon-based semiconductors. A possible scenario for this “post-miniaturization” is superseded by new material of ”graphene”, an ultimately monoatomically layered graphite sheet. Although many researchers focus on the ultra-high electron mobility of graphene, absence of the band gap in graphene sets limitation on using for current switching devices. But it have been gradually found out that band gap of graphene can be created by effect of external field or structural change. In this study, we focus on the way of applying a time dependent external field (e.g., laser light irradiation) as a method of modulating electrical characteristic of graphene [1]. With such motivation, we study numerically the effect of laser irradiation on the electronic transport through single layer graphene, where we employ the wave packet dynamics to take into account the effect of laser field with various polarizations irradiated only through the finite channel region of graphene device.

MODEL AND METHOD

In Fig. 1 we show the schematic illustration of the device assumed in this work. The laser field with the electric field intensity E_0 and the frequency ω is irradiated only through a central finite region of graphene, while the left and the right electrode regions are doped by electrons so that the band structure is shifted lower in energy by 1 eV. In prior to the simulation of electronic transport, the electronic property of the laser irradiated graphene is explored by analyzing the dynamical band structure, which is obtained by Fourier transforming the real time evolution of the wave function for a given set of the $\mathbf{k} = (k_x, k_y)$ (electronic wavenumber), E_0, and ω. The transmission of an electron through the central laser irradiated region is analyzed by the real-time evolution of the incident Gaussian wave packet through the device shown in Fig. 1.

RESULTS AND DISCUSSIONS

As shown in Fig. 2-4, the calculated dynamical band structures are strongly dependent on the polarization of the irradiated light. In particular, the finite bandgap can be induced at the Fermi level $E = 0$ when the circularly polarized light is irradiated as shown in Fig. 4. When such circularly polarized light is irradiated through a finite region of graphene, the incident wavepacket is strongly reflected at the laser irradiated region, in a way dependent on the field intensity E_0.

CONCLUSION

Our simulations have shown that the transmission through graphene can be significantly modulated by irradiating the laser field with the circular polarization, in a way consistent with the generation of the dynamical band gap by the circularly polarized light plotted. The detailed discussion on the channel length dependence of the transmission will be given in the presentation.

REFERENCES

[1] T. Oka and H. Aoki, Phys. Rev. B 79, 081406(R) (2010)..

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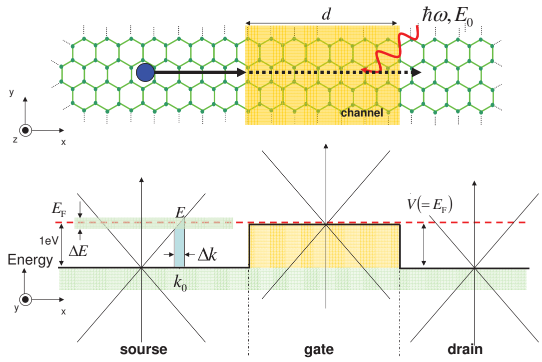

Fig. 1. Schematic illustration of the device assumed in this work. The laser field with the electric field intensity E_0 and the frequency ω is irradiated only through a central finite region of graphene, while the left and the right electrode regions are doped by electrons so that the band structure is shifted lower in energy by 1 eV.

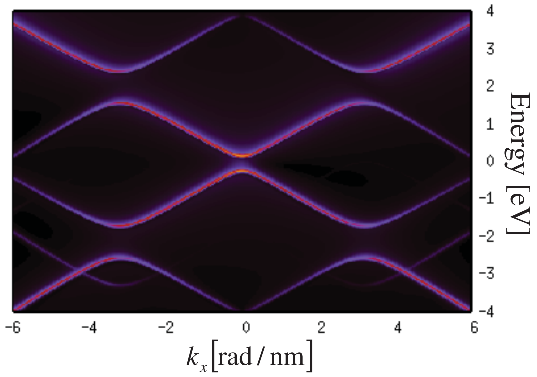

Fig. 4. Dynamical band structure of graphene irradiated by the circularly polarized light with $E_0 = 6.0$ V/nm and $\omega = 6.28$ rad/fs.

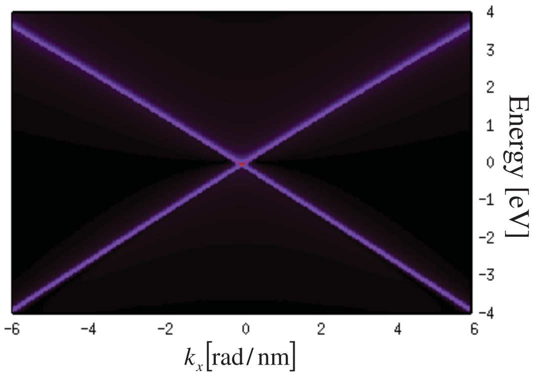

Fig. 2. Dynamical band structure of graphene near the Fermi level $E = 0$ calculated for the vanishing laser field. Brighter color corresponds to the higher intensity of the Fourier transformed wavefunction data.

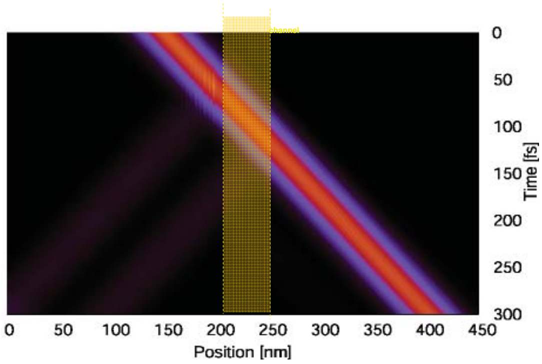

Fig. 5. Time propagation of the Gaussian wave packet through the graphene in the vanishing laser field.

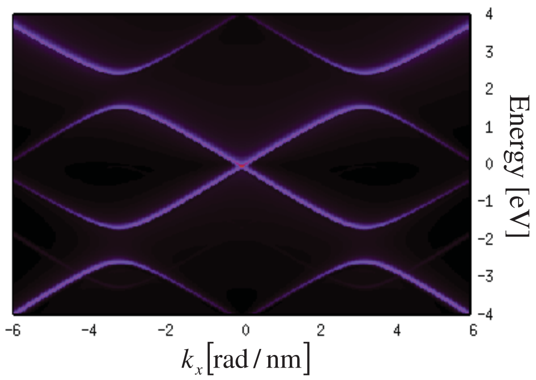

Fig. 3. Dynamical band structure of graphene irradiated by y-polarized light with $E_0 = 6.0$ V/nm and $\omega = 6.28$ rad/fs.

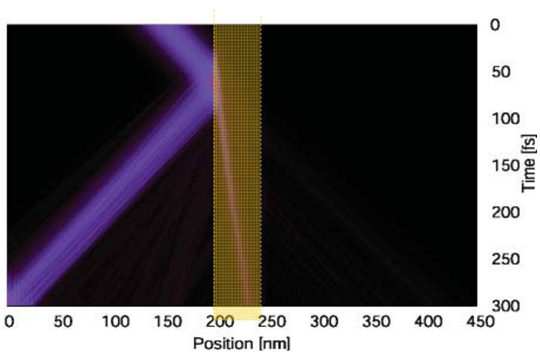

Fig. 6. Time propagation of the Gaussian wave packet through the graphene irradiated by the circularly polarized light through the central shaded region.