Anisotropic photoconductivity in graphene

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We investigate the photoconductivity of graphene within the relaxation time approximation. In presence of the inter-band transitions induced by the linearly polarized light the photoconductivity turns out to be highly anisotropic due to the pseudospin selection rule for Dirac-like carriers. The possible observations and applications of this phenomenon are discussed.

One of the most unusual properties of carriers in graphene is the additional quantum degree of freedom which is dubbed as a pseudospin but, in fact, is connected with the sublattice index and has nothing to do with the real spin. Nevertheless, in some cases it turns out to be possible to deal with the pseudospin in a similar way as with the real electron spin. The experiment proposed below involves the optical excitation of the valence electrons to the conduction band in the intrinsic (or undoped) graphene. The idea is that the Hamiltonian describing the interaction between the electromagnetic wave and charge carriers inherits the pseudospin-momentum entangled structure from the effective Dirac-like Hamiltonian relevant for the electron pi-system of the single layer graphene near half filling. Assuming the normal incidence of a linear polarized electromagnetic wave one can arrive at the electron generation rate which strongly depends on the relative orientation between the electron momentum and the linear polarization plane, see Fig. 1. As consequence the photoconductivity parallel to the light polarization plane is 3 times smaller than the perpendicular one, i. e. the photoconductivity turns out to be highly anisotropic. Thus, changing the linear polarization angle from 0 to 2-Pi one can observe two minima (and two maxima) in the current flow, as depicted in the inset of Fig. 1. These double extrema can be seen as a signature of the effect proposed.

To evaluate the plausibility of the photoconductivity response proposed above one has to compare the residual carrier concentration due to the unintentional doping with the number of the photo-excited carriers. Assuming the CH3OH laser [1] operating at the wavelength 0.118 nm with the power 20 mW we find that the concentration of the photo-induced electrons is of the order of the residual carrier concentration in graphene after annealing. Thus, to observe the effect, we suggest utilizing the undoped suspended graphene samples which allow the laser beam to excite the substantial number of photo-carriers from the valence band. The cleaner samples are expected to demonstrate the better results. They can be used as the polarized light detectors.

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References

[1] J. Karch *et al*., ArXiv:1002.1047

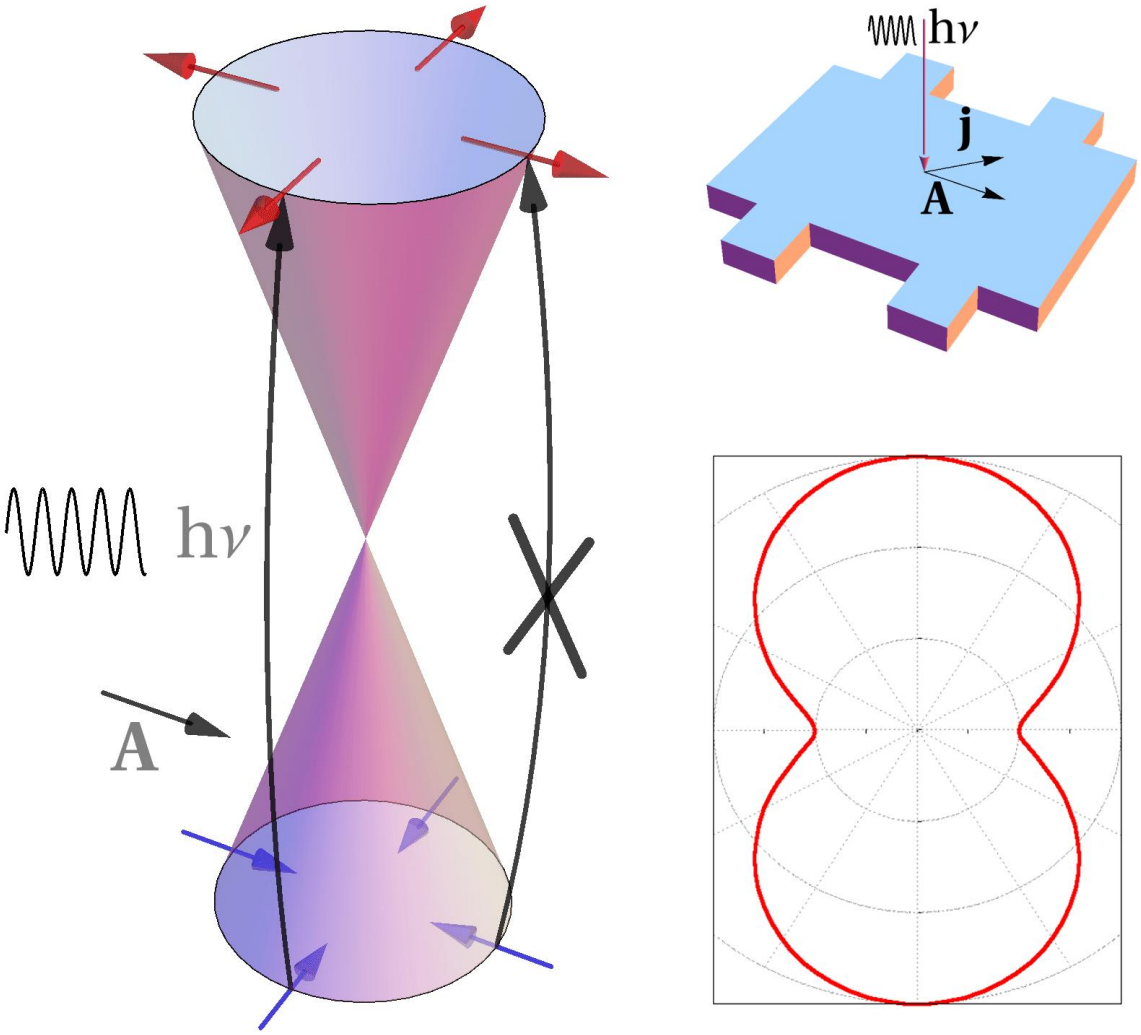

Fig. 1: The sample represents a Hall bar made of graphene which is irradiated by the linearly polarized electromagnetic wave characterized by the vector potential ***A****. Applying the bias voltage one can observe the electrical current* ***j*** *which depends on the photo-induced carrier concentration. The carriers in graphene described by Dirac Hamiltonian with the cone-shaped dispersion law acquire additional degree of freedom known as pseudospin whose orientation entangled with the particle momentum is shown by arrows. The electrons in the valence band absorbing the photon energy are excited to the conduction band producing the photoconductivity response. The electron-hole excitation rate is zero if the light is polarized along the pseudospins of the excited particles. In contrast, the excitation rate is maximal if the vector potential and pseudospin are perpendicular to each other. Since the pseudospin orientation is coupled with the particle's momentum the resulting photoconductivity depends on the angle between* ***A*** *and* ***j****, as shown in the inset.*