Graphene in periodic deformation fields

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Electronic properties of graphene can be strongly affected by deformations generating certain scalar and vector gauge fields. Such fields act on electrons as effective pseudo-electric and pseudo-magnetic fields, which can have enermously high magnitude [1]. For example, the pseudo-magnetic field is estimated to reach up to 300 T. It gives us an additional tool for very effective manipulation of electrons in graphene by the strains (strain engineering). Especially important is using periodic deformations creating periodic pseudo-electric and magnetic fields, which do not necessarily break the periodicity of the lattice. As a result, we can obtain a substantially modified electronic structure of graphene. One of the existing possibilties is related to creation of a standing strain wave in graphene.

Here we present the results of our theoretical calculations of the effect of periodic scalar and vector potentials generated by periodic deformations of the graphene crystal lattice, on the electron energy spectrum [2]. It is found that the periodic fields do not create the gap in the Dirac point but they change substantially the velocity of electrons near the Dirac point, and the resulting electron energy spectrum can be strongly anisotropic.

We also discuss the effect of screening of the periodic scalar potential. For this purpose we calculated the dielectric function as a function of the wave length of the scalar potential. This calculation shows that the periodic scalar field can be in fact strongly suppressed by the screening, so that only the pseudo-magnetic periodic field is of importance. The screening is relevant at nonzero chemical potential and is due only to the presence of free electrons and holes, which means that virtual transitions associated with electron polarization are not important.

Self-consisting consideration of the screening, which in its turn is depending on the electron spectrum (electron velocity), leads to rather nontrivial renormalization of the electron velocity. We solved the renormalization group equations for velocity components and found their asymptotic isotropization behavior and an increase of velocity with the renormalization parameter.

By using the dependence of electron velocity on the periodic field we also studied the variation of the plasmon spectra in graphene. We found that the spectrum of plasmon excitations can be also effectively controlled by the periodic strain field. Namely, the plasmon velocity in its linear part can be effectively manipulated by the periodic strain.

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