Effect of electron interaction and spin in electronic and transport properties of graphene nanoribbons in the integer quantum Hall regime

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In the present work [1] we study a system consisting of a graphene nanoribbon (GNR) which is located on an insulating substrate and attached to semi-infinite leads acting as electron reservoirs. The system is subjected to a perpendicular magnetic field. The effects of electron interaction on the magnetoconductance are studied within the Hartree approximation. Self-consistent numerical calculations are based on the tight-binding p-orbital Hamiltonian. Local density of states and distribution of charge density are calculated using the Green's function technique.

We find that the perpendicular magnetic field leads to suppression instead of an expected improvement of the conductance quantization. This suppression is traced back to interaction-induced modifications of the band structure which is strongly modified in comparison to the single-particle case. The distortion of subbands leads to formation of compressible strips in the middle of GNRs. The compressible strips are partially filled and hence the system has a metallic character. As a result, the electron density can be easily redistributed in order to effectively screen the external potential. The detailed structure of propagating states of interacting electrons in GNRs shows that there are two types of states which have a different microscopic character. The first type corresponds to edge states propagating near the boundaries. These states have the same structure for interacting and noninteracting cases. The second type corresponds to states which form compressible strips in the center of the ribbon as discussed above. The most prominent feature of these states is that their direction of propagation is opposite to that one of the edge states residing in the same half of the GNR. This is in contrast to the noninteracting picture, where due to the presence of the magnetic field, forward and backward propagating states are localized at different boundaries by Lorentz forces. We demonstrate that the drastic modification of the GNR band structure by electron interaction leading, in particular, to the formation of compressible strips in the middle of the ribbon causes suppression instead of expected improvement of the conductance quantization. We predict that overlaps between forward and backward propagating states may significantly enhance backscattering in realistic GNRs.

We also discuss electronic and transport properties of GRNs in the lowest Landau level regime. The interaction between electrons with opposite spin orientation is described by the Hubbard term, and the conductance is calculated within the Landauer formalism by the recursive Green's function technique. Due to Zeeman interaction the self-consistent band structure is spin-split exhibiting two states of different spin orientation propagating in the opposite directions at the same edge. We study the effects of warping and short-range impurities on conductance of interacting electrons in GRNs. Our results show that these states are robust and the conductance near the Dirac point is almost unaffected. We therefore predict that the effect of increase of the magnetoresistance in the vicinity of the Dirac point commonly observed in bulk graphene samples, should be absent in confined geometry of GNRs.

[1] A. A. Shylau, I. V. Zozoulenko, Hengyi Xu, T. Heinzel, *Generic suppression of conductance quantization of interacting electrons in graphene nanoribbons in a perpendicular magnetic field*, Phys. Rev. B **82**, 121410(R) (2010).