Edge effects in graphene nanostructures: spectral density and quantum transport

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We investigate the effect of different edge types on the statistical properties of both the energy spectrum of closed graphene billiards [1] and the conductance of open graphene cavities [2] in the semiclassical limit. To this end, we develop an exact expansion for the single particle Green's function of ballistic graphene structures in terms of multiple reflections from the system boundary, that allows for a natural treatment of edge effects. We first apply this formalism to calculate the average density of states of graphene billiards. While the leading term in the corresponding Weyl expansion is proportional to the billiard area, we find that the contribution that usually scales with the total length of the system boundary differs significantly from what one finds in semiconductor-based, Schr\"odinger type billiards: The latter term vanishes for armchair and infinite mass edges and is proportional to the zigzag edge length, highlighting the prominent role of zigzag edges in graphene. We then compute analytical expressions for the density of states oscillations and energy levels within a trajectory based semiclassical approach. We derive a Dirac version of Gutzwiller's trace formula for classically chaotic graphene billiards and further obtain semiclassical trace formulae for the density of states oscillations in regular graphene cavities. Next we study the spectral two point correlation function, or more precisely its Fourier transform the spectral form factor. We calculate the two leading order contributions to the spectral form factor, paying particular attention to the influence of the edge characteristics of the system. Then we consider transport properties of open graphene cavities. We derive generic analytical expressions for the classical conductance, the weak localization correction, the size of the universal conductance fluctuations and the shot noise power of a ballistic graphene cavity. Again we focus on the effects of the edge structure. For both, the conductance and the spectral prperties, we find that edge induced pseudospin interference affects the results significantly. In particular intervalley coupling mediated through scattering from armchair edges is the key mechanism that governs the coherent quantum interference effects in ballistic graphene cavities.an event.

References

[1] Jürgen Wurm, Klaus Richter, and İnanç Adagideli Phys. Rev. B 84, (2011) 075468

[2] Jürgen Wurm, Klaus Richter, and İnanç Adagideli; Phys. Rev. B 84, (2011) 205421