Edge Effects in Graphene Nanostructures - Spectral and Transport Properties

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In this work we study edge specific effects on spectral and transport properties of nanostructured graphene. In particular, we focus on the different types of edges and show how they affect the spectrum and the conductance. Previously we have investigated the effects of edges on the transport and spectral properties of graphene quantum dots, as well as on the conductance of graphene nanoribbons numerically [1,2]. Some edges can lead to effective (e.g. zigzag and infinite mass edges) or real (magnetic edges) time reversal symmetry breaking, others are effective intervalley scatterers (e.g. armchair edges).

Here we describe the quasiparticle dynamics in graphene analytically using the effective 2D Dirac Hamiltonian and imposing appropriate boundary conditions that depend on the specific structure of the graphene edges. Starting from the multiple reflection expansion for the exact Green function, we develop a theory that naturally incorporates the influence of the edges.

We then use our formalism to study the density of states (DOS) of closed graphene billiards and the conductance of open cavities. For the DOS we derive the Weyl expansion for the smoothed DOS, where we find that the surface contribution is exclusively due to the zigzag edges. That allows us to relate the DOS directly to the total number of zigzag edges. Furthermore, we derive trace formulae that connect the oscillating part of the DOS with the periodic classical orbits of the system. The correlations of the spectrum are found to depend on the structure of the edges, especially on the amount of intervalley scattering boundary parts. The reason is that the effective symmetry classes are changed depending on the ratio of the different time scales of the system.

Related effects are found also in the average conductance and the universal conductance fluctuations of open systems. By means of a semiclassical theory we show that a finite weak localization correction relies on the existence of armchair edges. Furthermore we obtain the size of both the weak localization and the universal conductance fluctuations as a function of the relevant time scales.

References

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[2] J.Wurm, M.Wimmer, I.Adagideli, K.Richter and H.U.Baranger. New J. Phys. **11** (2009) 095022