Quantum transport of Dirac fermions in graphene nanosystems away from the charge-neutrality point

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Peculiar electronic properties of graphene, including the universal *dc* conductivity, the pseudodiffusive shot noise, or the anomalous Lorentz number [1] are usually attributed to a small vicinity of the charge-neutrality point, away from which electron's effective mass raises, and nanostructures in graphene start to behave similarly to familiar Sharvin contacts in semiconducting heterostructures. Recently, it was pointed out that as long as abrupt potential steps separate the sample area from the leads, some graphene-specific features can be identified relatively far from the charge-neutrality point [2,3]. These features include conductance reduction and shot noise enhancement compared to the standard Sharvin values. We extend the previous analysis based on the effective Dirac equation, and derive the formulas that allow the calculation of the arbitrary charge-transfer cumulant for doped graphene [4]. Next, the results of analytic considerations are compared with numerical simulations of quantum transport on the honeycomb lattice, for selected nanosystems for which considerations starting from the Dirac equation cannot be directly adapted. For a wedge-shaped constriction with zigzag edges, the transport characteristics can be tuned from graphene-specific (*sub-Sharvin*) values to standard Sharvin values by varying the electrostatic potential profile in the narrowest section. A similar scenario is followed by the half-Corbino disk. In contrast, a circular quantum dot with two narrow openings shows a mixed behavior appears: the conductance is close to the Sharvin value, while the Fano factor approaches the value characterizing the symmetric chaotic cavity. Our results suggest that experimental attempts to verify the predictions for the sub-Sharvin transport regime should focus on systems with relatively wide openings, where the scattering at the sample edges is insignificant next to the scattering at the sample-lead interfaces.

References

1. A. Rycerz, Materials, 14 (2021) 2704
2. A. Rycerz and P. Witkowski, Phys. Rev. B, 104 (2021) 165413
3. A. Rycerz and P. Witkowski, Phys. Rev. B, 106 (2022) 155428
4. A. Rycerz, e-print: arXiv:2411.16032 (unpublished)

Figures

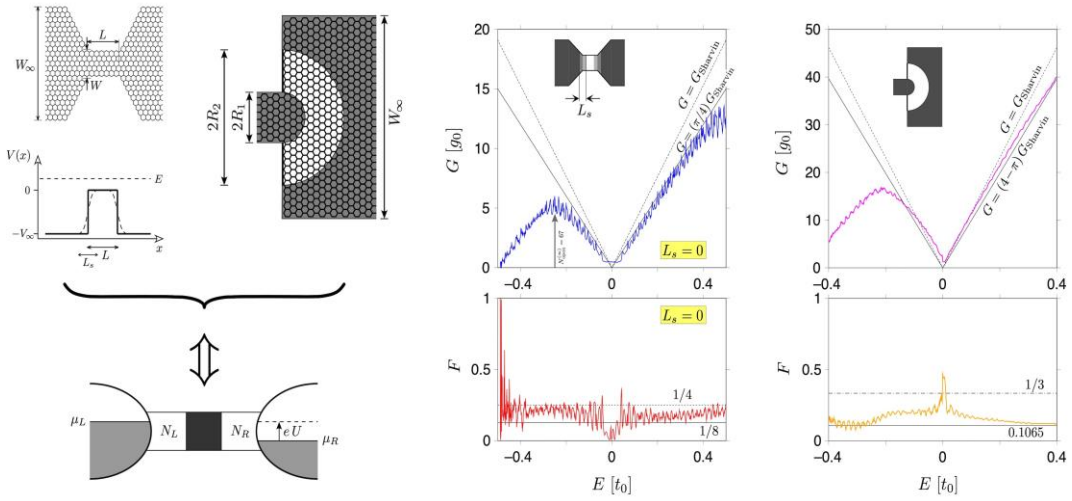

Figure 1: Top left: Selected systems studied numerically. Bottom left: Summary of the Landauer-Büttiker formalism. Center–right: Conductance (G) and Fano factor (F) versus the Fermi energy.