Bound States in Graphene Point Contacts

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Abstract

Quantum point contacts (QPC) are narrow constrictions connecting wider samples. A QPC acts as an effective potential barrier and reflects electrons incident upon it [1]. The possibility of formation of bound states in conventional semiconductor QPCs has been extensively studied [2].

In the present work, we study bound states in graphene QPCs, which has recently received much attention thanks to the unique properties of graphene [3]. It is found that long-lived quasi-bound states (QBSs) can exist in a class of ultra-short graphene QPC as sketched in Figure 1. Such QBSs are shown to originate from the dispersionless edge states – which exist on zigzag-shaped graphene edges – and to dominate the low-energy electronic transport. The formation mechanism is elucidated using Green's function theory [4]. The energy, lifetime and wave functions of QBSs are calculated. Sample size effects are discussed. It is shown that, while the QBS energy is roughly independent of sample sizes, its lifetime strongly depends on sample sizes following a power law (see Figure 2). The conductance is also evaluated. Due to QBSs, resonant transport is observed in the conductance, which can be controlled by tuning the QPC sizes. The results are checked by exact numerical calculations.

The results can be useful in designing graphene nanostructures. Especially, in the presence of Coulomb interactions, the QBS may admit of local magnetic moments and lead to spin-dependent transport phenomena [5], thus allowing possible applications in graphene-based spintronics.

References

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Figure

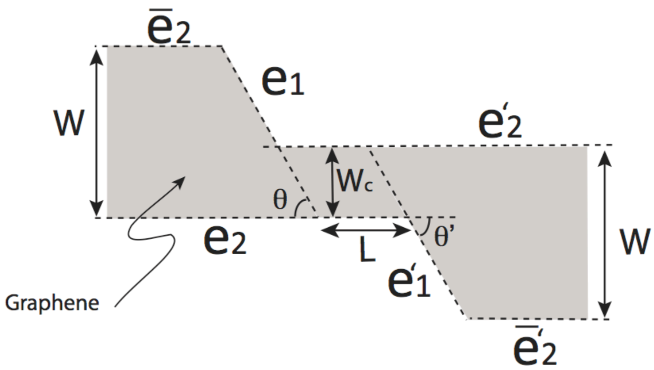

Figure 1: Geometry of the QPC. Two graphene samples of width W are connected via the QPC of width W_c.

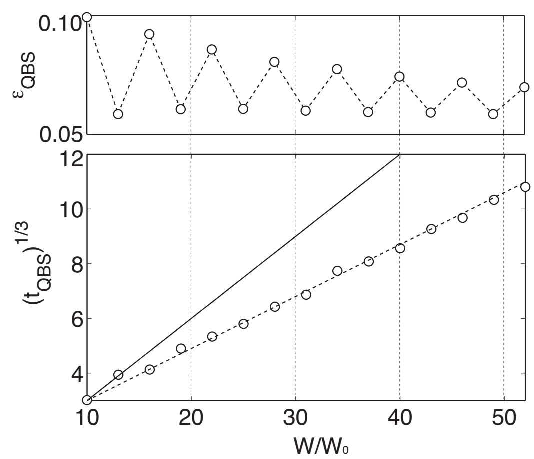

Figure 2: Energy (upper panel) and lifetime (lower panel) of QBS plotted against sample sizes. W_0 is a length scale of order of the lattice constant.