GRAPHENE NANOCONSTRICTION AS A SINGLE-LEVEL QUANTUM DOT

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Quantum dot having a single relevant electronic level, that shows only spin degeneracy, is widely considered as a key ingredient for solid-state quantum information processing. Recently, such a single-level quantum dot (SQD) was proposed to be realized in graphene constrictions with predominantly *armchair* edges [1, 2] in order to exploit the superior spin coherence expected in carbon nanostructures.

This is the theoretical proposal to build SQD by using graphene nanoconstriction with *zigzag* edges only. The work was motivated by recent experiment by Li *et al.* [3] reporting fabrication of a 120-degree graphene kink with zigzag edges, and partly by an analytical finding by Akhmerov and Beenakker [4] that the zigzag-boundary condition applies generically to the terminated honeycomb lattice of any crystallographic orientation of the edge, except the case of a perfect armchair edge. Therefore, the armchair-boundary condition constitutes an academic, experimentally inaccessible situation. On the other hand, in the existing proposals to build SQD in graphene [1, 2] the sections of an insulating-armchair nanoribbon are used to trap an electron in the device [5].

Earlier, we have shown [6] using tight-binding calculations, that the *asymmetric* kink consists of two nanoribbons with zigzag edges rotated to form a 120-degree kink, blocks the lowest propagating mode. Here, we first briefly discuss the evolutions of the kink conductance with its geometrical parameters W_1 and W_2 to show the blocking mechanism works effectively except from the *symmetric* case $W_1 \approx W_2$, when the resonant tunneling may appear. The analysis is extended to the case of nonzero edge magnetization, which may appear in nanoribbons with zigzag edges [7].

Then, the two kinks are joined together to form a *double kink*, which shows narrow conductance peaks associated with a charge density localized in a central section. The decay rates of such localized states comparable as of their counterparts in the system of Ref. [2]. This indicates each kink traps an electron as effectively as an insulating-armchair nanoribbon of the similar size and, subsequently, the double kink operates as SQD in graphene. We also consider a *double quantum dot* (DQD), formed in nanostructure containing *four* kinks, to illustrate the scalability of the proposed device. The work is complemented with estimation of the Coulomb-interaction integrals for the localized states, and of the subsequent effective parameters, like the Heisenberg-type exchange and the Kondo couplings in different situations.

References:

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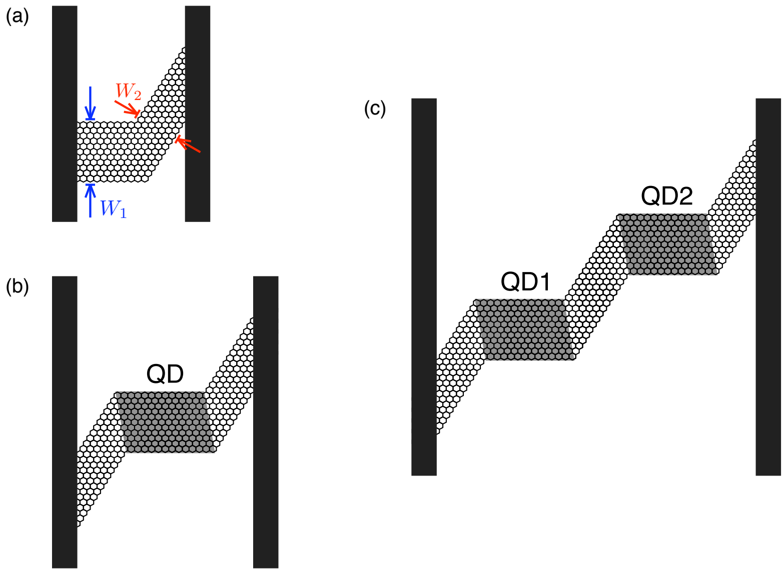
Figures:



Graphene nanoconstrictions with zigzag edges studied in the present work. 120-degree kink (a) blocks the current at low bias for $W_1 \neq W_2$. Double kink (b) traps an electron in the *shadow* area and thus operates as a single-level quantum dot, whereas constriction with four kinks (c) operates as a double quantum dot. Each of the devices is connected to heavily-doped graphene leads marked with the dark bars.