Quasi-bound States in Axially Symmetric Graphene Nanostructures

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Abstract: Generally, due to Klein tunneling, not strictly localized states, but only quasi-bound states (QBS) with finite trapping time may be induced in the graphene nanostructures created by an electrostatic confinement potential. Each BQS is entirely determined by its energy level and trapping time. Theoretically, to study a QBS-spectrum one has to solve the Dirac equation with an appropriate boundary condition that brings a complex energy spectrum. While the real parts of these complex energies give the QBS-energy levels, their imaginary parts give the corresponding level widths which, in turn, measure the inverse of QBS-trapping times. On the other hand, QBSs give rise to resonances in the local density of states (LDOS). The positions and widths of these resonances describe the energies and widths of QBS-levels, respectively. So, detecting the LDOS is an alternative way to study QBS-spectra. Experimentally, recent scanning tunneling spectroscopy (STM) was extensively used to explore confined electron states in graphene quantum dots [Zhao et al. Science 348, 672 (2015); Gutierrez et al. Nature Phys 12, 1069 (2016); Freitage et al. Nano Lett. 16, 5798 (2016)]. By probing the tunneling current, which is sensitive to LDOS, STM provides precise information on the QBS-spectra of the graphene quantum dots (GQD) that are induced by STM-tips and are circular in shape. Simulated by the STM-experiments, we suggest an approach to efficiently calculate QBS-spectra of any realistic graphene nanostructure created by an axially symmetric electrostatic potential. As illustrations, we calculate QBS-spectra of various circular graphene quantum dots and rings which may electrostatically induced by potentials different in shape. For the GQD measured by Gutierrez et al. our approach shows an excellent experiment-theoretical agreement. These results have been partly published in Nguyen et al. J.Phys.: Consend. Matter 28, 275301 (2016) and 29, 405301 (2017). Describing the approach and updating new results are the aim of this report.

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