Bound states in the continuum with Dirac-like fermions in trilayer graphene nanoribbons

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Abstract

The new material denominated graphene is a single layer of carbon atoms, which can be fabricated by different methods like mechanical peeling or epitaxial growth [1]. Nanoribbons are stripes of graphene, which can be obtained through high-resolution lithography [2] by controlled cutting processes [3] or by unzipping multiwalled carbon nanotubes [4]. The electronic behavior of all these nanostructures is mainly determined by their geometric confinement, which allows the observation of quantum effects such as quantum interference effects, resonant tunneling and localization effects. The possibility to control these quantum effects, by applying external perturbations to the nanostructures or by modifying the geometrical confinement, could be used to develop new technological applications, such as graphene-based composite materials [5], molecular sensor devices [6] and nanotransistors [7].

An interesting feature of certain confined nanostructures is the presence of bound states in the continuum (BICs). The formation of BICs is a result of interference between quasi-stationary states via indirect coupling through the continuum. von Neumann and Wigner predicted the existence of BICs at the dawn of quantum mechanics by for certain spatially oscillating attractive potentials for a one-particle Schrödinger equation [8]. Bound states in the continuum have also shown to be present in electronic transport in mesoscopic structures. There are theoretical works showing the formation of these states in a four-terminal junction [9] and in a ballistic channel with intersections [10]. Until nowadays, there is only one experimental work, reported by Capasso and co-workers[11], in which BICs were measured in semiconductor heterostructures grown by molecular beam epitaxy. Thereby, the search of new systems, which could be able to reveal the existence of BICs and with the capability of do measurements of these states, is a very interesting and important field of research. In this sense, we believe that our findings indicate that trilayer graphene heterostructures are suitable systems to observe bound states in the continuum.

The experimental feasibility exhibited by graphene-based systems, the great advances in the controlled manipulation and measurements reported in graphene, and the feasibility of modified their electronic properties by apply external potentials, suggests that BICs could be observable in trilayer graphene nanoribbon.

In this work we study the formation of these exotic states with Dirac-like fermions in heterostructures composed by trilayer graphene nanoribbon. We identify the existence of bound states in the continuum in this system by means of the calculation of the local density of states and electronic conductance of the systems. We discuss the feasibility to observe the bound state in the continuum experimentally in this kind of system.

We focus on the properties of a system like the one depicted in Fig. 1, namely, an armchair nanoribbon of infinite length with two equal flakes of the same width as the ribbon, symmetrically placed above and below it. This can be viewed as three graphene flakes with AAA stacking with two contacts made of semi-infinite graphene nanoribbons of the same widths as the flakes.

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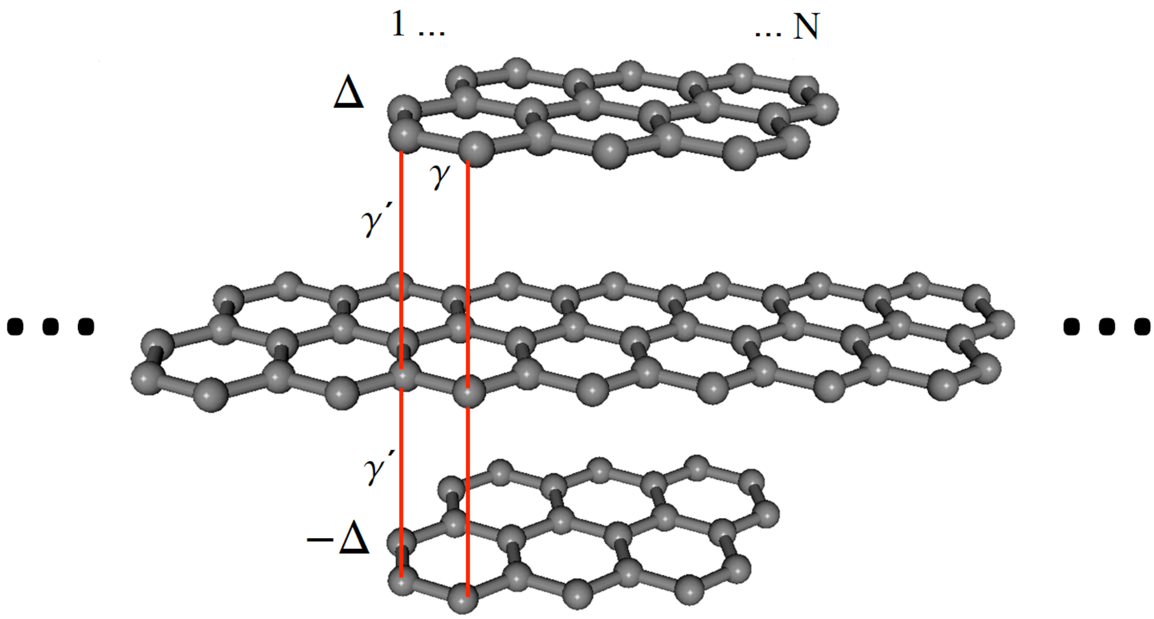

Figure 1. - Schematic view of a hybrid system composed of an armchair nanoribbon of infinite length with two equal flakes of the same width as the ribbon, symmetrically placed above and below it.