Annex - 01

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A quantum dot in topological insulator nanofilm

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Abstract

We introduce a quantum dot in topological insulator nanofilm as a bump at the surface of the nanofilm. Such a quantum dot can localize an electron if the size of the dot is large enough, $\gtrsim$5 nm. The quantum dot in topological insulator nanofilm has states of two types, which belong to two ('conduction' and 'valence') bands of the topological insulator nanofilm. We study the energy spectra of such defined quantum dots. We also consider intraband and interband optical transitions within the dot. The optical transitions of the two types have the same selection rules. While the interband absorption spectra have multi-peak structure, each of the intraband spectra has one strong peak and a few weak high frequency satellites.

Keywords: quantum dot, topological insulator, absorption spectrum

(Some figures may appear in colour only in the online journal)

1. Introduction

Unique properties of semiconductor quantum dots, or 'artificial atoms', are determined by their discrete energy spectrum, which can be tuned externally through the nature and the strength of the confinement potential [1]. Such zero-dimensional systems show both specific electron transport with nonlinear features and controllable optical properties. The main interest in the quantum dots is related to their potential for applications, ranging from those in novel lasers and photodetectors to those in quantum information processing.

In conventional semiconductor systems, quantum dots are introduced either by placing one nanosized material into another material, e.g. by the Stranski–Krastanov growth technique, or by applying a specially designed electrostatic confinement potential to low-dimensional systems. In both cases the confinement potential is introduced, which results in electron localization within the quantum dot region. Recently, quantum dots of a new type, graphene quantum dots [2–4] with electrostatic confinement potential, were considered. In such quantum dots, due to the Klein paradox, the electrons cannot be localized, and can only be trapped for a long enough time [3]. The longest trapping time is realized in a confinement potential with smooth boundaries. Such non-conventional behavior of electrons in graphene is determined by their unique low energy dispersion, which is gapless and relativistic, while the corresponding states are chiral [5, 6]. The electrons in graphene behave as massless Dirac fermions.

Another system showing a dispersion law similar to that of graphene and correspondingly similar localization properties is that of the 3D topological insulators (TI) [7–13], which were first predicted theoretically and then observed experimentally in Bi_xSb_{1-x}, Bi_2Te_3, Sb_2Te_3, and Bi_2Se_3 materials. The unique features of 3D TIs are gapless surface states with a low energy dispersion; its law is similar to the dispersion law of a massless Dirac fermion. Such relativistic dispersion laws have been observed by different experimental techniques [9, 10, 12–21].

Like for graphene, the conventional quantum dots, which can localize an electron, cannot be realized in TIs through an electrostatic confinement potential. To introduce a quantum dot in TI, one can consider a TI of finite nanoscale size [22, 23] or introduce a gap in the dispersion law of the surface states. Such a gap in the energy dispersion is opened for TI nanofilm [24–26]. Due to the finite extension of the surface states into the bulk, the surface states at two

