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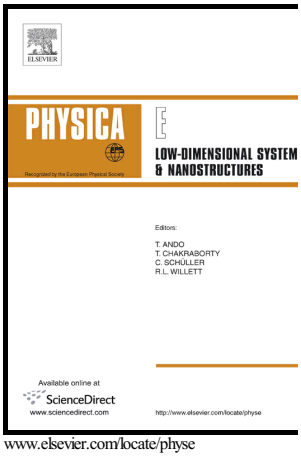

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Impurity-related intraband absorption in coupled quantum dot-ring structure under lateral electric field

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Abstract

The effects of a lateral electric field on intraband absorption in $GaAs/GaAlAs$ two-dimensional coupled quantum dot-ring structure with an on-centre hydrogenic donor impurity is investigated. The confining potential of the system consists of two parabolas with various confinement energies. The calculations are made using the exact diagonalization technique. A selection rule for intraband transitions was found for x-polarized incident light. The absorption spectrum mainly exhibits a redshift with the increment of electric field strength. On the other hand, the absorption spectrum can exhibit either a blue- or redshift depending on the values of confinement energies of dot and ring. Additionally, electric field changes the energetic shift direction influenced by the variation of barrier thickness of the structure.

Keywords: Coupled quantum dot-ring, Lateral electric field, Exact diagonalization method, Hydrogenic donor impurity

1. Introduction

Infrared photodetectors have been the subject of intensive experimental and theoretical research during the last few decades [1]. Such photodetectors are based on either intrinsic free carriers, impurity absorptions of incident light or on intersubband photoabsorption in low-dimensional systems, like quantum wells (QW), dots and rings. An attractive advantage of using QWs [2], quantum dot (QD) [3] and quantum ring (QR) [4] photodetectors is the reduced dimensionality of these systems, which yields a narrower photoresponse. Additionally, QR and QD photodetectors are sensitive to light polarization parallel and perpendicular to the growth axis (z), while QW photodetectors are only affected be z-directed light polarization. This polarization dependence gives QR and QD photodetectors an advantage over QW photodetectors. These optical characteristics have recently initiated a great interest to investigate theoretically the intraband optical properties of semiconductor QDs and QRs, taking into account the influence of external electromagnetic fields [5–15].

Additionally, the impurity problem in QRs and QDs is also of interest and helps understand the optical properties of these structures. Impurity related phenomena, such as donor binding energy, electronic structure in external electric and magnetic fields and photoionization cross section, leads to numerous controlling possibilities of physical properties of optical devices based on QR and QD structures [16, 17]. Many works have been devoted to the theoretical investigation of these phenomena [18–28].

Recently, there has been an increasing demand for the development of complex quantum confined systems [29] for both practical applications and fundamental studies, which include geometrical quantum phases [30], spin-spin interactions [31] and quantum state couplings [32]. Theoretical investigations indicate that changes in the nanostructure's shape are accompanied by an alteration of the total spin of the ground state [31, 33], which could lead to the design of tunneling spin switches if dot-ring coupled nanostructures. Recently a $GaAs/AlGaAs$ laterally coupled quantum dot-ring (CQDR) nanostructure has been developed by Somaschini et al. [34].

Although the physical properties of novel CQDR structure have not been investigated theoretically on large scales, some of the following articles are worth mentioning. Few-electron systems confined in CQDR in the presence of an external magnetic field have been studied by exact diagonalization technique [35]. The authors investigated the distribution of electrons between the QD and QR. It has been shown that this distribution depends not only on the parameters of the confinement potential but it can also be altered by external magnetic fields. Linear and nonlinear optical susceptibilities in CQDR have been theoretically studied in [36], where a model for the potential, that assumes parabolic confinement in both the

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