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Influence of position dependent effective mass on impurity binding energy and absorption in quantum wells with the Konwent potential

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ABSTRACT

In this work, we perform a theoretical investigation on the effect of position-dependent effective mass on binding energy and optical absorption coefficient for donor impurities in single and double quantum wells defined by Konwent potential. We have used the diagonalization method by choosing a wave function based on the trigonometric orthonormal base functions that are solutions of an infinite square quantum well to get the energy spectrum of the system, the variational method for impurity binding energy is used and also linear absorption coefficient is deduced from the density matrix approach and perturbation expansion method. Numerical results reveal that impurity binding energy as well as the linear optical absorption coefficient are remarkably affected by the confinement potential parameters, position of an impurity and the approach used for the effective electron mass. Moreover, it is seen that with an appropriate choice of the structure parameters and position dependence effective mass distribution, the optical response of the system can be tailored in a controllable manner.

1. Introduction

Rapid development in nanotechnology has enabled the growth of low dimensional systems with intriguing electronic and optical properties. These structures are focus of special and increasing attention due to their extensive application area in optoelectronic device technology [1–6]. Tunability of the physical properties to fulfill the practical needs can be realized by a proper choice of structure geometry, material parameters and in a cost-effective way by using the external agents as electric, magnetic and laser fields [7–10]. Progress in material growth techniques render possible the growth of quantum wells (QWs) with varying confinement potentials being symmetric or asymmetric with respect to well center. Interaction potentials as Gaussian, Morse, Tietz–Hua, Razavy, Mathieu etc. are widely used in material physics for specifying the realistic confinement of charge carriers [11–16]. In this context Konwent potential stands as an interesting function for representing the confinement effect in QW with ductile geometry [17–19]. Besides it is well known that the presence of impurity states affects remarkably the electrical and optical characteristics of nanomaterials that are more pronounced than their bulk counterparts [20]. Therefore, it is significant to figure out deeply the impurity-related effects on the semiconductor nanostructures in order to control the performance of optoelectronic devices. The concept of position-dependent electronic effective mass (PDM) is relying on spatial variation of electron effective mass in layered heterostructures [21–25]. Along with the knowledge that the effective mass of charge carriers differs close to the interlayer surface of multilayered heterostructures, appropriate theory for the electronic and optical characteristics of low dimensional systems can be established with a convenient model for potential profile and considering the PDM-effect [26,27]. Intensive research has been carried out for better understanding of the physical properties of QW with impurity by considering the PDM effect [28–30]. The effects of spatially dependent effective mass on the optical properties in parabolic quantum wells have been examined by Herling and Rustagi [31]. The donor ionization energies in different quantum structures under the effects of the constant effective mass and position dependent effective mass have been reported in Ref. [20]. Panahi et al. studied the binding energy in QW under magnetic field by taking into account the spatially varying effective mass effects [32]. Classical particle in 1D and 2D harmonic potential has been discussed by Khlevniuk and coworkers [33]. Intersubband optical transitions and bound energy states in QW defined with Tietz–Hua potential considering PDM has been analyzed by Sari et al. [13]. Ovando et al. [34] studied the solution of position-dependent mass Schrödinger equation with Morse potential. Researches on spatially varying effective mass in low-dimensional

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