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Harmonic-Gaussian Symmetric and Asymmetric Double Quantum Wells: Magnetic Field Effects

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Abstract: In this study, we considered the linear and non-linear optical properties of an electron in both symmetrical and asymmetrical double quantum wells, which consist of the sum of an internal Gaussian barrier and a harmonic potential under an applied magnetic field. Calculations are in the effective mass and parabolic band approximations. We have used the diagonalization method to find eigenvalues and eigenfunctions of the electron confined within the symmetric and asymmetric double well formed by the sum of a parabolic and Gaussian potential. A two-level approach is used in the density matrix expansion to calculate the linear and third-order non-linear optical absorption and refractive index coefficients. The potential model proposed in this study is useful for simulating and manipulating the optical and electronic properties of symmetric and asymmetric double quantum heterostructures, such as double quantum wells and double quantum dots, with controllable coupling and subjected to externally applied magnetic fields.

Keywords: harmonic-Gaussian potential; double quantum well; magnetic field

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1. Introduction

It is very important to construct a universal empirical potential energy function for diatomic and/or polyatomic molecules. For example, the first simple empirical analytical potential function proposed by Morse in 1929 [1] was used to study transition frequencies and intensities in a series of diatomic and polyatomic molecules [2]. For diatomic molecules, by employing the dissociation energy and the equilibrium bond length as explicit parameters, the Rosen–Morse, Manning–Rosen, Schiöberg, and Tietz potential-energy functions have been generated [3–5]. The modified Lennard–Jones potential energy function [6] has been used to perform potential fits experimental data to diatomic molecules.

As is known, double quantum wells (DQW) that characterize the bilayer systems are the semiconductor heterostructures exhibiting tunnel coupling. DQWs, which consist of various semiconductor materials, frequently appear in lasers emitting light in a wide range of wavelengths [7,8]. DQW's potential energy functions, suggested to obtain information about diatomic molecules, are known as quasi-exactly solvable (QES) potentials. The quartic [9], sextic–decatic [10], Razavy [11], and Manning [12] double well potentials which provide a useful approximation for the potential energy of a diatomic molecule are some of them. Dong and Lemus reported the ladder operators for the modified Pöschl–Teller potential [13]. Particularly, they found a closed form of the normalization constants of the wave function by using two different methods and calculated analytical expressions for the matrix elements derived from the ladder operators. Using the exact quantization rule, Gu et al. calculated the energy spectra for modified Rosen–Morse potential [14]. In the same way, Dong et al. reported semi-exact solutions of the Razavy potential [15]. In their work, they show how to find the wave function exact solutions, which are given by the