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Position-Dependent Effective Mass and Asymmetry Effects on the Electronic and Optical Properties of Quantum Wells with Improved Rosen–Morse Potential

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Abstract: In this study, we investigated, for the first time, the effects of the spatially varying effective mass, asymmetry parameter, and well width on the electronic and optical properties of a quantum well which has an improved Rosen–Morse potential. Calculations were made within the framework of the effective mass and parabolic band approximations. We have used the diagonalization method by choosing a wave function based on the trigonometric orthonormal functions to find eigenvalues and eigenfunctions of the electron confined within the improved Rosen–Morse potential. Our results show that the position dependence mass, asymmetry, and confinement parameters cause significant changes in the electronic and optical properties of the structure we focus on since these effects create a significant increase in electron energies and a blue shift in the absorption spectrum. The increase in energy levels enables the development of optoelectronic devices that can operate at wider wavelengths and absorb higher-energy photons. Through an appropriate choice of parameters, the Rosen–Morse potential offers, among many advantages, the possibility of simulating heterostructures close to surfaces exposed to air or vacuum, thus giving the possibility of substantially enriching the allowed optical transitions given the breaking of the system´s symmetries. Similarly, the one-dimensional Rosen–Morse potential model proposed here can be extended to one- and zero-dimensional structures such as core/shell quantum well wires and quantum dots. This offers potential advancements in fields such as optical communication, imaging technology, and solar cells.

Keywords: improved Rosen–Morse potential; quantum well; position-dependent effective mas

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1. Introduction

Constructing a universal empirical potential energy function for diatomic and/or polyatomic molecules holds significant importance. The fitting quality between the function and experimental data improves with an increased number of parameters in the analytical potential energy function. To illustrate, Morse proposed the first simple empirical analytical potential function in 1929 [1], which found utility in studying transition frequencies and intensities in diatomic and polyatomic molecules [2]. Several potential-energy functions, namely the Manning–Rosen, Schiöberg, Tietz, and Rosen–Morse potential functions, have been derived for diatomic molecules by explicitly incorporating the dissociation energy and equilibrium bond length as parameters [3–5].

The improved Rosen–Morse potential (IRMP) or exponential Rosen–Morse potential has more independent fitting parameters for experimental data than the trigonometric Rosen–Morse potential. Quantum well potentials are often used in combination with other materials to create heterostructures. By stacking different layers of materials with varying bandgaps and compositions, researchers can create quantum wells with different geometries.