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Effects of applied electric and magnetic fields on the nonlinear optical properties of asymmetric GaAs/$Ga_{1-x}Al_xAs$ double inverse parabolic quantum well

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ABSTRACT

The combined effects of electric and magnetic fields on the optical absorption coefficients and refractive index changes related to the intersubband transitions within the conduction band of asymmetric GaAs/$Ga_{1-x}Al_xAs$ double inverse parabolic quantum wells are studied using the effective-mass approximation and the compact density-matrix approach. The results are presented as a function of the incident photon energy for the different values of the electromagnetic fields and the structure parameters such as quantum well width and the Al concentration at the well center. It is found that the optical absorption coefficients and the refractive index changes are strongly affected not only by the magnitudes of the electric and magnetic fields but also by the structure parameters of the system.

1. Introduction

Recently, there has been a remarkable interest in the study of the physical properties of the low-dimensional semiconductor heterostructures such as quantum wells (QWs), quantum well wires (QWWs), and quantum dots (QDs). The studies on these structures open a new field in solid state physics, and thus get a lot of potential applications for optoelectronic devices such as hig h-speed-electron-optical-modulators [1], field-effect transistors [2], infrared detectors [3] and semiconductor lasers [4]. Because of the vast variety of technological applications, single and multiple QWs have been extensively investigated in various circumstances such as hydrostatic pressure, temperature, electric, magnetic and laser fields, different doping processes and so on [5–9]. By applying these circumstances, the subband state energies and their related wave functions can be modified according to the request. Thus, with the confinement of the carriers in the QWs, discrete energy levels are formed within the well, and this results in major optical nonlinearity in the semiconductor structure by comparison with that in the bulk material [10,11].

In recent years, the inverse parabolic quantum wells (IPQWs) have attracted considerable attention owing to their unusual electronic and optical properties and possible practical applications [12–17]. Chen et al. [12,13] growed IPQWs by molecular-beam epitaxy using digital and analog techniques and studied its quantum-confined Stark effect. Vlaev et al. [14] studied an IPQW in the framework of a technique for doping practical tight-binding calculations and compare the results with experimental data. The linear an nonlinear optical absorption coefficients in IPQWs under static external electric field was calculated by Baskoutas et al. [15]. Niculescu [16] investigated the combined effects of the intense laser radiation and applied magnetic field on the shallow donor binding energy in IPQWs by using a nonperturbative theory within the effective mass approximation. The electron states and related optical responses in asymmetric IPQWs are studied by Duque and Mora-Ramos [17].

The linear and nonlinear optical properties of low-dimensional semiconductor systems have been studied by many authors in recent years [18–24]. Radu [18] has discussed the laser-dressing of electronic quantum states in graded semiconductor nano-structures. Karimi and Vafaei [19] studied the optical rectification and the second harmonic generation coefficients in a strained InGaN/AlGaN quantum well by taking into account impacts of the spontaneous and piezoelectric polarization fields on the potential profile. Zeiri et al. [20] calculated intersubband (ISB) resonant enhancement of the nonlinear optical properties in asymmetric (CdS/ZnSe)/X-BeTe based QWs. Keshavarz and Karimi

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