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Effects of applied external fields on the nonlinear optical rectification, second, and third harmonic generation in a quantum well with exponentially confinement potential

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Abstract. In the present study, the nonlinear optical rectification (NOR), second harmonic generation (SHG), and third harmonic generation (THG) coefficients in GaAs/GaAlAs quantum well (QW) with exponentially confinement potential were theoretically analyzed for different applied static electric and magnetic fields as well as the non-resonant intense laser field (ILF). In addition, the effect of adjustable physical parameters (η and κ) on the optical properties was also investigated. The subband energy levels and their corresponding envelope wave functions of an electron confined in a QW with exponentially confinement potential are calculated by diagonalization method within the framework of effective mass and single parabolic band approximations. The analytical expressions of the NOR, SHG, and THG are obtained using compact density matrix approach via iterative method. The numerical results show that the applied external fields and physical parameters have a great effect on the optical characteristics of the considered system. In particular, we have found the applied external fields have a significant effect on the position and magnitude of resonant peaks of NOR, SHG, and THG.

1 Introduction

State-of-the-art growth technologies such as metal organic vapor phase epitaxy (MOVPE) and molecular beam epitaxy (MBE) systems have enabled to scientists to design and fabricate various electronic and optoelectronic devices [1]. The developed research on this topic have also triggered studies about low-dimensional semiconductor quantum wells (QWs). The obtained results in (QWs) show exceptional properties compared to the bulk semiconductors owing to the quantum confinement effect. The QW heterostructures, one of the low-dimensional systems, have become a target of dense research for the last 40 years due to its extraordinary properties that contribute greatly to the development of electronic and optoelectronic devices [2,3] Especially, GaAs/GaAlAs-based QW heterostructures have been frequently utilized to develop high-tech devices such as quantum cascade laser, quantum well-infrared photodetector (QWIP), etc. [4–6]. The optical properties of these QW heterostructures can be controlled by many parameters such as the shape of the potential profile, QW-thickness, quantum barrier height, QWs- number, and carrier density [7,8]. The different shapes of QW potentials formed from these parameters result in obtaining different discrete energy levels. Many studies which exist in the literature have analyzed the impact of different shapes on the nonlinear optical properties and they published important results about semi-parabolic QWs [9], square QWs [10], and graded QWs [11], etc. Apart from these potentials, exponentially confining potential is also crucial because of providing extreme confinement strength without infinite hard boundaries [12]. In addition to the potential profiles, the studies have revealed that the external fields have a huge effect on the optical properties of the system. For example, the existence of the ILF, one of the external fields, plays a remarkable role to adjust the optical properties of the optoelectronic device due to its effect on the confined potential. Ozturk et al. [13] showed the effect of altering ILF on the optical properties of the QWs. The selection of the laser dressing parameter is important because it has an effect on the shape of the potential well. Lima et al. derived an analytical expression between the well width and the laser dressing parameter [14]. In addition to laser field, the linear and nonlinear optical properties of QW heterostructure can be controlled by other external fields such as magnetic, electric, temperature, hydrostatic pressure, etc. For instance, Zhang and Liu et al. have studied the effect of applied electrical and magnetic fields on optical properties of QWs with asymmetrical and symmetrical Gaussian potential [15,16]. Ungan et al. [17] have concluded that both

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