Superlattices and Microstructures 76 (2014) 163–173

Contents lists available at ScienceDirect

Superlattices and Microstructures

journal homepage: www.elsevier.com/locate/superlattices

The second and third-harmonic generation of modified Gaussian quantum dots under influence of polaron effects

R. Khordad *, H. Bahramiyan

Department of Physics, College of Sciences, Yasouj University, Yasouj, Iran

ARTICLE INFO

Article history:
Received 25 June 2014
Received in revised form 18 September 2014
Accepted 19 September 2014
Available online 13 October 2014

Keywords:
Quantum dot
Polaron effect
Optical properties

ABSTRACT

In this paper, we have studied the effect of electron–phonon (e–p) interaction on the second harmonic generation (SHG) and third harmonic generation (THG) of modified Gaussian quantum dots within the framework of the compact density matrix approach and iterative method. We have obtained the energy eigenvalues and their corresponding eigenfunctions of the system without e–p interaction and under the influence of electron–LO phonon, electron–SO phonon, and electron–LO + SO phonon interaction. It is found that the effect of the electron–phonon interaction has a great influence on the second and third harmonic generation of the system. The effect of electron–SO phonon on the SHG and THG is greater than the electron–LO phonon. The electron–LO + SO-phonon interaction has the largest contribution to the SHG and THG.

1. Introduction

In the past few decades, an increasing interest has been devoted on the topic of optical properties of nanostructure systems like quantum dots and quantum wires. Hitherto, the electronic and optical properties of quantum dots have been widely studied [1–6]. With development of the novel nanofabrication technologies such as chemical lithography, molecular beam epitaxy (MBE), etching method and Stranski–Krastanov, it has been possible to fabricate semiconductor quantum dots with various geometrical shapes and sizes like spherical, pyramidal, ellipsoidal, lens-shaped, cone-like [7–10].

* Corresponding author.
E-mail address: rezakh2025@yahoo.com (R. Khordad).

http://dx.doi.org/10.1016/j.spmi.2014.09.036
0749-6036/

In the past few years, the various confinement potential models have usually employed in the study of physical properties of quantum dots. Examples of these models are parabolic potential [11], Tietz potential [12] and asymmetrical Gaussian potential and spherical potential [13]. In addition, Adamowski et al. [14,15] and Xie [16,17] considered a new confinement potential in quantum dots which is called the spherical Gaussian potential. Also, Ciurla et al. [18] proposed a new class of the confinement potentials, called the power-exponential potentials. Recently, we have proposed a new confinement potential in quantum dots which is called the modified Gaussian potential [19]. The confinement potentials can open a new field in fundamental physics, and also offer a wide range of potential applications for semiconductor optoelectronic devices.

It is fully known that the research in optical properties of low-dimensional structures can be applied in the design of electronic devices as laser diodes. For this reason, optical properties of semiconductor heterostructures have attracted much attention. Among various optical properties, considerable attention has been devoted to the second harmonic generation (SHG) and third harmonic generation (THG). In the past few years, several theoretical works have been done on the SHG and THG of quantum wells, quantum wires and quantum dots. For example, Wang [20] calculated third harmonic generation in cylindrical parabolic quantum wires with an applied electric field. Also, he and coworkers studied third-harmonic generation in cylindrical parabolic quantum wires with static magnetic fields [21]. Third-harmonic generation in InAs/GaAs self-assembled quantum wires in both theoretical and experimental cases was studied by Sauvage et al. [22]. Shao et al. [23] investigated third harmonic generation in cylindrical quantum dot with an applied electric field. Liu et al. [24] studied the third order nonlinear optical susceptibility for $In_xGa_{1-x}N/GaN$ cylinder quantum dots.

They obtained an analytic formula by using the compact-density-matrix approach and an iterative method.

Recently, great attention has been focused to the study of electron–phonon (e–p) interaction and its effect on optical properties of nanostructures. It is obvious that the research on electron–phonon interaction has become a main subject in the condensed matter physics. Hitherto, several authors have studied the influence of the electron–phonon interaction on physical properties on nanostructures. For first time, Lucas et al. [25] studied the electron–phonon interaction in a dielectric confined system. Wendler developed the framework of the theory of optical phonon and electron–phonon interaction for the spatially confined systems [26]. Li and Chen [27] studied electron–phonon interaction in a cylindrical quantum dot and they found that there exist two types of SO phonon modes. Xie and Chen [28] have investigated the phonon contribution to the binding energy of the on center and off center impurities in a spherical quantum dot. Li et al. [29] investigated the ground-state lifetime of bound polaron in a parabolic quantum dot. Recently, we have studied the effect of electron–phonon interaction on optical properties of a triangular quantum wire [30].

In practice, the study on the polaron effect has an important role in the physical properties of low-dimensional quantum systems such as optical properties. So far, some works have been performed for studying polaron effect on SHG and THG of nanostructures. For instance, Guo and Chen [31] presented the polaron effects on second-harmonic generation in quantum well under an applied electric field. Zhang and Guo [32] studied the polaron effects on the second and third-order nonlinear optical susceptibility in asymmetrical semi-parabolic quantum wells. Lu and Guo [33] investigated polaronic electron–phonon interaction on the THG in square quantum wells. Li and coworkers [34] investigated polaron effects on the optical absorption coefficients and refractive index change in a two-dimensional quantum pseudodot. In 2008, Wang and Guo [35] investigated excitonic effects on the third-harmonic generation for typical GaAs/AlGaAs parabolic quantum dots. We recently calculated the polaronic energy shift for both ground-state and excited-state energy levels by applying the perturbative approach in parallelogram and triangular quantum wires [36].

It is worth mentioning that more and more authors are paying considerable attention to the study of the polaron effect of LO phonons in nanostructures. It is to be noted that the electronic and optical properties of nanostructures change significantly when the electron–LO-phonon interaction is considered. Although several works have been done about the polaron effects on the optical properties of quantum dots, but the polaron effect on SHG and THG of modified Gaussian quantum dot has not been studied so far. So, it is meaningful and important to calculate polaron effects on SHG and THG of a modified Gaussian quantum dot by considering the electron–LO-phonon and electron–SO-phonon