Physica E 70 (2015) 210–216

Contents lists available at ScienceDirect

Physica E

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

Effect of interdiffusion on nonlinear intraband light absorption in Gaussian-shaped double quantum rings

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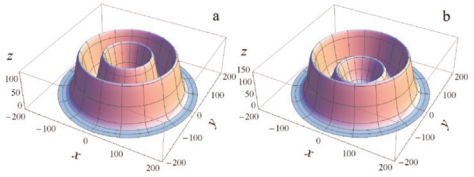
HIGHLIGHTS

- The effect of interdiffusion is considered in Gaussian-Shaped double rings.
- The confining potential profiles have been obtained.
- The electron energy spectrum is calculated.
- The probability densities of electron are obtained for various values of parameters.
- The nonlinear absorption coefficients are calculated as well.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 7 February 2015
Accepted 16 March 2015
Available online 17 March 2015

Keywords:
Double quantum ring
Interdiffusion
Electronic states
Nonlinear absorption

ABSTRACT

The effect of interdiffusion on electronic states and nonlinear light absorption in Gaussian-shaped double quantum rings is studied. The confining potential, electron energy spectrum, wave functions and absorption coefficient are obtained for different values of diffusion parameter. The effect of the variation of Gaussian parameters is considered as well. The selection rules for the intraband transitions in the cases of the light polarization parallel and perpendicular to the quantum rings' axis are obtained. It is shown that the interdiffusion can be used as an effective tool for the purposeful manipulation of the electric and optical properties of the considered structure.

1. Introduction

Electronic properties of low-dimensional semiconductor heterostructures have become an active field of both theoretical and experimental studies. Advances with respect to growth as well as high-resolution electron-beam lithography techniques allow the fabrication of novel structures called quantum rings (QR) [1].

Formation and characterization of QR complexes [2] open a new route to measurement of quantum interference effects [3,4] promised by ring geometry. Using droplet epitaxial technique, authors of [2] performed self-assembly of concentric double quantum rings (DQR) with high uniformity and excellent rotational symmetry.

The intraband optical absorption in QRs has attracted an enormous interest in recent years [5–7] because a large optical nonlinearity in these structures has been observed. Note that both linear and nonlinear intraband optical absorptions can be used for practical applications in photodetectors and high-speed electro-optical devices [8,9].

The potential application of QRs in nano-devices has given rise to theoretical investigation of their optoelectronic properties [10]. In some works the influences of spin–orbit coupling [11,12], intense laser field [13] and polaronic effects [14] are examined. Analytical treatments of electronic and optical properties of QRs and spherical layers have also been suggested [15,16]. Recently,

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http://dx.doi.org/10.1016/j.physe.2015.03.012
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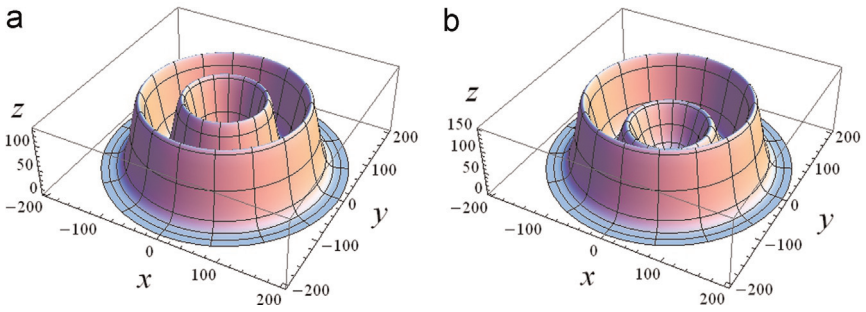

Fig. 1. GS DQRs with the heights of the inner and the outer rings $h_1=h_2=2R/3$ (a) and $h_1=90$ Å, $h_2=150$ Å (b). The positions of the inner and the outer rings' tops are at $R/3$ and $2R/3$, respectively. x, y and z are given in Å.

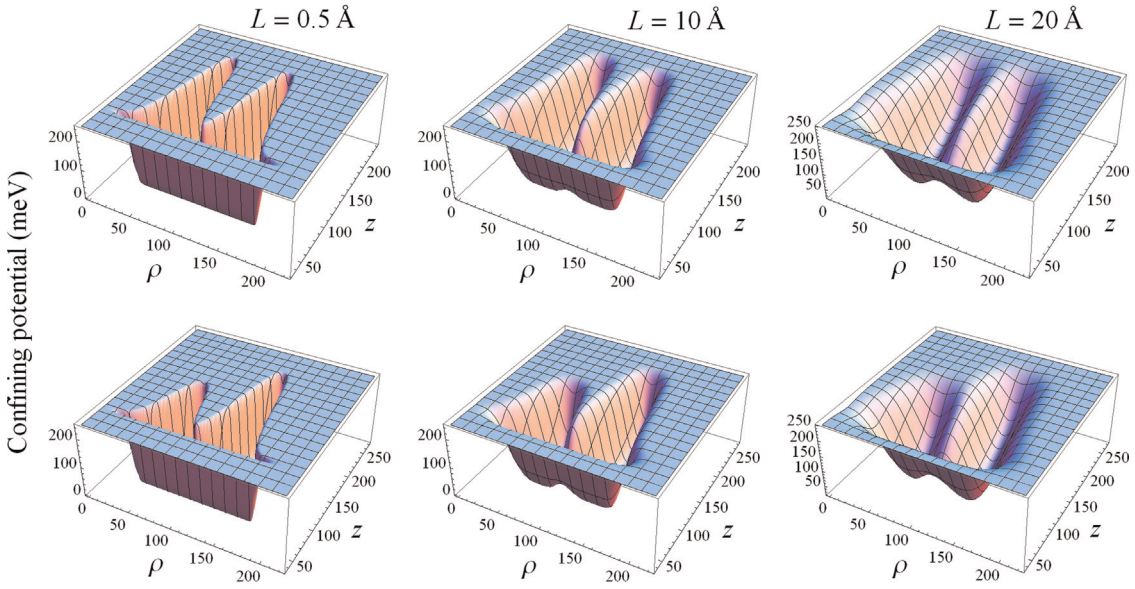

Fig. 2. Confining potential of the GS DQRs with the same (the first row) and different (the second row) heights of the inner and the outer rings. ρ and z are given in Å.

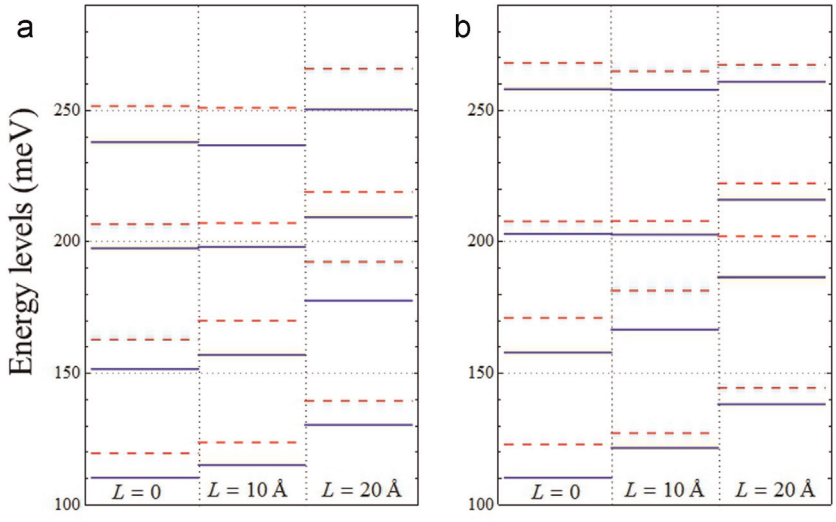

Fig. 3. Energy levels in GS DQRs with the same (a) and different (b) heights of the inner and outer rings. The solid lines correspond to the value of azimuthal quantum number $l=0$ and the dashed ones to $l=1$.

some authors studied the linear and nonlinear optical intraband absorption coefficients of quantum dots with two, or three electrons [6–19].

It is shown that the post growth rapid thermal annealing (RTA) plays a major role in modifying the electronic structure and in the improvement of material quality due to the interdiffusion of the compound materials of heterojunction [20–23]. Theoretical calculations indicate to the blueshift of the interband absorption spectrum of QDs [24,25] and QD superlattices [26,27] due to interdiffusion, which is in accordance with experiment [23].