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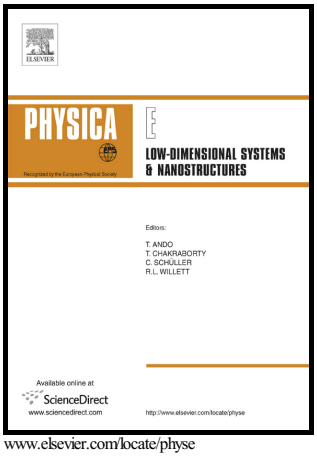

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Effect of interdiffusion and external magnetic field on electronic states and light absorption in Gaussian-shaped double quantum ring

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The effect of interdiffusion and magnetic field on confined states of electron and heavy hole as well as on interband absorption spectrum in a $Ga_{1-x}Al_xAs/GaAs$ Gaussian-shaped double quantum ring are investigated. It is shown that both interdiffusion and magnetic field lead to the change of the charge carriers' quantum states arrangement by their energies. The oscillating behavior of the electron ground state energy as a function of magnetic field induction gradually disappears with the increase of diffusion parameter due to the enhanced tunneling of electron to the central region of the ring. For the heavy hole the ground state energy oscillations are not observable in the region of the values of magnetic field induction $B = 0 - 10$T. For considered transitions both the magnetic field and the interdiffusion lead to a blue-shift of the absorption spectrum and to decreasing of the absorption intensity. The obtained results indicate on the opportunity of purposeful manipulation of energy states and absorption spectrum of a Gaussian-shaped double quantum ring by means of the post growth annealing and the external magnetic field.

Keywords: Gaussian-shaped double quantum ring; Interdiffusion; Magnetic field; Energy spectrum; Absorption coefficient

I. INTRODUCTION

One of the promising courses of development of present day optoelectronics and computational electronics is the transition to zero dimensional (0D) nanostructures, such as quantum dots (QD) [1] and quantum rings (QR) [2]. Optoelectronic devices based on QD systems possess a number of advantages: temperature stability, wide spectral range, small dark current, high signal-to-noise ratio, and the possibility of the absorption of incident light beam as well as the multiexcitonic absorption [3, 4]. Electrons confined in a nanometer-sized QR manifest their quantum nature by an oscillatory behavior of their energy levels as a function of an applied magnetic field (the Aharonov-Bohm effect). This effect originates from the periodic dependence of the phase of the electron wave function on the magnetic flux through the ring [5] and is usually associated with the occurrence of persistent currents [6–11]. Using the droplet epitaxial technique, authors of [12] 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 [13–15] because of a large optical nonlinearity in these structures. Note that both linear and nonlinear intraband optical transitions can be used for practical applications in photodetectors and high-speed electro-optical devices [16–19]. 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]. Recently several works have been done to theoretically predict the necessary conditions of realiziation of layered nanotructures (QR, spherical layer et al.) with desirable optical characteristics [24–26]. Theoretical calculations indicate to the blueshift of the interband absorption spectrum of QDs [27, 28] and QD superlattices [29, 30] due to interdiffusion, which is in accordance with experiment [23]. However a redshift is theoretically predicted for intersubband absorption threshold in QR superlattices [31]. In Ref. [32] RTA was used to improve the optical quality of strain-free DQR solar cells fabricated by droplet epitaxy. The shape of DQRs obtained in [32] can be successfully modeled by two shifted Gaussians as it was shown in [31]. Our previous works are devoted to the theoretical investigation of the effect of interdiffusion on electronic band structure of the SL composed of Gaussian-shaped (GS) DQRs and on the intraband nonlinear absorption spectrum of a GSDQR [31, 33]. In the present work the effect of interdiffusion and the external magnetic field on electron and heavy hole (HH) energy spectrum and interband absorption coefficient of a $Ga_{1-x}Al_xAs/GaAs$ GSDQR is considered. The article is organized as follows. In Sec. II the theoretical model to calculate electron energy spectrum and interband absorption coefficient is described. Sec. III is devoted to the discussion of the obtained results and the conclusions are presented in Sec. IV.

II. THEORY

In the framework of effective mass approach the Hamiltonian of electron (HH) in GSDQR in the presence of transversal magnetic field can be written in the following

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