Superlattices and Microstructures 84 (2015) 192–197

Contents lists available at ScienceDirect

Superlattices and Microstructures

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

The non parabolicity and the enhancement of the intersubband absorption in GaAs/GaAlAs quantum wells

A. Rajira, H. Akabli, A. Almaggousi, A. Abounadi *

Groupe d'Étude des Matériaux Optoélectroniques (G.E.M.O.), F.S.T.G, Cadi Ayyad University, BP 549 Marrakech, Morocco

ARTICLE INFO

Article history:
Received 2 May 2015
Accepted 6 May 2015
Available online 14 May 2015

Keywords:
Quantum well
Intersubband transitions
Non parabolicity
Absorption enhancement

ABSTRACT

We have performed calculations of the transition energies in a GaAs/AlGaAs quantum well with 38% of Aluminum. Three energy levels could be confined below a certain well width leading to two allowed transitions. Calculations were made in both the parabolic and the non parabolic cases. While the E_{23} transition stands above the E_{12} one in the first case, there is a clear crossing between these two transitions in the second case for a specific geometry ($Lw = 7.7$ nm). This suggests the possible enhancement in the absorption if a radiation has the appropriate frequency such that $h\nu = E_{12} = E_{23}$. This interesting proposition was investigated after the comparison of the absorption coefficient calculations for two different geometries. Such structures may be used in two photons absorption devices because the E_3 level is close to the continuum.

1. Introduction

Unipolar devices, based on intersubband transitions, are widely used in several applications. They are used on the absorption, the detection, and the emission of radiations, especially in photonic filters [1,2], Quantum Well Infrared Photodetectors (QWIP) [3–5] and in Quantum Cascade Lasers (QCLs) [6,7].

* Corresponding author.
E-mail address: aabounadi@yahoo.fr (A. Abounadi).

http://dx.doi.org/10.1016/j.spmi.2015.05.008
0749-6036/

More recently, there is a growing interest on mid-infrared and terahertz radiation sources [8,9]. However, these are often weak emitters. Innovative concepts are then needed for detecting the resulting weak signals. Good sensitivity was demonstrated in a quadratic two photon detector showing optical non linearity for a radiation with power as low as 0.1 W/cm^2 [10]. These quadratic detectors are mostly based on three levels quantum well structures and require transitions of equal energy. The third level has, also, to be resonant with the continuum. In such devices, the modeling of absorption properties is closely linked to the accurate determination of energy levels and wave functions of electron. This can help to design devices with improved absorption. In this optic we explore GaAs/AlGaAs systems having three confined levels and study the behavior of the resulting two distinct transitions. The Aluminum composition was taken as high as 38% because it insures intersubband transitions for mid-infrared applications.

Our electronic states calculations, presented in Section 2, show that below a given well width, there exit at most two distinct transitions. However, and particularly when including bands non parabolicity, our calculations predict the existence of a specific geometry for which the two transitions coincide in energy. In such geometry and for this energy the optical absorption could increase significantly. This was investigated on Section 3 through the absorption coefficient calculations.

2. Electronic states and transition energies

The conduction band (C.B.) electronic states are calculated in the GaAs/AlGaAs symmetrical quantum well using the envelop function approximation and taking an offset [11]

$$V_b = \Delta E_c = 0.65\Delta E_g = 308\ \text{meV}$$

The calculations are developed within the parabolic approximation on one hand, and by taking into account the non parabolicity effects on another hand. In the last case the effective mass energy dependence follows Nelson's model [12]:

$$m_w(\varepsilon) = m_w\left(1 + \frac{\varepsilon}{E_w}\right); \quad m_b(\varepsilon) = m_b\left(1 - \frac{V_b - \varepsilon}{E_b}\right)$$

$E_{w(b)}$: the well's (the barrier's) band gap.
$m_{w(b)}$: the C.B. electron effective mass in the parabolic approximation in the well (in the barrier).

The numerical resolution is based on the finite difference method. It considers the structure as a succession of $n + 1$ layers of very small but equal thicknesses, Δz. In each layer the mass (m_n), the potential (U_n) and the envelop functions (χ_n) are considered constants. The envelop functions in the different layers, within this model, are linked together by:

$$\chi_{n+1} = \chi_n\left((\Delta z)^2 k_n^2 + \frac{m_n}{m_{n+1}} + 1\right) + \frac{m_n}{m_{m-1}}\chi_{n-1} \tag{1}$$

$$k_n^2 = \frac{2m_n(U_n - E)}{\hbar^2}.$$

The confined eigenenergies and the corresponding envelop functions are determined by expressing the boundary conditions.

The evolution versus the well width, Lw, of the three confined levels (E_{1p}, E_{2p}, E_{3p}) and $(E_{1np}, E_{2np}, E_{3np})$ respectively for the parabolic and the non parabolic cases is reported in Fig. 1.

In the parabolic approximation the E_3 level increases but slows down before joining the continuum of states (E_3 is no more confined below $Lw = 8$ nm). However, the results show that including the bands non parabolicity has the effect of lowering the positions of the excited levels (E_2 and E_3) whom reach the continuum for lower well widths (when compared to the parabolic case). Moreover, the slowing down of E_3, around, V_b, is more pronounced. E_3 seems to be "pinned" before reaching the continuum. The E_3 level quits the well around 6 nm.