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Analysis of electron transport phenomena in quantum well laser diode

KAILAS PARANDE, KANCHAN TALELE, E.P. SAMUEL and D.S. PATIL

Department of Electronics, North Maharashtra University, Jalgaon (India)

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ABSTRACT

The electron transport phenomena are a very complex in a quantum structures. The quantization effect in the quantum well is analyzed by solving the Schrodinger equation using quasi-transmitting boundary condition method and transfer matrix method. The current density dependence of Eigen energy and quantum well width has been reported in this paper. The current density observed to be increasing nonlinearly with respect to Eigen energy and quantum well width has been. The transmission coefficient has been analyzed as a function of Aluminum mole fraction and quantum well width. The immense effect of Aluminum mole fraction has been observed over transmission coefficient, while the effect of the quantum well width is trifling.

Key words: Electron transport phenomena, Quantum well laser diode.

INTRODUCTION

Major developments in wide band gap III-V nitride semiconductors, which have led to the commercial production of high brightness, light emitting diodes (LEDs) and laser diodes (LDs) operating in continuous wave[1]. Hence, GaN has emerged as an excellent material for fabrication of blue to ultraviolet (UV) light emitting devices. The quantum wells are of great interest due to applications for a variety of optoelectronics devices such as modulators, waveguides and laser diodes, which are suitable for wireless communications[2]. The quantization effect arises due to the fabrication of very thin films can be analyzed through Schrödinger equation. Since, the introduction of quantum well in heterostructure changes the physical properties of the light emitting device such as, quantum efficiency, and threshold current, optical and carrier confinement. These properties shows great dependence on current density has forced us to analyze the current density variation as a function of quantum well width and Eigen energy. The electron transport phenomena cannot be completed without investigating the transmission coefficient particularly for varying Aluminum concentration and the well width.

Mathematical approach

The appropriate boundary conditions have been applied to the general solutions of the Schrödinger equations. Thereafter, by normalization the arbitrary constants have been deduced. The transfer matrix method has been applied to obtain Eigen energy, which was very crucial to determine the current density. The current density was realized from equation (1) by solving the integration over the region R using Trapezoidal method.

$$J_s = \frac{eh}{2m\pi}\int_R g(p)\,\mathrm{Im}\,\overline{(\psi_p(x)}\psi'_p(x))\,dp \quad \ldots(1)$$

where g(p) is alimentation function, given in equation (2) which is again a function of Fermi energy.

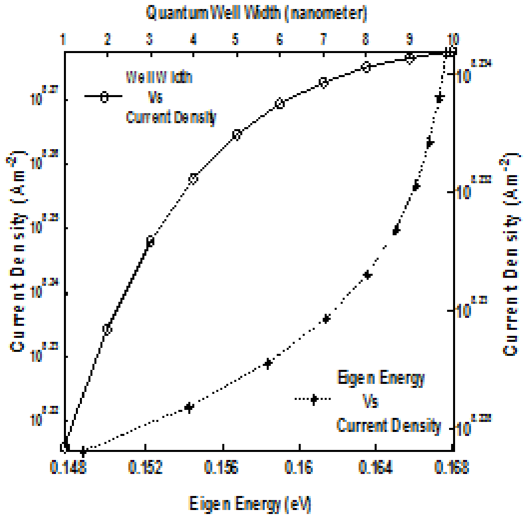

Fig. 1: Current density dependence on Eigen energy and Quantum well width

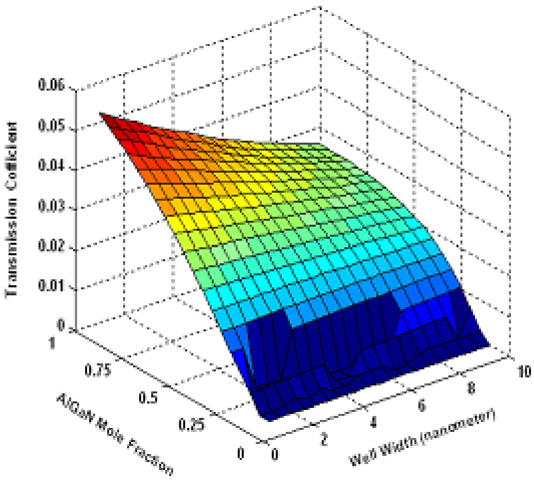

Fig. 2: Transmission Coefficient variation with Aluminum mole fraction and well width

$$g(p) = \frac{4m\pi k_B T_0}{h^3} \ln\left\{1 + \exp\left[\frac{1}{k_B T_0}\left(-\frac{p^2}{2m} + E_F\right)\right]\right\} \quad ...(2)$$

at this instant e is the electron charge, m is the mass of electron, h is Planck's constant, p is the momentum of the carrier, k_B is the Boltzmann constant and E_F is the Fermi energy .

RESULTS AND DISCUSSION

The perceptive of electron transport in quantum well is very essential concept to realize a better and efficient performance of quantum well laser diode. Hence, we had carried out the analysis of current density and the transmission coefficient for a quantum well. Fig. 1 reveals the dependence of current density on the quantum well width and Eigen energy. The current density increases with the increase of the Eigen energy due to the enhancement in band offset of quantum well region and the barrier region. The increase in the quantum well width increases the values of the wave vector which causes the greater potential depth to confine more carriers in the quantum well ultimately results in the increase of the current density within the quantum well region.

In Fig. 2 the transmission coefficient has been shown as a function of Aluminum mole fraction and quantum well width. Significant variation in the transmission coefficient has been observed with the increase in the Aluminum mole fraction. This is due to vast increment in the Eigen energy with the increase of Aluminum concentration in AlGaN. The variation in transmission coefficient with the increase in quantum well width is very trivial. The transmission coefficient for wider well width is having lower values in spite of high Aluminum mole fraction as observed in Fig. 2.

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