Gain Simulation of InGaP/GaAs Heterostructure

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***Abstract*- We have proposed a step SCH based $In_{0.45}Ga_{0.55}P$/GaAs lasing nano-heterostructure for the application of optical fiber based communication systems. Under simulation, we have calculated the anti-guiding factor and differential gain as a function of carrier density. In addition, the material gain of lasing heterostructure as a function of wavelength and photonic energy has also been calculated and reported. On behalf of calculations, we have shown that the modeled lasing structure has maximum material gain at ~ 0.625 µm. The results obtained ensure the usefulness of InGaP/GaAs lasing structure in communication systems based on optical fiber.**

I. INTRODUCTION

The lasing nano-heterostructures [1-3] have played a very important role for the opto-electronic device applications and optical fiber based communication systems. It is therefore natural to design light sources such as light emitting diodes, laser diodes, semiconductor modulators and photodetectors operating at the desired wavelengths useful for optical communication systems.

Experimental work on low threshold current quantum well lasers [4] has been reported for different material systems, such as GaAs/AlGaAs, InGaAsP/InP, and InGaAs/InGaAsP. Advantages of the quantum well lasers such as higher temperature stability, improved linewidth enhancement factor and wavelength tenability have also been demonstrated. These devices are based on the energy band structure engineering concept using, for example, a separate-confinement-heterostructure (SCH) quantum well structure to enhance the carrier and the optical confinements.

II. BRIEF FORMALISM

Due to the reason that the differential gain is increased, and there is a reduction in the Auger coefficient and inter-valence band absorption for quantum well structures, we use QW structure in the active region [5]. The simulated model is based on the fact that it consists of a single quantum well (thickness~60Å) of $In_{0.45}Ga_{0.55}P$, sandwiched between InGaAlP (Barrier) followed by cladding of InAlP.

When the thickness of the active region becomes comparable to the de Broglie wavelength ($\lambda \approx h/p$), quantum mechanical effects are expected to occur. Under the situations, the kinetic energy corresponding to the carrier motion is quantized.

The optical gain coefficient is a function of the photon energy and can be written as [6];

$$G(E') = \frac{q^2 |M_B|^2}{E' \varepsilon_o m_o^2 c\hbar n_{eff} W} \sum_{i,j} \int_{E_g}^{E_{gb}} m_{r,ij} C_{ij} A_{ij} (f_c - f_v) L(E) dE$$

where the symbols are abbreviated in [7-10].

III. RESULTS AND DISCUSSION

In figure 2, for the InGaP/GaAs lasing heterostructure the behavior of anti-guiding factor with current density is plotted and reported. For InGaP/GaAs lasing structure, it has been found to have its value in between 1.0 and 3.0. The anti-guiding factor relates the depression in the real part of the index of refraction due to the presence of gain through the free-carrier and band-edge effects.

Next, the differential gain is an important material parameter of the active layer of semiconductor laser and is obtained by differentiating the optical material gain to the injected carrier density (i.e. g=dG/dN), hence the differential gain is reduced as the optical intensity is increased i.e. differential gain found to be reduce exponentially with carrier density, as shown in figure 3.

In the modeling and simulation, we have calculated gain spectra as a function of photonic energy and lasing wavelength, range in which lasing is likely to occur is specified. The optical gain spectrum for InGaP/GaAs lasing heterostructure has been calculated and plotted in figure 4 and 5.

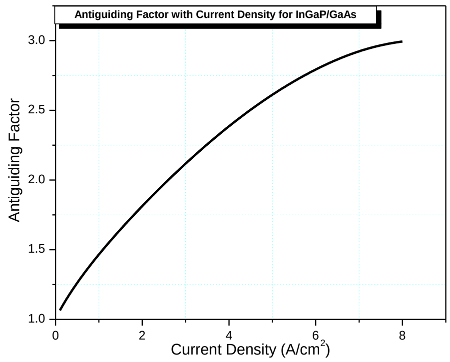

Figure 2. Behaviour of antiguiding factor with current density.

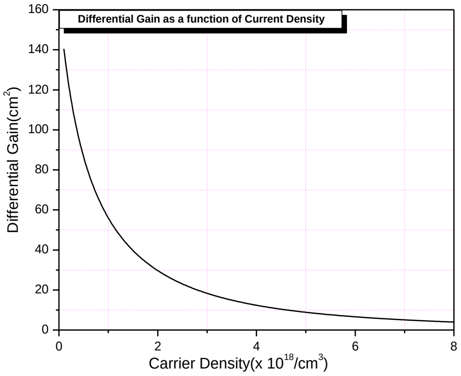

Figure 3. Differential gain with carrier density.

The maximum optical gain has been achieved at the photonic energy ~1.98 eV and the corresponding wavelength of ~ 0.625 µm which indicates approximate wavelength of the lasing mode. Moreover, in the region of photonic energy greater than approximately 2.02 eV and corresponding wavelengths below 0.61 µm, there is a negative optical gain that indicates losses in optical gain due to absorption of light within the waveguide. The results obtained ensure the usefulness of InGaP/GaAs lasing structure in communication systems based on optical fiber.

IV. CONCLUSION

The numerical simulation has been performed for lasing characteristics of InGaP/GaAs lasing heterostructure, for which the maximum optical gain has been achieved at ~0.625µm for lasing action. The results obtained ensure the usefulness of InGaP/GaAs lasing structure in communication systems based on optical fiber.

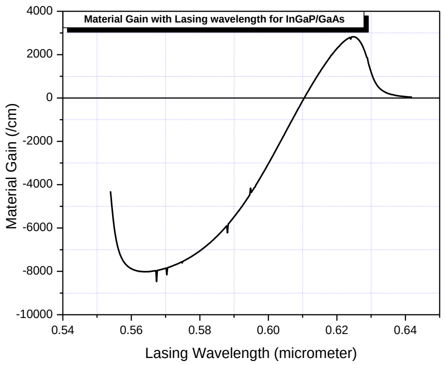

Figure 5. Material gain of InGaP/GaAs laser with lasing wavelength.

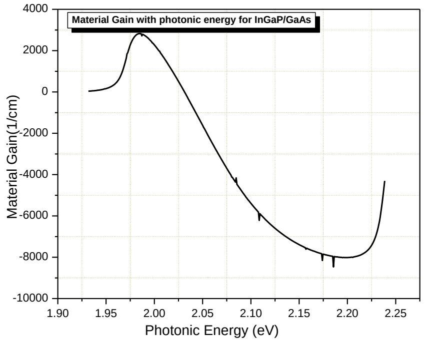

Figure 4. Material gain of InGaP/GaAs laser with photonic energy.

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