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Differential Quantum Efficiency of Distributed Reflector (DR) Laser

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Abstract
The research on all optical communication is going on all around the world to meet the high demand of data and telecommunication. Laser which was invented for emitting electromagnetic radiation is the most important component in optical communication. In this study we calculate the differential quantum efficiency of a DR(Distributed Reflector laser) with wire like active region. The internal quantum efficiency is shown to be a strong function of cavity length. The results for single and multiple quantum well structures are compared.
Keywords: Distributed Reflector laser(DR), Quantum Well(QW),Distributed Feedback Laser (DFB), Distributed Bragg Reflector (DBR), Cavity Length(CL).

1. Introduction

Strongly index-coupled and gain-matched distributed feedback (DFB) lasers with periodic wirelike active regions can be also operated at low threshold current due to high internal reflection [1]-[2]. For high efficiency operation, distributed reflector (DR) lasers which consist of a DFB and a DBR sections have been investigated and it was found that they have superior dynamic properties such as modulation sensitivity and spectral chirping. In addition, DR lasers with the vertical grating (VG) were demonstrated to have high-efficiency and single-mode operation due to their high-reflection DBR by deep etching technology [3].

The quantum efficiency (or *quantum yield*) is often of interest for processes which convert light in some way. It is defined as the percentage of the input photons which contribute to the desired effect. The quantum efficiency is dependent of the geometrical properties of the laser device, such as the cavity length or the stripe width [4].

Fig. 1 shows the illustration and the grating structure of a DR laser, where *La* ,Λa , and *Wa* denote the section length, the grating pitch, and the width of the wirelike active regions, respectively, and *Lp,* Λp, and

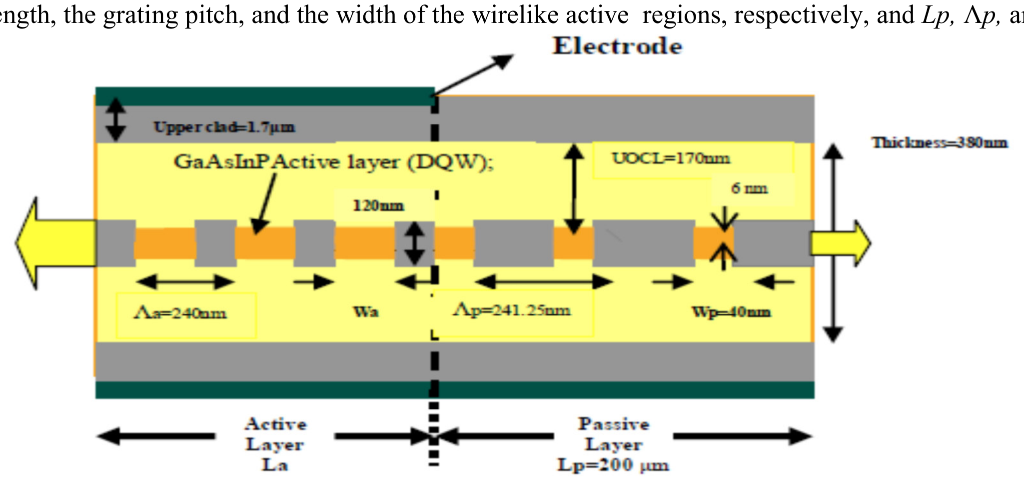

Figure 1: Schematic structure of DR laser (Single Quantum Wire)

Wp denote those of the passive sections. This laser has an active section with a DFB grating (left-hand side) and a passive section with a Q-wire DBR (right-hand side).

In this structure the thickness of upper cladding layer is 1.7µm, lower cladding layer is also 1.7µm. Optical confinement layer (OCL) is 170nm on both sides. Thickness of a single well is 6nm and thickness of the barrier is 9nm. Lp is 200µm, Wp is 40 nm, Λp is 241.25nm. La and Wa are different for different conditions. Λa is 240nm.Thickness of the active layer is different for different number of quantum wire stacked.

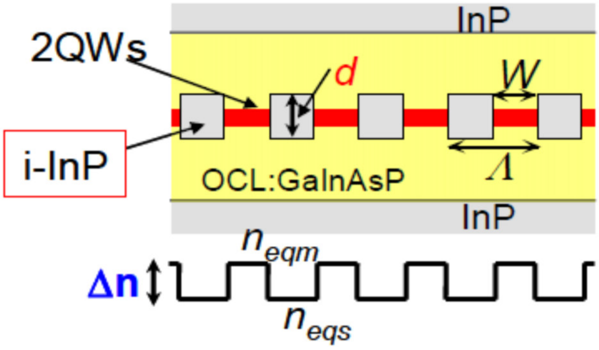

Figure 2: Refractive index profile of the active region

Figure 2 shows the refractive index profile of the active region where the equivalent refractive indices of gain and non-gain regions are denoted as n_{eqm} and n_{eqs}, respectively. The difference of these two equivalent refractive indices has been denoted as Δn as mentioned earlier. For a wire like DFB region with a wire width ratio (Wa/ Λ a) of 0.5 and Δn=0.03 (n_{eqm}= 3.21, n_{eqs}=3.18), the maximum value of the index coupling coefficient becomes approximately 400 cm-1. However, as the number of Quantum well increased the depth of the groove is also increased. For SQW depth of the groove is 104nm, for DQW it is 120 nm, for 5QW it is 164 nm and for 10 QW it is 240 nm. The equivalent refractive index (n_{eqs}) of the etched region is decreased due to increased volume of InP, while the refractive index of the gain region (n_{eqm}) remains (approximately) the same; therefore, net Δn value is enhanced. In our study we calculate refractive index (n_{eqs}) of the etched region and gain region (n_{eqm}) using C programs.

For single Quantum well n_{eqm}= 3.23065 n_{eqs}= 3.20136 .For double Quantum well n_{eqm}= 3.2356 n_{eqs} = 3.201356. For 5 Quantum well n_{eqm} = 3.25 n_{eqs} = 3.1989. For 10 Quantum well n_{eqm}= 3.272 n_{eqs} = 3.1955.

2. Differential Quantum efficiency

Differential quantum efficiency is one of the important aspects of dynamic characteristics. Higher the η_d higher the gain of transfer function. If η_d is low then transfer function may less than 0dB. At lower CL η_d is less, it increases as the CL increase and reached its peak. After that it decreases as CL increases. In the following figures (fig 3-fig 6) η_d VS CL is shown for different wire width and different number of QW.

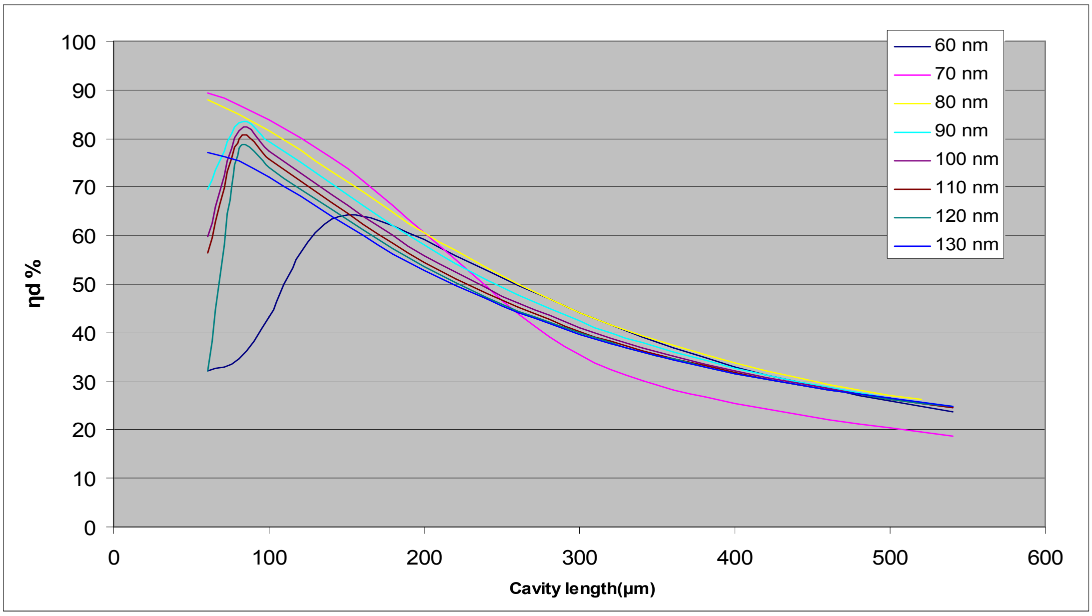

Figure 3: Dependence of differential quantum efficiency on cavity length for Single Quantum well.

For single QW at 90nm wire width η_d is 69% at 60μm cavity length then it increases to 83.2% at 80 μm cavity length. After that it decreases as cavity length increases. At 540μm cavity length η_d is 24.86%. At 100 nm wire width highest η_d obtained is 81.47% at 80μm CL. For different wire width highest η_d's are different and obtained at different CL (as shown in fig 3)

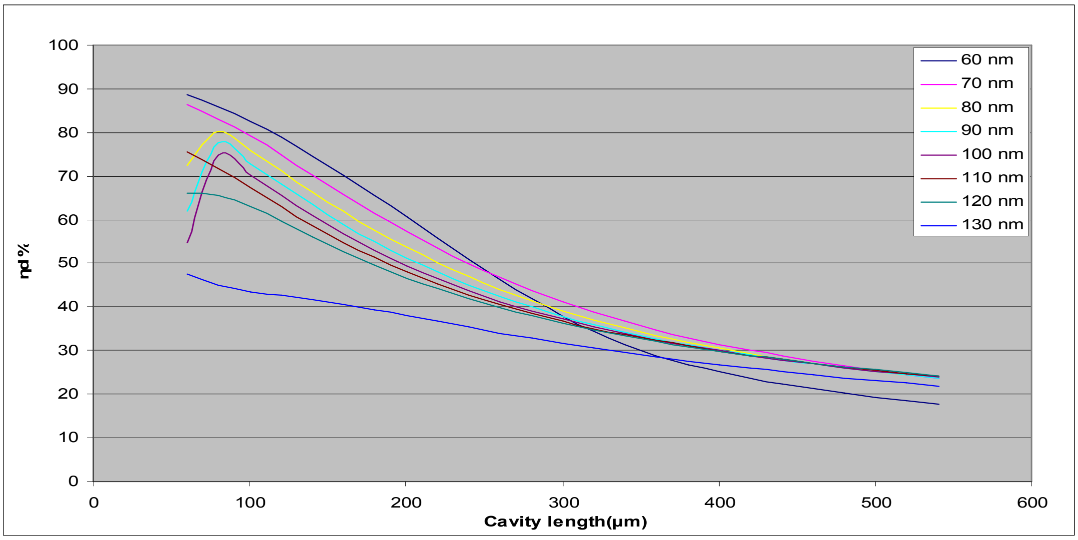

Figure 4: Dependence of differential quantum efficiency on cavity length for Double Quantum well

From fig 4 it is found that for double QW at 90nm wire width η_d is 61.9% at 60µm cavity length then it increases to 77.5% at 80µm cavity length. After that it decreases as cavity length increases. At 540µm cavity length η_d is 23.65%. At 100nm wire width highest η_d obtained is 74.86% at 80µm CL.

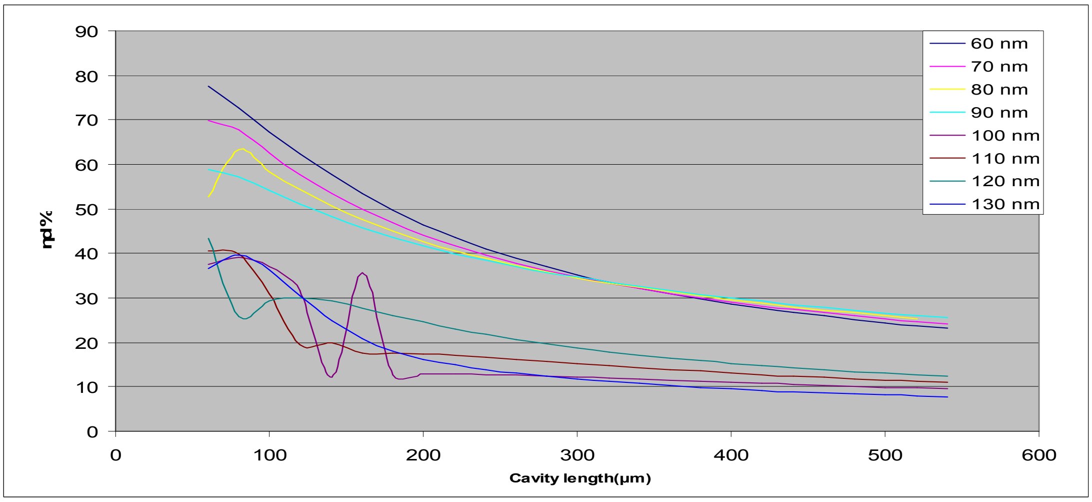

Figure 5: Dependence of differential quantum efficiency on cavity length for 5 Quantum well.

For 5 QW at 90nm wire width η_d is 58.82% at 60µm cavity length.After that it decreases as cavity length increases. At 540µm cavity length η_d is 25.45%. At 100nm wire width highest η_d obtained is 39.14% at 80µm CL. Lowest η_d obtained is 9.54%(as shown in fig 5).

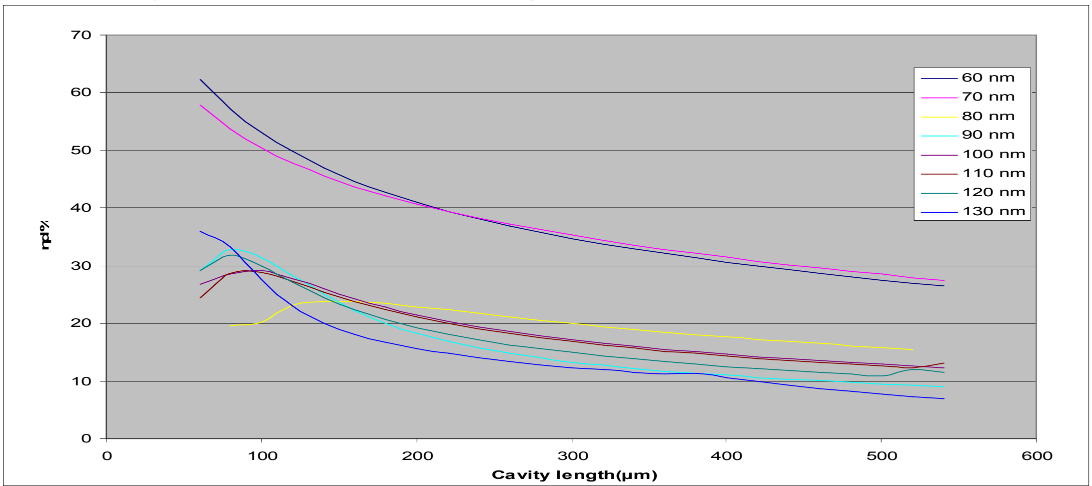

Figure 6: Dependence of differential quantum efficiency on cavity length for 10 Quantum well.

For 10 QW at 90nm wire width η_d is 29.2% at 60µm cavity length then it increases to 32.85% at 80µm cavity length. After that it decreases as cavity length increases. At 540µm cavity length η_d is 9.06%. At 100nm wire width highest η_d obtained is 29.1% at 100 µm CL. At 540µm CL η_d is 12.3% (shown in fig 6).

3. Conclusion

In this study dependence of differential quantum efficiency on cavity length and wire width is studied for different number of quantum wire stack. We studied for single QW, double QW , 5 QW and 10 QW. Simulation software is used to determine the values. We found

that highest differential quantum efficiency η_d of 81.47% at 100 nm wire width at 80µm cavity length for single quantum well Laser.

References

1. M. Nakamura, N. Nunoya, H. Yasumoto, M. Morshed, K. Fukuda, S. Tamura, and S. Arai, "Very low threshold current density operation of 1.5 µm DFB lasers with wire-like active regions." *Electron. Lett*., vol. 36, no. 7, pp.639-640, Mar. 2000.
2. N. Nunoya, M. Nakamura, H. Yasumoto, M. Morshed, K. Fukuda, S. Tamura, and S. Arai, "Sub-milliampere operation of 1.55 µm wavelength high index-coupled buried heterostructure distributed feedback lasers," *Electron. Lett*., vol. 36, no.14, pp. 1213 1214, July 2000.
3. S.M. Ullah "Monolithic Integration of Photonic Devices with Wire width Modulated Active Regions", PhD Thesis, Tokyo Institute of Technology.
4. Smowton Peter M et al 'The differential efficiency of quantum-well lasers' .Selected Topics in Quantum Electronics, IEEE Journal of (Volume:3 , Issue: 2) Page(s):491 - 498 ISSN : 1077-260X ,Apr 1997