Low threshold operation of Distributed Reflector (DR) Laser with Quantum Wire Structures

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Abstract

In this study Distributed Reflector (DR) laser consisting of a DFB laser with high reflection DBR at the rear end is studied by considering wirelike active region. Minimum threshold current of GaInAsP/InP laser has been analyzed. Lowest threshold of 0.305 mA has been observed is the DR laser with Double Quantum wire stack, 240µm cavity length of the active section, 90nm wire width and 2µm strip width. The proposed structure also provides very high differential quantum efficiency of about 63%.

Key word-Distributed reflector laser, Threshold Current, Quantum wire

1. INTRODUCTION

Distributed reflector Laser with DFB section is widely used in optical communication. To improve the performance the DR laser should have lower threshold current .Buried heterostructure lasers made from GaAs with wide stripe widths with a minimum threshold of 1.0mA has been reported. [1] A high differential quantum efficiency of about 50% from the front facet and low threshold current operation have been achieved by modifying the doping profile in 1.55 -mum distributed reflector lasers, waveguide loss Injection currents of 4.2 and 3.6 mA were obtained to achieve a 1-mW output power for lasers with uniform and phase-shifted grating structures, respectively.[2] A threshold current as low as 1.5 mA has been achieved for a distributed reflector (DR) laser consisting of an active DFB section and a passive DBR section by modulating widths of wirelike active regions.[3]

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 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).

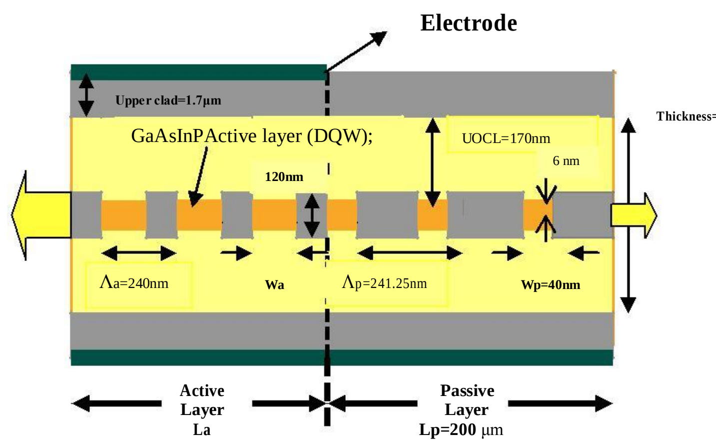

Fig 1 Schematic structure of DR laser (Single Quantum Wire)

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 wire 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.

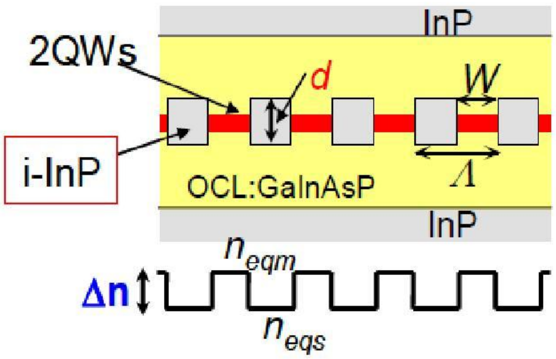

Figure 2: Refractive index profile

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 neqm and neqs, 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 (neqm= 3.21, neqs=3.18), the maximum value of the index coupling coefficient becomes approximately 400 cm-1. However, as the number of Quantum wire 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 (neqs) of the etched region is decreased due to increased volume of InP, while the refractive index of the gain region (neqm) remains (approximately) the same; therefore, net Δn value is enhanced. In our study we calculate refractive index (neqs) of the etched region and gain region (neqm) using C programs. For single Quantum wire neqm= 3.23065, neqs = 3.20136 for double Quantum wire neqm = 3.2356,neqs = 3.201356 for 5 Quantum wire neqm = 3.25, neqs = 3.1989 for 10 Quantum wire neqm = 3.272 , neqs = 3.1955.

2. Static characteristics of DR Laser

In this study C++ program is used to calculate the threshold current Ith and differential quantum efficiency
ηd of DR laser.

In this paper we study on the dependence of threshold current on cavity length (CL) for different wire width of the active region. For different number of quantum wire it is shown in the following figures. It is found that Ith is very high for lower cavity length. It reduces as the cavity length increases and it reaches lowest value at certain cavity length. After that it begins to increase slowly.

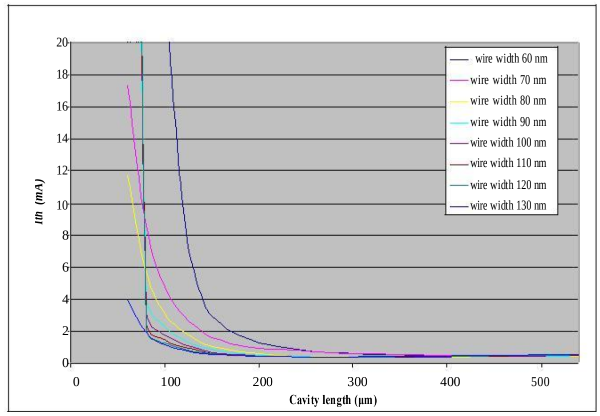

Fig 3 Dependence of threshold current on cavity length for Single Quantum wire.

From fig 3 it is shown that for Single Quantum Wire (SQW) at lower cavity length Ith is very high. For 60nm wire width it is 172mA (not shown in fig 3) then it reduce to minimum at 460µm cavity length to 0.4814mA. Similarly, the lowest threshold currents are obtained at different cavity length for different wire width. From all the data it is seen that minimum threshold current obtained at 100nm wire width which is 0.373mA where the cavity length is 300µm.

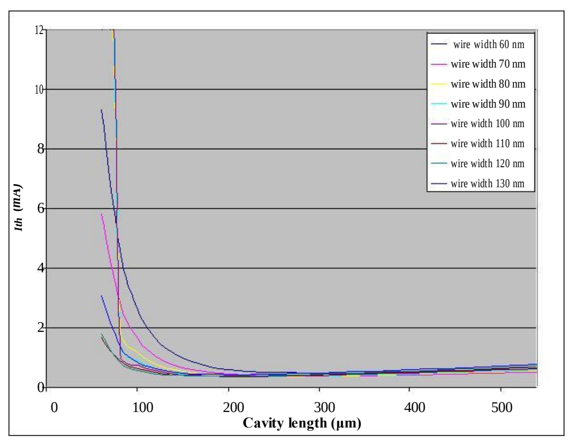

Fig 4 Dependence of threshold current on cavity length for Double Quantum wire.

For Double Quantum wire (DQW) Ith at lower cavity length is not that high as SQW. For 60nm wire length it is 9.33mA. But at 80nm, 90nm and 100nm wire width it is at higher side i.e. 39.8mA, 43mA and 48mA respectively (not shown in fig). From the entire wire width lowest threshold current is achieved at 90nm where Ith is 0.305mA where cavity length is 240µm. (shown in fig 4)

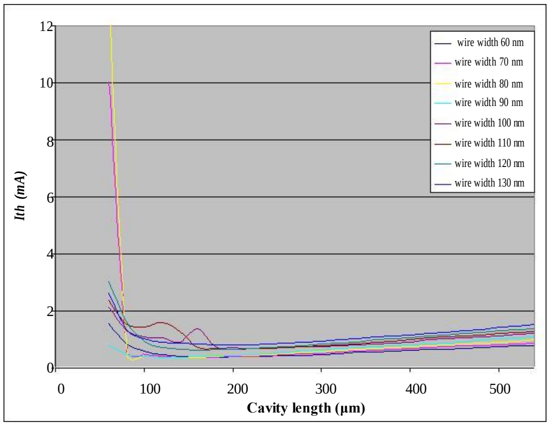

Fig 5 Dependence of threshold current on cavity length for 5 Quantum wire.

For 5 Quantum Well (5QW) Ith at lower cavity length (CL) is less than DQW. Here higher Ith are obtain at 70nm and 80nm wire width. Minimum Ith is obtained at 80nm wire width which is 0.371mA where the cavity length is 140 μm(as shown in fig 5.).

Figure 6 provides the dependence of threshold current on CL for 10 Quantum wire.

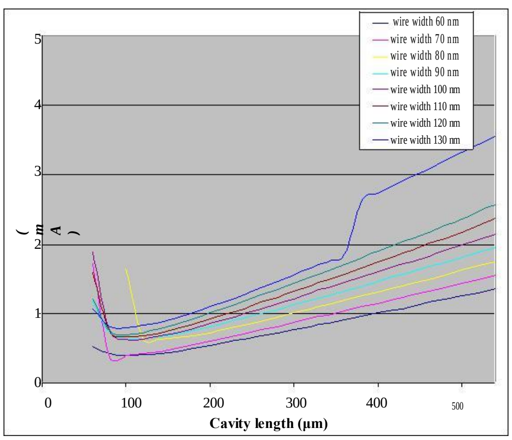

Fig 6 Dependence of threshold current on cavity length for 10 Quantum wire

For 10 Quantum Wire (10QW) Ith at lower cavity length (CL) is less than 5QW. So, in this section, it is seen that as the number of QW increases Ith at lower cavity length decreases. Here the minimum threshold current obtained at
70nm wire width where the CL is 80μm and Ith is 0.381mA.

Conclusion:

After all these analysis it is found that lowest threshold current is obtained for single quantum well at 100nm wire width which is 0.373mA where the cavity length is 300μm. For double quantum wire structure it is 0.305mA at 90nm wire width and 240μm cavity length. For 5 QW minimum Ith is obtained at 80nm wire width which is 0.371mA where the cavity length is 140 μm and for 10 QW minimum.

threshold current obtained at 70nm wire width where the
CL is 80μm and Ith is 0.381mA. It is observed that as the number of well increases required cavity length and wire width decreases for minimum threshold current. But confining to such a short length is very difficult. So we prefer double quantum wire structure at 90nm wire width with cavity length 240μm where minimum threshold current is 0.305mA.

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