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Transverse Mode Characteristics of a DBR-Surface Emitting Laser with Buried Heterostructure

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Distributed Bragg reflector(DBR)-surface emitting laser(SEL) with buried hetero-structure(BH) are fabricated with the combination of MOCVD, ECR dry-etching and LPE regrowth techniques. Low threshold and stable fundamental lateral-mode characteristics are realized by the optimum design of the cavity diameter and refractive indices. Other important characteristics such as polarization characteristics, series resistance and thermal resistance are also discussed.

Low threshold and stable transverse mode characteristics are required for a surface emitting laser (SEL), which is expected to be a key device for the parallel optical communication and high speed printing. The low threshold operation of the SELs is realized by the BH structure[1] and quantum-well microcavity-structure[2], however, large optical cavity size caused higher and unstable transverse mode operation.

In this paper, stable fundamental lateral-mode characteristics are realized by the index guided waveguide structure with reduced cavity diameter. The effect of the cavity size on the threshold current, series resistance and thermal resistance is also discussed.

Figure 1 shows the schematic drawing of the DBR-SEL with buried heterostructure. A quarter wavelength stack of N-type $Al_{0.1}GaAs$ / $Al_{0.7}GaAs$ multilayer reflector and double heterostructure are formed by the metal organic chemical vapor deposition (MOCVD)

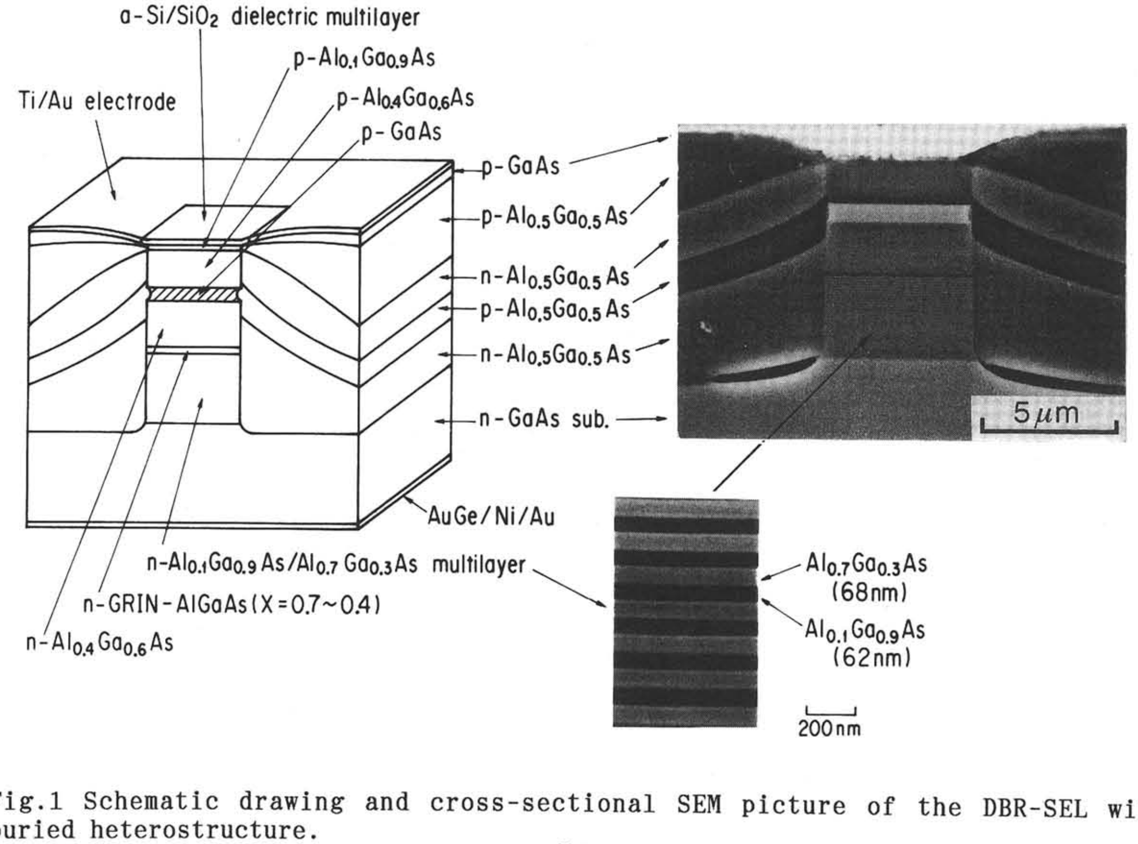

Fig.1 Schematic drawing and cross-sectional SEM picture of the DBR-SEL with buried heterostructure.

technique. A pillar like optical cavity is formed by the reactive ion beam etching techniques, and embedded by the PNPN-AlGaAs current blocking structure with the liquid phase epitaxy (LPE). Because the active region is surrounded by the current blocking structure, the hole current is introduced from the side of the P-type cladding region, and injected into the active region vertically. A perpendicular waveguide is formed by choosing the aluminum content of the current blocking layer (x=0.5) higher than that of the cladding region and the average of the multilayer (x=0.4).

Figure 2 shows the distribution of the threshold current against the cavity size. The SELs with the cavity opening of 2.5 x 2.5 μm square, 3μm in diameter, 3 x 3 μm square, 4 μm in diameter, 4 x 4μm and 5 x 5 μm square are prepared on the same wafer. The threshold current was around 9 mA at the cavity size of 5 x 5 μm square and it decreases to 3-4 mA with decreasing cavity size. The threshold current was in proportion to the cavity area S to the power of 0.6.

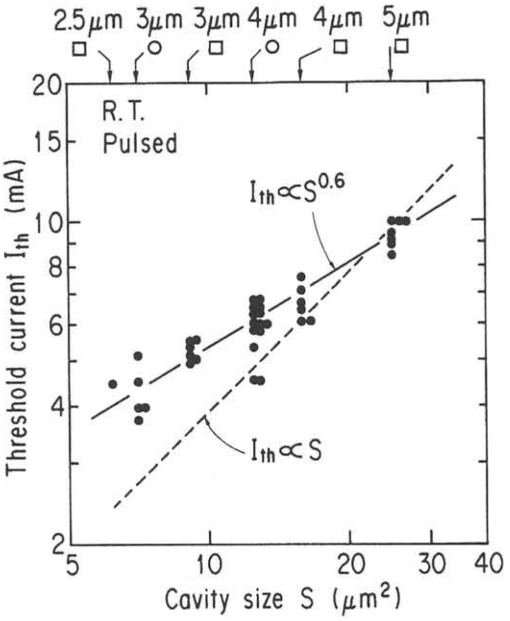

Fig.2 Distribution of the threshold current vs. cavity size.

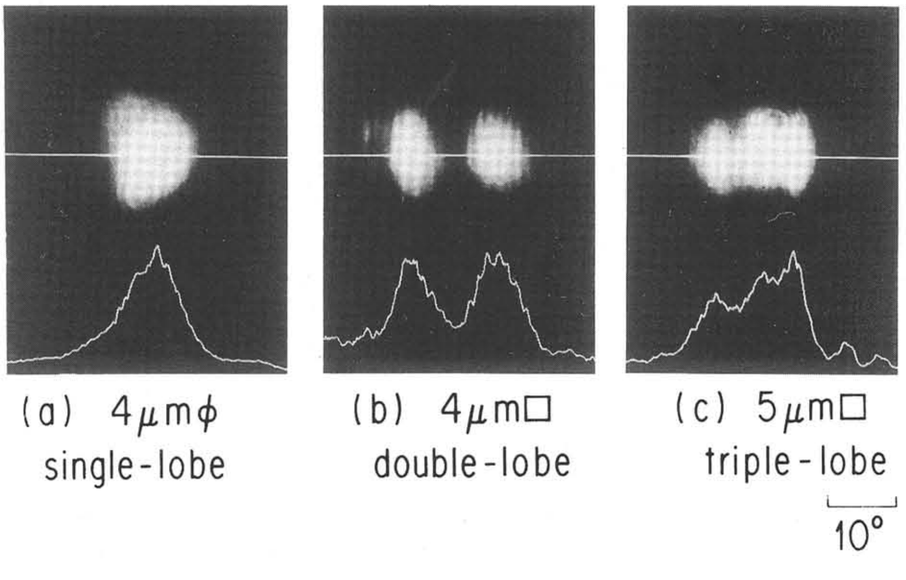

Fig.3 Far field pattern of the DBR-SEL with different cavity size. Operated at 1.1 times the threshold.

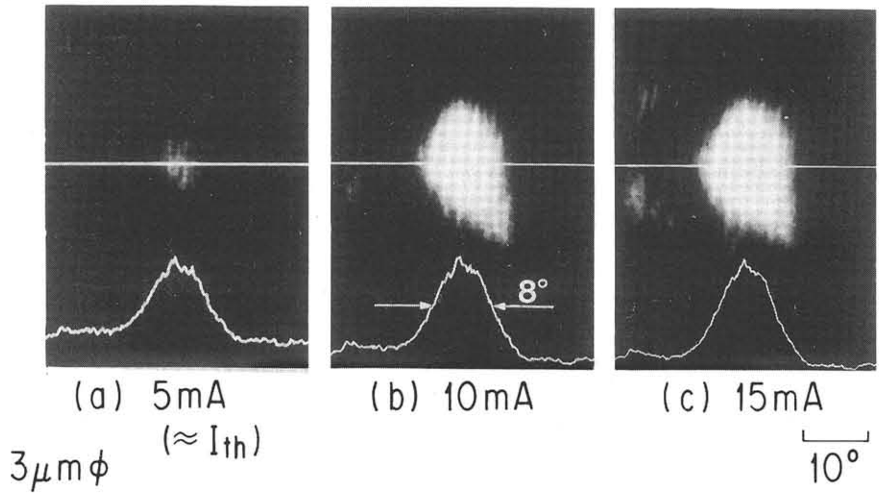

Fig.4 Far field pattern of the SEL with increasing driving current.

Figure 3 shows the far field patterns of the SELs with different cavity sizes of 4 μm in diameter (a), 4 x 4 μm square (b) and 5 x 5 μm square (c). They are operated at 1.1 times the threshold current. A F-θ lens system (Hamamatsu, #A3267) was employed to convert the emission angle into 2-dimensional image. A fundamental mode was obtained at the cavity size of 4 μm in diameter and smaller sizes. Higher lateral modes are observed at larger cavity sizes of 4 x 4 and 5 x 5 μm square. Figure 4 shows the far-field pattern from the cavity size of 3 μm in diameter at the higher operational current. The threshold current was increased 1.2 times in (a), 2 times in (b), and 3 times the threshold in (c). The fundamental transverse mode remained stable in all 3 cases. Half width of the far field pattern is 8 degrees. Unlike a gain guided structure, these fundamental and higher transverse modes are stable with various operational conditions. The V number[3] of each vertical cavity is expressed as 2.3 multiplied by the cavity diameter D, therefore, single mode condition (V= 2.4) is not required for the fundamental transverse mode operation of these SELs.

The polarization of the light output is linear in all cases. The direction of the polarization is random for the circular cavity and parallel to one or the other side of the opening for the square cavity.

Figure 5 shows the distribution of the series resistance against the area of the optical cavity. The resistance is inversely proportion to diameter (D) for large cavity and is inversely proportional to the cavity area (S) for small cavity. This indicates that either the resistance through the side wall dominates or the resistance inside of the cavity dominates.

Figure 6 shows the thermal resistance of the SELs. The junction temperature was estimated by the shift of the lasing wavelength between the pulsed and CW operational conditions. The thermal resistance of the order of thousands kelvin per watt seems inherent to the SELs in the junction up configuration. The thermal resistance increases further with the reduction of the cavity size. The threshold current decreased with the cavity diameter up to 2.5 μmφ as was previously shown in Fig.2. However, reduction of the cavity size causes increase of the electric and thermal resistance. Therefore, medium cavity size and lower refractive index differences should be considered for the optimized lateral mode, threshold current, and output power of the SELs.

References

1) M.Shimada, T.Asaka, Y.Yamasaki, H.Iwano, M.Ogura and S.Mukai, Appl. Phys. Let.57 (1990) 1289.

2) C.J.Chang-Hasnain, M.Orenstein, A.Von Lehmen, L.T.Flores, J.P.Harbison, and N.G.Stoffel, Appl.Phys.Lett. 57 (1990) 218.

3) For example, T.Okoshi, "Optical Fibers", Academic Press 1982.

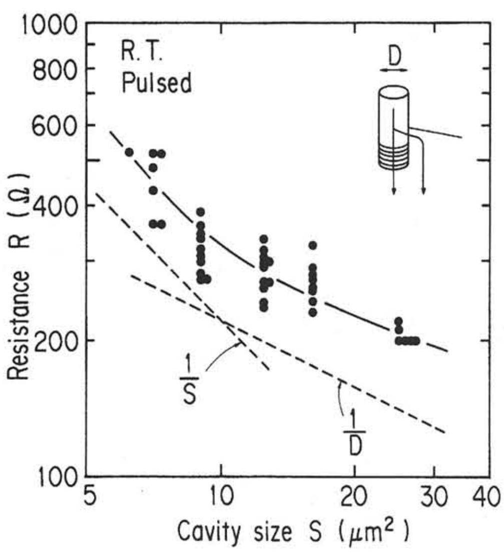

Fig.5 Series resistance of the SELs against cavity size.

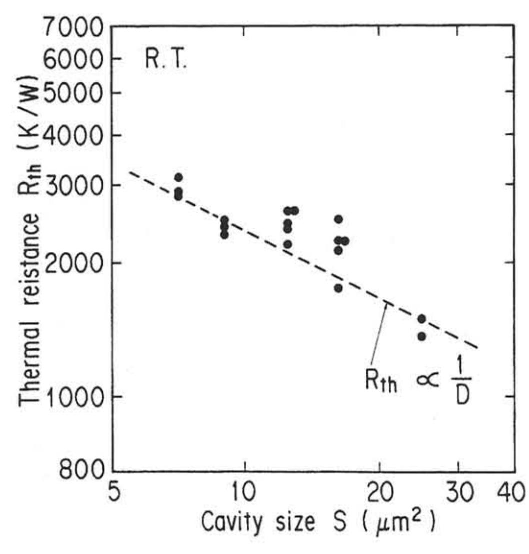

Fig.6 Thermal resistance of the SELs against cavity size.