내부 Stripe구조와 휜 활성층의 AlGaAs 다이오드 레이저
Curved active layer inner stripe AlGaAs diode laser

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ABSTRACT

The curved active layer inner stripe(CALIS) laser diode has been developed. The tight confinements of current and carrier result in low threshold current(20-30 mA) with stable fundamental transverse mode operation up to the output power of 30 mW CW.

I. INTRODUCTION

In recent years, there has been an increasing demand for devices operating at powers over 15 mW for the novel applications such as optical recording, laser printing, and space communications. Those applications, however, require lasers with the low threshold current and the stable fundamental transverse mode oscillation. Various laser structures have been developed to satisfy those requirements for high power and stable mode. These include constricted double heterojunction with large optical cavity(CDH-LOC)[1], stripe buried heterostructure(SBH)[2], channeled substrate planar structure(CSP)[3], and V channeled inner stripe(VSIS)[4]. Especially, VSIS and CSP lasers with an effective refractive index/loss guiding mechanism operate stably in a fundamental transverse mode up to 25 mW power level because the high order modal gain is restrained by the light absorption in GaAs outside the channel. However their threshold currents are relatively high (40-70mA) because the current in the cladding layer and the carrier in the active layer spread outwards from the channel. Although Yamamoto and Hijikata have proposed the B-VSIS laser using highly resistive AlGaAs burying layer and have reduced threshold currents of those lasers by half, require three LPE growth steps.[5] In this paper we report the newly developed high power laser, which has low threshold current(20 -35 mA), and stable fundamental transverse mode up to the output power level as high as 30 mW through two LPE growth steps. This laser diode has an optical waveguide performing an effective refractive index/loss guiding mechanism[3-4], strong index guiding of which especially with the curved active layer, has resulted in low threshold current. We named it the curved active layer inner stripe (CALIS) laser, which is shown schematically in Fig.1.

II. FABRICATION

The fabrication of the CALIS laser require two LPE growth steps. First, an n-GaAs current blocking layer(1 μm thick, Te doped, n-4X10^{18}cm^{-3}) was grown on (100) oriented p-GaAs substrate(Zn doped, p-1X10^{19}cm^{-3}). After that, channels with 4 μm width(W_c) and 1.8 μm depth(d) was etched in the <1$\bar{1}$0> direction by H_2SO_4:H_2O_2:$C_2H_4(OH)_2$= 1:2:7. In the second growth, the four layer including the first p-$Al_{0.5}Ga_{0.5}As$ cladding layer (0.35 μm thick, Mg doped, p-1X10^{18}cm^{-3}), the p-$Al_{0.15}Ga_{0.85}As$ active layer(0.06-0.08 μm thick, Mg doped, p-1X10^{18}cm^{-3}), the second n-$Al_{0.5}Ga_{0.5}As$ cladding layer (2.5 μm thick, Te doped, n-5X10^{17}cm^{-3}), and the n-GaAs cap layer (5 μm thick, Te doped, n-2X10^{18}cm^{-3}) were grown successively after the initial super-cooling of 4°C from 760 °C with the cooling rate of 0.4°C/min.. To make an abrupt built-in refracitve index distribution along the junction, the shoulders of each channel were carefully meltbacked during the growth of the first p-$Al_{0.5}Ga_{0.5}As$ cladding layer, and the thickness(t) of the first p-cladding layer on the outer sides of the channel was controlled so as to be in a range of 0.3 - 0.4 μm. Consequently as the channel with 1.8 μm depth came to be only partially filled, the curved active layer could be easily achieved. Fig.2 shows a scanning electron microscopy(SEM) image of cleaved cross section of the CALIS laser. Next, ohmic contacts were formed after evaporating Au-Ge/Ni/Au on the cap layer and Cr/Au on the back surface of the substrate, respectively. The metallized wafer was cleaved into chips with 250 μm length. The individual laser was mounted p-side down on a Cu heat sink with Sn solder.

III. RESULTS AND DISCUSSION

Fig.3 shows the typical characteristics of CALIS laser with 250 μm cavity length and 5 μm channel width in CW operation under room temperature. Light-current (L-I) characteristics and far-field patterns are shown in Fig.3(a) and 3(b), respectively. CW threshold currents I_{th} as low as 27 mA and stable fundamental transverse mode up to 30 mW were obtained without mirror-coatings. Also, no kinks were observed in the L-I characteristics up to the CW output power of 30 mW. The full widths at half maximum(FWHM) of the far field intensity were 12° and 23° in parallel($\theta_{/\!/}$) and perpendicular($\theta_{\perp}$) to the junction plane, respectively. The best threshold current measured was I_{th}=20 mA for the laser with 250 μm length and 5 μm width. This means the threshold current density J_{th} = 1.6 KA/cm^2. This low value verifies that the current leakage is reduced in the curved active layer buried in the current confining channel. In Fig.1, the curved active layer is buried in V channel and slightly buried in the layers of high-AlAs mole fraction. Thus, the current passing through the inner stripe rarely spreads in the p-cladding layer and further, the carrier injected into the active layer rarely diffuses outwards from the channel without any burying layer.[5] In this way, the tight confinements of current and carrier result in a high differential quantum efficiency and a low threshold current. Besides, the effective refractive index/loss guiding mechanism is more effective for achieving the stable fundamental transverse mode up to a high output power operation.

IV. SUMMARY

In conclusion, we have recently developed the curved active layer inner stripe (CALIS) laser. As described above, low threshold current (I_{th}= 20-35 mA, J_{th}= 1.6 KA/cm^2), and stable fundamental transverse mode operation up the power of 30 mW were achieved for the channel of 5 μm width without mirror-coatings.

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REFERENCES

[1] D. Botez, Appl. Phys. Lett., **36**, pp.190-192, 1980

[2] W. T. Tsang, R. A. Logan, and M. Ilegems, *ibid.*, **32**, pp.311-314, 1978

[3] K. Aiki, M. Nakamura, T. Kuroda, and J. Umeda, J., *ibid.*, **30**, pp.649-651, 1977

[4] S. Yamamoto, H. Hayashi, S. Yano, T. Samurai, and T. Hijikata, *ibid.*, **40**, pp.372-374, 1982

[5] S. Yamamoto and T. Hijikata, J. Appl. Phys., **61**, pp. 3108-3110, 1987

[6] K. Funakoshi, K. Doi, K. Aiki, and R. Ito, J.Cryst. Growth, **45**, pp.252-256, 1978

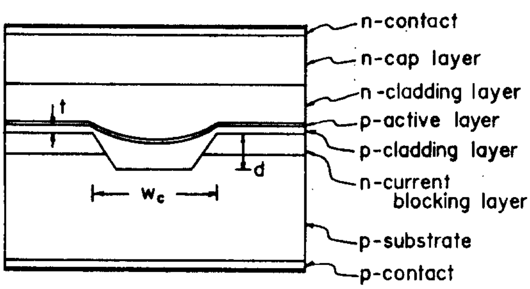

Fig.1 Schematic cleaved cross-section of the CALIS laser.

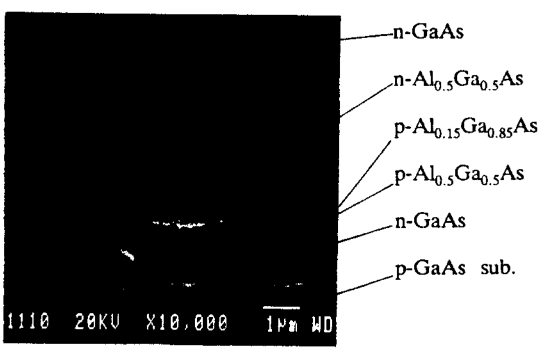

Fig.2 Scanning electron microscopy(SEM) image of cleaved cross-section of the CALIS laser.

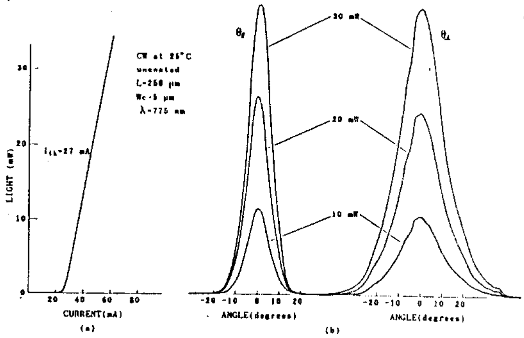

Fig.3 Typical characteristics of the CALIS laser in CW operation under room temperature. (a) Light-current characteristics. (b)Far-field patterns in parallel ($\theta_{//}$) and prependicular ($\theta_{\perp}$) to the junction plane at different power levels.