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MOCVD Grown SA-CM DFB Laser Arrays with Wavelengths Identical to within 1Å

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A 4-channel SA-CM DFB laser array with wavelengths identical to within 1Å has been obtained. Excellent Bragg wavelength uniformity with an accuracy of ±10Å has been achieved in a DFB wafer using self-aligned constricted mesa (SA-CM) structure and metalorganic chemical vapour deposition (MOCVD) technique.

1.Introduction

InGaAsP/InP DFB lasers are promising light sources for coherent transmission systems. In heterodyne network systems such as FDM (Frequency Division Multiplexing), a large number of lasers with identical wavelengths are indispensable for use as transmitters and local oscillators. However wide wavelength distributions of ±150Å in a wafer and ±5Å in a laser array have been reported[(1),(2)]. On the other hand, good results on lasing wavelength uniformity has been reported in some previous work[(3),(4)]. However, this data did not show stop-bands clearly which must accompany conventional DFB lasers and the Bragg wavelength distribution was not investigated.

The Bragg wavelength is mainly determined by the thickness and width of the active layer[(2)]. It is very important to control device dimensions to decrease wavelength fluctuations. We demonstrate excellent Bragg wavelength uniformity with an accuracy of ±10Å in an MOCVD DFB wafer. A 4-channel SA-CM DFB laser array with wavelengths identical to within 1Å was obtained without intentional wavelength tuning.

2.Experimental

A new self-aligning (SA) process[(5)] and MOCVD growth for 1.5μm SA-CM DFB laser arrays were developed to control active layer demensions. Figures 1,2 show the basic structure of the SA-CM DFB laser and the top view of the laser array, respectively. In the early stage of the SA-CM process, the active layer was directly and precisely patterned in a stripe with dual channels by a conventional photolithography process. Finally, selective undercut etching of the side quaternary region was performed using SH etchant. The controllability of the widths of the active region was dramatically improved. The active region width was 1.5μm.

All epitaxial growth was carried out by low pressure MOCVD. The layers were grown on n-type (100) InP substrates using TMIn, TMGa, PH_3 and AsH_3 in a vertical quartz reactor. The growth temperature and pressure

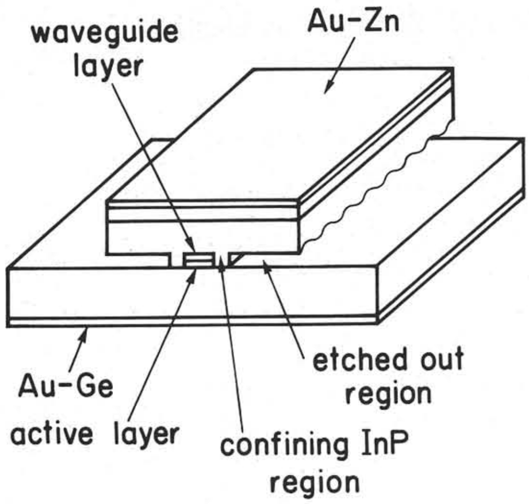

Fig. 1 Schematic structure of SA-CM DFB laser

were 620°C and 200Torr., respectively. The active layer thickness was 0.12μm with an accuracy of ±2% over the 10mm*10mm area. A first order grating with 2400Å pitch on the waveguide layer was not deformed during crystal growth.

The SA-CM lasers had conventional DFB structure and a phase shift structure was not adopted. Both facets were cleaved. In all measurements, pulsed current was applied

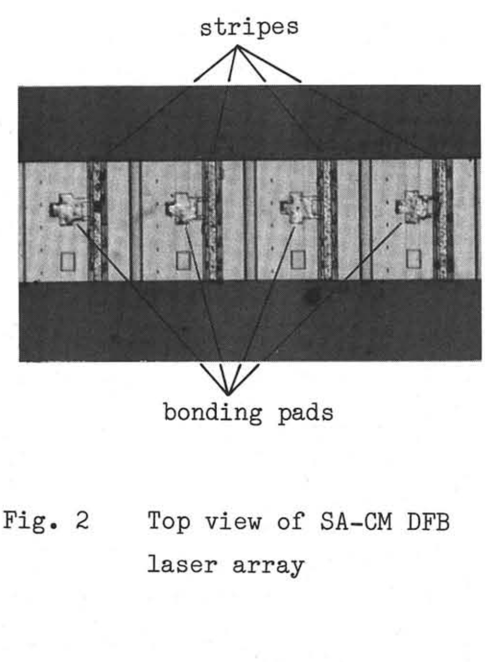

Fig. 2 Top view of SA-CM DFB laser array

to the lasers to eliminate wavelength changes due to thermal effects.

3.Results

Single mode lasers were selected prior to lasing wavelength measurements as follows. First, 94 laser diodes in bars with various cavity lengths were randomly selected from the 10mm*10mm wafer. From these lasers, extremely high threshold lasers obtained from the wafer edge were rejected. Moreover multimode lasers at 3 times threshold current were omitted. Figure 3 shows the cavity length dependence of SLM (single longitudinal mode) probability. The data agrees well with the calculated line. The lasers with around 250μm length had relatively high SLM probability. Shorter and longer cavity lengths gave Fabry-Perot modes and more than 2 DFB modes, respectively. After all, 35 single mode lasers were obtained.

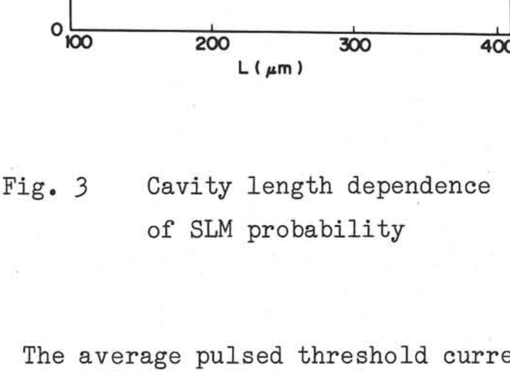

Fig. 3 Cavity length dependence of SLM probability

The average pulsed threshold current of the single mode lasers was 19.8mA with a standard deviation of 4.0mA. In Fig.4, threshold currents of the succesive 8 lasers in the same bar are shown. Very uniform threshold currents were obtained.

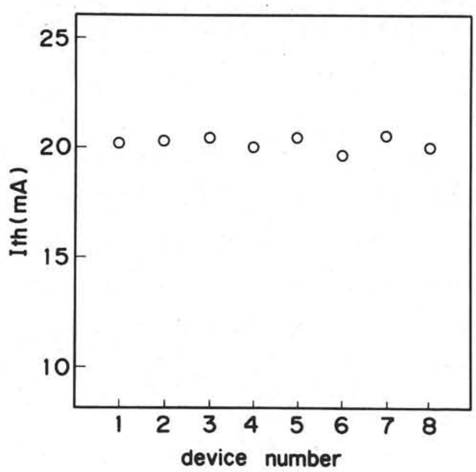

Fig. 4 Threshold currents of the lasers in the same bar

The Bragg wavelength of as-cleaved SA-CM DFB lasers were precisely controlled in the MOCVD wafer. As shown in Fig.5(a), the distribution of normalized lasing wavelengths δL (deviation from assumed Bragg wavelength) showed two clearly defined peaks on either side of the stop-band of which the center corresponds to the Bragg wavelength.

The δL for the +1st mode was in the range of 0 to 6. The main reason of this small distribution is partly Bragg wavelength variation and partly facet phase change. The results agree well with a calculation considering facet-phase probability as shown in Fig.5(b). The calculation was made using coupled wave theory for the DFB lasers with facet mirrors. The facet phase was changed in 16*16 cases. Single mode conditions used here were to have 0.03cm-1 gain difference between main and sub modes and to have field ratio (FR) more than 0.5. The FR was defined as the ratio of minimum electric field to maximum electric field along the laser cavity axis. The coupling coefficient (k) was estimated to be 35cm^{-1}. According to the calculation, the δL for each mode lies between 2 and 5. Fluctuation of Bragg wavelength was estimated to be ±10Å from the comparison of experimental data and caluculated results. This deviation corresponds to a variation of ±30Å thickness and ±0.2μm width of the active region. As a

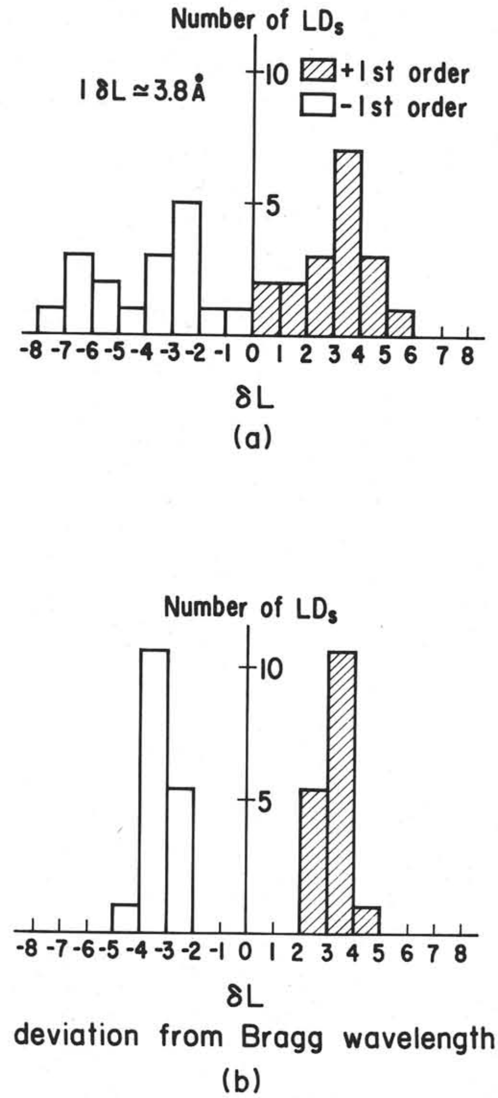

Fig. 5 Lasing wavelength distribution
(a)experiment
(b)theoretical calculation

result, the 4-channel laser array with wavelengths identical to within 1Å was obtained without intentional tuning for the first time(Fig.6). All 4 lasers oscillated at 1.5120Å(+1st mode). Such excellent homogeneity was achieved by (1)precisely controlled MOCVD layer thickness and by (2)exactly controlled stripe width of SA-CM structure. Lasing wavelength controllability will be further increased by quarter wave phase shift and wavelength tuning. Using these techniques, it will be possible to make the lasing wavelengths of almost all lasers from one MOCVD wafer coincident.

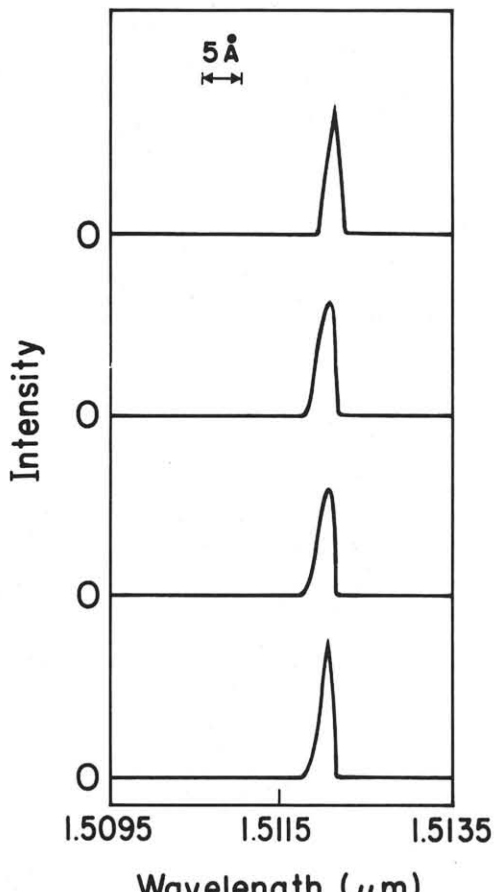

Fig. 6 Lasing spectra of SA-CM DFB laser array

4.Conclusion

In conclusion, lasing wavelengths of MOCVD grown SA-CM DFB lasers were investigated. The wavelength distribution showed two peaks correspond to +1st mode and -1st mode, respectively. From the comparison with the calculated wavelength distribution, the Bragg wavelength fluctuation was estimated. Bragg wavelengths identical to within ±10Å in a wafer and within 1Å in an SA-CM DFB laser array were achieved by laser dimension control using self-aligned process and MOCVD growth.

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References

(1)B.I.Miller et al.;Appl.Phys.Lett.51 (1987)2260
(2)H.Okuda et al.;IEEE J.QuantumElectron. QE-23(1987)843
(3)M.Oishi et al.;ibid.QE-23(1987)822
(4)T.Nishibe et al.;Inst.Phys.Conf.Ser. 79(1985)715
(5)Y.Hirayama et al.;Electron.Lett.24 (1988)452