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Beam Deflection and Mode Switching Caharacteristics in Coupled Twin-Stripe Lasers

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A stable single-lobe beam deflection in coupled twin-stripe semiconductor lasers is studied both experimentally and theoretically. It is also demonstrated that the laser oscillation can be switched between a single-longitudinal mode oscillation and a multi-longitudinal mode oscillation by simply varying the ratio of current injection into the two stripes.

1. Introduction

In view of expanding the application fields of semiconductor lasers, a large amount of efforts has been devoted to the development of new functional laser devices. Among them are the coupled twin-stripe lasers (CTLs) which provide such attractive functions applicable to dynamic optical interconnections and optical signal processing as the output beam deflection[1] and the multi-stable operations.[2,3]

In this paper, we report on the first comprehensive study on the beam deflection in CTLs, experimentally demonstrating as well as theoretically analyzing a stable single-lobe beam deflection achieved by varying current injection into the two stripes. Also described is a newly-found unique feature of CTLs, the capability of electrically tailoring the laser coherency to be fit for various applications; one can choose between a single-longitudinal mode oscillation and a multi-longitudinal mode oscillation by simply adjusting the ratio of injection levels between the two stripes.

2. Experiments

The structure of our CTLs is shown in Fig. 1. The double-heterostructure wafer consists of a 0.5

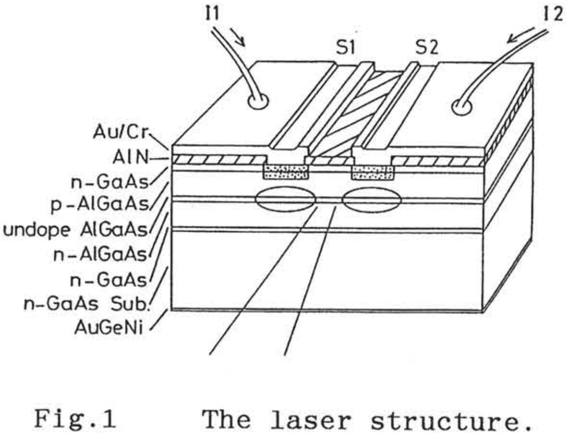

Fig.1 The laser structure.

μm-thick n-GaAs buffer layer, a 1.5 μm-thick n-$Al_{0.5}Ga_{0.5}As$ cladding layer, a 0.1 μm thick undoped $Al_{0.1}Ga_{0.9}As$ active layer, a 1.5 μm-thick p-$Al_{0.5}Ga_{0.5}As$ cladding layer and a 0.5 μm thick n-GaAs current-blocking layer grown on an n-GaAs substrate by MOVPE. A pair of stripes 2 μm wide separated from each other by 4 μm is delineated by Zn diffusion through the n-GaAs top layer utilizing an AlN film as a mask. On the AlN film is a Au/Cr electrode which is split into two parts by chemical etching in order that the two stripes may be independently pumped.

Figure 2 shows the far-field patterns of a CTL as a function of

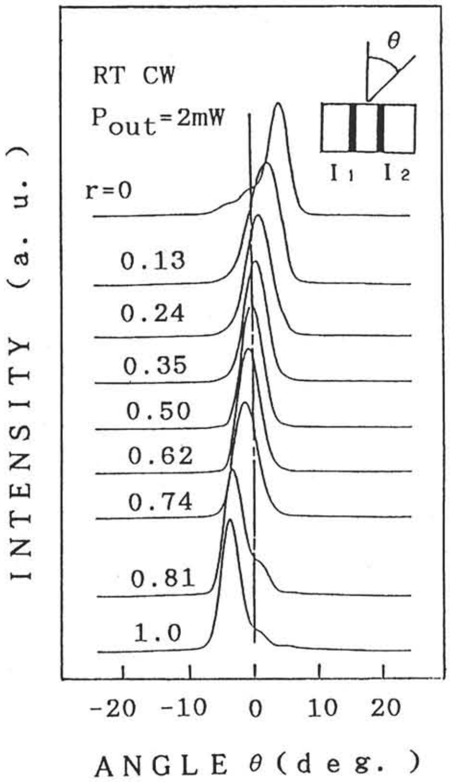

Fig.2 Variation of far-field patterns with r. Output power is fixed at 2 mW.

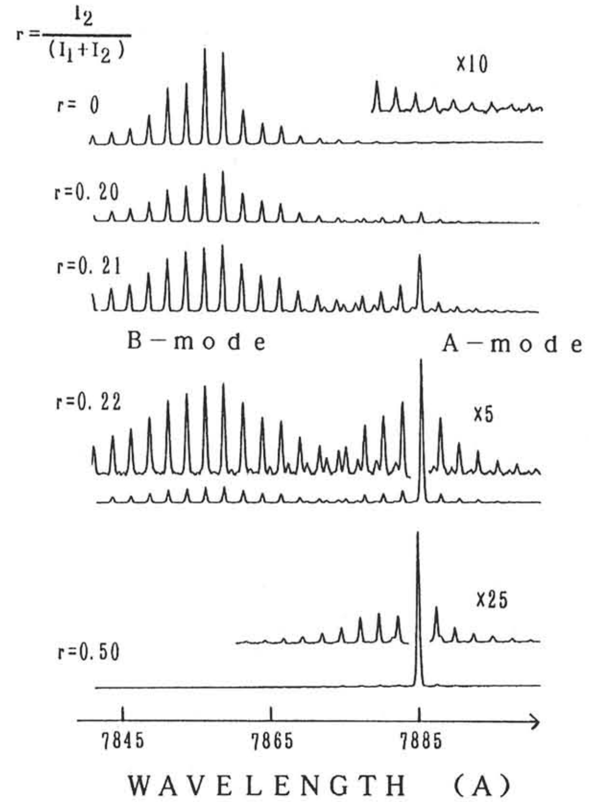

Fig.3 Variation of lasing spectrum with r. Output power is fixed at 2 mW.

the current injection ratio r = I_2 / (I_1 + I_2), where I_1 and I_2 are the injection currents applied to the individual stripes and the laser output is fixed at 2 mW. It can be seen that, as the degree of asymmetry in the injection levels is increased ($r \to 0$, $r \to 1.0$), the output beam is deflected towards the stripe with lower injection levels and a clear beam deflection of $\pm$ 4.5^{o} is achieved for $0 \leq r \leq 1$. It can be also seen that, while the far-field pattern is of pure single lobe in a certain region of r around the symmetric injection (r = 0.5), a small shoulder appears on one side of the main lobe under highly asymmetric injections ($r \sim 0$, $r \sim 1.0$).

In order to gain further insight into the mechanism of the change in the far-field patterns with r, the lasing spectra has been measured as a function of r as shown in Fig. 3. It can be seen in Fig. 3 that a single-longitudinal mode oscillation at comparatively longer wavelengths under the symmetric injection is replaced by a multi-longitudinal mode oscillation at comparatively shorter wavelengths as the asymmetry is increased.

A careful observation of these phenomena including the observation of spectrally resolved far-field and near-field patterns has revealed that the variation of r causes a switching between two distinct lateral modes, A and B, leading to the switching between the single- and multi-longitudinal mode oscillations.

3. Analysis and Discussion

The lateral mode behavior of CTLs has been numerically analyzed taking account of the effects of the carrier-induced refractive-index change on the waveguiding.

Figure 4 shows the modal gain calculated as a function of r. The solid curves are for the fundamental mode under the symmetric injection (A-mode). The broken curves are for the lasing mode under asymmetric injections (B-mode). Shown in Fig. 5 are the calculated far-field pat-

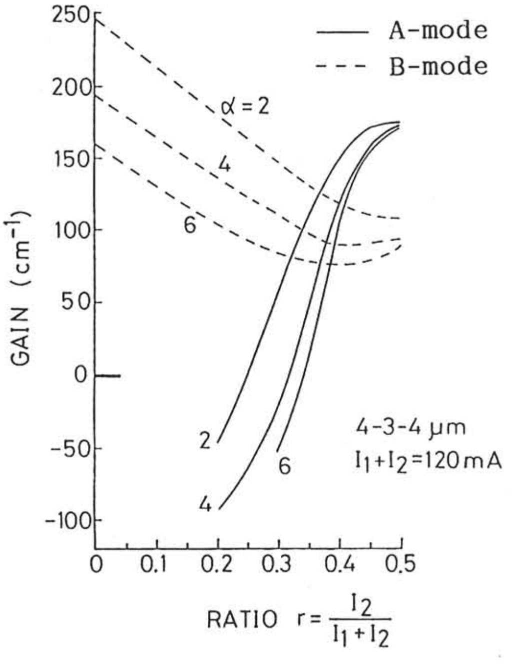

Fig.4 Calculated modal gains. The linewidth enhancement factor α = 2, 4, 6. Stripe width:4 μm. Separation:3 μm.

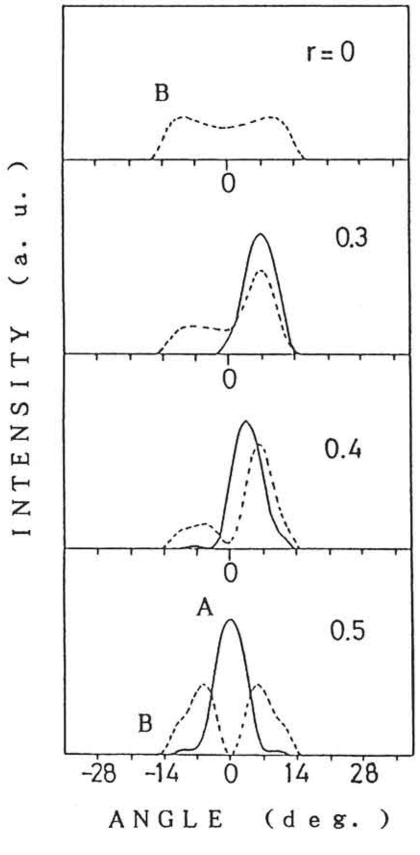

Fig.5 Calculated far-field patterns. α = 2.

terns of A-mode (the solid lines) and B-mode (the broken lines).

The analysis shows that, when the injection asymmetry is moderate, the laser oscillates in A-mode which exhibits appreciable single-lobe beam deflection with an increase in the asymmetry since the phase front is deflected towards the region with higher refractive index, and a further increase in the asymmetry gives rise to the oscillation in B-mode which, for r = 0 and r = 1.0, exhibits twin-lobe and multi-longitudinal mode behavior inherent in narrow-stripe gain-guided lasers.

Thus, the analysis explains the essential features of the experimental results and can be used in optimizing the laser structure for beam deflection.

4. Conclusion

In summary, the modal behavior of CTLs has been studied both experimentally and theoretically, and a stable beam deflection of $\pm$ 4.5° as well as the capability of tailoring the laser coherency has been demonstrated. These results show that CTLs are one of the promising devices in the future opto-electronic systems.

References

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