Stripe Width Dependence of Internal Quantum Efficiency and Carrier Injection Delay in Lateral Current Injection GaInAsP/InP Lasers

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Abstract

Internal quantum efficiency and carrier injection delay time in lateral-current-injection (LCI) lasers fabricated on a semi-insulating (SI)-InP substrate were evaluated for various stripe widths. As the results, it was confirmed that narrower stripe width (< 2 μm) can give better static and dynamic performances.

1. Introduction

Semiconductor lasers based on high index-contrast waveguides have been getting much attention for compact and low power consumption photonic integrated circuits. As one of promising light sources, we proposed a GaInAsP/InP membrane distributed feedback laser which consists of a thin semiconductor core layer sandwiched by polymer claddings [1], and demonstrated low threshold operation under an optical pumping [2]. A lateral current injection (LCI) structure [3] was adopted to realize injection type membrane laser, and its room-temperature continuous-wave (RT-CW) operation was achieved with a LCI buried-hetero structure (BH) laser fabricated on a SI-InP substrate [4]. An injection type membrane DFB laser was recently reported [5], however poor lasing performances compared to those of conventional lasers with vertical injection structure remain key issues.

In order to realize better performances of the LCI membrane lasers, efficient carrier injection into the thin semiconductor core layer is essentially required. In this paper, we discuss stripe width dependence of the internal quantum efficiency measured from static lasing characteristics as well as the carrier injection delay time measured from direct modulation characteristics of LCI lasers fabricated on a SI-InP substrate.

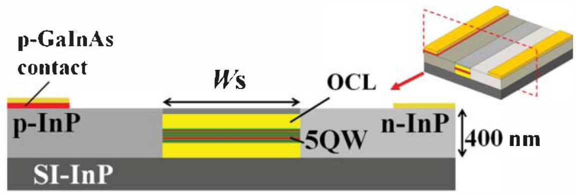

Fig. 1 Cross-sectional structure of LCI lasers on SI-InP.

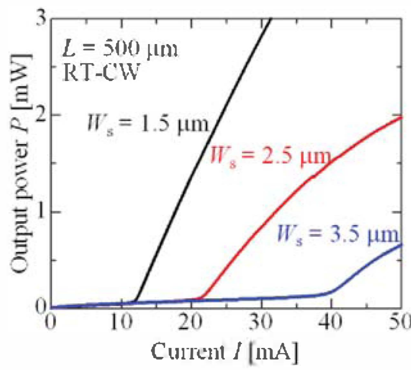

Fig.2 Lasing characteristics of LCI laser for various stripe widths.

2. Experiment

LCI lasers were fabricated by two-step OMVPE regrowth on a SI-InP substrate [4]. Figure 1 shows a cross-sectional structure of the fabricated LCI laser. As can be seen, a GaInAsP core layer (400 nm thick), consisting of compressively-strained 5 quantum-wells

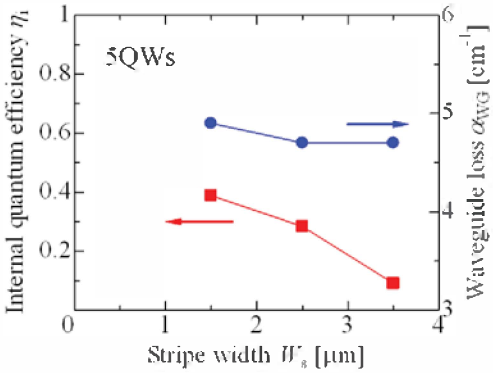

Fig.3 Stripe width dependences of internal quantum efficiency and waveguide loss.

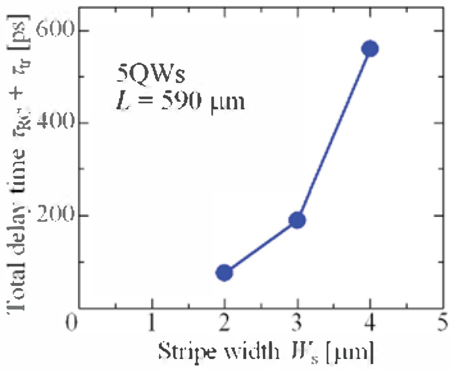

Fig.4 Stripe width dependences of carrier injection delay.

(5QWs) vertically sandwiched by optical confinement layers (OCLs), is laterally sandwiched by regrown p-InP and n-InP cladding layers as the LCI BH structure. We prepared devices with various stripe widths on the same wafer. Figure 2 shows light output of the LCI laser with stripe widths of 1.5 µm, 2.5µm, 3.5µm. As indicated by Fig.2, the lasing characteristics degraded with broadening of stripe widths. This is partly because the internal quantum efficiencies (η_i) for LCI lasers are dependent on stripe widths as described below.

Figure 3 shows a stripe width dependence of η_i and waveguide loss of the LCI lasers evaluated from the cavity length dependence of the external differential quantum efficiency for samples with each stripe width measured under a RT-CW condition. η_i monotonically decreased as the stripe width became wider. This may be attributed to a nonuniformity of the carrier density along the stripe width direction caused from mobility difference between holes and electrons.

Then we measured direct modulation response under a small signal condition and evaluated the sum of RC delay time and carrier transport time ($\tau_{RC}+\tau_{tr}$) for various stripe widths samples as shown in Fig. 4. As can be seen, narrower stripe width device showed smaller delay time. This means that the modulation response of these LCI lasers is limited by carrier transport time τ_{tr} rather than RC products. In the LCI laser with stipe width of 2 µm, the 3 dB bandwidth f_{3dB} with a bias current of 40 mA was 4.9 GHz, and this result is smaller than the f_{3dB} limited by f_r, which is mainly attributed to τ_{tr} as described above. To realize higher modulation, therefore, the stripe width of less than 2 µm will be required. Since the reduction of the stripe width will push the optical field into the SI-InP substrate side and result in lower the optical confinement into the active layer, a high index-contrast membrane waveguide structure will be required for not only for low threshold operation but also for high-speed modulation.

3. Conclusions

Lateral current injection type buried-hetero structure lasers were investigated for electrically driven low power consumption membrane lasers. This result can be applied to realize high performance membrane photonic devices for future on-chip optical interconnections.

Acknowledgment

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