Extended Abstracts of the 2001 International Conference on Solid State Devices and Materials, Tokyo, 2001, pp. 606–607

E-8-3

Current and Wavelength Characteristics of Polarization-Insensitive SOAs with Strained-Bulk Active Layers

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1. Introduction

Semiconductor optical amplifiers (SOAs) are attracting much interest as possible key devices in future all-optical networks. In these networks, it is very important to have polarization-insensitivity of gain for the SOA in actual devices.

There are several techniques for achieving polarization insensitivity. One is to use a sub-micrometer square bulk active layer [1], [2]. However, the fabrication process for this structure, especially its sub-micrometer process is not so easy and has little flexibility for design and fabrication of the device structure. Using a strained multi-quantum well (MQW) active layer [3], [4] is also another available technique. Another approach is a strained-bulk rectangular active layer [5], [6]. In any case, the low-polarization-sensitivity area for the driving current and wavelength of low-polarization-sensitivity SOAs with strained active layers as actual network devices is not yet clear. In this paper, we clarify the current and wavelength characteristics of low-polarization-sensitivity SOAs with strained-bulk active layers for network device application.

2. Fabrication

1.55-µm tensile-strained-bulk SOAs were fabricated by metalorganic vapor phase epitaxy (MOVPE). A 0.2-µm-thick undoped tensile-strained-bulk InGaAsP active layer (λ_g = 1.55 µm) with both upper and lower sides cladded by 0.1-µm-thick separate confinement heterostructure (SCH) layers (λ_g = 1.18 µm) were successively grown on (100) n-InP substrate. Waveguide-width (W) was varied to be 0.8, 1.0, 1.3, and 1.5 µm by CH_4/H_2 dry-etching. The waveguides were buried by p and n type InP layers. The confinement factor of TE polarization would be larger than that of TM polarization due to the asymmetry of the active layer shapes. So we introduced small tensile-strain in the active layers to cancel the polarization difference [7]. The active layer strain (ε) was varied to be 0, -0.12, -0.17, -0.2, and -0.27 %. The device length (L) was 300 or 600 µm. The sample facets were coated with anti-reflective (AR) films.

3. Results and Discussion

The strain dependence of the difference between the TE-gain and TM-gain ($\Delta G_{TE\text{-}TM}$) with each chip gain of 10 dB is shown in Fig.1. The data both cavity lengths, 300 µm and 600 µm, are shown. In each sample, the $\Delta G_{TE\text{-}TM}$ gradually decreases with increasing tensile strain. The polarization-insensitive strain is estimated to be about –0.11 %. No remarkable waveguide-width dependence of $\Delta G_{TE\text{-}TM}$ is observed.

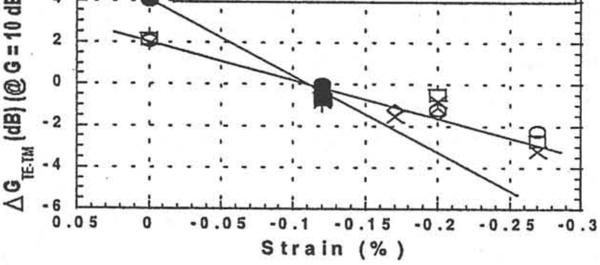

Fig. 1 The strain dependence of $\Delta G_{TE\text{-}TM}$ for various waveguide-widths and two types of cavity lengths with chip gain of 10 dB.

Figure 2 shows typical gain characteristics for the –0.12%-strain sample. The waveguide-width is 0.8 µm and the cavity length is 300 µm. The $\Delta G_{TE\text{-}TM}$ stays less than 0.8 dB. The ASE spectra of both the TE-mode and TM-mode were measured. Figure 3 shows ASE spectra of TE-mode. The driving current ranges from 5 to 50 mA in the wavelength range from 1.4 to 1.62 µm. Each spectrum has its own peak power, which gradually shifts toward a smaller wavelength with increasing current due to the band-filling effect. Assuming that the difference of the optical power between TE-mode and TM-mode is the $\Delta G_{TE\text{-}TM}$, the low-polarization-sensitivity range can be estimated. Figure 4 shows the $\Delta G_{TE\text{-}TM}$ estimated from these ASE measurements in the wavelength range from 1.4 to 1.62 μm. In this range, the ΔG_{TE-TM} stays less than 0.9 dB.

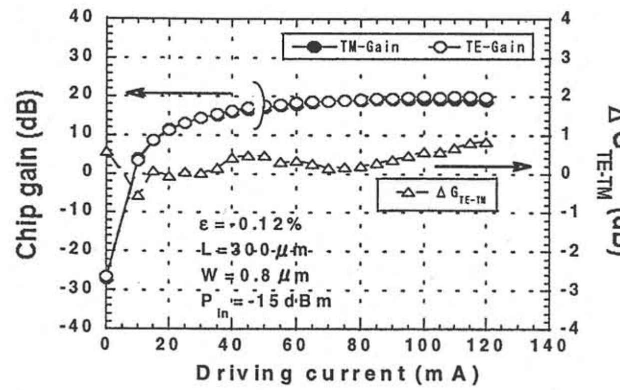

Fig. 2 The gain characteristics for a –0.12 %-strain sample having waveguide-width of 0.8 μm and cavity length of 300 μm.

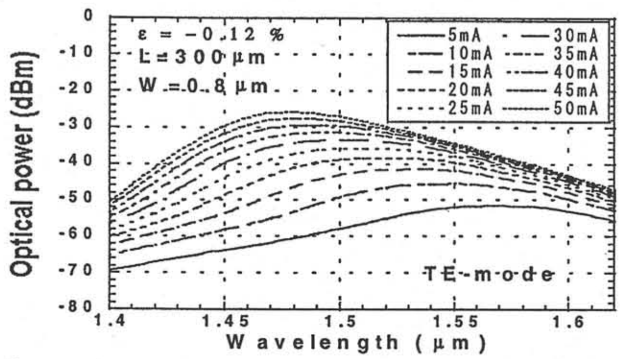

Fig. 3 The ASE spectra of TE-mode for –0.12 %-strain samples. The driving current ranges from 5 to 50 mA in the wavelength range from 1.4 to 1.62 μm.

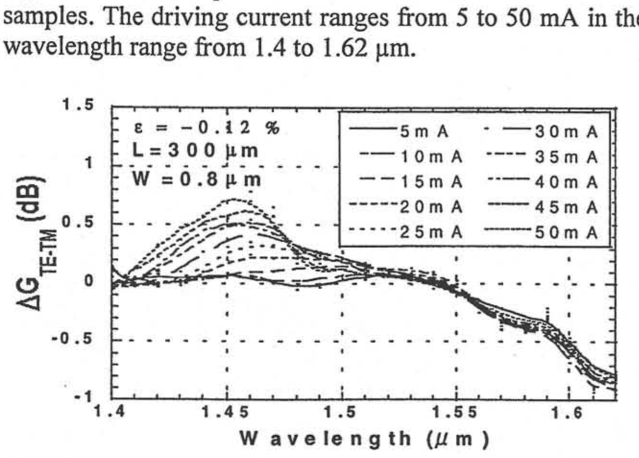

Fig. 4 The wavelength dependence of ΔG_{TE-TM} for a –0.12 %-strain sample having waveguide-width of 0.8 μm and cavity length of 300 μm.

In Fig. 2, when the chip gain is 0 dB, the driving current corresponds to about 8 mA. From these gain characteristics and ASE-spectra measurements, we obtained the relation among the optical power, wavelength and driving current of ΔG_{TE-TM} in an actual working device area for SOAs. The SOAs gains were estimated from these ASE measurements. By calculating the difference between TE-mode and TM-mode for the ASE spectra, we obtained the low-polarization- sensitivity relations among of the optical power, wavelength and driving current as shown in Fig. 5. The hatched area shows the optical power (corresponds to chip gain) in the range of more than 5 dB and the low-polarization- sensitivity (less than magnitude of 0.5 dB of ΔG_{TE-TM}) with changing driving current and wavelength for the –0.12 %-strain sample. It is clear that the low-polarization-sensitivity area is very wide. This means the tensile-strained bulk SOA has very wide range of current and wavelength characteristics and has great potential for network device application.

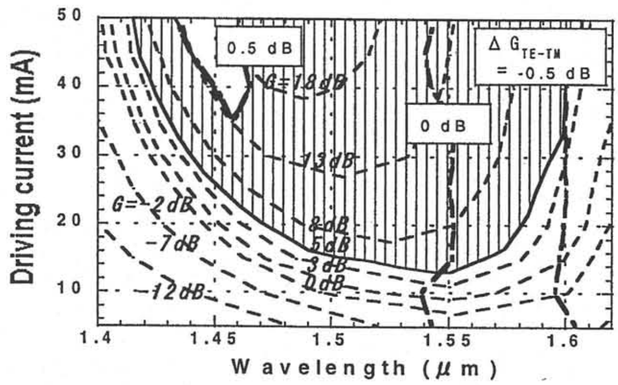

Fig. 5 The current and wavelength characteristics for a –0.12%-strain sample. The hatched area shows the optical power in the range of more than 5 dB and the low polarization-sensitivity in the range of less than 0.5 dB.

4. Conclusion

We investigated current and wavelength characteristics of 1.55-μm SOAs with tensile-strained-bulk active layers. A –0.12 %-strained bulk SOA had a very low polarization sensitivity of less than 0.8 dB in the gain characteristics at driving current ranging from 0 to 120 mA. In this sample, the low-polarization-sensitivity area is revealed to stay very wide with changing driving current and wavelength. The tensile-strained bulk SOA has great potential for network device application, and this structure is also well suitable for monolithic integration.

Acknowledgements

The authors wish to thank Y. Yoshikuni for his discussions on device application. They are also grateful to H. Iwamura and Y. Hasumi for their continuous encouragement throughout this work.

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