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Increased Saturation Intensity and High-Input-Power Allowable InGaAs/InAlAs MQW Modulators Buried in Semi-Insulating InP

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1. Introduction

Very-high-speed, low-drive-voltage modulators take further advantage of the capacity of optical-fiber transmission systems. At present, however, the insertion loss for semiconductor modulators is relatively great (at least 8 dB) because of the large mode-mismatch to the single-mode fiber. Moreover, wavelength-division-multiplexing (WDM) systems require high input power allowance and wide wavelength-range operation. Reported modulators, whose reliabilitiy we are concerned about, are usually high-mesa structures, and the p-n junction is bare. We have succeeded in reducing the insertion loss[1] and increasing the input power allowance by using a thin, narrow waveguide composed of strain-compensated InGaAs/InAlAs MQWs and InP SIBHs. The resultant modulators are also noteworthy for their polarization-insensitivity and low chirp. This is the first systematic report on input power allowance for MQW modulators.

2. Device structure

An MQW structure with tensile-strained (-0.35/ -0.40 %) InGaAs wells 11-12 nm thick and compressive-strained (0.5 %) InAlAs barriers 5 nm thick was fabricated to keep the polarization sensitivity low and compensated for the strain. Very thin (0.09 μm thick) 6-period MQW layers and semi-insulating InP burying layers reduced coupling loss. Figure 1 shows a cross-sectional photograph of a fabricated modulator. The waveguide was 1.0 μm wide and 200 μm long, and its absorption wavelength was 1.48 μm. Compared with usual high-mesa structures, the waveguide width was half or one third. Combining dry and wet etching, we have succeeded in burying InGaAs/InAlAs MQW structures with semi-insulating InP. A small leakage current (2 nA at 2V) was confirmed, which indicates the high-quality of the buried heterostructure and the low level damage induced by reactive ion etching.

3. Modulator characteristics

The transmitted optical power from the modulator is shown in Fig. 2 for incident light wavelengths of 1.54, 1.55, and 1.56 μm and for both TE and TM polarization. Even for thin guide layers, extinction ratios over 20 dB have been achieved at the bias voltage of 2V. This is due to the highly efficient electroabsorption effect of tensilely strained quantum wells [2]. The polarization insensitivity (<1 dB) is obvious, and the mean insertion loss at 1.55 μm is 6 dB from fiber-to-fiber. Investigating the frequency response for the small signal modulation revealed that the 3-dB bandwidth was about 18 GHz. Clear eye-opening of 10 Gbit/s was confirmed. No frequency degradation associated with the input power saturation has been observed to the power level of 16 dBm in the fiber as shown in Fig.3.

The dependence of the chirp parameter α on the insertion loss with prebias is shown in Fig. 4, where α is almost zero at the low loss of 12 dB. The small α parameters at the small prebias condition will greatly improve transmission. .

Fig. 5 shows the input power allowance for various high-mesa and SIBH modulators. We clarified that the deterioration level is limited by the product of absorbed photocurrent and the applied voltage, and that it depends on the optical confinement factor. Compared with high-mesa structures, the SIBH can withstand high input power and were not observed to deteriorate to the greatest of the experimentally-obtained power level (20 dBm). These results indicate that the allowance strongly depends on thermal conductivity. The obtained results are superior to those reported for bulk SIBH modulators [3]. We believe this is due to the more efficient electroabsorption effect in the strain-compensated MQW structures.

In conclusion, we have developed a low insertion loss and high-input-power allowance electroabsorption modulator with strained compensated InGaAs/InAlAs MQWs using a thin, narrow waveguide and a semi-insulating buried heterostrucuture. This modulator also operates at polarization insensitivity and low chirp with low insertion loss. This is promising for multigigabit intensity modulation and direct detection optical transmission systems.

References

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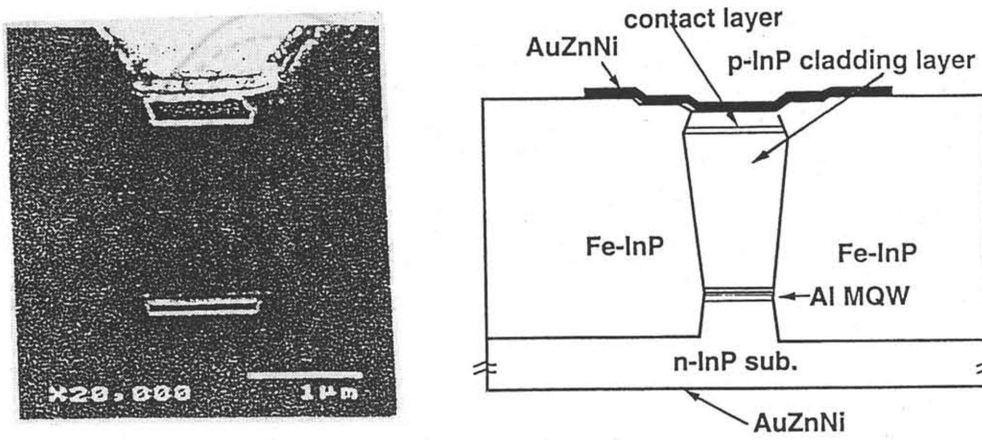

Fig. 1 A cross-sectional photograph of a fabricated modulator buried in semi-insulating InP.

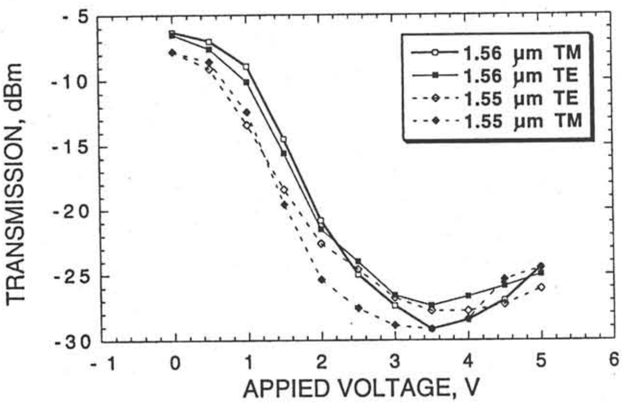

Fig. 2 Extinction ratio as a function of applied bias. Measured light is TE- and TM-polarized with wavelengths of 1.55 and 1.56 μm.

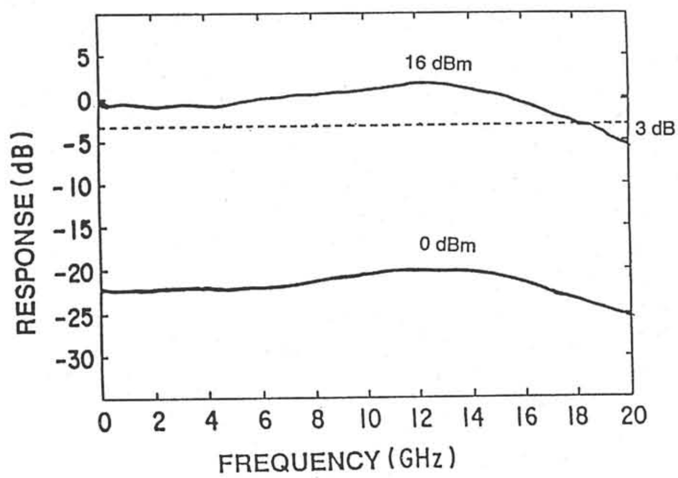

Fig. 3 Frequency response of modulators under input optical powers of 0 and 16 dBm.

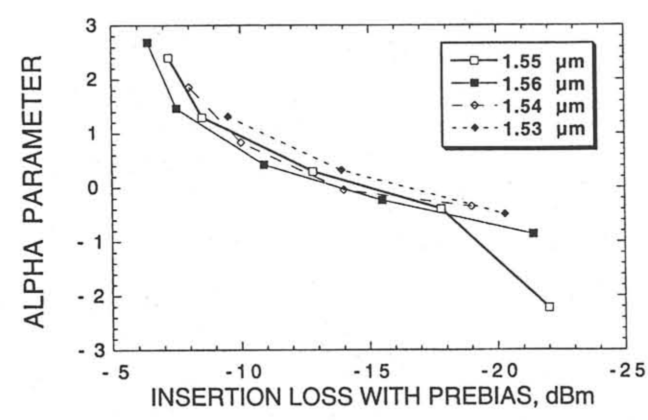

Fig. 4 Chirp parameter α as a function of insertion loss with prebias. Measured light is TE-polarized with wavelengths of 1.53, 1.54, 1.55, and 1.56 μm.

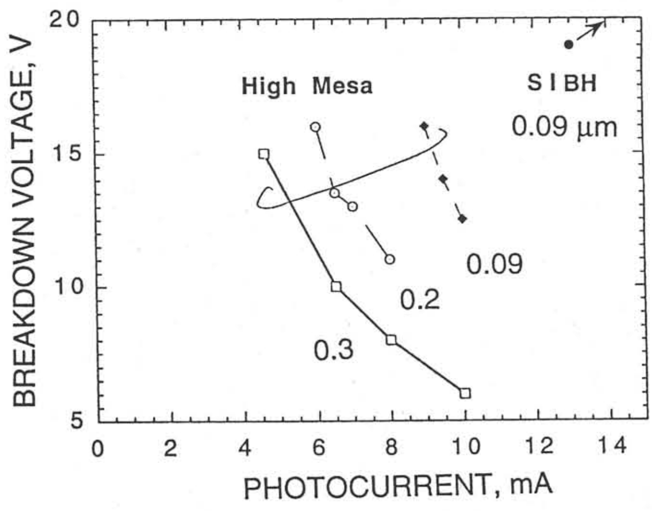

Fig. 5 Product of absorbed photocurrent vs. applied voltage for allowable input optical power. SIBH indicate buried heterostructure modulators. Numbers indicate the waveguide thickness.