INTEGRATED LASER/MODULATORS FOR HIGH CAPACITY WDM TRANSMISSION SYSTEMS

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ABSTRACT

Monolithically integrated electroabsorption modulated laser grown by selective-area epitaxy using MOVPE is a very essential source for multigigabit long-haul WDM transmission systems employing EDFAs. Such EML offers very low chirp, low drive voltage, long-term reliability and compact size.

INTRODUCTION

A dramatic increase has been achieved in loss-limited distance for multigigabit optical fiber transmission systems employing erbium-doped fiber amplifiers (EDFA). In such chirp-limited transmission, a low chirp transmitter in the 1.55 μm wavelength range is a very essential component. Therefore, very intensive efforts have been made on the integrated laser/modulator in which the distributed feedback laser is under cw operation and the electroabsorption modulator is encoded with high-speed signals. Such external modulation scheme significantly reduces the chirp compared with direct modulation of the laser diode. In addition to its low-chirp characteristic, such electroabsorption modulated laser (EML, as it is commonly referred to), offers compact size, low drive voltage and long-term stability.

Figure 1a shows schematically a transmission system using directly modulated DFB lasers. The repeater spacing at 2.5 Gb/s is typically about 40 km. Regenerators are employed for signal reconditioning. Employing EDFAs the system span can be extended to 360 km for practical system applications and 600 km in the laboratory demonstrations at 2.5 Gb/s. More importantly, an 8-channel WDM scheme has been employed to upgrade the system capacity of the existing networks which have non-dispersion-shifted fibers.

EML FABRICATION

EMLs have been demonstrated using etch-and-regrow [1] or butt-joined [2] processes, but these processes are complex and the introduction of additional regrown interfaces internal to the device poses reliability concerns. We focus on an EML fabricated using the selective-area MOVPE growth (SAG) technique [3, 5]. which results in a device with a continuous active layer and simplified processing. These devices show good reliability as well as excellent transmission performance.

Fabrication of the SAG-EML is by low pressure MOVPE. First, an etched grating is formed on the InP substrate, followed by a patterned $Si0_2$ layer, which is used to selectively protect the grating in the active region during mass transport smearing of the exposed grating, followed by removal of the $Si0_2$ and growth of an n-InP spacer layer. Next, another $Si0_2$ layer is deposited and patterned with two parallel stripes separated by a gap in the active region. The separate confinement waveguide and MQW active layers, consisting of 5 InGaAsP quantum wells and 1.28Q InGaAsP barriers, are formed during the SAG growth step, with the enhanced In concentration and quantum well thickness between the $Si0_2$ stripes resulting in a difference in bandgap energy between the laser and modulator. This is followed by the conventional capped- mesa buried heterostructure (CMBH) formation. Reactive ion etching is then used to electrically isolate the laser and modulator. Finally, ohmic contacts are formed, the chips are separated, and an AR coating is applied to the modulator facet. The completed SAG-EML is shown schematically in Fig. 2. The lengths of the DFB laser, isolation gap and modulator are 350, 100 and 200 μm.

DEVICE PERFORMANCE

Fig. 3 shows the light output-current characteristics for a fully packaged EML with optical isolator and fiber-pigtail. the different curves were obtained at different biased voltages applied to the modulator. Fig. 4 shows the extinction ratio as a function of applied voltages. The 3dB bandwidth of the package is typically 4.5 GHz. The time resolved wavelength chirp of the packaged EML was measured at 2.5 Gb/s NRZ modulation. The peak-to-peak wavelength deviation $\Delta\lambda < 0.02$ nm. Fig 5 shows an example having $\Delta\lambda = 0.008$ nm. The transmission performance was then measured over 517 km of standard fiber, with EDFAs spaced every 100 km. The dispersion penalty is only 1.2 dB at a BER of 10^{-10} as shown in Fig. 6.

With reduced modulator size, the 3 dB bandwith of the present SAG-EML device can be increased to 6.8 GHz. Eye diagrams were measured at 10 Gbit/s using a 2^{23}-1

PRBS signal with an amplitude of 3.4 Vp-p and a dc bias level of -1.9 V, giving a dynamic extinction ratio of 9 dB. The optical rise and fall times are 47 ps back-to-back (Fig. 7(a)). After transmission over 50 km of standard single-mode fiber, there is minimal excess distortion of the eye pattern, which is the result of low chirp modulation. 50 km is the dispersion limit of standard fiber at 10 Gb/s. The increase in noise is due to amplified spontaneous emission (ASE) from the 1480 nm-pumped EDFA, which is not filtered out. In system testing, a dispersion penalty of 2.4 dB is obtained at an error rate of 10^{-10}, as shown in Fig. 7(b). Better regenerator performance should be obtained by adding a filter to remove the ASE noise.

CONCLUSION

Monolithically integrated electroabsorption modulated laser grown by selective-area epitaxy using MOVPE is a very essential source for multigigabit long-haul WDM transmission systems employing EDFAs. Such EML offers very low chirp, low drive voltage, long-term reliability and compact size.

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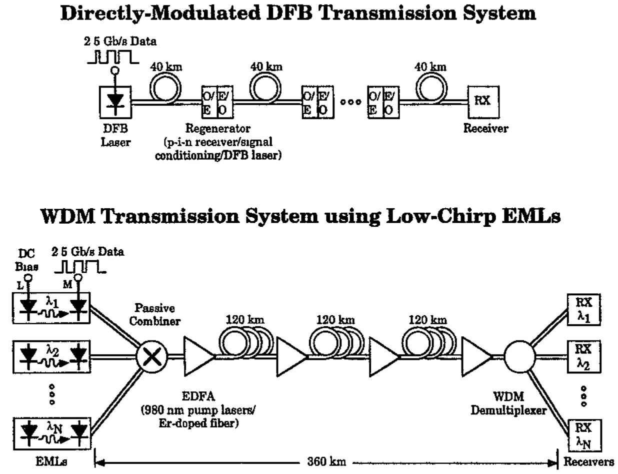

Fig. 1. (a) Directly modulated DFB transmission system.
(b) WMB transmission system using low-chirp EMLs.

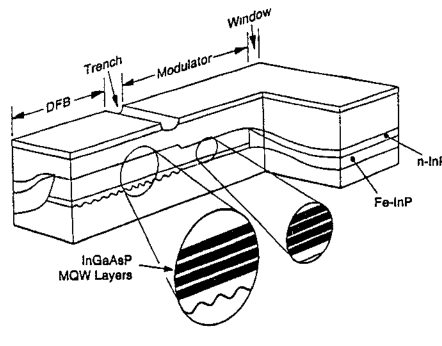

Fig. 2. Schematic illustration of the integrated EA modulatlr/DFB laser.

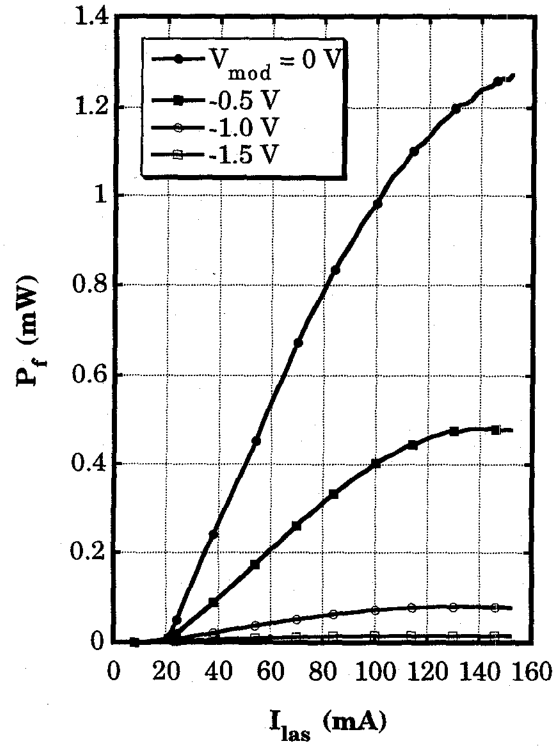

Fig. 3 Light-current characteristics at various modulator biased voltages of a fully packaged SAG-EML.

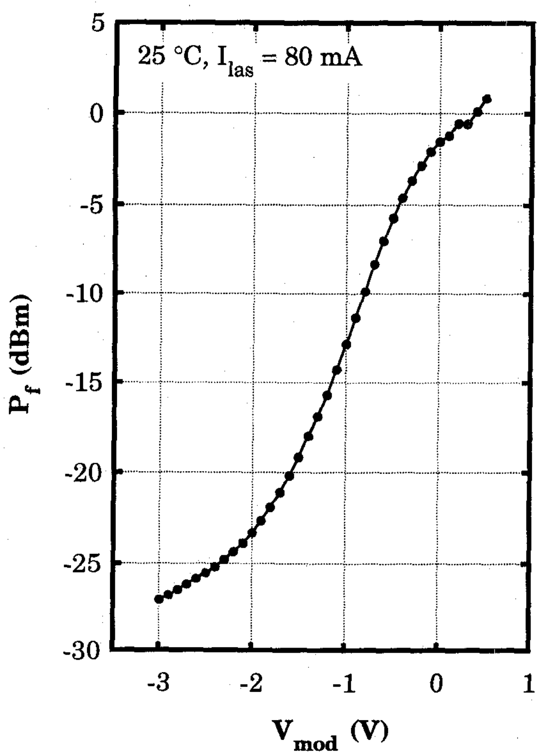

Fig. 4. The extinction ratio as a function of modulator voltage.

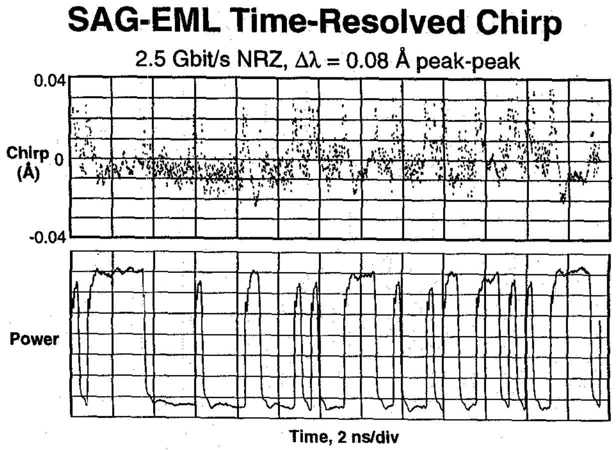

Fig. 5. The time-resolved chirp at 2.5 Gb/s for a packaged SAG-EML.

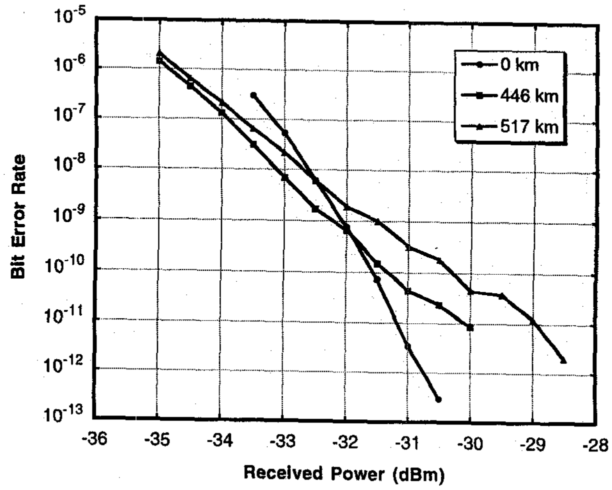

Fig. 6. The BER measurement at 2.5 Gb/s over standard fiber.

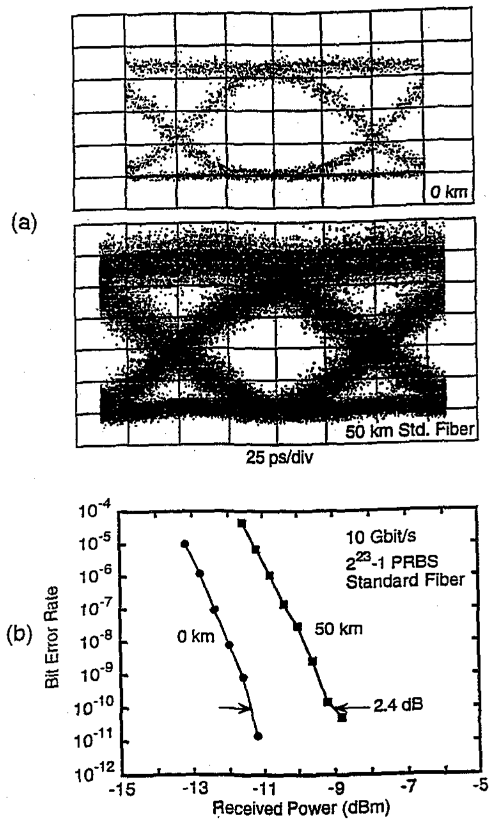

Fig. 7. (a)The eye-diagrams of a 10 Gb/s SAG-EML.
(b) The BER measurement at 10 Gb/s over standard fiber.