TuG1(Invited)
8:30am-10:00am

Low-Voltage Traveling-Wave Electroabsorption modulator

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Electroabsorption modulators (EAM) based on the quantum-confined-Stark (QCS) effect have attracted a lot of interest in optical fiber communication due to their integrability with lasers, high extinction ratios and low chirp. At high frequency, the performance of conventional lump-electrode EAMs is limited by the total parasitic capacitance of the device, thus the device length can not be increased to improve the extinction ratio and saturation power. Based on the distributed effects, traveling-wave EA modulators (TWEAM) have been proposed to eliminate the lumped-element limits [1-4]. In this paper, the practical issues of designing TWEAM for low-driving-voltage, high-speed and high-power operation are discussed.

Figure 1 shows the schematic diagram of TWEAM. Two CPW lines forming the traveling-wave circuit are used for the microwave power feed line and output impedance matching. The ridge is formed by reactive ion etching (RIE). Cladding layers of 1.7 μm p-InP (top) and 0.4 μm n-InP (bottom) are grown and sandwich the active region. As shown in figure 2, using InGaAsP strain-compensated multiple-quantum-wells (MQWs), it is allowable to increase well thickness to enhance the QCS effect, which leads to lower driving voltage. And also, decreasing the band offset to diminish the carrier blocking effecs, as a result, increasing the saturation power.

Figure 3 plots the measured microwave characteristics of p-i-n ridge waveguides (slow waveguide structures). Due to the highly loaded intrinsic capacitance (narrow i-layer) and the resistive p- and n- doped material, the waveguide suffers slower electrical velocity than the optical velocity, higher microwave propagation loss, lower characteristic impedance (<50Ω) than the CPW lines, which restrict the design. It is necessary to narrow the waveguide width in order to reduce the microwave propagation loss and veloctiy mismatch [4,5]. Terminating the right impedance in the output to diminish the reflections is necessary to optimize the bandwidth of long devices [4,5].

Devices with 2μm width were fabricated to test the travelling-wave electrodes. With 35Ω output impedance, over 20GHz bandwidth was achieved for 300μm and 500μm long devices, while less than 1 dB drop penalty at 20GHz for 500μm long device, indicating that the response is limited by microwave loss and velocity mismatch. To enhance the microwave characteristics, integrated tandem TWEAMs were used to generated high extinction ratio, high average power and short optical pulses in OTDM (optical time division multiplexing) , where a swithching window for > 100Gbit/sec (from 4 to 6 ps) was obtained [6]. Successful data transmission experiments at 30 Gbit/s have shown promising system performance with these devices[5]. As shown in figure4, low driving power (on/off ratio >20dB/V) with above 10 dBm saturation power were achieved from such kinds of TWEAMs.

[1]K. Kawano, et al, Electronics Lett 33,1580 1997.
[2]S. Z. Zhang et al., IEEE Photonics Technol. Lett. vol. 11 p. 191, Feb. 1999.
[3]G. L. Li, IEEE Trans. MTT-47, 1177 1999.
[4]S. Irmscher, 13th IPRM'01, WA3-3 2001.
[5]S. Z. Zhang et al., OFC/IOOC'99, p. 290 Feb.1999.
[6]K. Volkan IEEE Photo. Tech. Lett. vol 12, no 11, 2000

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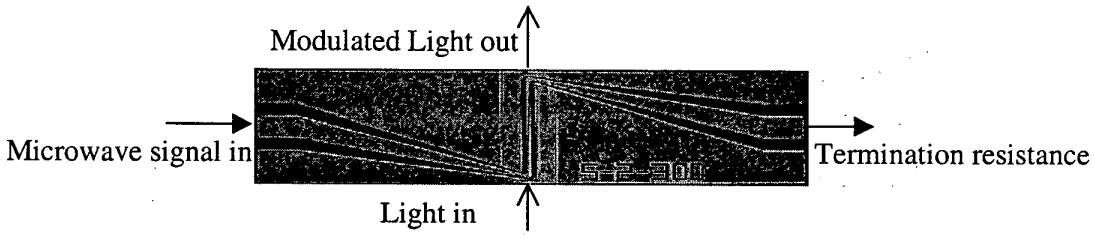

Figure 1. Top view of Traveling Wave EA-modulator

$$\Delta E \infty \frac{m^* e^2 F^2 L^4}{2}$$

Quantum confined Stark effect

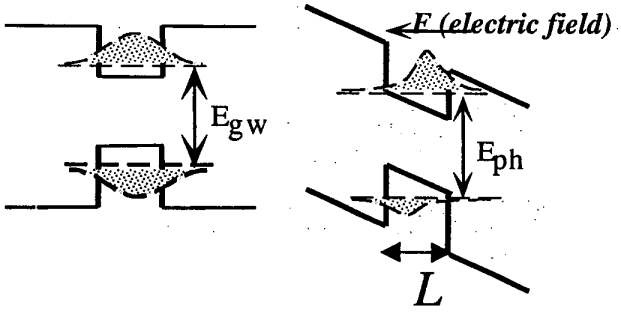

Figure 2. The schematic diagram of Quantum confined Stark effects.

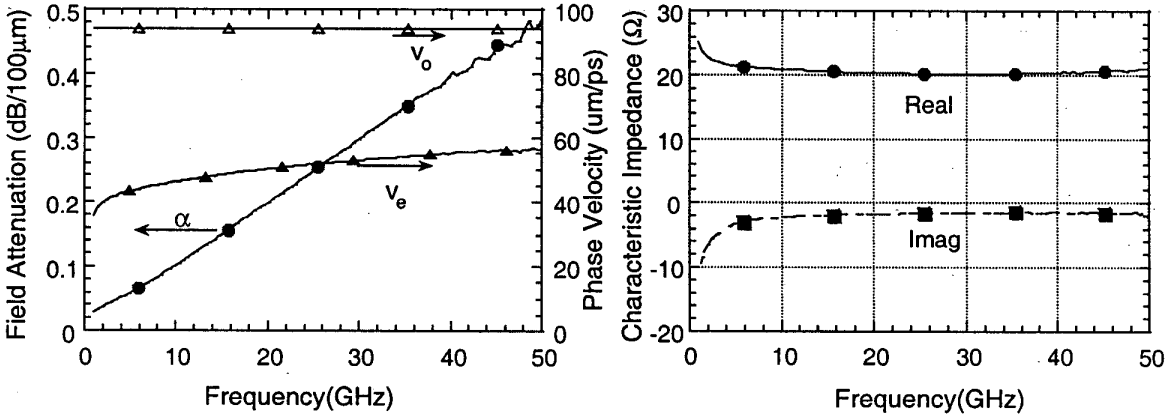

Figure 3. The microwave characteristics of p-i-n ridge waveguide (slow waveguide). The dimension is 2μ.m wide \with 2500nm thick intrinsic region.

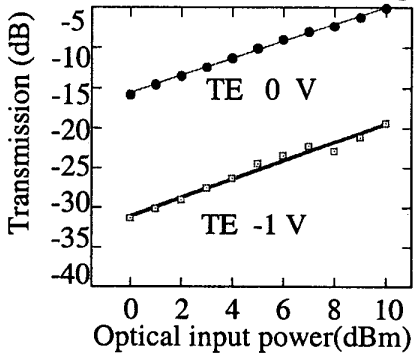

Figure 4. The optical transmission with optical input power at 1550nm. The linearity indicates that no power saturation was observed up to 10 dBm.