Standing-wave Enhanced Electroabsorption Modulator for 80Gb/s to 10Gb/s OTDM Demultiplexing

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Abstract *A novel standing-wave mode of operation of the electroabsorption modulator is proposed which reduces the required microwave driving voltage for error-free 80Gb/s to 10Gb/s OTDM demultiplexing.*

Introduction

Electroabsorption modulators (EAMs) have been demonstrated as efficient and compact data encoders, pulse generators, optical demultiplexers and clock-recovery components in many high-speed OTDM systems [1-2]. The compatibility with monolithic integration makes EAMs even more attractive in rendering cost-effective solutions [3]. Among all the applications, except for data encoding, the EAMs are operated mainly at one single electrical frequency which indicates the need to improve the narrow-band performance of EAMs. In this paper, we report on a novel standing-wave enhanced operation mode which can reduce the required microwave driving voltage for 10GHz operation. 80 to 10Gb/s demultiplexing is performed to demonstrate the improvement. Recently, we also used the standing-wave enhanced EAM as a demultiplexier in a label swapping experiment with 80Gb/s packets [4] and as a pulse generator at 40GHz [5]. Previously, 80 to 10Gb/s demultiplexing must be achieved with tandem EAMs [6] or a single EAM with a high bias and a high driving voltage [7].

Operation Modes

The EAM used in this work has traveling-wave electrodes (CPW lines) to overcome the RC time limitation [8]. The QWs are designed so that the TM mode has 20dB/V modulation efficiency in the 0 to 2V reverse bias region [9]. The TE mode is less efficient which causes some polarization dependence.

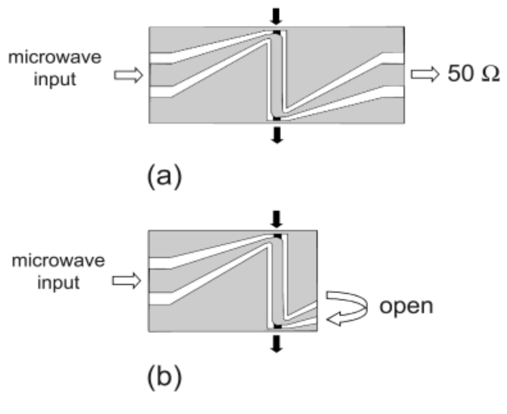

Figure 1: Schematic diagram of operation modes, (a) Traveling-wave mode, (b) Standing-wave mode. Solid arrows: Light propagation direction.

As shown in Fig. 1(a), in the traveling-wave mode, the EAM is terminated by a 50 Ω load. However, in the standing-wave mode, the 50 Ω termination is not applied and the CPW line is left open instead, as shown in Fig. 1(b). The applied microwave is reflected by the open and a standing-wave pattern is formed along the CPW line. Ideally, the amplitude of the microwave voltage swing at the open point can be doubled compared to the traveling-wave mode. The CPW line is cleaved shorter (~150µm) so that the active waveguide can be closer to the open ensuring the highest microwave voltage swing in this region. At 10GHz, the length of the active waveguide is 300µm which is only 1/20 of the microwave wavelength indicating that the voltage distribution is nearly even in the active waveguide.

The difference between the two operation modes is shown in Fig. 2, where the shortest pulse the EAM can generate is plotted as a function of the microwave driving voltage. The standing-wave mode generates shorter pulses than the traveling-wave mode at the same driving voltage until the decrease in pulse width saturates at high driving voltages. Very large driving voltages are not preferred because higher bias is required and the device might be driven to the breakdown region during part of the negative microwave swing which generates more heat.

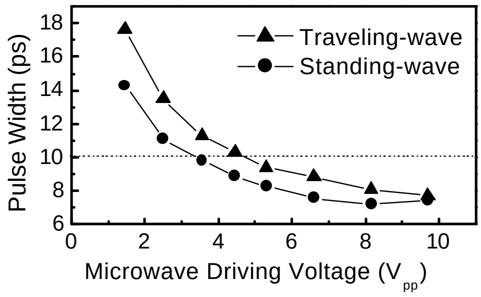

Figure 2: Shortest pulse generated as a function of microwave driving voltage

80 to 10Gb/s Demultiplexing

The performance of both operation modes are evaluated with a demultiplexing experiment shown in Fig. 3. The polarizations of the 8 channels are not

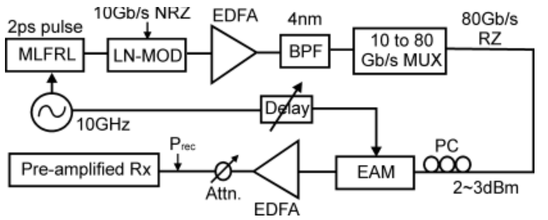

Figure 3: Experimental setup. MLFRL:mode-locked fiber ring laser at 1555nm; BPF: band-pass filter; PC: polarization controller

strictly controlled so that the gating window of the EAM must be short enough in both TE and TM modes to avoid inter symbol interference. The EAM operating conditions for demultiplexing can be obtained from the pulse generation results. Fig. 4 shows the pulse generation results for the standing-wave mode with a 6.7V_{pp} microwave drive and a 2dBm optical input at 1555nm. The bias voltage is chosen to be 4.5V so that both TE and TM modes have short enough

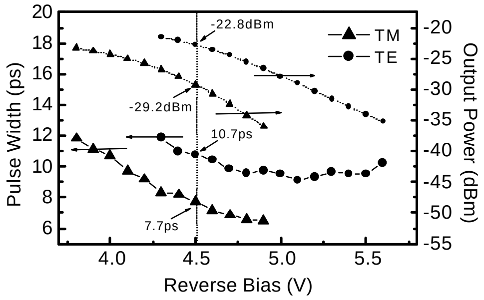

Figure 4: Standing-wave pulse generation with 6.7 V_{pp} microwave drive

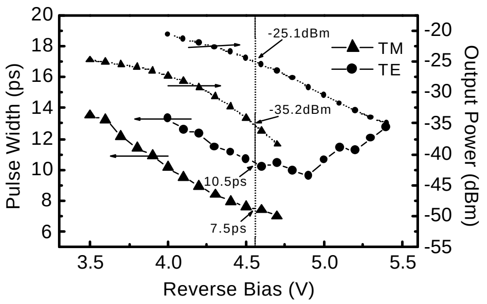

Figure 5: Traveling-wave pulse generation with 10 V_{pp} microwave drive

gating windows while giving the highest possible output power. The traveling-wave mode cannot generate a short enough gating window at 6.7V_{pp} in the TE polarization and a 10V_{pp} drive is required instead with 4.56V bias voltage as shown in Fig. 5.

Fig. 6 shows the bit-error-rate curves for the back-to-back and the 8 demultiplexed 10Gb/s channels

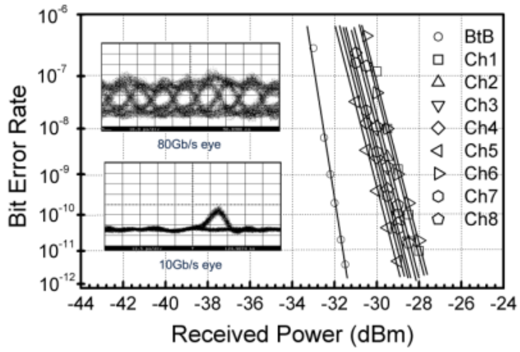

Figure 6: Bit error rate curves with 2^{31}-1 PRBS for back-to-back and the 8 demultiplexed channels. Inserts: the multiplexed 80Gb/s and the demultiplexed 10Gb/s eye diagrams

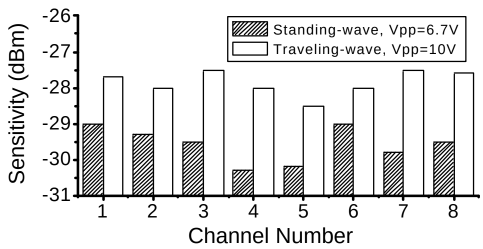

Figure 7: Comparison of receiver sensitivity for the two operation modes

with 2^{31}-1 PRBS data. The penalty of multiplexing and demultiplexing is about 2~3dB. Even lower driving voltage is possible if the polarization of all the OTDM channels is strictly controlled to the same state. Receiver sensitivity measurement is also performed for the traveling-wave mode and compared with the standing-wave results per channel in Fig. 7. The 1~2dB increase in power penalty for the traveling-wave mode is attributed to the 6dB decrease in the output power of the TM mode, which degrades the signal to noise ratio.

Conclusions

A novel standing-wave operation mode of the electroabsorption modulator is proposed to reduce the microwave driving voltage required for single frequency operation and is demonstrated in a 80 to 10Gb/s OTDM demultiplexing experiment to give lower power penalty with lower driving voltage.

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