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

Hsu-Feng Chou, Yi-Jen Chiu, and John E. Bowers
Ultrafast Optoelectronics Research Group, Dept. of ECE
University of California, Santa Barbara, CA 93106, USA, hubert@ece.ucsb.edu
Lavanya Rau, Suresh Rangarajan, and Daniel J. Blumenthal
Optical Communications and Photonic Networks Group, Dept. of ECE
University of California, Santa Barbara, CA 93106, USA

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.

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.
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 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 6.7Vpp 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 gating windows while giving the highest possible output power. The traveling-wave mode cannot generate a short enough gating window at 6.7Vpp in the TE polarization and a 10Vpp 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 with 231-1 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.

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.

References

4 L. Rau et al., OFC 2002, postdeadline paper, FD2-1
5 H.-F. Chou et al., CLEO 2002, paper CM12