EAM-based InP MZ modulator for 40-Gb/s PSBT using 20-Gb/s tributaries

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Abstract

We demonstrate a compact InP phase-shaped binary transmission (PSBT) modulator at 40 Gb/s. It consists of two electro-absorption modulators in a Mach-Zehnder configuration, each driven with 20-Gb/s tributaries with a half bit offset.

Introduction

The use of electro absorption modulators (EAM) integrated with distributed feedback (DFB) lasers has allowed compact form factor transceivers at 10Gb/s. Extending this approach to higher data rates such as 40 Gb/s has been problematic since dispersion limits the useful transmission distance and 40-Gb/s drive electronics are required. We demonstrate an EAM based modulator for 40 Gb/s that that addresses both issues while allowing simple direct detection by using the phase shaped binary transmission (PSBT), also called optical duobinary, format which encodes the data as 1,0,-1. This has been shown to provide high spectral efficiency and tolerance to dispersion [1], and unlike other spectrally compact formats such as differential quadrature phase-shift keying (DQPSK) requires only a single photodiode for detection. Previously PSBT has been generated by using a phase based Mach-Zehnder modulator (MZM), a full rate signal and low pass filtering it either using an external filter or by using the modulator itself as the low pass filter. Driving two 5-Gb/s tributaries with a half bit period offset onto the two arms of a LiNbO3 MZM allowing them to be multiplexed to 10Gb/s was also demonstrated [2], and although the format was referred to as NRZ it is actually PSBT format.

However, high-speed phase modulators require a traveling-wave structure, which has two main drawbacks. The first is that they are long, and a long structure consumes valuable chip real-estate and precludes the modulator from fitting inside a compact transceiver. The second drawback is that traveling-wave structures are demanding to design and fabricate and making potential integration with lasers more difficult.

The use of the electro-absorption (EA) effect in InP has been shown to overcome these limitations and allow the construction of high data rate DQPSK [3] and PSK modulators [4]. Here we show that that a similar approach can be used to create a PSBT data stream from two half rate tributaries.

PSBT EAM Modulator

It consists of EAMs in two arms of a Mach-Zehnder interferometer. The two outer arms with the EAMs have a 180° phase difference and the power splitting ratio is 50/50% as illustrated in figure 1. The EAMs are driven with independent data steams Data1 and Data2 which are offset by one half a bit period and are multiplexed by the modulator to produce PSBT. The modulator has 6dB of excess loss.

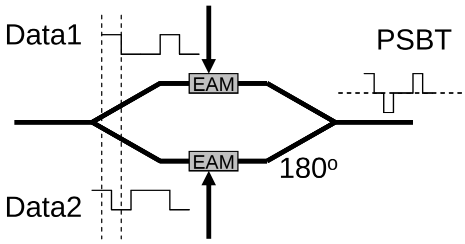

Figure 1: Schematic of EAM MZ for PSBT generation. There is a 180° phase shift between the arms and 50/50% power splitting ratios.

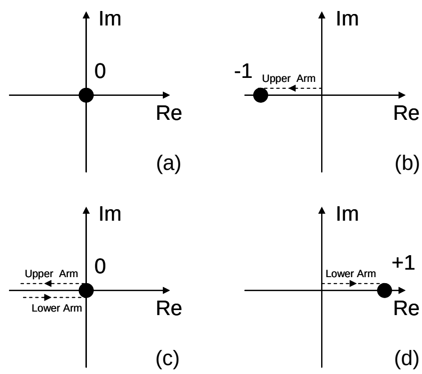

Figure 2 : Output states for (a) both arms off (b) upper arm on; (c) both lower and upper arm on and (d) lower arm on.

Figure 2 explains how the three PSBT symbols are achieved. The four states produced by turning on and off the two EAMs lie on the real axis of the complex plane and two are degenerate at zero. For example, when both EAMs are fully attenuating, the output is zero (a). Setting either EAM to transparency moves the phasor left (b) or to the right (d). Setting both to transparency moves the phasor to zero (c).

Since the upper and lower arms are run at half rate (20 Gb/s) and with a half bit (25 ps) offset only one of the arms can turn on or off during a bit period (40 Gb/s)

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For this initial demonstration a three arm MZM originally designed for DQPSK was used [3]. The center arm was completely attenuated by reverse biasing the phase shifter in the center arm using, and the outer arms phase shifters were forward biased to give 180 degree phase shift between the arms. Since the splitting ratio of this device was 37% this introduces an additional 2.6dB excess loss over the ideal case described above.

The waveguides are Benzocyclobutene-clad ridge waveguides with 10 quantum wells in a p-i-n structure. The QWs are 0.3% tensile strained with compressive strained barriers. For fabrication convenience, the composition is identical for both the EAMs and the passive waveguides. The EAM waveguide width is 1.8 um on the mask, and the length is 115 um.

Results

The chip was soldered to a sub-mount and packaged in a prototype package shown in figure 3 with two lensed fibers and 50-ohm terminated transmission lines.

All experiments were performed at room temperature. The waveguide loss is ~1 dB/mm at wavelengths well above the band edge. We launched a CW laser signal at 1545 nm into the modulator.

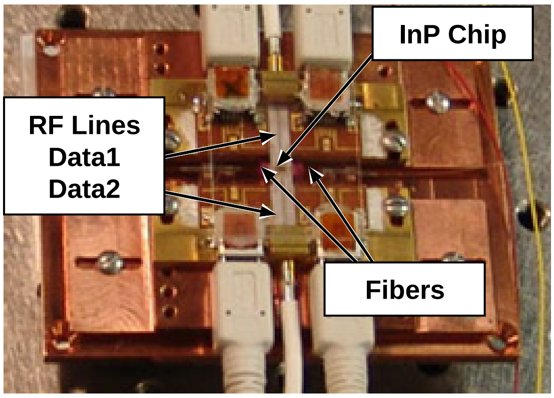

Figure 3 : Modulator in prototype package.

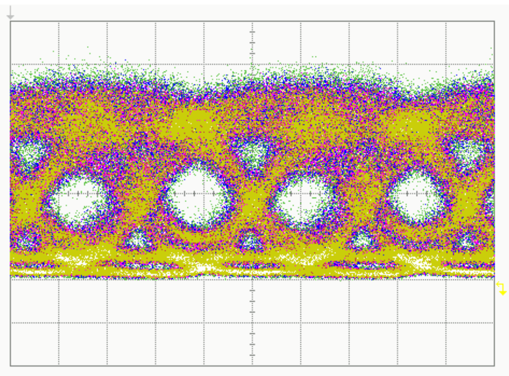

Figure 4 : Received eye from the 44Gb/s PSBT. 10ps/div.

The modulators were driven with inverted copies of a 22.0-Gb/s 2^{15}-1 pseudo-random bit sequence (PRBS), delayed by 15.5 bits with respect to each other. The driving condition was 5.5 V peak-to-peak with -2.4-V bias. The optical signal was detected by a 40-Gb/s pin photo-receiver and the eye diagram is shown in figure 4.

We adjusted the DC phase shifters to minimize the carrier in the optical spectrum as shown in Fig. 5 and open the demodulated eye diagram as much as possible. The received signal was electrically demodulated by a 4:1 demultiplexer, and the error rate was measured at 11.0 Gb/s using the expected pattern generated by the PSBT.

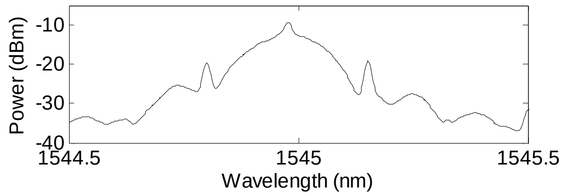

Figure 5 : Optical spectrum for the 44Gb/s PSBT.

The measured results are shown in Fig. 6. The performance was limited by one tributary which we attribute to imbalance between the EAMs. At the best optical signal-to-noise ratio (OSNR) (0.1-nm bandwidth) we could achieve, the error rate was ~1×10^{-8}. There is no apparent error floor.

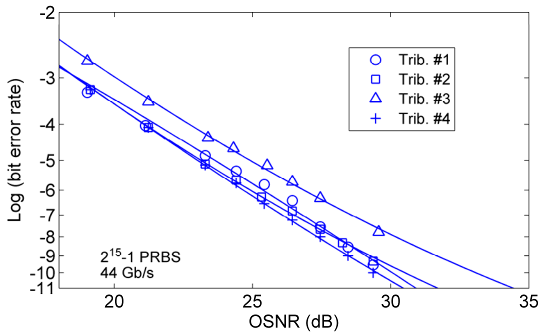

Figure 6 : BER as function of received OSNR.

Conclusion

We have demonstrated a compact EAM-based PSBT modulator for 40Gb/s operation that also acts as multiplexer for lower rate tributaries.

References

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