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Transmission of 10 Gbps Duobinary Signals Using an Integrated Laser-Mach Zehnder Modulator

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Abstract: Generation and transmission of 10 Gbps duobinary signals is demonstrated using an integrated widely-tunable SGDBR laser and Mach-Zehnder modulator over a wavelength range of 1538nm – 1564nm.

OCIS codes: (250.5300) Photonic Integrated Circuits; (060.2330) Fiber Optics Communications

1. Introduction

Duobinary modulation has the advantage of more compact modulated optical spectral width compared to standard NRZ modulation [1]. This provides improved dispersion tolerance and longer transmission distances over non-dispersion managed fiber. It also allows greater spectral efficiency, allowing closer spacing of optical channels, or reduced requirements for wavelength multiplexing components [2]. A second advantage is the possibility of using lower speed drive electronics to generate very high data rates, optical generation of up to 107 Gbps duobinary signals has been demonstrated [3]. Duobinary transmission using $LiNbO_3$ MZ modulators have been long demonstrated, allowing transmission of 10Gbps data over 200 km of standard singlemode fiber [4]. More recently, demonstrations using InP MZ modulators have been performed, demonstrating a similar performance with generally lower drive voltage [5,6].

In this paper, we demonstrate generation and transmission of 10 Gbps duobinary signals using an integrated widely-tunable SGDBR laser and Mach-Zehnder modulator over a wavelength range of 1538nm – 1564nm. This is the first demonstration of 200km reach with an integrated laser-Mach Zehnder (ILMZ). Previous work either did not use integrated devices [5,6] or it was performed using standard NRZ modulation with lower reach; 100km [7].

2. Device and Experiment

The device used in this work consists of a sampled-grating DBR laser integrated to an SOA and a dual-drive Mach-Zehnder modulator. All sections of the device are integrated onto one single Indium-Phosphide chip using an offset quantum-well structure to define sections with optical gain. The sampled-grating DBR laser can be tuned throughout the C-band and the integrated SOA provides power leveling over this wavelength range and compensates for cavity and modulator losses. The Mach-Zehnder modulator consist of two optical waveguide segments with RF electrodes situated in-between two multimode interference couplers. More details of this type of device can be found in [7] where transmission of negative-chirp 10 Gbps NRZ signals over 100km standard singlemode fiber was demonstrated.

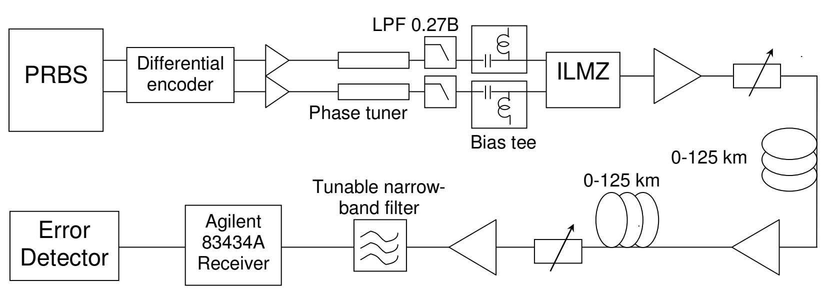

Fig. 1. Schematic of experimental arrangement used to generate and transmit 10 Gbps duobinary modulation using the integrated SGDBR laser – Mach-Zehnder modulator

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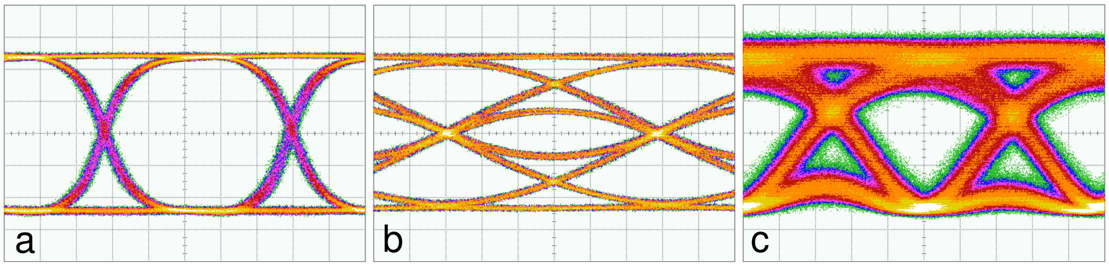

Fig. 2a: Eye diagram of output of PRBS. 2b: filtered electrical duobinary drive signal. 2c. Corresponding optical eye.

Figure 1 shows the experimental arrangement used to generate and transmit the 10 Gbps duobinary optical modulation. The two complementary outputs from a 10 Gbps pseudo-random bit sequencer (PRBS) were differentially encoded, amplified and synchronized. Figure 2a shows that output eye diagram of the PRBS. A 0.27B risetime filter (156ps risetime) was used to filter the NRZ eye diagram and to generate the duobinary drive signal shown in Fig. 2b. After push-pull drive of the InP modulator (2x3.6V) the optical eye is formed and shown in Fig. 2c. The optical signal was transmitted through up to 250km of standard singlemode fiber (200km Corning SMF-28, 50 km Lucent SMF). Booster, inline and receiver optical amplification were used where required.

3. Results

Figure 3 shows captured eye diagrams after transmission through 0km to 250 km of standard singlemode fiber at 1551nm wavelength. Open eye diagrams are obtained at 250km. At transmission distances above 200km, the required launch power was in the 10 dBm range which causes pulse compression and a corresponding shift in power penalty compared to purely dispersion limited performance.

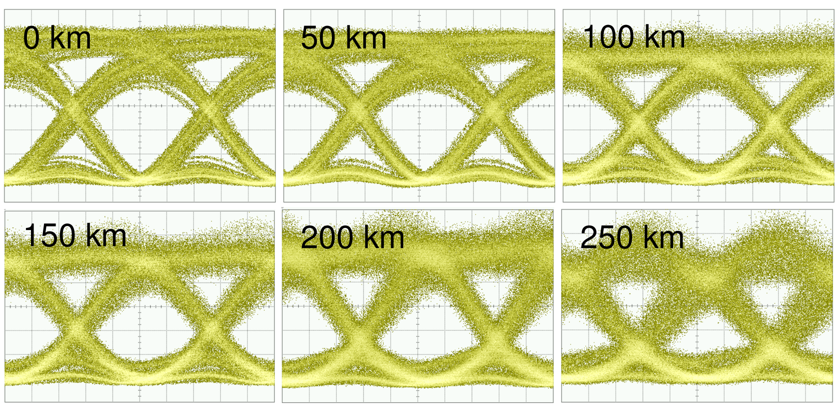

Fig. 3: Received optical eye diagrams at 1551nm after transmission through 0km, 50km, 100km, 150km, 200km and 250 km fiber, respectively.

Figure 4, left shows bit-error-rate performance for 0-250km transmission distance at 1551 nm wavelength using a 2^7-1 PRBS signal. Error-free transmission using long word-lengths (eg. 2^{31}-1) was not possible. The exact cause for this has not been established, but several factors can contribute, including electrical or optical crosstalk, thermal effects, or pattern dependence in the electronic drive circuitry. The receiver sensitivity varies over a ~2dB range with a small further degradation at 250km transmission. The lowest penalty was observed in the 100km-150km range. No error floor could be detected at any transmission distance.

The fiber transmission performance was also verified at the lower and higher end of the laser tuning range, 1538nm, and 1568nm respectively. The power penalty at a BER of 10^{-9} versus transmission distance for all three wavelengths is summarized in fig. 4, right. A similar trend in power penalty can be observed over all wavelengths with a mid-range optimum around 100-150km. Indications of better performance at longer wavelengths can be observed, both in the point of lowest power penalty and the transmission penalty at 250 km.

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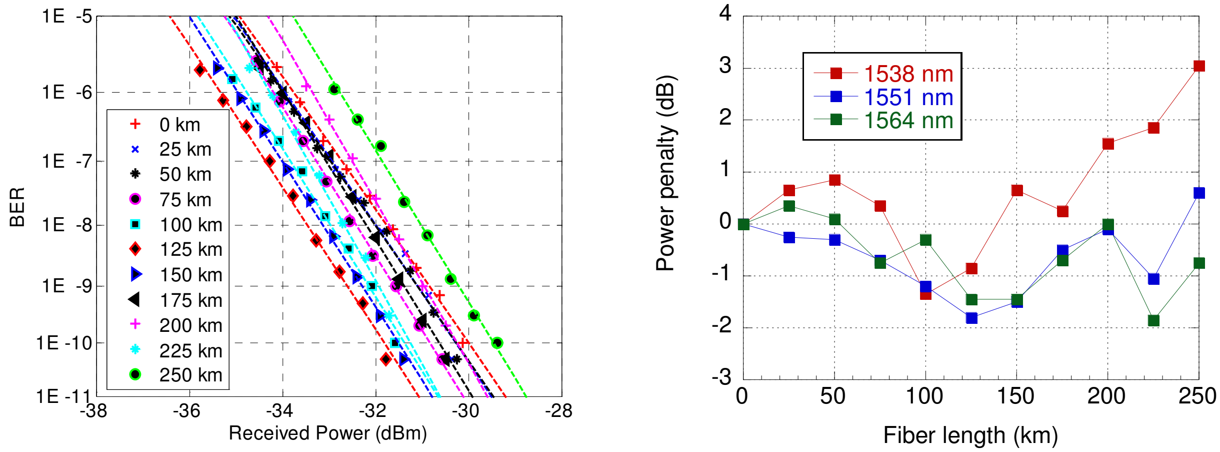

Fig. 4: Left: Detected error rates at the preamplifier optical receiver at 1551nm for different fiber transmission distances. Right: equivalent power penalty at a BER of 10^{-9} at 1538nm, 1551nm and 1564 nm optical wavelength.

4. Conclusion

We demonstrated generation and transmission of 10 Gbps duobinary signals using an integrated widely-tunable SGDBR laser and Mach-Zehnder modulator over a wavelength range of 1538nm – 1564nm. Transmission up to 250 km of standard singlemode fiber with low power penalty and no error floor was achieved. This is the first time an integrated laser-Mach Zehnder is used to transport 10 Gbps signals over 200km of standard singlemode fiber.

5. References

[1] X. Gu and L. C. Blank, “10 Gb/s unrepeatered three-level optical transmission over 100 km of standard fiber,” Electron. Lett., vol. 29, pp. 2209–2211, 1993.

[2] M. Duelk, J. Cripp, J. Simsarian, A. Bhardwaj, P. Bernasconi, M. Zirngibl, 0. Laznicka "Fast Packet Routing in a 2.5 Tb/s Optical Switch Fabric with 40 Gb/s Duobinary Signals at 0.8 b/s/Hz Spectral Efficiency," in Optical Fiber Communication Conference on CD-ROM (Optical Society of America, Washington, DC, 2003), PD8-1.

[3] P.J. Winzer, G. Raybon, M. Duelk, "107-Gb/s optical ETDM transmitter for 100G Ethernet transport," 31st European Conference on Optical Communication, 2005. Vol. 6, pp:1-2, 25-29 Sept. 2005.

[4] K. Yonenaga and S. Kuwano, "Dispersion-Tolerant Optical Transmission System Using Duobinary Transmitter and Binary Receiver," IEEE J. Lightwave Technol., vol. 15, no. 8, pp. 1530-1537, 1997.

[5] R. A. Griffin, A. Tipper and I. Betty, "Performance of MQW InP Mach-Zehnder Modulators for Advanced Modulation Formats," in Optical Fiber Communication Conference on CD-ROM (Optical Society of America, Washington, DC, OFC 2005), OTuL5.

[6] Takeshi Kurosaki, Yasuo Shibata, Nobuhiro Kikuchi, Ken Tsuzuki, Wataru Kobayashi, Hiroshi Yasaka, and Kazutoshi Kato, "200-km 10-Gbit/S Optical Duobinary Transmission Using An N-I-N Inp Mach-Zehnder Modulator," 2007 International Conference on Indium Phosphide and Related Materials, Matsue, Japan, 14-18 May, 2007, WeBI-3.

[7] Y. A. Akulova, G. A. Fish, P. Koh, P. Kozodoy, M. Larson, C. Schow, E. Hall, H. Marchaod, P. Abraham, L. A. Coldren, "10 Gb/s Mach-Zehnder modulator integrated with widely-tunable sampled grating DBR Laser," in Optical Fiber Communication Conference on CD-ROM (Optical Society of America, Washington, DC, 2003), TuE4.