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Published in:
Technical Digest Optical Fiber Communication Conference 2004

Link to article, DOI:
10.1109/OFC.2004.1359236

Publication date:
2004

Document Version
Publisher's PDF, also known as Version of record

8×40 Gb/s RZ all-optical broadcasting utilizing an electroabsorption modulator

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Abstract: We experimentally demonstrate all-optical broadcasting through simultaneous 8×40 Gb/s wavelength conversion in the RZ format based on cross absorption modulation in an electroabsorption modulator. The original intensity-modulated information is successfully duplicated onto eight wavelengths that comply with the ITU-T proposal. The advantages of the proposed wavelength conversion scheme are discussed.

OCIS codes: (070.4560) Optical data processing, (060.2360) Fiber optics links and subsystems

1. Introduction

The electroabsorption modulator (EAM) has proven to be a versatile component in ultra fast WDM and OTDM systems with its ability to perform several different functionalities, combined with advantages such as simple structure, compactness, suitability for integration, low power consumption and environmental stability. Recently, various all-optical functionalities based on cross-absorption modulation (XAM) [1] have been demonstrated, such as demultiplexing [2,3], wavelength conversion [4,5] and all-optical regeneration [6-8].

As to wavelength conversion, investigations have so far focused on only one converted wavelength. In advanced WDM networks, however, applications like network broadcasting require a multi-wavelength optical data source. In this paper we report, for the first time to the best of our knowledge, on an EAM-based multiple wavelength conversion scheme where eight WDM channels are data-encoded simultaneously by an OTDM RZ signal at 40 Gb/s through XAM in an EAM. All the wavelength-converted channels, which comply with the ITU-T proposal for the WDM wavelength grid, show clear and open eyes with an error free bit error rate (BER) performance.

2. Experimental setup

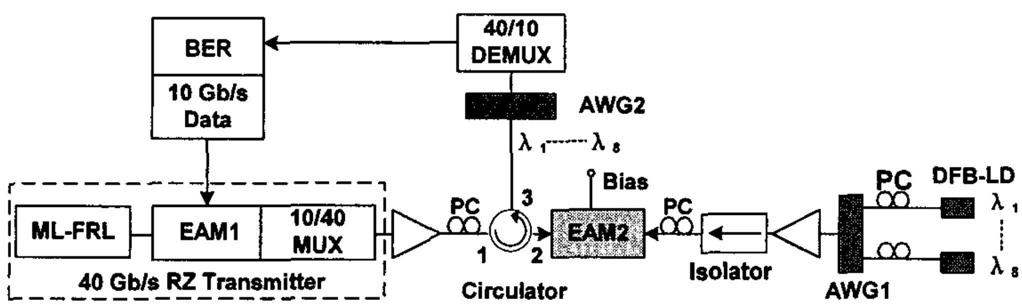

Fig. 1 The experimental setup.

The experimental setup is shown in Fig. 1. The outputs of eight distributed feedback lasers (DFB-LD) at a wavelength spacing of 1.6 nm are combined in an arrayed-waveguide grating (AWG) 1. These lasers operate at the ITU-standardized wavelengths. The wavelengths are 1549.31 nm (λ1), 1550.90 nm (λ2), 1552.52 nm (λ3), 1554.12 nm (λ4), 1555.72 nm (λ5), 1557.33 nm (λ6), 1558.96 nm (λ7) and 1560.60 nm (λ8). The combined signals of the eight channels are amplified to an average power of 15 dBm, and injected into EAM2 from the right port. The control laser is a mode-locked fiber ring laser (ML-FRL) operating at 1545 nm, which generates 2.5 ps (FWHM) pulses with a repetition rate of 10 GHz. The control pulses are modulated in a packaged electroaborption modulator (EAM1) by a pseudorandom bit sequence (PRBS) of length 2^{15}-1 from a 10 Gb/s pattern generator, resulting in an RZ data signal at 10 Gb/s which is then optically multiplexed to 40 Gb/s by a fiber-based timing interleaver. The generated 40 Gb/s signal is amplified to an average power of 16 dBm, and injected into EAM2 from the left port.

Due to the counter-propagating configuration used for EAM2, an isolator (right side) and an optical circulator (left side) are used. The 3rd output of the circulator is connected to another commercial AWG2, which selects out each wavelength from the combined WDM signal. The converted signal occupying one wavelength is afterwards demultiplexed back to 10 Gb/s by a nonlinear optical loop mirror (NOLM), which consists of 500 m highly non-linear dispersion-shifted fiber (HN-DSF). A pre-amplified receiver is used for BER measurement.

The EAMs used in this paper are multiple-quantum -well (MQW) devices, which are 150 μm long and consist of 15 quantum wells.

3. Experimental procedures and results

In our experiment two tapered fibers are used to couple light into and out of EAM2. Having optimized the coupling between EAM2 and the tapered fibers at 1550 nm, the fiber-to-fiber loss at zero bias is about 10 dB. The static transfer curve (transmittance as function of bias) is a quasi-linear curve up to about -2.5 V with a slope of –9 dB/V. The bias of EAM2 is set to –2 V in the experiment yielding a potentially high saturation induced extinction ratio (ER).

The polarizations of the eight channels are optimized individually by use of eight polarization controllers (PC). The polarization of the control signal is adjusted by its own PC and remains unchanged once optimized.

Fig. 2 depicts the spectrum of the eight channels in three cases: (a) at the input of EAM2, (b) at the output of EAM2 with the control signal and (c) at the output of EAM2 without the control signal. It is clearly seen that in the presence of the control signal all channels are modulated due to XAM and each acquires a broadened spectrum as shown in Fig. 2 (b). In case of no control signal, we find new frequency components at the output of the EAM as shown in Fig. 2 (c). The new components are the fingerprint of Four Wave Mixing (FWM) in the EAM; they are 30 dB weaker than the original signals, and hence their impact is negligible.

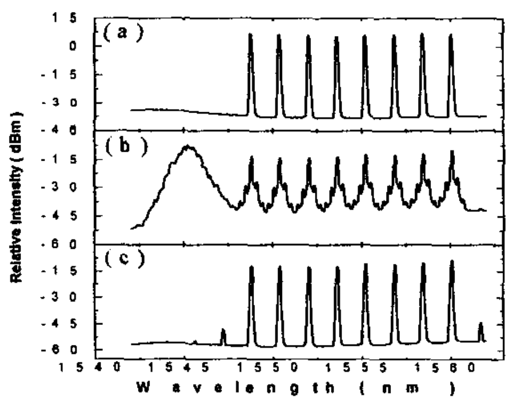

Fig. 2 Spectra of the WDM signals at (a) input of EAM2, (b) output of EAM2 with the control signal injected, (c) output of EAM2 without control signal.

As an example, we display in detail the performance of one channel at 1555.7 nm in Fig. 3, where the bit-error-rates of the original signal (back-to-back) and the converted signal at 10 Gb/s are depicted. The inserts of Fig. 3 show the spectrum and the eye diagram of the converted signal (at 40 Gb/s and 10 Gb/s), as well as the eyes of the control signal (at 10 Gb/s and 40 Gb/s). It can be seen that AWG #2 filters out one wavelength with a side mode suppression ratio larger than 30 dB. The converted signal has clear and open eyes which are comfortably error free. The BER measurement shows that the converted signal at 1555.7 nm has no error floor but indicates a power penalty of 8 dB compared to the control signal. This penalty is mainly due to the reduced optical signal-to-noise ratio (OSNR) resulting from the insertion loss of the EAM, but is also due to the decreased ER stemming from the insufficient cross absorption modulation in the EAM.

The 40 Gb/s eye diagrams of all the eight channels are displayed in Fig. 4, where the receiver sensitivities at different wavelengths are depicted for an overview comparison. It is found that all the converted channels have clear and open eyes and are error free. We also find that the wavelength near 1555 nm has the best receiver sensitivity as suggested by the valley shown in Fig. 4. This can be understood by the fact that EAM2 used in this experiment has the optimum performance near 1555 nm considering the tradeoff between the static ER and the insertion loss.

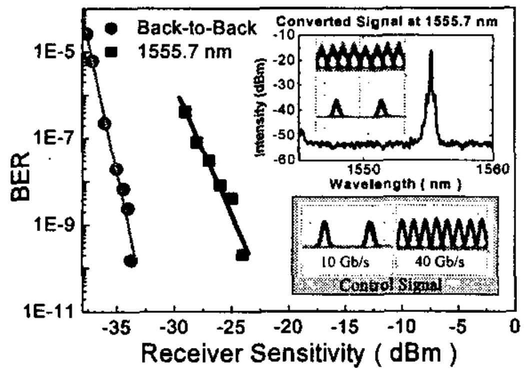

Fig. 3 The BERs of the control signal and the converted signal at 1555.7 nm. The inserts show the spectrum and the eye diagram of the converted signal, as well as the eye diagram of the control signal.

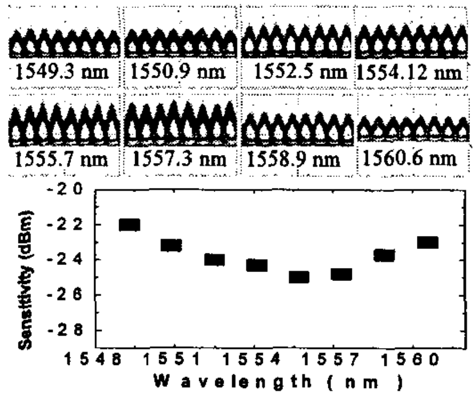

Fig. 4 Receiver sensitivity and 40 Gb/s eye diagrams of all the converted signals.

4. Discussion

Compared to a NOLM-based solution [9], an EAM offers several advantages like potential for compactness, suitability for integration as well as stability against environmental conditions such as temperature drifts and vibrations.

The receiver sensitivity of the converted signals could be improved by reducing the insertion loss of the EAM, which would increase both the OSNR and XAM efficiency by getting more useful power into and out of the device.

5. Conclusion

We have experimentally demonstrated all-optical broadcasting through 8×40 Gb/s wavelength conversion in the RZ modulation format using the XAM effect in an EAM. Our results suggest that an EAM is a promising component for all-optical processing in coming photonic networks.

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