10 Gb/s RSOA Transmission by Direct Duobinary Modulation

M. Omella, V. Polo, J. Lazaro, B. Schrenk and J. Prat
Universitat Politècnica de Catalunya (UPC), Dept. of Signal Theory and Comm., mireia.omella@tsc.upc.edu

Abstract *An ultra low-cost electronic solution to achieve 10 Gb/s transmission by means of passive equalization and duobinary encoding using an RSOA with 1.5GHz electrical bandwidth is demonstrated.*

Introduction

Next generation FTTH passive optical networks (PONs) depend on the availability of low cost broadband ONUs that can operate in a wide wavelength range. A first candidate for it is the reflective semiconductor optical amplifiers (RSOA) since combines optical broadband amplification, remodulation capability and integration [1]. However, its modulation bandwidth may not be sufficient for the next step in the PON standard bit rate of 10 Gb/s, that is being proposed in both FSAN and IEEE bodies. To overcome its bandwidth limitation, some techniques can be applied; we propose here to apply simple electronic techniques that do not require optical elements and maintain the colourlessness: passive pre-equalization and duobinary encoding techniques, with the aim of reaching higher bit rate with direct modulation and direct detection. In literature, duobinary has been demonstrated as an alternative to NRZ due to its reduced bandwidth requirement with external modulators and also for direct modulated sources [2-4].

Set-Up description

The system corresponds to the up-stream transmission of a WDM-PON with ONU based on RSOA and focuses on the RSOA modulation bandwidth enhancement. The scheme of the test set-up is shown in Fig.1. A variable length of fibre for unidirectional transmission (L-km) and 1 km of bidirectional fibre link has been set according to the fibre distribution in the network in [1]. We have set the resultant electro-optic frequency response to a 4th order Bessel filter type, whose 3-dB bandwidth matches $0.25R_b$ in the duobinary case. Now, the device bandwidth requirement is strongly reduced compared to the standard $0.75R_b$ bandwidth. At the receiver side, the binary signal is recovered by means of an electrical full-wave rectifier, and the output signal is lead into the error detector (ED).

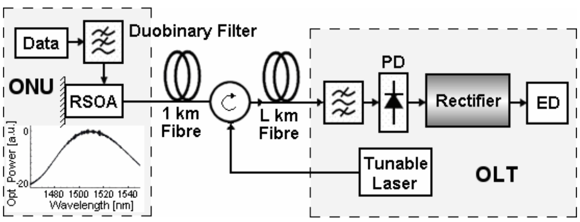

Fig. 1. Scheme of the simplified duobinary system. The inset shows the gain spectrum of the RSOA.

Experimental results

For the experiment, we use an Alcatel-Thales III-V Labs RSOA module (R-SOA-0603) with 18 dB peak gain at 1510 nm and 1.5 GHz modulation frequency cut-off. Fig.2 presents the measured electrical bandwidth of the RSOA and the eye diagrams with and without electrical equalization. It has been biased with 62mA DC current and modulated with a current of ±25mA. Considering this E/O response, and the RSOA impedance, a passive microstrip RLC pre-equalizer is optimized for the combination of the RSOA and the electrical filter produces a resulting electro-optic bandwidth adjusted to match the response of a 2.5GHz cut-off 4th order Bessel filter, which allows the binary signal to be converted into duobinary three-level signal for transmission at 10Gbps. The low and higher frequencies are attenuated as shown in Fig.2, increasing the bandwidth from 1.5 to 2.5 GHz.

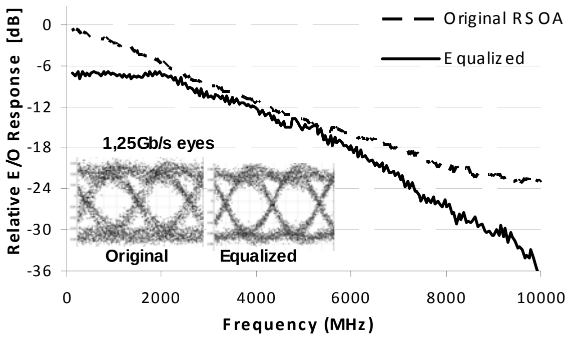

Fig. 2. E/O frequency response of the RSOA, with and without passive equalizer, at 1535nm.

An APD module with a sensitivity of -27dBm is used as the receiver photodetector. The implemented full-wave rectifier is based on a couple of balanced high frequency diodes, and a highly linear differential amplifier. The obtained 2.5Gb/s and 5Gb/s eye diagrams after transmission along L=10km of fibre link are shown in Fig.3. For the same experimental conditions, the duobinary 3-level eye diagram is naturally obtained due to strong filtering as shown in Fig.4 (left) and the binary signal at 10Gb/s after the rectifier in Fig.4 (right). Neither optical amplifier nor narrow optical filter is used for this experiment.

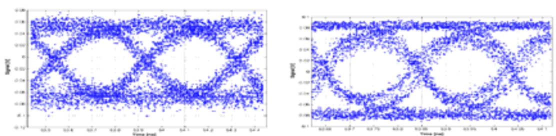

Fig.3. Eye diagrams for 2.5Gb/s and 5Gb/s after a 10km fibre link.

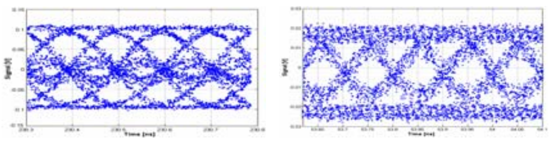

Fig.4. Duobinary transmitted signal and its detected eye diagrams at 10Gb/s after a 10km fibre link.

978-1-4244-2229-6/08/$25.00 ©2008 IEEE

The summary of the measured bit error ratio (BER) from 1.25Gb/s up to 10Gb/s is presented in Fig.5. In back-to-back, using a variable attenuator at the RX input, the electrical equalizer penalizes the sensitivity with 2 dB for the 1.25Gb/s transmission relative to the original RSOA response, due to the amplitude reduction in the low frequencies once the bandwidth has been enhanced. The penalty for 2.5Gb/s is 3dB as it is expected because of doubling the bit rate, while it is up to 11dB for 5Gb/s. At 10Gb/s, the rectifier is inserted, and 16dB penalty is obtained for the duobinary signal (D+EQ in the legend). The duobinary penalty is higher due to the compression of the signal. No BER floor is found in any case.

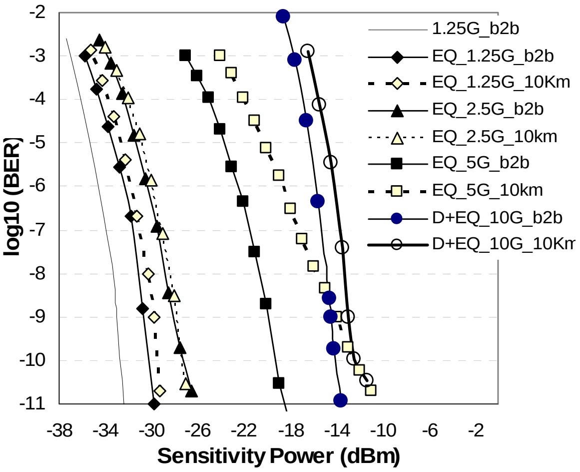

Fig.5. Bit error ratio as function of the bit rate for back-to-back transmission and over 10km SMF at a wavelength of 1535nm, with and without equalizer and duobinary decoding.

On the other hand, the penalty due to the fibre link is negligible up to 2.5Gbps as it is expected, while it becomes important for 5Gb/s due to the broadening of the signal spectrum. The transmission over the 10 Km fibre link at 5Gb/s leads to a penalty of 6dB, while for the 10Gb/s it is only 1.5dB. The 5Gb/s binary and 10Gb/s duobinary signals have the same signal spectrum bandwidth of about 5GHz as it is explained in [spectral]and they lead to almost the same sensitivity level for the 10km fibre link.

Nowadays, RSOA technology centres the maximum gain of the device in the lower wavelength range outside of the C-band which results into a drawback to achieve good transmission performance in the channels according to the DWDM grid. At 1535nm, we have measured a 3dB penalty in the BER for 2.5Gb/s transmission with respect to 1510nm, where the device exhibits its best performance, while it rises up to 7dB for 5Gb/s. This wavelength dependence limits the gain and therefore the reachable length of the fibre link, creating also a dependence on the optical input power. Next generation devices are going to be designed for this application.

In Fig.6 the sensitivity of the RSOA device over the standardized bit rates is presented for several fibre links. We have achieved transmission up to the standard maximum of 20km at 2.5Gb/s. The 5Gb/s and the duobinary 10Gb/s transmission allow to achieve a few more than 10+1km with this set-up.

Fig.7 shows the sensitivity of the RSOA device as a function of the bit rate for several optical input power values of the RSOA. From the measured results we can conclude that the RSOA presents good performance at 1.25Gb/s and 2.5Gb/s even for the lower input power of -20dBm, while it demands higher input power to transmit at 5Gb/s and even more (P_{in} = -10 dBm) to permit 10Gb/s transmission.

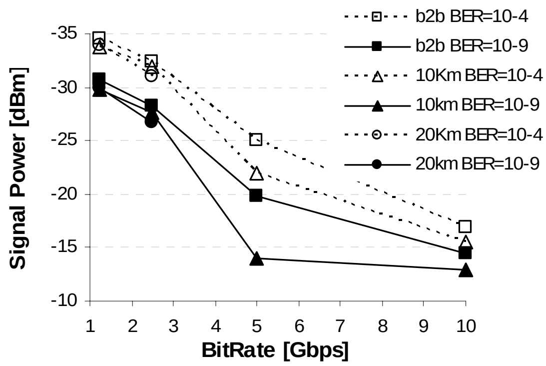

Fig.6. Sensitivity versus bit rate as a function of the fibre length for BER=10^{-9} and BER=10^{-4}.

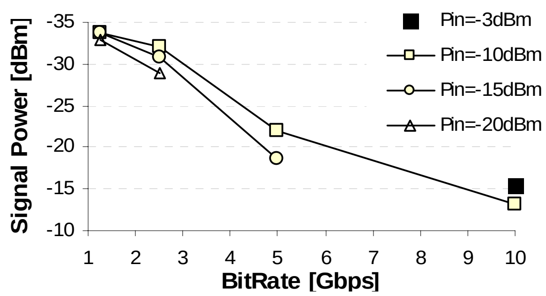

Fig.7. Sensitivity versus bit rate as a function of the RSOA input power for BER=10^{-4}.

Conclusions

For the first time an ultra low cost implementation of 10Gb/s transmission by direct modulation of a RSOA with simple electronic equalization has been proposed and demonstrated. The work shows that duobinary encoding together with passive electronic pre-equalization is feasible for applications in access networks. The RSOA limits due to the nowadays SOA technology have been analyzed considering the bit rate, the fibre link length and the optical input power.

This work was supported by the FP7 European SARDANA project, the Spanish MEC Ramon y Cajal Program and the MEC PTA-2003-02-00874 grant. The authors wish to thank Alcatel-Thales III-V Lab for the technical resources.

References

1. J. A. Lazaro et al., ECOC2007, Proc.6-4-3, vol. 3, pp. 93.
2. J. Prat et al., Electronics Letters, vol. 42, no. 10, pp. 591, 2006.
3. Gene et al. Photonics Technology Letters, vol. 16, no. 1, pp. 311, Jan. 2004
4. Shtaif et al. Photonics Technology Letters, vol.11 no. 6, 1999.