Transmission Performance Improvement Studies for Low-Cost 2.5 Gb/s Rated DML Sources Operated at 10 Gb/s

I. Papagiannakis (1), D. Klonidis (2), J. Kikidis (3), A. N. Birbas (1) and I. Tomkos (2)
1 : Electrical & Computer Eng. Dept, University of Patras, Rio, 26500 Patras, Greece (birbas@ee.upatras.gr)
2 : Athens Information Technology, 0.8km Markopoulo Av. Peania, Athens, Greece (dikl@ait.edu.gr)
3 : Analog Integrated Electronic Systems S.A, Greece (john.kikidis@analogies.eu)

Abstract

Performance improvement methods for the operation of 2.5Gbps rated low-cost DML sources at 10Gbps over record distances are studied by means of chirp characteristics, offset receiver filtering and DFE equalization.

Introduction

For the design of cost efficient terminal nodes in metro/access systems, the use of directly modulated lasers (DMLs) is preferable due to their low cost, low driving voltage, small size and high output power.

According to current standards (ITU-T G984.1), 2.5Gb/s transmitters must support distances up to 20 Km. Although current DML-based products satisfy this requirement, the frequency chirp characteristics and the limited bandwidth of 2.5Gb/s rated DMLs prevent their operation at 10Gb/s. However, research efforts are underway to extend the reach of PONs to longer distances and operating rates up to 10Gb/s [1]. It would be highly desirable if the common transmitters used at 2.5Gb/s (and not specially developed DML solutions like [2,3]) could also be used at 10Gb/s while satisfying the requirements for increased reach [4]. A significant work that first studied this concept was presented in [4], where a different set of DML sources ranging from 1310 to 1600nm were used for CDWM systems and assisted by equalization.

The work presented here focuses on the performance improvement studies of conventional 2.5Gb/s rated low-cost DML sources operated at 10Gb/s and be applicable in extended reach access or even metro DWDM-based systems. A combination of methods was considered, DML sources with different chirp - transient (TR) and adiabatic (AD) - characteristics [5] according to different driving conditions [6] are studied, and their performance improvement is achieved by combining: a) off-set optical filtering [7] and b) post-receiver equalization using FFE/DFE [4] at the receiver end. Although these techniques have been studied individually for various DML sources [4]-[7], here the combined effect of equalization and off-set filtering is demonstrated both for transient and adiabatic chirp dominated DMLs. Measurements are presented in terms of OSNR improvement for various fibre spans and BER values of 10^{-9} but also 10^{-3} for systems that could be further assisted by FEC.

Experimental set up and parameters

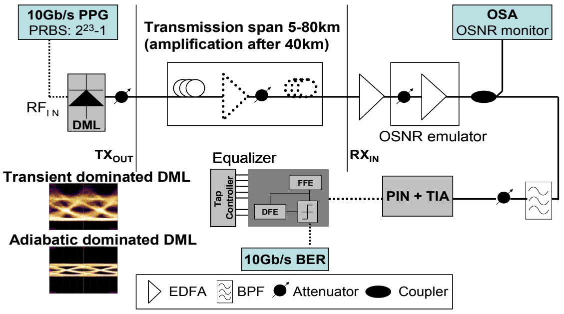

Figure 1: Experimental set-up and eye diagrams. (after PIN+TIA and in back-to-back configuration)

The experimental set up is shown in Fig. 1. The transmitter consisted of a common DFB laser emitting at 1542.14 nm and rated for 2.5Gb/s operation. The laser was driven at 9.95Gb/s with NRZ modulation format and a 2^{23}-1 long PRBS. Depending on the current threshold and the peak-to-peak voltage of the input signal, the DML was operated either as adiabatic (AD) or transient (TR) chirp dominated source. The small bandwidth of the DML affects significantly the extinction ratio (ER) (5.5 dB and 2.5 dB for TR and AD chirp dominated DML respectively) when the laser is modulated at 10Gb/s. The transmission link was SMF-28 and an EDFA with noise figure ~5dB was added after 40Km. The launch power in both spans was 0 dBm in order to minimize nonlinearities. No optical dispersion compensation was used. At the receiver end, an OSNR emulator (VOA + EDFA) was used first to alter the OSNR. Following this, a 40 GHz tuneable optical bandpass filter (BPF) was inserted before the PIN. After the receiver, an integrated electronic equalization circuit was used, consisted of a 5-stage FFE, clock/data recovery and a 2-stage DFE. The taps for each case were adjusted in terms of optimum BER.

Experimental results

Fig. 2 shows measurements on required OSNR (for 10^{-9} BER) versus transmission length for TR and AD chirp dominated DMLs with FFE (5) and DFE (5,2) and optimum filter offset at the receiver end. Extensive experimental measurements of OSNR versus filter detuning around the laser's central wavelength revealed that optimum signal reception can be achieved with small filter offsets of -0.1nm for AD and -0.07nm for TR DMLs [7]. It is noted that it was impossible to achieve error free ($BER>10^{-9}$)

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

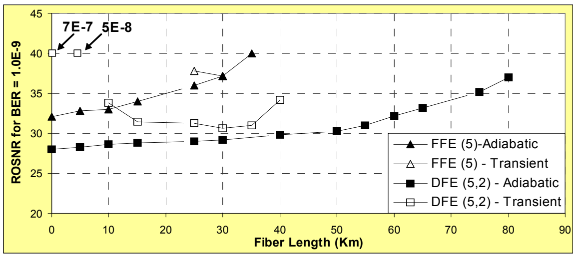

Figure 2: Required OSNR for10^{-9} BER vs. fibre length for the combination of FFE/DFE with optimum filtering.

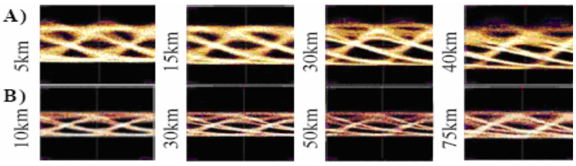

Figure 3: Eye diagrams for various distances for a) transient and b) adiabatic chirp dominated DML.

Fibre Length (Km)	Transient (BER)	Adiabatic (BER)
0	1.0E - 4	6.0E - 6
5	3.0E - 5	9.0E - 5
10	1.0E - 5	3.0E - 4
15	1.0E - 5	1.0E – 4
25	1.0E - 5	9.0E - 5
30	1.0E - 3	1.0E - 4

Table 1: BER at max OSNR for transient and adiabatic chirp dominated DML without equalizer.

measurements without equalization and for any distances (Table 1). Moreover, in the case of TR chirp DML with equalization, error free transmission was achieved only after 10Km and 25Km for the case of DFE and FFE respectively (indicative BER values for shorter spans are given in Fig. 2). The reason for the performance improvement after a certain distance stems from the fact that the transmitted distorted chirped pulses interact with the fibre chromatic dispersion and consequently the signal distortions smooth out, resulting in improved signal quality (see also the shape of eyes in Fig. 3).

These studies show that when equalization is combined with optimum offset filtering at the receiver end, a maximum transmission distance of 75Km and 40Km can be achieved for AD and TR chirp dominated DMLs respectively (at a reference OSNR value of 35dB). The reason why the equalizer performs better for the case of AD rather than TR chirp dominated DMLs is due to the fact that the pattern dependence effects are significantly lower in the first case. Since the transient chirp is proportional to the derivative of the power, whereas the adiabatic chirp is proportional to the power waveform [5], it is expected that for the case of TR DMLs, any variations in the power waveform (due to the various bit-by-bit transitions) will cause a large number of chirp patterns, resulting, after transmission, in larger pattern dependent effects (i.e. nonlinear behaviour). Consequently, this will affect the ability of the equalizer to correct the signal based on the knowledge of the previously received bits.

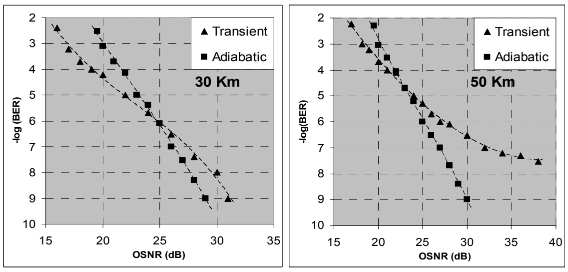

Figure 4: BER vs. OSNR with DFE for 30 and 50 Km for transient and adiabatic chirp dominated DMLs.

In order to study the behaviour of TR and AD chirp dominated lasers in combination with optimum offset filtering and equalization and at different BER values, the results shown in Fig. 4 have been obtained after transmission over 30Km and 50Km. AD DMLs show better performance compared to TR DMLs at 10^{-9} BER. This stems from the ability of the equalizer to better correct signals with no intense patterning effects as explained before. Moreover, for longer transmission distances and as the pattern dependent effects in transient DMLs increase, their BER performance versus OSNR degrades, resulting in an increasing noise floor. On the other hand, for high BER values (10^{-3}) (if FEC is additionally considered), transient DMLs show better performance in terms of OSNR when compared with AD DMLs, mainly due to their higher ER. However, this is true for moderate transmission distances as the continuously decreasing performance of TR DMLs in terms of OSNR will prevent their use beyond 100Km at a BER of 10^{-3}. On contrary and despite their small ER, adiabatic DMLs sources can extend the transmission reach well beyond 100Km when combined with offset filtering, equalization and FEC. For this case, measurements obtained in our lab at a BER of 10^{-3} shown that an impressive record distance of 150Km can be reached at an OSNR value of 21dB.

Conclusions

This work experimentally demonstrates that 2.5Gb/s rated conventional low-cost DMLs can be used as 10Gb/s sources in extended future PONs and metro networks. This can be achieved by means of offset filtering and equalization at the receiver end and according to the chirp properties of the DML sources.

Acknowledgment

This work has been supported by the European Commission under 7FP project SARDANA (217122).

References

1. J.A. Lázaro, et al., OFC 2008, OThL2.
2. L. Nelson, et al., OFC 2002, 422.
3. D. Mahgerefteh, et al., El.Lett., 41 (2005),543.
4. P. J. Winzer et al.,IEEE JLT., 1 (2005), 203.
5. I. Tomkos et al., Opt. Comm., 194 (2001), 109.
6. R.S. Vodhanel, et al., IEEE JLT, 8 (1990), 1379.
7. P.A. Morton, et al., El.Lett., 33 (1997), 310