Demonstration of Asynchronous, 10Gbps OCDMA PON system with Colorless and Sourceless ONUs

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Abstract

We experimentally demonstrate for the first time an error-free asynchronous, 10-Gbps full-duplex DPSK OCDMA system that does not require any laser source at the users premises.

Introduction

The commonly held view is that the evolution of the next generation access network (NGAN) will be directed toward wavelength division multiplexing (WDM) passive optical network (PON) systems, that can provide symmetric multi-gigabit fiber to the home (FTTH) services [1]. However, recent research activities have been demonstrated that the optical code division multiple access (OCDMA) technology is a valid alternative for the NGAN, with enhanced flexibility and a reduced cost equipment [2, 3]. Like WDM-based systems, an OCDMA-PON can simultaneously provide contentionless gigabit-class up- and downlink bandwidth to end users, offering additional advantages of optical layer security and larger spectral efficiency. In addition, it is possible to extend the overall system capacity by integrating OCDMA and WDM technologies [4]. Among the many research topics, the two key issues are the migration and upgrade path from the current generation of time division multiple access (TDMA)-based to WDM-based PONs, and the development of 'sourceless' (without a laser source) and 'colorless' (non-wavelength specific) optical network units (ONU). In the latter case, a centralized broadband signal is distributed from the optical line terminal (OLT) to all users for re-modulation and upstream retransmission, to reduce the installation, operation and maintenance costs.

This year, the upgrade feasibility from standard TDM- to OCDMA-PONs has been demonstrated using a cost-effective multi-port encoder/decoder (E/D) in the OLT, and polarization-independent compact superstructured fiber Bragg grating (SSFBG) E/Ds at the ONUs [5].

In this paper, we demonstrate for the first time a full-duplex, asynchronous, 10-Gbps OCDMA system on the same wavelength, in a 'colorless' and 'sourceless' configuration, i.e. without any laser source in all the identical ONUs. Both up- and down-link error-free transmissions ($BER<10^{-9}$) hasve been successfully achieved, using differential phase shift keying (DPSK) modulation.

Experiment of a colorless and sourceless OCDMA-PON

Figure 1 shows the schematic of the proposed OCDMA-PON system: at the OLT, a 31-port E/D is used and two codes, i.e. two E/D ports, are assigned to each user for the downlink and uplink transmission, respectively. Therefore, with a 31-port device we could accommodate 15 different users, but to reduce the multiple access interference (MAI) noise, only the odd ports have been used. A 10 Gbps seed pulse train from a mode locked laser diode (MLLD) is asynchronously transmitted at the same wavelength, overlapped to the OCDMA downlink signal, by using a 3dB coupler. This signal is used at each ONU to be re-modulated by a $LiNbO_3$ phase modulator (LN-PM) and upstream retransmitted. All the ONUs are identical and consist of a 31-port E/D and an OCDMA receiver (Rx): each subscriber simply selects this two assigned E/D ports ('colorless' architecture). Although this is one of the key requirement from network operators, the confidentiality of this architecture is extremely weak, since a malicious user could easily sift data directed to another user, by using the corresponding E/D ports. Therefore, this OCDMA-based PON architecture would present the same security vulnerability of standard TDM-based systems; to overcome this limitation, it is possible to refer to an hybrid configuration, where a multiport E/D is used in the OLT and two low-cost SSFBG E/Ds are used at each ONU [5].

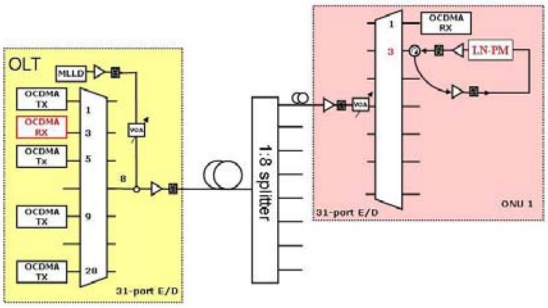

Figure 1: Schematic of the OCDMA-based PON.

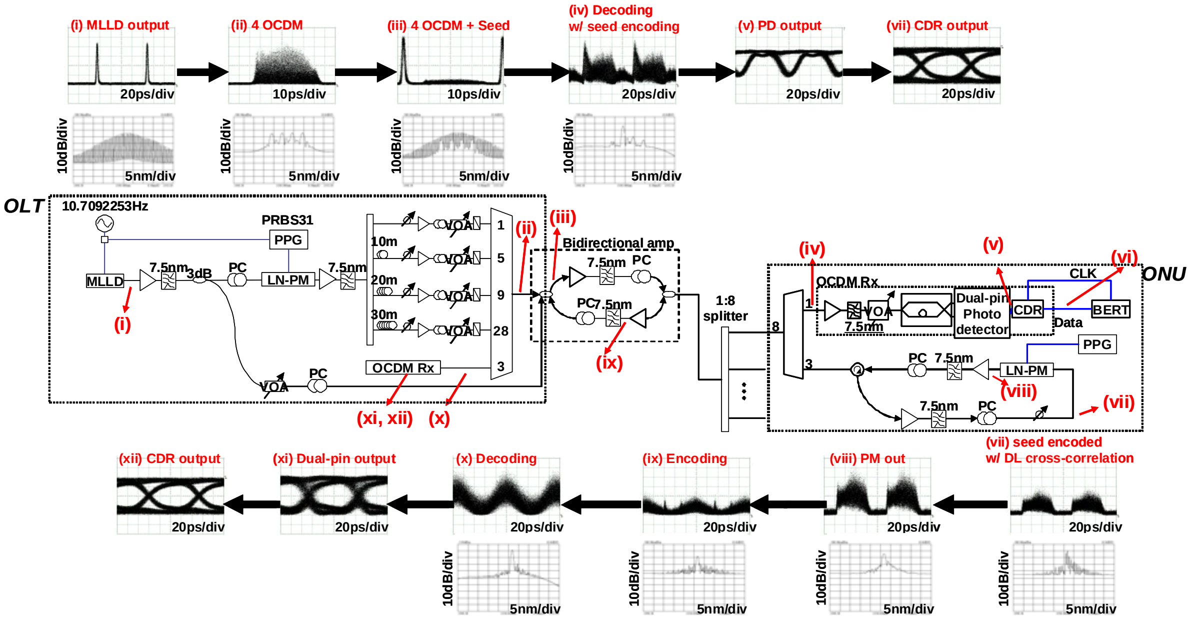

Figure 2: Experimental setup and results.

Figure 2 shows the experimental setup and results of the full-duplex, 10 Gbps, DPSK-OCDMA system with 4-downlink and 1-uplink users. The OLT consists of a MLLD, a LN-PM, a single 31-port E/D, erbium-doped fiber amplifiers (EDFA), and couplers. The MLLD generates 1.8 ps optical pulses, with 10.7 GHz repetition rate, at 1550 nm central wavelength (Fig.2 (i)). These pulses are divided into two parts by a 3dB coupler to be modulated by the LN-PM (PRBS: 2^{31}-1) and to become the seed pulse train that is used at the ONUs for re-modulation and uplink retransmission. The phase modulated signal is split and launched into 4 different input ports of the 31-port E/D, in a worse case scenario with equal power, random delays, and random bit phases. As a result, 4 OCDMA signals are generated at the E/D output port (Fig.2 (ii)), and asynchronously combined with the seed pulse train by using another coupler, to become the downlink transmission (Fig. 2 (iii)). This signal is then amplified by a bidirectional amplifier, which consists of a set of EDFAs, polarization controllers (PCs), optical band pass filters (OBPFs) and couplers. At the ONU, the received downlink signal is sent into the input port of a 31-port E/D, and at the matched port, the decoded signal (Fig.2 (iv)) is DPSK detected by a fiber-based 1-bit delay line and a dual-pin photodetector (PD) (Fig. 2 (v)). For BER measurements, the detected DPSK signal is recovered by the clock-and-data-recovery (CDR) circuit (Fig. 2 (vi)) and forwarded to the BER tester (BERT). On the other hand, all the other unmatched E/D output ports simultaneously generate encoded signals (from the seed pulse train) overlapped to cross-correlation signals (from the 4-OCDMA signal), that correspond to the MAI noise (Fig. 2 (vii). The signal at the output port 3 is modulated by the LN-PM for the upstream transmission and loop-backed to E/D by a circulator (Fig. 2 (viii)). The clock recovery for the uplink is manually adjusted. Figure 2 (ix) shows the encoded waveform and spectrum of the uplink signal. The uplink signal is amplified by the bidirectional amplifier and sent into the input port of the 31-port E/D in OLT. Finally, the decoded signal is detected at the matched port (port 3) by the DPSK detector and CDR. Figures 2 (x-xii) show the waveforms of the 31-port E/D, PD, and CDR outputs, respectively. Figures 3 show the BER performances in case of (a) down-link and (b) up-link: error free (BER<10^{-9}) transmission has been achieved for all the users, for both cases.

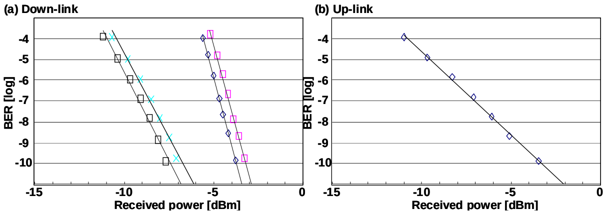

Figure 3: BER measurements.

Conclusions

We demonstrate for the first time an innovative low-cost OCDMA-based PON system that does not require any laser source at the ONUs. Up- and down-link error-free transmission (BER<10^{-9}) has been successfully experimented,

References

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