FIELD DEMONSTRATION OF 25G-PON AND XGS-PON BURST-MODE UPSTREAM COEXISTENCE

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Abstract

We perform a field demonstration of 25 Gb/s burst-mode upstream duobinary transmission in O-band using 10G optoelectronics and APD-based optical receiver with memory-aided adaptive equalization, coexisting with XGS-PON transmission. We achieve 31 dB ODN loss budget and show marginal interference penalty between the two systems.

1 Introduction

Passive Optical Network (PON) new standardization proposals are rapidly evolving and are today ready for the definition of 25 Gb/s PON (25G-PON) [1-3]. In this paper, we focus on a 25G-PON implementation and we experimentally demonstrate its feasibility for the upstream direction over an installed urban fibre testbed and the possibility to coexist with commercial XGS-PON. In previous contributions [4-6], our group have analysed the feasibility of 25G-PON using 10 Gb/s technology components, electrical duobinary (EDB) format, external modulation, C-band operation and adaptive equalisation (AE). Under this scenario, we experimentally demonstrated continuous [5] and burst-mode [6] transmission through 20 km of fibre achieving an optical distribution network (ODN) loss of up to 29 dB. In this new ECOC2019 contribution, we largely extend our previous work by introducing the following updates:

- A field experimental setup using 16 km installed SMF fibres between Telecom Italia (TIM) research centre in Turin (Italy) and Politecnico di Torino (PT) laboratories. The used fibre has a significant extra loss because it traverses several central offices and manholes and it is thus a good emulation of a real PON installed link. We focus on upstream transmission and we placed the Optical Network Termination (ONT) in PT lab and the Optical Line Terminal (OLT) in TIM lab.
- We show the coexistence of our 25G-PON proposed solution with XGS-PON commercial technology, demonstrating burst-mode transmission for both systems and investigating on the impact of residual crosstalk between them.
- O-band operation has been selected for 25G-PON transmission, to be in line with the latest standardization groups' decisions for 25G-PON and, moreover, to be able to use a commercial "coexistence element" (CEx), i.e. the wavelength multiplexer used to combine the two systems.
- For 25G-PON, and thanks to the choice of O-band operation, we used a cost-effective (as compared to external modulator) 10G-class directly modulated laser (DML).

The paper is organized as follows: in Sect. 2, we describe the demonstrator and the details of the experimental setup while in Sect. 3 we show the performance results of both 25G-PON and XGS-PON in different configurations.

2 Demonstrator setup

The demonstrator setup is shown in Fig. 1. For the XGS-PON, we used commercial devices (ODN class E2 33 dB) and a real traffic generator, while for 25G-PON we performed an off-line processing approach. The digital transmitter (TX) and receiver (RX) blocks for 25G-PON that we proposed are described in detail in [5] and, shortly, they are based on the EDB approach in a flavour in which a binary NRZ pre-coded TX in the ONT and a duobinary equaliser-based receiver in the OLT are used. At PT side, a random 25 Gb/s signal is generated by a 92 GSa/s arbitrary waveform generator (AWG). This electrical signal $i(t)$, after amplification and DC-bias addition, modulates an O-band 1310 nm 10G-class DML. The resulting optical signal is then combined with the 10 Gb/s XGS-PON 1270 nm upstream signal, and they are then launched into the fibre. At TIM side, a variable optical attenuator (VOA) is used to set the total ODN loss. The 10 and 25 Gb/s signals are separated by a CEx

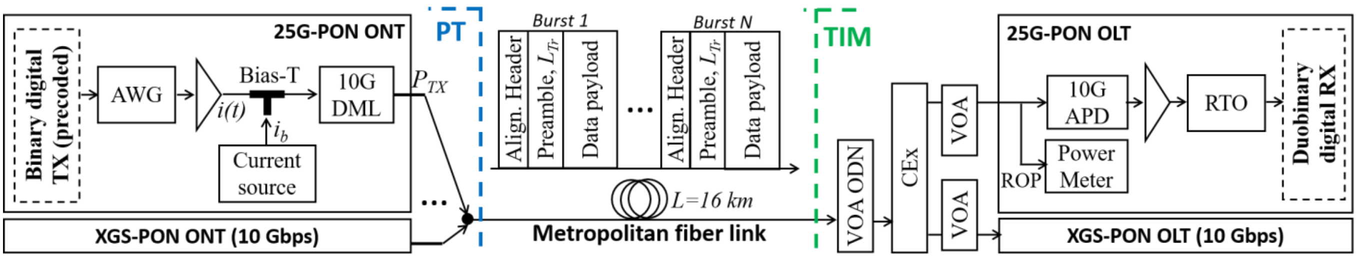

Fig. 1 Field demonstrator setup

(insertion loss ≤ 1 dB, isolation ≥ 30dB), a device composed of WDM filters to (de)multiplex XGS-PON, G-PON, and NG-PON2 signals, where we have used the GPON port for our 25G-PON wavelength at 1310 nm, and obviously the "regular" port for XGS-PON. The 10 Gb/s signal is sent to the XGS-PON OLT and then to a traffic analyser for bit error count (estimated through a frame loss count). The 25 Gb/s is received using a 10G-class avalanche photodiode (APD), followed by a transimpedance amplifier (TIA), an RF amplifier and a real time oscilloscope (RTO) with a sampling rate of 100 GSa/s. We measured the ODN loss as the difference between the transmitted power (P_{TX}) at the DML output and the received optical power (ROP) at the APD input. Since the 25G-PON RX algorithm is one key point of our work, we now describe it in detail. The received digitized signal is off-line processed using a burst-mode adaptive equaliser (BM-AE), described in detail in [6]. The BM-AE is based on Feed-Forward Equalisation (FFE) with a preamble-aided training stage. For alignment between the RX signal and the BM-AE training sequence, a FIR-based block aided by a PRBS header of 2^7 bits inside the TX packets is used. This block acts as a correlator block and automatically finds the beginning of the training preamble inside the RX packets. After equalisation and decoding, the fine-time resolved bit error ratio (FTR-BER) is evaluated, as explained in [6], by dividing the data payload in time slots and counting the accumulated errors in all the bursts on a time slot basis. The standard BER is computed by averaging the FTR-BER over all time slots. For continuous mode experiments, the length of the training preamble (L_{Tr}) is 2^{14} bits and the length of the payload is 2^{17} bits. For burst-mode experiments, L_{Tr} is a variable parameter and the length of the data payload is the same for all bursts, set equal to 2^{12} minus L_{Tr} bits. When employing the burst-mode memory-aided approach [6,7], which consists of using a set of pre-evaluated tap coefficients to initialize the BM-AE, a first burst transmission (2^{14} bits long) is used to compute the initial tap coefficients of the equaliser (operated in full-training mode only in this case). Transmission of N=400 bursts is analysed. A simplified burst-mode scheme, in which the amplitude of the received bursts at the input of the BM-AE is assumed to be already equalised using a gain control technique [7,8], is emulated. When XGS-PON and 25G-PON are transmitted simultaneously in the link to perform coexistence testing, we set the power of the desired (under-test) and interfering signals to obtain a given signal-to-interference ratio (S/I) using two VOAs. The minimum S/I that can be set is constrained by the sensitivity and maximum transmitted power of each system.

3 Results

3.1 Single 25G-PON continuous mode transmission

A first set of experiments in continuous mode transmission were performed in order to optimize the TX parameters. The XGS-PON transmission was turned off. The obtained results are also useful for comparison against the burst-mode case presented in next sub-sections. Figure 2 shows contour plots of the maximum achievable ODN loss in order to reach the BER target (10^{-3} or 10^{-2}) as a function of the bias current of the laser, i_b (directly proportional to its output power and bandwidth) and the peak-to-peak amplitude of the modulating signal $i(t)$, i_{pp} (directly related to the extinction ratio (ER)). An ODN loss ≥29 dB is achievable for both BER targets. The suggested maximum current to drive the DML is 100 mA. A combination of i_b = 60 mA (P_{TX} = 11.5 dBm) and i_{pp} = 80 mA maintains the operation of the DML in the safe side, while guaranteeing an ODN loss of ~30.5 dB at BER=10^{-3}. Therefore, these i_b and i_{pp} values are selected as the DML operating point also for the burst-mode experiments presented in next sub-section. Under this condition, the DML bandwidth is ~12 GHz (the total system bandwidth is ~6 GHz, mainly limited by the APD) and its output power is 11.6 dBm.

3.2 Single 25G-PON burst-mode transmission

After setting the optimum TX parameters, several bursts were transmitted (maintaining the XGS-PON off), stored and off-line post-processed. The payload of the bursts was divided in time-slots (size equal to 400 bits) to compute FTR-BER. The purpose of evaluating this metric (somehow an "instantaneous" BER [6]) is to select the minimum length of the training preamble (thus increasing the system transmission efficiency) that guarantees a BER below the target since the very beginning of the payload. For instance, the FTR-BER over each payload time-slot for an ODN loss of 28.7 dB is plotted in Fig. 3. BM-AE memory-aided and memoryless

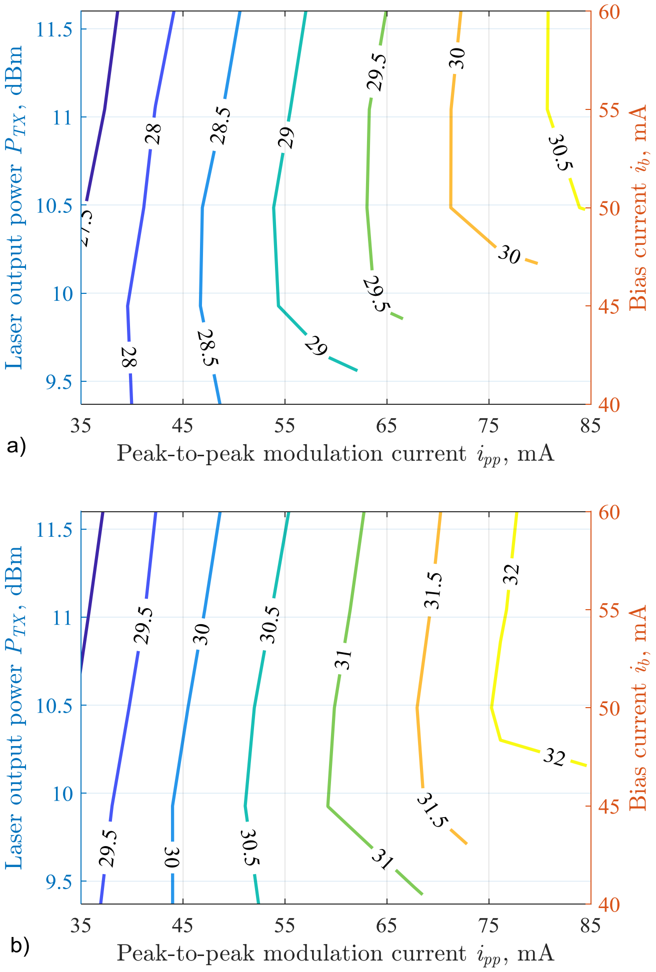

Fig. 2 Maximum ODN loss as a function of TX parameters targeting a) BER = 10^{-3}, b) BER = 10^{-2}

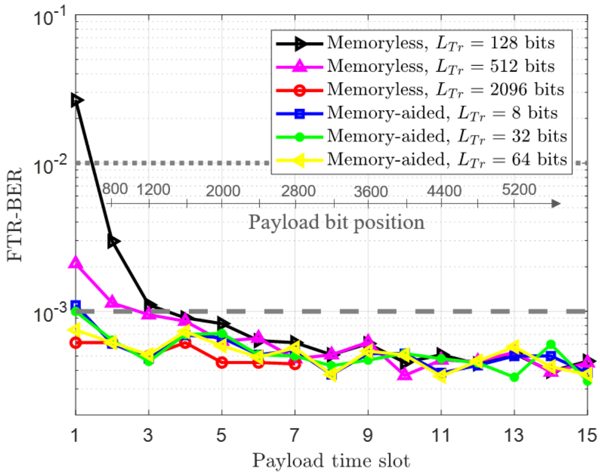

Fig. 3 FTR-BER over each of the 400-bits time slots for memory-aided and memoryless BM-AE approaches with different training length L_{Tr}. ODN loss = 28.7 dB

approaches are compared for different lengths of the training stage. While the memoryless BM-AE needs ~2000 bits to converge, thus guaranteeing a uniform error distribution along the full payload (see curve with circles), the memory-aided approach requires a much shorter training stage (8 bits) to attain the same condition. Once a uniform error distribution along the payload is verified (thus avoiding the risk of masking failure BER conditions), the standard BER is evaluated for every ODN loss value by counting the errors in the full payload of all bursts. The BER thus obtained is graphed as a function of ODN loss for memory-aided burst-mode transmission (L_{Tr} = 8 bits) in Fig. 4a (curve with circles). For the sake of comparison, the continuous mode BER versus ODN loss curve obtained under the same experimental conditions is also plotted in Fig. 4a (curve with squares). The burst-mode operation introduces a penalty of 1 dB and 1.3 dB, for BER = 10^{-2} and 10^{-3} respectively.

3.3 Coexistence of 25G-PON and XGS-PON systems

As a final step, the coexistence of the 25G-PON and XGS-PON technologies is analysed. To this purpose, we performed the 25G-PON BER versus ODN loss measurements, for burst and continuous modes, under the same assumptions reported in previous sub-sections but now turning on the XGS-PON transmission (interference signal) setting it a stronger ROP than that of 25G-PON (to have a fixed S/I = -17 dB irrespective of the ODN loss). The obtained curves are shown in Fig. 4a (curves with stars and triangles). A negligible penalty due to XGS-PON interference can be observed (less than 0.1 dB in both burst and continuous modes). A 29 dB (BER=10^{-3}) and 31 dB (BER=10^{-2}) ODN loss can be attained, in 25G-PON burst-mode transmission.
The influence of the 25G-PON signal on the XGS-PON one is also tested. The performance of the XGS-PON system (burst-mode) was measured in two conditions: 25G-PON turned off and on (setting an S/I = -20 dB in the latter case). The obtained post-FEC BER values as a function of the ODN loss are plotted in Fig.4b. A marginal penalty due to 25G-PON interference is also observed in this case (less than 0.2 dB difference between both curves for any BER value).

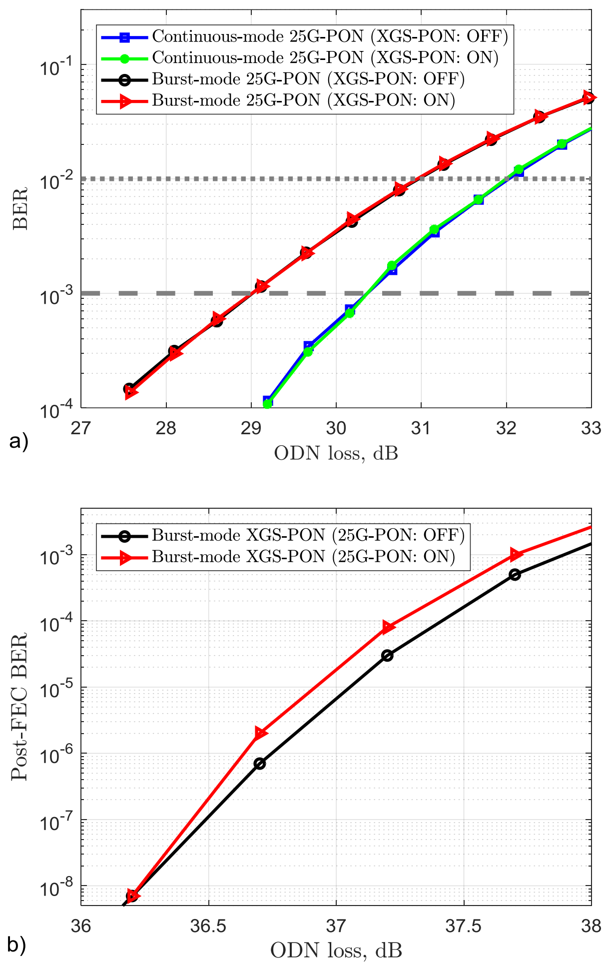

Fig. 4 System performance as a function of ODN loss under different scenarios; a) 25G-PON under test and XGS-PON interfering with a S/I = -17 dB; b) XGS-PON under test and 25G-PON interfering with a S/I = -20 dB

4 Conclusion

A field demonstration of 25G-PON and XGS-PON coexistence for upstream (burst-mode) transmission was performed. A maximum ODN loss of 31 dB (BER=10^{-2}) for 25G-PON in O-band and using 10G-class devices was achieved using a memory-aided burst-mode adaptive equaliser. Marginal penalties (≤0.2 dB) due to interference between next-generation and legacy PON systems were measured.

5 Acknowledgements

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