SOA impact on high-capacity DMT signals in switching/aggregation node for future MAN

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Abstract: The impact of the crossing of SOA-based MAN nodes on DMT high-capacity transmission is experimentally evaluated. We provide an optimization of the saturation levels of the SOAs, enabling add/drop functionalities, to preserve the transmitted throughput.

1. Introduction

Future metropolitan area networks (MANs) will manage different aggregated data traffic volumes and operate at heterogenous granularities, assuring a huge total throughput in transmission and routing in order to support a large range of applications and services (such as 5G, mobile edge computing, UHD TV, etc.). Flexibility and scalability together with sustainability in terms of costs and power consumption become paramount for all the network elements operation. New photonic technologies are essential to satisfy all the challenging requirements of the future agile MAN; in particular we adopt a modular approach in the design of both the transmitter [1] and the switching node [2]. The exploitation of discrete multitone (DMT) modulation allows to adaptively load/manipulate the transmission bandwidth [3] targeting multi-Tb/s capacities photonic integrated circuit (PIC) [4]. On the other side, the switching node architecture featuring different levels of aggregation delivers on-chip node functionalities thanks to either Indium phosphide (InP) monolithical integration or hybrid integration of low-loss Silicon photonics (SiPh) passives and InP actives [5-7] operating for NRZ OOK. In this paper we focus on the analysis of the performance of a high-capacity DMT signal crossing a metro node (HL4) at the bottom layer of the IP network in the MAN organized in a layered topology [4]. This HL4 node, according to the above requirements, is based on low-cost switches providing the add/drop operation realized by semiconductor optical amplifier (SOA) wavelength blockers, combined with a demultiplexing arrayed waveguide grating (AWG) and a splitter at the input and a multiplexing AWG and a combiner at the output (Fig. 1a inset). Owing to the presence of a high carrier to signal power ratio (CSPR), DMT modulation could be more impaired by SOA nonlinear effects with respect to single carrier signals, such as OOK or QAM ones [8]. We thus experimentally evaluate the impact of SOA saturation conditions induced by variable bias current and SOA input power on the DMT signal resilience to the crossing of the considered low-cost HL4 nodes.

2. Experimental set up and results

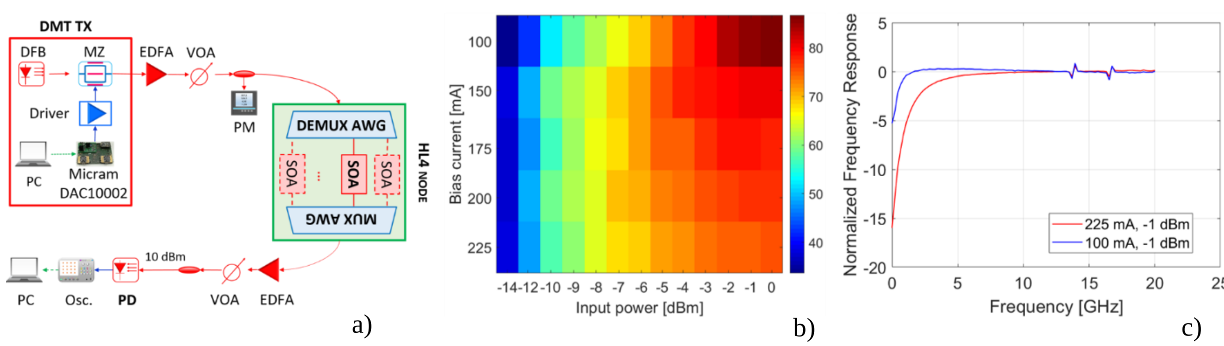

Fig. 1: a) Experimental setup; b) Heatmap of the transmitted capacity for several bias currents; c) Comparison between transfer functions for 100 mA (blue curve) and 225 mA (red curve) for -1 dBm input power.

The impact of the HL4 node crossing on the high-capacity DMT signal performance is evaluated in the experimental set up reported in Fig. 1a). In particular the presence of the two AWGs in the HL4 node is emulated by two Finisar WS1000s Waveshapers, each one providing the transfer function of a 100-GHz flat top AWG, while transmission and PIC losses are accounted for by varying the SOA input signal. In particular, a 1558-nm DFB laser is externally modulated by a 25-GHz intensity Mach-Zehnder modulator using a DMT signal. The signal is generated by a 100

GS/s MICRAM digital-to-analog converter (DAC10002) with 40-GHz electrical bandwidth and 6 bits vertical resolution, it is calculated by Matlab® and it is composed of 256 sub-carriers in a 20 GHz range, i.e. the sub-carrier spacing is 78.125 MHz. A cyclic prefix (CP) of about 2.1% of the symbol length is also added. After amplification in an Erbium-doped fiber amplifier (EDFA) the power is varied at the input of the HL4 node between 0 dBm and -14 dBm by a variable optical attenuator (VOA). The employed SOA is a polarization insensitive 500-μm Optospeed 1550MRI/P device, its bias current is varied between 100 mA and 225 mA, to modify the saturation conditions within the SOA working range. The optical signal is received by a 50-GHz PIN photodiode maintaining a constant power of 10 dBm for all the measurement conditions; the received signal is then acquired by a Tektronix real-time oscilloscope with 8 bits vertical resolution, 100 GS/s and 33-GHz electrical bandwidth. Off-line processing provides digital symbol synchronization, CP removal, sub-carriers phase recovery and demodulation and BER count. The system performance is measured in terms of total transported capacity for different SOA bias currents and SOA input optical powers.
Firstly, the estimation of the channel characteristics is performed by transmitting a probe DMT signal mapped with uniform QPSK loading, providing the signal-to-noise ratio (SNR) of each sub-carrier. The measured SNRs are then exploited for performing the standard bit- and power-loading Chow's algorithm [9] to obtain a good assessment of the maximum capacity achievable by the system; the target bit error rate (BER) is set to $3.8 \cdot 10^{-3}$ (useful for exploiting an advanced hard-decision forward error correction code with 7% overhead). In Fig. 1b) the capacity dependence on the input power and SOA bias current is reported. As expected, for each bias current the capacity increases for higher SOA input powers, thanks to the higher optical signal-to-noise ratios (OSNR) achievable in gain-saturated conditions. However, for deeper saturation conditions, i.e. for higher bias currents, the maximum capacity obtained at higher input powers is reduced. This capacity reduction is determined by the more effective SOA gain compression, which leads to a SOA electrical transfer function that acts as a high-pass filter [10]. Fig. 1c) shows examples of SOA transfer functions measured by a Network Analyzer in case of -1 dBm input power for 100 mA and 225 mA bias currents, respectively. Both the magnitude and the width of the low-frequency notch is significantly enhanced for higher bias currents leading to a reduction in the SNR achievable by low-frequency sub-carriers and limiting the overall capacity. Since the performance is a trade-off between the OSNR and the SOA gain saturation, an optimum bias condition with respect to the input optical power can be identified by Fig. 1b) in order to maximize the transported capacity after the HL4 node. The system reference capacity in back-to-back (BTB) condition, i.e. without the SOA, is about 100 Gb/s, depending on the signal power reaching the HL4 node, which is both due to transmission losses and PIC insertion losses, the capacity reduction in HL4 crossing can range between 15% and 60%.

3. Conclusions

Innovative low-cost nodes providing add/drop operations thanks to the employment of SOAs as wavelength blockers were considered for a future flexible and high-capacity MAN organized in a network layered topology. In case of DMT exploitation to increase the rate per wavelength, we demonstrated the impact of the SOA saturation conditions, experimentally evaluating the performance when a HL4 node is crossed. A suitable choice of the SOA operating conditions in terms of bias current and input power assures a trade-off between OSNR and nonlinear impairments preserving the maximum transported capacity, close to the reference value measured in BTB without node crossing.

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4. References

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