Demonstration of a full duplex PON featuring 2.5 Gbps Sub Carrier Multiplexing downstream and 1.25 Gbps upstream with colourless ONU and simple optics

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Abstract

We demonstrate a full-duplex DPSK SCM PON operating at 2.5Gbps/1.25Gbps bitrates, with RSOA ONU and simplified scheme. It achieves low sensitivity and is implemented with low-cost components.

Introduction

Access Passive Optical Networks (PONs) have emerged as an effective platform to deploy advanced bandwidth demanding services. Thus, next generation PONs have to match several issues, including high bandwidth delivering and WDM. An interesting specification is the use of one single fibre for both, upstream and downstream transmission, to reduce the size of the external plant and the complexity of the optical network unit (ONU).

In the past, some advanced designs which avoid the generation of light at the ONU by using different modulation schemes for downlink and uplink transmission have been demonstrated [1-5]. However, these methods may not be cost-effective due to the components needed for the modulation and detection of the up/downstream signals. A more cost-effective solution is the use of a subcarrier multiplex (SCM) technique with direct modulation [6-7]. But they have been limited to 1.25 Gbps downstream, with the electrical schemes not optimized.

In this paper, we demonstrate a full duplex PON operating at a rate of 2.5 Gbps downstream and 1.25 Gbps upstream using the SCM technique. With electrical DPSK in a 5 GHz subcarrier for downstream, we are avoiding the phase-locking errors and the electrical scheme becomes simple and easy to implement.

Experiments and results

Fig. 1 shows the experimental setup. For the 2.5 Gbps downstream signal we used a Mach-Zehnder Modulator (MZM) preceded by a laser. This configuration gave us an Extinction Ratio of 8.4 dB, quite enough for our purposes.

The downstream signal, once precoded inside the downstream Pulse Pattern Generator (PPG1), was mixed with a 5 GHz electrical oscillator. The mixer used in this stage was a standard double balanced mixer. Also, the oscillator was not synchronized with the PPG1 clock, giving a more realistic platform for evaluating frequency drifts. Please note that the band-pass filter used in the OLT was not required, because of the mixer's frequency response, which ensures a band-pass filtering. By using the three-mixer method [8], its bandwidth was measured and found to be ± 1.9 GHz centered at 5 GHz, enough for our purpose. A rejection better than 20 dB, was found for frequencies beyond ± 2.9 GHz. This is shown in fig. 2.

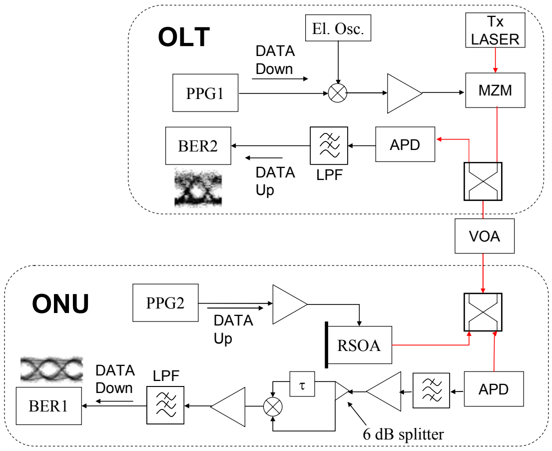

Figure 1: Experimental setup

At the electrical side of the ONU receiver, after the optical coupler and the APD, a delay-and-multiply scheme was implemented, also using a double balanced mixer. This simplifies the data detection, since it does not require any electrical oscillator placed in the ONU, and avoids the phase-locking between detected carrier and electrical oscillator.

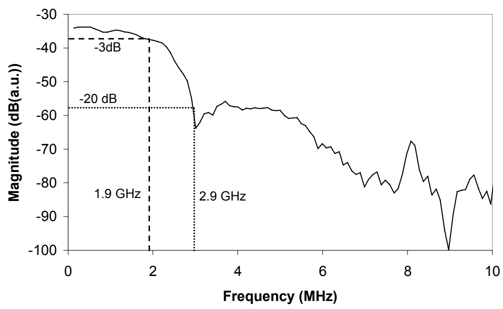

Figure 2:Low pass equivalent of the mixer's response for a 5 GHz carrier.

For the 1.25 Gbps upstream signal, we used another pulse pattern generator (PPG2) independent from PPG1, driving an RSOA in the ONU, , through a bias-T. The RSOA small signal gain was of 17 dB. We remodulate the downstream signal by modulating the RSOA gain with the upstream data, and then send it back to the OLT. Note that the downstream signal has not constant power, but sinusoidal. Since it oscillates a frequency four times upstream data rate, it is well averaged in the bit time with the reception low-pass filter, also assisted by the RSOA saturation dynamics. At the OLT side, after photodetection, a low pass filter was placed in order to properly reject remodulation noise from downstream signal. Fig. 3 shows the detected power spectrums at the OLT side after and before filtering. The residual downstream signal detected could be rejected by more than 20 dB.

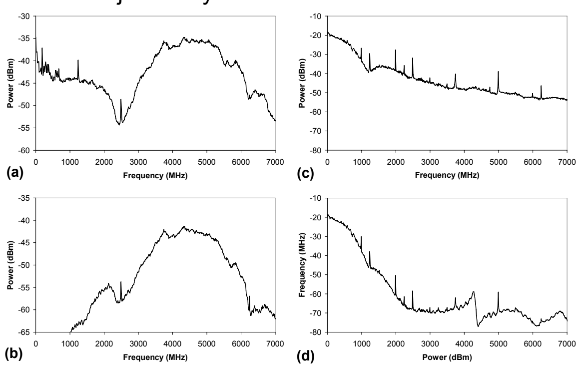

Figure 3: Electrical power spectrums at the receiver side: (a) before filtering at the ONU, (b) after filtering at the ONU; (c) before filtering at the OLT, and (d) after filtering at the OLT.

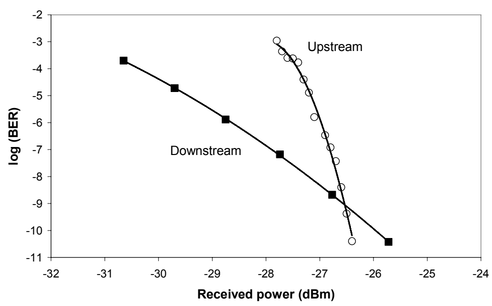

Figure 4: Sensitivity results for the proposed OLT and ONU architectures

Sensitivity and electrical oscillator's frequency drift impacts were evaluated. Regarding sensitivity, both directions are measured (upstream and downstream) at a reference wavelength of 1550.00 nm. Results are shown in fig. 4. For the downstream we achieved -26.0 dBm for a BER of 10^{-10} and -26.5 dBm for a BER of 10^{-9}. This is shown in fig. 4. This represents a substantial improvement respect to other work [7], and with doubled bitrate. For the upstream, -26.4 dBm were measured for a BER of 10^{-10}; and -26.5 dBm for a BER of 10^{-9}. Note that we vary the attenuation of the link, so the upstream slope is squared respect to the downstream.

To analyse the dependency on the intermediate frequency, we changed the frequency of the electrical oscillator on the OLT, and measured the penalty for a BER of 10^{-10}. Results for the downstream signal are shown in Fig. 5. For a penalty of less than 1 dB, we can only move the frequency inside a range of ± 40 MHz. This is explained because of the high confinement of the mixers frequency response. Also, its effect on the upstream signal was evaluated. In this case we moved the frequency inside a large margin (from 5 GHz to 2 GHz) reporting a power penalty for a BER 10^{-10} of less than 0.1 dB. This implies low crosstalk between downstream and upstream.

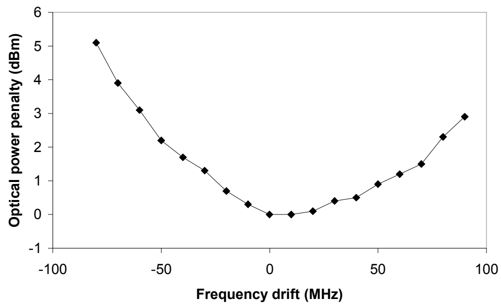

Figure 5: Downstream power penalty at BER 10^{-10} as a function of the SCM oscillator frequency.

Conclusions

We have demonstrated the bi-directional transmission of 2.5 Gbps / 1.25 Gbps in a SCM PON. In this network, the downstream signal was DPSK coded and up-converted by using a 5 GHz subcarrier, while the upstream data was transmitted in NRZ. A simplified scheme for the electrical parts of the ONU and OLT was proposed and demonstrated. The sensitivities found were -26.0 dBm for the downstream and -26.5 dBm for the upstream, for a BER of 10^{-10}.

This constitutes an enabling technique towards next generation PONs, featuring simple architecture, full bi-directionality, and low sensitivity.

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