TWDM-PON ONUs Optical Frequency Drift versus Tuning

G. Simon(1-2), F. Saliou(1), P. Chanclou(1), B. Le Guyader(1), L. Guillo(1), L. Anet Neto(1), D. Erasme(2)

(1) Orange Labs - 2, avenue Pierre Marzin, 22307, Lannion, France, gael.simon@orange.com
(2) Télécom ParisTech - CNRS LTCI, 46 rue Barrault, F-75634 Paris Cedex 13, France

Abstract *A vendor's TWDM-PON system and a commercial laser permit to demonstrate that reaching optical budget requirements for all NG-PON2 capable channels signifies failing upstream spectral excursion requirements, and reciprocally.*

Introduction

Time and Wavelength Division Multiplexing (TWDM) has been selected as a primary solution for Next Generation Passive Optical Networks (NG-PON2) to meet the future requirements of residential markets[1]. Based on 4 pairs of downstream/upstream wavelength channels (8 pairs optional), the optical channels should be separated by 50GHz, 100GHz, or 200GHz[2].

The bit-rate specified by TWDM-NG-PON2 can either be 2.5Gb/s or 10Gb/s for both upstream and downstream, as long as the upstream bit rate does not exceed the downstream bit rate.

Moreover, NG-PON2 requires colourless ONUs, able to tune and transmit on every channel of the system. Considering their low cost, thermally tuned lasers are the preferred solution[1].Time Division Multiplexing (TDM) is adopted for each downstream channel, whereas Time Division Multiple Access (TDMA) is required for each upstream channel. Consequently, Optical Network Units (ONUs) must support burst mode operation, meaning that each emitter at the customer side has a given time slot (few microseconds to a few hundred of microseconds) to transmit data.

Both direct and external modulations can achieve burst mode transmissions. However, when using external modulation, the sum of the low powers coming from the optical signals of numerous ONUs not being absolutely turned off by the modulators between two burst emissions would introduce an important source of noise at the emitting ONU signal.

Thus, either using an external modulator or not, the laser has to be rapidly turned off between two burst transmissions. It has been shown[3,4] that this fast on/off switching introduces brief perturbations in the semiconductor, leading to a rapid wavelength drift during the burst emission through the phenomena known as thermal chirp[5] and adiabatic chirp[6].

As a consequence, considering the low channel spacing of NG-PON2, and the potential ONU tuning error previously mentioned, the drift of a given emitter wavelength could disturb the considered and neighbour channels.

We propose here to study the wavelength drift of an efficient TWDM-PON system and a tunable commercial laser versus the different tuning channels as the peak power varies and the bias current is adjusted.

Experimental setup

A heterodyne detection method, whose setup is presented in Fig. 1, is used to measure the wavelength drift of the laser source. Two optical waves are generated by the laser under test on the one side, and a low phase noise external cavity laser on the other side. By mixing both signals with a coherent receiver, we generate a third wave, from the beating between them and whose instantaneous frequency depends on the difference of the optical frequency of the two lasers. Assuming that the wavelength of an external cavity laser used as Local Oscillator (LO) is stationary, the instantaneous frequency of the beating signal directly depends on the optical frequency of the Device Under Test (DUT). When the two laser wavelengths are close, the beating frequency is low enough to be

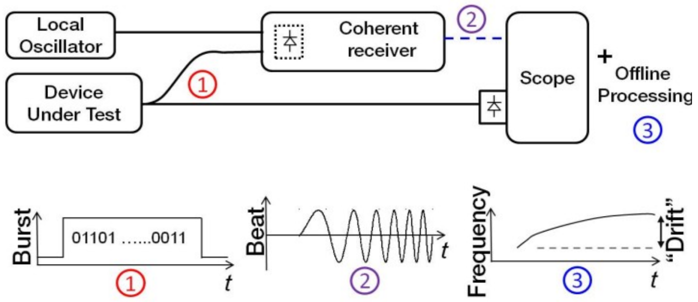

Fig. 1: Wavelength drift measurement experimental setup

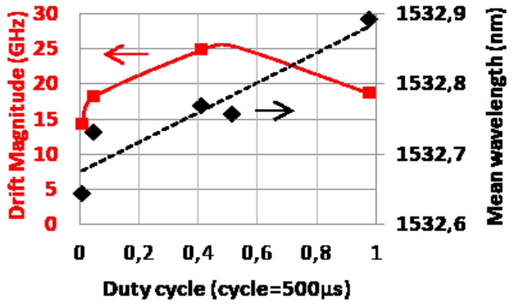

Fig. 2:TWDM system drift magnitude & mean wavelength

 © VDE VERLAG GMBH · Berlin · Offenbach

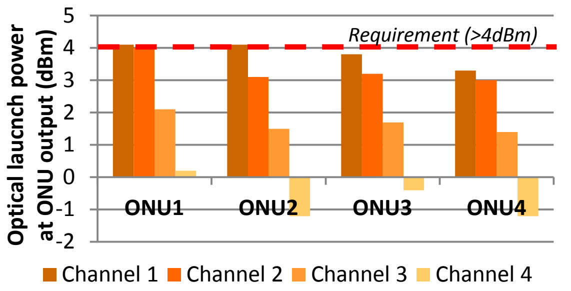

Fig. 3: Optical launch power at ONU output of the four ONUs under test, over the four channels (burst: 256µs)

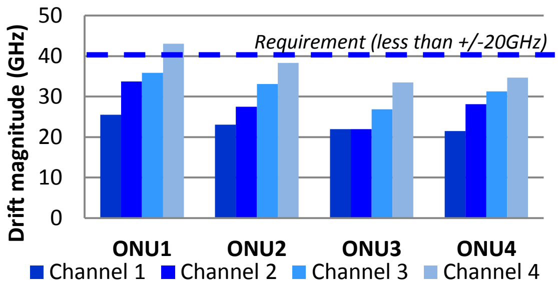

Fig. 4: Wavelength drift of the four ONUs under test, over the four channels

captured by the 14GHz bandwidth photodiode and then extracted by an offline processing detailed in a previous work[4].

TWDM-PON system results

The TWDM-PON prototype system under test is composed of 4 pairs of upstream/downstream channels separated by 100GHz, and working at 10Gb/s in downstream and 2.5Gb/s in upstream. Each of the four colourless thermally tuned ONUs emitters under burst mode operation consist in a C-band directly modulated laser receiving the burst envelop, followed by an external modulator generating a 2.5Gb/s Non-Return to Zero (NRZ) optical signal. Finally, a flattop 70GHz -3dB bandwidth MUX/DeMUX is used at the OLT side for separating the user channels. The TWDM system achieves 23.5dB to 29.5dB optical budget, depending on the channel and the ONU.

First, the wavelength drift magnitude is measured against the burst duty cycle, with the cycle duration being fixed to 500µs. As previously observed[4], Fig. 2 shows that the most important drift is observed when the duty cycle is close to 0.5, i.e. when emission (or warming) duration is close to the non-emitting (or cooling) duration, which implies the most important thermal chirp swing. However, the mean wavelength, defined as the mean value between the wavelengths at the beginning and at the end of a burst,, increases with the duty cycle as depicted in Fig. 2. Such wavelength shift, which depends on the burst duration, should then be compensated by a tuning mechanism that would have to be able to react to fast variations on the burst durations.

Peak optical power and wavelength drift are also measured for each of the four ONUs working on each of the four channels, when emitting a 256µs long burst every 500µs.

Figure 3 shows the mean optical power launched by the ONUs. The recommended power range is of 4dBm to 9dBm for unamplified optical line termination receivers. The four ONUs show optical powers of more than 3dBm on channel 1 and 2, but this performance is not kept for channels 3 and 4. Indeed, the power emitted by ONU 2 decreases down to -1.2dBm in channel 4. The average optical power reduction for the four ONUs is of about 4.5dB between channel 1 and channel 4, which consequently implies the same penalty on the optical budget.

The wavelength drift of the four ONUs increases when warming up the emitter to reach each of the four channels, as shown in Fig. 4. The mean wavelength drift increase is 60% from channel 1 to channel 4. The wavelength drift of ONU 1 increases from 25.5GHz on channel 1 to 43.1GHz on channel 4 (+69%), slightly exceeding the +/-20GHz Maximum Spectral Excursion across channel center defined in G.989.2[2] and discussed in a previous work[4].

Commercial laser results

Complementary experiments are then performed on a commercial C-band laser in order to better understand interactions between tuning (global temperature), wavelength drift and optical power. The DUT is thermally tuned over eight channels separated by 100GHz. The

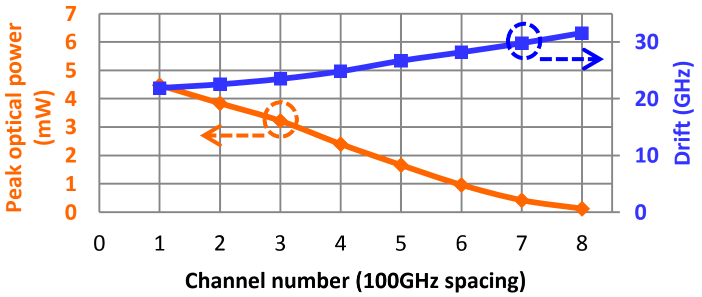

Fig. 5: Commercial laser's peak optical power and wavelength drift for various channels (burst current: 40mA)

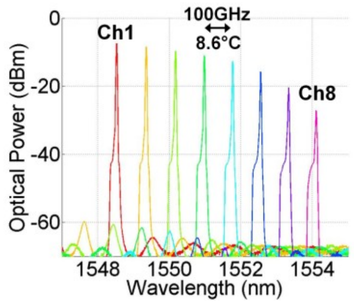

Fig. 6: Optical spectrums for 40mA bursts (constant electrical power)

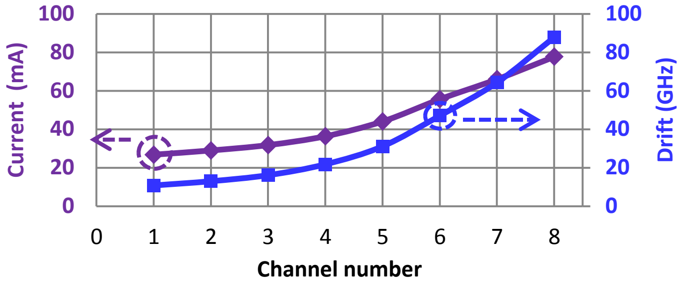

Fig. 7: Commercial laser's electrical current and wavelength drift for various channels (peak optical power: 3dBm)

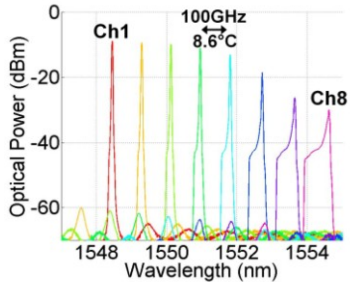

Fig. 8: Optical spectrums for 3dBm bursts (constant optical power)

thermal tuning response is measured to be 8.6°C/100GHz, and the temperature range goes from 5°C for channel 1 to 65°C for channel 8. The laser receives a 40mA and 62.5µs long electrical signal every 125µs. No current is sent for the remaining 62.5µs of the cycle. The resulting electrical signal characterizes thus the burst envelope. Assuming the drift to be generated by the laser on/off switching, no external modulator was introduced (no data).

Wavelength drift and peak optical power results versus the channel are presented in Fig. 5. Reaching 21.9GHz on channel 1, the drift increases to 24.9GHz on channel 4 (+13.5% compared to channel 1) and 31.6GHz on channel 8 (+44% compared to channel 1).

The peak optical power is simultaneously measured. It decreases from 4.5mW on channel 1 to 2.4mW on channel 4 (-2.7dB compared to channel 1) and to 0.12mW on channel 8 (-16dB compared to channel 1). The measured peak power decrease shown in Fig. 5 has a linear profile and corresponds to 0.66mW/100GHz (or 0.66mW/channel). The corresponding optical spectrums are presented in Fig. 6.

Consequently, for a constant electrical current applied at the emitter, the wavelength drift increases when warming the emitter, affecting the optical power and consequently the optical budget. However, it could be possible to adapt the electrical current for each channel in order to maintain the output optical power and budget constant. The target peak optical power was fixed to 3dBm in our experiments.

This is shown in Fig. 7 and the corresponding optical spectrums are displayed in Fig. 8. A 26.7mA electrical current is enough to reach the target optical power for channel 1 (5°C), but has to be increased to 36.3mA and 77.7mA to reach channel 4and channel 8 powers respectively

According to the theory of thermal chirp[5], the drift also increases with the current. Consequently, even if the drift for channel 1 is 10.7GHz, it would double to 21.7GHz for channel 4 and would increase by 720% (87.8GHz) for channel 8.

Discussion and conclusion

Experiments based on a vendor's TWDM-PON prototype and a commercial laser proved that for a given bias current, thermal tuning of the ONU's laser implies a significant increase in the wavelength drift of the directly modulated ONUs laser under burst mode operation. At the same time, the optical output power of the emitter and consequently the corresponding optical budget appears to decrease considerably. Moreover, the ONU tuning mechanism should compensate the wavelength shifts induced by a burst profile, in addition to the wavelength drift.

We also showed that increasing the bias current of the laser to compensate ONU's optical output power decrease (possibly with a feedback control mechanism) automatically implies on an important wavelength drift increase. Even for a four channel prototype as the one presented here, difficulties still exist in implementing a system that respects at the same time optical budget and spectral excursion recommendations on all channels. Worst performances would be expected for an eith channel system.

To conclude it is essential that TWDM PHY layer recommendations include measurements of launch power and spectral excursion for each ONU and every capable channel.

Acknowledgements

This work has been partially funded by the French LAMPION project (ANR-13-INFR-0002). The authors wish also to thank the vendor, for the loan of the TWDM-PON system.

References

[1] D. Nesset, "NG-PON2 Technology and Standards," JLT, Vol. **33**, no. 5, pp. 1136-1143, March1, 1 2015.
[2] ITU-T.G.989.2, "40-Gigabit-capable passive optical networks (NG PON2): PMD layer specification"
[3] W. Poehlmann et al., "Wavelength drift of burst-mode DML for TWDM-PON [invited]," JOCN,vol. 7, no.1, 2015.
[4] G. Simon et al., "Focus on Time-Dependent Wavelength Drift of DMLs under Burst-Mode Operation for NG-PON2," JLT, doi:10.1109/JLT.2016.2552719
[5] E. G. Vicente de Vera et al., "Switching-time limitation in tunable multisection lasers," PTL, vol. 2, no. 11, 1990
[6] Krehlik, P., "Characterization of semiconductor laser frequency chirp based on signal distortion in dispersive optical fiber", Opt-Elec. Rev., Vol. 14, Iss. 2, pp.119-124

 © VDE VERLAG GMBH · Berlin · Offenbach