Experimental Assessment of Stimulated Raman Scattering Impairments between XGS-PON and 50G-(E)PON

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Abstract: Critical 0.68dB of power depletion due to SRS on the upstream signals of 50G-(E)PON US and XGS-PON US is measured experimentally when contra-propagating in 20km SMF with 50G-(E)PON Downstream. © 2022 The Author(s)

1. Introduction

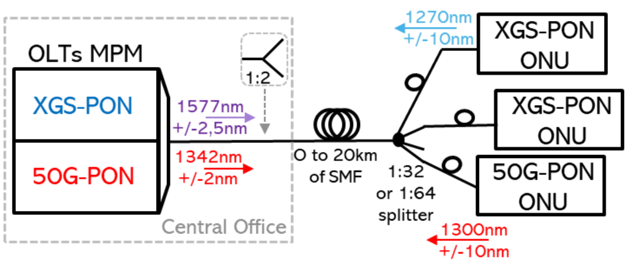

Fig. 1. Scheme of XGS-PON and 50G-PON co-existing over the same ODN

ITU-T PONs G9804 & G9807	Wavelength range (nm)	Class N1 [14-29] dB ALP (dBm)	Class C+ [17-32] dB ALP (dBm)
MPM 50G-PON DS	1340-1344	Min: 5,5 dBm Max: 11 dBm	Min: 8,5 dBm Max: 14 dBm
ONU 50G-PON US @24,88Gbit/s	1260-1280 or 1290-1310	Min: 5 dBm ; Max: 9 dBm	
ONU 50G-PON US @49,77Gbit/s		Min: 6 dBm Max: 11,8 dBm	Not yet specified
ONU XGS-PON US	1260-1280	Min: 4 dBm ; Max: 9 dBm	

Table 1. ITU-T specifications recap

Recent progress in standardization bodies permits to identify a clear path for post Gigabit and 10Gbit/s Symmetrical PON technologies (G-PON and XGS-PON): 50G-PON [1] and 25G/50G-EPON [2] has been edited in ITU-T and IEEE respectively. The ITU-T specified wavelength ranges that allow co-existence in wavelength overlay of 50G-PON with either G-PON or XGS-PON. Figure 1 proposes a scheme of 50G-PON co-existing with XGS-PON over a typical fibre plant (Optical Distribution Network – ODN) that is still being deployed for G-PON. The configuration of current ODNs varies depending on the density of the area and the fibre reach needed to deliver services to Fibre To The Home (FTTH) users. The fibre reach varies mainly from few hundreds of meters to 15km most of the current deployments in France as reported in [3]. For each PON, the splitting ratio of the ODN is based on 2 or 3 cascaded stages of powers splitters: for dense areas 2 stages of 1:8 splitters are installed in street cabinets, most of them being less than 1km away from the homes; for medium and less dense areas a 1:2 splitter is placed at the CO, directly at the OLT output port, and a 1:32 is placed in the street cabinet. Both 50G-PON and XGS-PON ONUs or 25G/50G-EPON and 10G-EPON will share this ODN infrastructure in the future, both operating with different specifications though. Also, for the first time in PONs, both upstream (US) and downstream (DS) of the 50G-PON carriers are specified in the O-band. Also, optical budget classes are the same as for XGS-PON to avoid extra costs if renewing the fibre plant would be required. However, reaching optical budgets as high as 29dB for class N1 or 32dB for class C+ imposes the use of emitters with very high Average Launched Powers (ALPs) and very low sensitivity receivers, both capable to operate at 50Gbit/s. Table 1 summarizes some of the specifications of 50G-PON DS and XGS-PON US showing ALPs as high as 14dBm to be launched at the output of 50G-PON Multi-PON Module (MPM) at the Optical Line Terminal (OLT). On the other side, each Optical Network Unit (ONUs) is allowed to emit up to an ALP of 9dBm in burst mode. Figure 2 depicts the wavelength plan of all the PON systems, with a focus on the O-band where up to 3 signals would be carried in the same fibre plant if ITU-T systems would be deployed (XGS-PON US and 50G-PON DS and US carriers) and up to 5 signals in the case of IEEE PON systems (10G-EPON US, 50G-EPON DS1+DS2 and US1+US2). Indeed, unlike ITU-T, IEEE chose to propose a smoother upgrade to higher bitrates with its 25G-EPON that can co-exist with 10G-EPON systems. A higher rate option is also possible with 50G-EPON, adding another 25Gbit/s channel in wavelength overlay for both downstream and upstream transmissions. Table 2 presents a recap of some specifications of 25G-EPON and 50G-EPON standards.

With that many signals being transmitted in the same fibre at such high powers, Stimulated Raman Scattering (SRS) could modify the transmission performances with power interactions between the different carriers [4,5]. Raman interactions in Standard Single Mode Fibre G.652 depends on the frequency spacing between pumping and amplified carriers, and a maximum Raman gain is expected at approximately ~13 THz frequency spacing [6] as plotted on Figure 2, with the estimated Raman gain profile reported on the PON wavelength plan. In this paper, we propose to investigate experimentally on the Raman interactions between PONs systems transmitting in O-band.

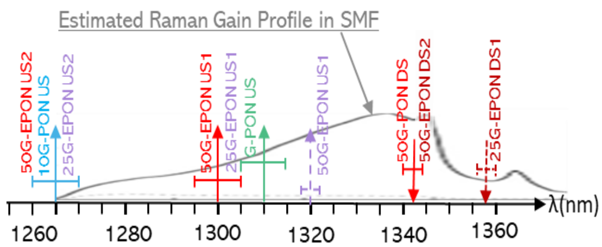

Fig. 2. PON systems wavelength plan in O-band and Raman Gain profile

IEEE PONs 802.3c/802.3av	Wavelength range (nm)	Class PQ/R20X–D2&U2 [10-24] dB	Class PQ/R30X-D3&U3 [15-29] dB
25G-EPON DS	1356-1360	Average Power : 5dBm for each channel Total max : 8dBm	Average Power : 7,8dBm for each channel Total max:10,8dBm
50G-EPON DS (2 channels)	1356-1360 & 1342-1344		
25G-EPON US	1260-1280 or 1290-1310	Average Power : 7dBm for each channel Total max : 10dBm	Average Power : 9dBm for each channel Total max : 12dBm
50G-EPON US (2 channels)	1260-1280 & 1290-1310 Or 1290-1310 & 1318-1322		
10G-EPON US	1260-1280	Average Launched Power Min : 4dBm Average Launched Power Min : 4dBm	

Table 2. IEEE specifications recap

2. Experimental setup, results, and discussions

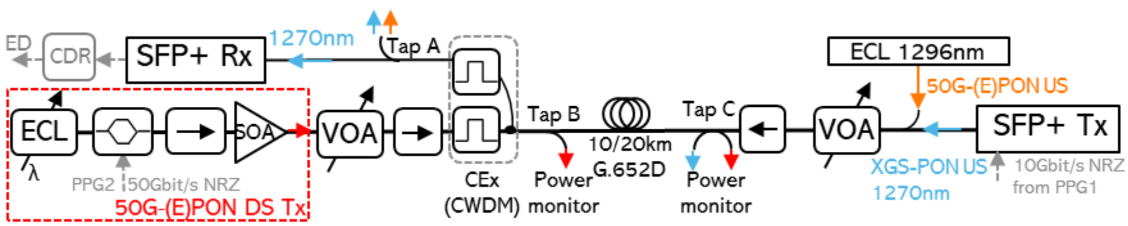

Fig. 3. Experimental setup to measure SRS with 50G-(E)PON DS and US signals

Figure 3 depicts our experimental setup to assess SRS between XGS-PON US and 50G-(E)PON DS and US signals. The 50G-PON DS transmission consist of an External Cavity Laser (ECL) tuned at 1344nm, followed by a Mach-Zehnder Modulator (MZM) that modulates the carrier with a Non-Return to Zero Pseudo Random Bit Sequence (PRBS) of length 2^{31}-1 at 50 Gbit/s. Then an isolator is placed to avoid back reflections to the modulator and a SOA must be used to reach Tx output power as high as 14dBm, as specified in the standard. At the Tx output, a Coarse Wavelength Division Multiplexing filter followed by a power splitter plays a role of Co-Existing element (CEx) or US/DS diplexer and in addition it helps on reducing part of the ASE noise emitted by the SOA. Hereafter, a Variable Optical Attenuator followed by an isolator is inserted to vary the amount of optical power to reach the input of 10 or 20 km G.652.D Standard Single Mode Fibre. For the other way, we injected either an XGS-PON US signal at 1270nm coming from a commercial SFP+ transmitter modulated by a continuous PRBS31 sequence at 10Gbit/s, or an US signal from an ECL tuned at 1296nm to stand for the 50G-(E)PON US (not modulated). Each signal is transmitted by varying the launched power in the SMF with a VOA followed by an isolator. For each way of transmissions, the powers injected in the fibre are monitored with Tap B and Tap C splitters, and we measure the impact of SRS on the US signals reaching Tap A splitter, either at 1270nm when a CWDM filter centered at 1271nm is inserted in the CEx or at 1296nm which is at the maximum of the CWDM filter centered at 1291nm. No polarization controller was used to maximize the SRS on the case of co-polarized transmitted signals since we are investigating on SRS with contra-propagating signals that will statically meet co-polarized states along transmission in the SMF. This was confirmed experimentally. In addition, we also measured the Bit Error Rate of the XGS-PON transmission to estimate SRS Optical Power Penalties, we observed no penalty on the receiver sensitivity, which is limited mainly by its thermal noise, but it took less attenuation (depends on the injected power levels) to reach the same receiver sensitivities.

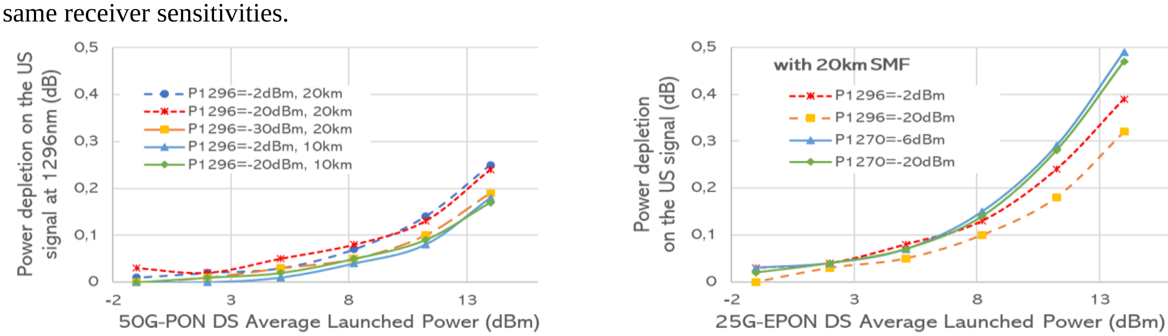

Fig. 4. (a) Power depletion on carrier at 1296nm when contra-propagating in 10 or 20km SMF with a 50G-(E)PON signal at 1344nm.
(b) Power depletion on carrier at 1296nm or 1270nm when contra-propagating in 20km SMF with a 25G-EPON signal at 1356nm

Indeed, Figure 4(a) presents the power depletion due to the co-propagation in 10 or 20km of SMF of 50G-(E)PON DS and US signals, considering a DS carrier at 1344nm and the US carrier at 1296nm. We observe with high repeatability on the measurements, that for high injected DS power (after Tap B) in 20km of fiber, the power depletion on the US is the highest and reaches 0.25dB, either for a weak US signal injected or a strong one (-20dBm corresponds to an ONU emitting at 5dBm followed by a 1:64 splitter (>15dB losses) in the street cabinet; -2dBm corresponds to an ONU emitting at its maximum of 11.8Bm followed by ~13dB losses of a 1:32 splitter). This depletion might seem negligible, but this will happen when the OLT must send its highest power to reach far users, so with the maximal reach capable and the highest losses in the ODN. In that case, the 50G-(E)PON OLT US sensitivity will be even more challenged due to this SRS power depletion. For 10km of SMF, the depletion is reduced to a maximum of 0.19dB when the US reaches the fibre with low power (-30dBm) and when the DS emits at its maximum (14dBm). Figure 4(b) report of the measurements of the power depletion on the US signal for the specific case of 50G-EPON DS when the carrier is chosen to be centered at 1358nm (+/-2nm). Due to spectral limitations of our CWDM filter centered at 1251nm, we now tune the ECL of the 50Gbit/s DS signal to emit at 1256nm and stand for the 25G-EPON or one of 2 DS carriers of the 50G-EPONs. We observe a maximum power depletion of ~0.48dB when the DS at 1256nm is emitting at 14dBm and contra-propagating with an US signal emitted at 1270nm (10G-EPON US) is injected in 20km of fibre at -6dBm or -20dBm. The SRS penalty on the US power is lower when the contra-propagating US signal is set at 1296nm since the wavelength difference does not correspond to the maximal SRS interactions in SMF [6].

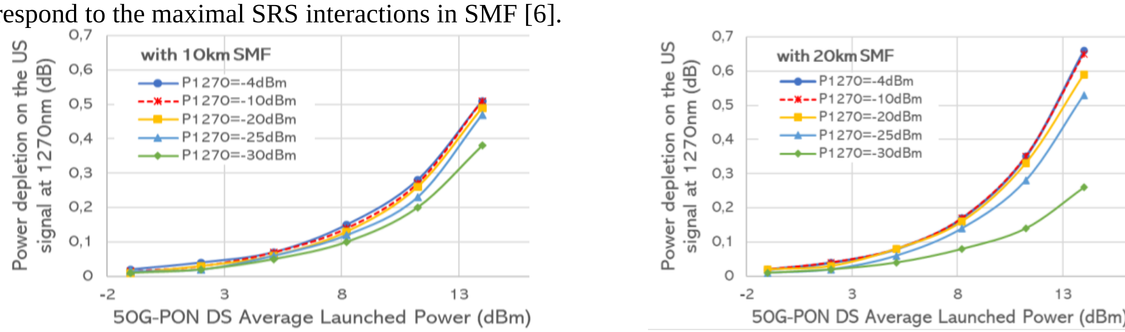

Fig. 5. (a) Power depletion on carrier at 1270nm when contra-propagating in 10km SMF with a 50G-PON signal at 1344nm.
(b) Power depletion on carrier at 1270nm when contra-propagating in 20km SMF with a 50G-PON signal at 1344nm

Now, we focused the measurements on the SRS interactions between the 50G-PON DS at 1344nm and the XGS-PON US at 1270nm, as presented in Figure 5(a) for 10km and Figure 5(b) for 20 km fibre reach. We observe that the power depletion on the XGS-PON US can reach up to 0.5 dB and 0.68 dB when contra-propagating with the 50G-PON DS signal, respectively in 10km and 20 km of SMF. The XGS-PON being already deployed in some countries, we know that power margins on the US are really limited compared to GPON commercial transceivers: a class C+ MPM G/XGS-PON transceiver is specified for -32 dBm sensitivity for the XGS-PON US and we measured a margin of only 0,5 to 1.5 dB for different samples of commercial transceivers, which makes the SRS penalties to be considered seriously. A solution to limit SRS would be to decrease the DS signal injected in the fibre, either decreasing the emitted power at the OLT when possible and/or inserting a 1:2 power splitter at the OLT output as it is done today for mean/less dense areas. Thus, reaching the fibre with 3dB less power on DS would limit the power depletion to 0.35 dB (in 20 km SMF). It is worth noting that no gain was measured during the measurements, since the high wavelength signal power (50G-PON/25G-EPON/50G-EPON at 1356 or 1344nm) is already high, and the additional energy extracted from the low wavelength signal is then negligible.

3. Conclusions

We experimentally measured, with high repeatability without polarization controllers, Stimulated Raman Scattering power penalties of 0.5 and 0.67 dB depletion on the US signal(s) of 50G-(E)PON and XGS-PON when contra-propagating respectively through 10 or 20 km of SMF with the 50G-(E)PON DS. This could lead to numerous outages on upstream XGS-PON customers when introducing the next generation PON.

Acknowledgements: This work was carried out in OCTAPUS HORIZON-CL4-2021-DIGITAL-EMERGING-01-06 project (number: 101070009) and MARSAL H2020-ICT-52 project.

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