Analysis of backscattered optical signals in narrow spectrum remote feeding single-fibre links employing RSOAs

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Abstract *We assess the bounds that Brillouin and Rayleigh backscattering impose to single fibre optical links that use narrow spectrum optical sources acting as feeders of RSOAs for upstream transmission.*

Introduction

Most of the Wavelength Division Multiplexing Passive Optical Network (WDM-PON) architectures are based in using the same fibre for both up and downstream transmission [1]. Remotely seeded RSOAs are often used to avoid the need of an optical source emitting in a specific wavelength in each ONU, which is fixed in a WDM environment. In this type of architecture the signals propagating in the upstream direction can experiment degradation due to the backscattering effects arising at the standard single mode fibre (SMF). Rayleigh scattering (RayS) has been thoroughly studied in this environment [2,3] as it has been claimed to impose certain limits in the optical power that a CW or modulated laser can introduce into the optical fibre [4]. By increasing the spectrum width of the seeding wavelength and maintaining an adequate signal to backscattered power ratio it is possible to avoid high power penalties caused by RayS. Brillouin scattering (BS) has not been studied so extensively because the back-scattered power is produced at a different wavelength, out of the bandwidth of typical detectors used in WDM-PONs. However, the amount of backreflected power can be very high in these situations, and may affect in some way the upstream transmission even in the sub-10G range. In this communication we will analyze experimentally the combined effect of RayS and BS by measurements in RSOA based 1.25 Gbps upstream links fed by CW or narrow-spectrum lasers.

Experimental Set-up

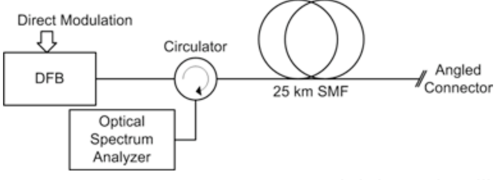

Figure 1.- Set-up to measure Rayleigh and Brillouin effects.

First we assessed the different scattering effects that reflect back to the source in a simplified scheme of a link with remotely seeded RSOAs. The basic set-up is shown in Figure 1. We used a 1545 nm DFB laser set at different CW bias currents to study the behaviour of the backscattered optical power; the laser was also directly modulated with a square signal with an excursion of 1.5 and 2.5 mA from the bias current with the purpose of broadening the spectrum of the emitted signal by means of the chirp of the laser. The emitted spectrum was in the range of the GHz for both modulation intensities and did not change more than 10% when varying the bias current of the DFB over the studied range. The incoming signals were measured using a high-resolution optical spectrum analyzer (BOSA-C from Aragon Photonics). The different backscattering phenomena took place into 25 km of standard SMF, terminated in an angled connector to make sure that there are no direct reflections of the emitted signal in the measurements with the HR-OSA.

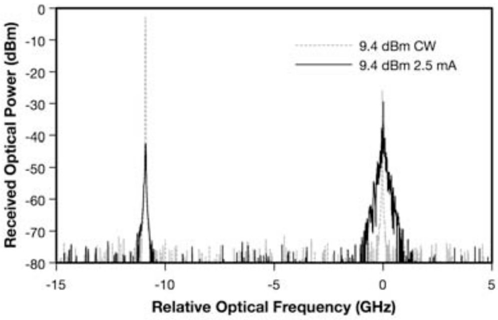

Figure 2.- Directly measured optical spectrum of Brillouin and Rayleigh backscattering signal.

Figure 2 displays a typical spectrum obtained in reception for a CW and 2.5 mA modulated signals. The Brillouin peak can clearly be seen 10.8 GHz below the Rayleigh peak, which is at the central wavelength of the DFB. A noticeable decrease of the Brillouin peak is produced when the signal is broadened, which is not found for the Rayleigh peak.

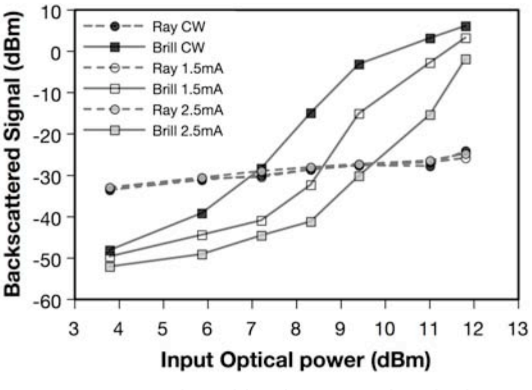

Figure 3.- Detected total backscattered optical power.

The total backscattered power at the peaks of RayS and BS wavelengths is displayed in Figure 3 as a function of the power injected by the DFB into the fibre. We obtained different curves by changing the amplitude of the modulation current applied to the DFB. RayS total power rises slower than BS with increasing input power and does not suffer noticeable variations with different modulation intensities. The Brillouin effect, however, varies strongly and is mitigated by spectrum broadening in agreement with the behaviour observed in the spectra shown in Figure 2. In any case, as RayS noise is interferometric noise, it can be the limiting factor even although it is not increasing so steeply.

Link Behaviour

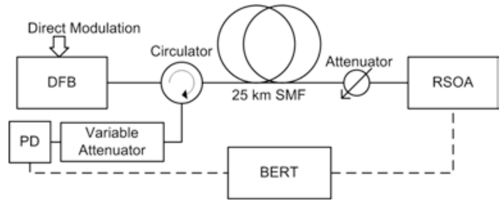

Figure 4.- Set-up to test the performance of the reflected transmission.

The scheme depicted in figure 4 was utilized to study the influence of backscattered power in the upstream transmission of a reflective type of ONU. A 20 dB gain RSOA with +5 dBm saturation optical power was used to reflect and amplify the upstream channel, which was modulated and detected at 1.25 Gbps by a Bit Error Rate Tester (BERT). An attenuation of about 5 dB was placed just before the RSOA to avoid high saturation operation.

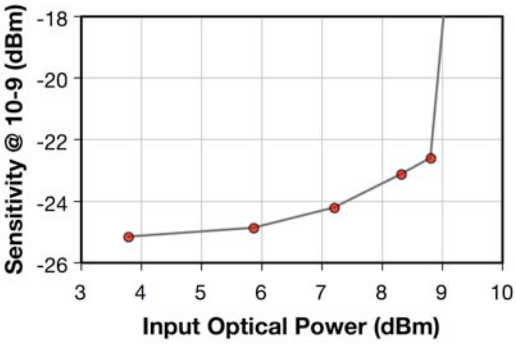

Figure 5.- Sensitivity at 10^{-9} BER as a function of the input optical power (broadened by 2.5 mA).

Figure 5 shows the sensitivity of the link (at a 10^{-9} BER) when the DFB source spectrum is broadened by an excursion current of 2.5 mA, for different optical input powers in the SMF. The sensitivity decreases when the optical fibre input power increases until a value of 9 dBm is reached, because the signal is maintained almost constant at the output of the RSOA but the RayS increases. According to [4] this should lead to a raise in the received power penalty, which is observed. Further input power increase degrades the link reaching a threshold around 9.5 dBm, from where it is impossible to obtain a low BER. We think that this behaviour cannot be attributed only to RayS, because the increase in power penalty due to this effect does not follow he observed behaviour. So BS has to help introducing some instability to the signal. In fact, optical power at the BS wavelength even increases when placing a RSOA at the end of the link. To confirm this point, optical spectra were measured with the set-up of figure 4 by placing the HR-OSA instead of attenuator and PD. The total power at the BS and the upstream signal is shown in Figure 6. Direct comparison with Figure 3 shows that the increase in the BS optical power is slightly steeper than in the case without RSOA. On the other hand, signal optical power is nearly constant at the output of the RSOA, which is in saturation. It is marked with arrows the approximate optical power inserted in the fibre where the link fails completely. This threshold takes place at lower optical power inputs for narrower spectrum widths, even with the presence of high attenuation in front of the RSOA, because the signal is attenuated at the detector but RayS and BS remain constant.

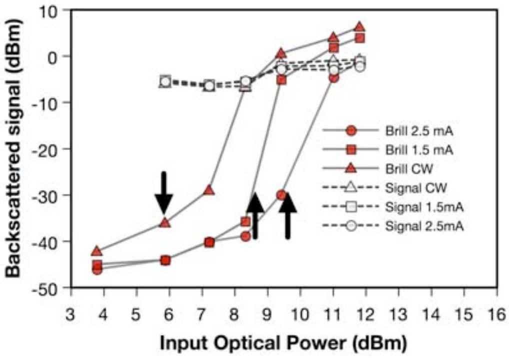

Figure 6.- Backscattered signal as a function of the optical input power for figure 4 set-up. The threshold optical power for each condition is shown.

Conclusions

A study of the different backscattered signals in a single fibre bidirectional link employing RSOAs has been presented. It has been shown that the combined effect of RayS and BS can be catastrophic in this type of links when using narrow spectrum optical sources acting as power feeders of RSOAs.

Acknowledgements

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References

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