Rayleigh Backscattering-suppression in a WDM Access Network employing a Reflective Semiconductor Optical Amplifier

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Rayleigh Backscattering feeding back an Optical Network Unit with a Reflective Semiconductor Optical Amplifier is an important distortion factor in a drop link of access network. Amplitude-to-phase coupling induced by RSOA bias dithering is used to mitigate this crosstalk and it brings power penalty improvement of around 3dB.

Introduction

The increasing bandwidth demand in Fiber to the Home networks for existing and future applications drives the research on access network technologies. This research includes the development of cost-effective devices, the improvement of network towards reconfigurability and migration scenarios from TDM-PONs to WDM/TDM-PONs [1-4].

An RSOA represents a promising solution as a cost-efficient wavelength-independent (i.e. colourless) transmitter at the ONUs. However, next to the advantage of having no wavelength-specific source at the ONU (which is very attractive in WDM-PON architectures), a drawback is the high sensitivity to reflected or backscatterred power coming back to the RSOA. This power interferes with the original CW seeding beam and power instabilities rise up. This so called in-band crosstalk causes the degradation of Signal-to-Noise Ratio (SNR).

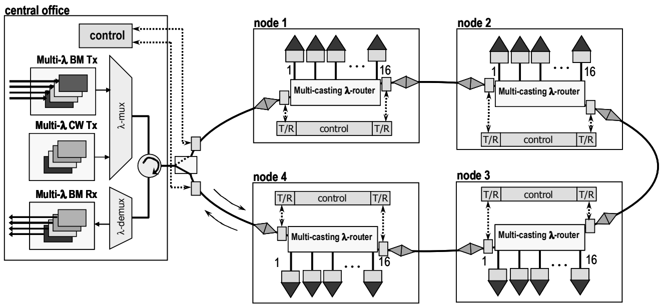
There are some solutions to decrease the in-band crosstalk, a. o. additional phase modulation, polarization scrambling and low coherence source deployment [5]. Recently, a novel method was proposed to fight with coherent crosstalk arising from interference between CW seeding beam and reflected power [6]. This method is based on the dithering of the RSOA bias current.

In this paper we apply the same method as in [6] to fight with the backscattered power feeding the RSOA.

Network concept

The network consists of the distribution part in the ring topology and point-to-point connections between Remote Nodes (RN) and ONUs (Fig. 1). The design of the distribution part provides redundancy. It means that the physical topology does not determine whether the downstream or upstream should go along upper or lower branch of the ring, since bidirectional single fiber transmission is applied. Detailed description of the network architecture is given in [3]. Here, we focus on the ONU architecture.

The ONU consists of a Mach-Zehnder Interferometer (MZI), RSOA and a receiver, see Fig. 2. MZI separates or combines downstream and upstream signals. The downstream data is sent to the photodetector. The downstream CW beam generated in the Central Office (CO) goes to the RSOA where by the means of the intensity modulation the upstream data is imposed on the optical carrier and returned to the CO. The capability to provide gain and modulation in the same time rejects the need for additional amplification, while the wide amplification bandwidth of the RSOA implies wavelength independence.



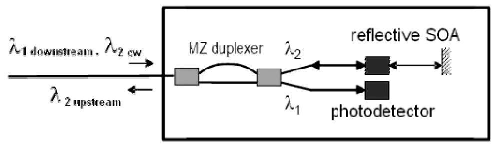


Fig. 1: Access network architecture

Fig. 2: ONU architecture

Rayleigh Backscattering crosstalk

The Rayleigh Backscattering (RBS) in the fibre is caused by material density imperfections occuring during fibre manufacture. The intensity of backscattered power increases with the fibre length until it converges at around 25km, achieving -35dBm (at 0dBm input power). If a bidirectional transmission over a single fibre is considered, the backscattered power is added to the copropagating signal on the same wavelength and this mixing converts phase fluctuations to intensity fluctuations. The degradation of the signal depends on the power ratio between the copropagating signals, so called Signal-to-Crosstalk Ratio (SCR).

Most of the experimental works on RBS concerns the RBS power influencing directly the receiver. However, here, we investigate the influence of RBS on the performance of the reflective modulator and propose a solution to mitigate this influence.

Crosstalk mitigation method

To reduce the influence of the RBS we apply a method based on the spectral broadening. The optical spectrum of the signal can be broadened deploying the amplitude-to-phase coupling in the RSOA, which is described by linewidth enhancement factor. Due to the change in the carrier density caused by a variable current applied to the device, the refractive index of the active material also changes and so does the phase of the signal. This causes spectral broadening and coherence length reduction. Consequently, the RBS-induced in-band crosstalk is suppressed. The desired amplitude-to-phase coupling is achieved when an extra modulation signal with an appropriate amplitude and frequency (dithering signal) is applied to the RSOA together with the bit stream. In the electrical spectrum, if the frequency of the dithering is high enough, the noise from baseband is moved to the higher harmonics out of the data bandwidth. Thus, by applying low-pass filtering at the receiver the noise is rejected [8].

Experimental setup

The experimental setup is given in Fig. 3. The CW signal goes from the laser through the variable attenuator, the circulator, the polarization controller and 3dB coupler into a commercially available RSOA. The signal is modulated in the RSOA by a composition of the data signal (2^{31}-1 PRBS at 1.25Gbit/s) and the bias dithering (2.5 GHz sine-wave signal). Part of the returning modulated signal power goes through the polarization controller into the 25km SMF span, where the RBS power is accumulated. The RBS power propagates back to the ROSA and after coupling into the feeding fiber it causes power instabilities of the RSOA input signal. Such distorted signal is modulated and sent to the receiver via the coupler, the polarization controller, the circulator and an ASE filter. In order to measure the BER versus Received Optical Power (ROP), the optical power is adjusted with a variable attenuator and fed to a receiver followed by a BER measurement testset (BERT).

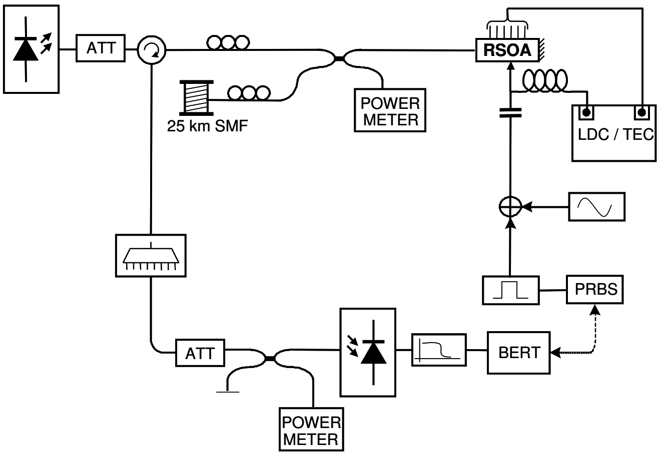


Fig. 3: Experimental setup

Results and discussion

The CW input power together with the RBS power accumulated over 25km SMF results in a SCR equal to 18.5dB. This ratio introduces around 5dB power penalty and an error floor (at BER = $10^{-8.8}$), Fig. 4. The spectrum of the reference signal at the output of the RSOA, where no dithering is applied and no RBS is present, is shown in Fig 5a. The spectrum of the backscatterred signal is shown in Fig. 5b. One can see that besides the Rayleigh backscattering there is also Brillouin BS power. However, the latter has much lower signal than the former and, thus, it does not influence the useful signal.

After applying the bias dithering at the RSOA the spectrum of the output signal broadens (Fig. 5c), and the power penalty due to RBS is reduced with around 3dB.

The dithering frequency of 2.5GHz is out of the receiver bandwidth and the RBS-induced crosstalk shifted with this frequency can be sufficiently suppressed by the stopband of the receiver low-pass filter.

The amplitude of the dithering is equal to the double of the data amplitude. The requirement for this relatively high amplitude is due to the low linewidth enhancement factor (around 2-3) for the applied MQW-RSOA. For bulk materials this parameter is higher, up to 8-10, thus the dither amplitude may be much lower.

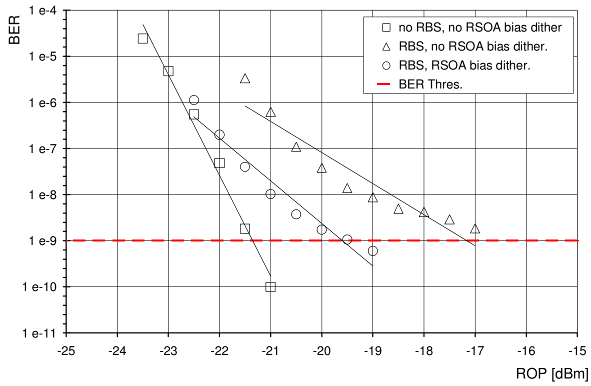


Fig. 4: BER results

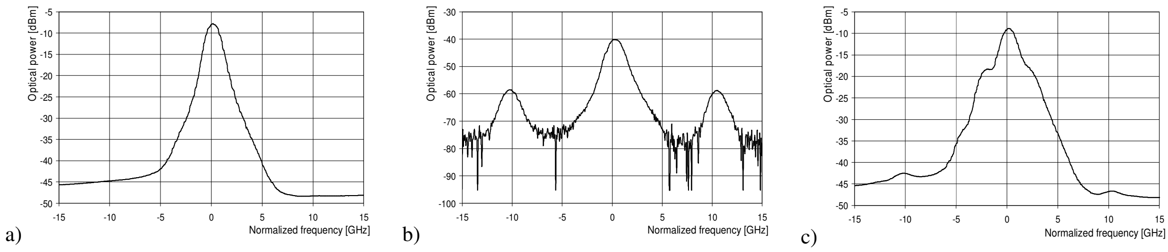


Fig. 5: RSOA output spectrum when no RBS or bias dithering is present a), spectrum of the backscattered power b), RSOA output spectrum when RBS and bias dithering are present c)

Conclusions

In this paper we have shown that the Rayleigh backscattering will cause serious power penalty in the link deploying an RSOA. An easy-to-implement and effective method using RSOA bias dithering reduced RBS-induced crosstalk power penalty with 3dB. This power penalty can be improved further by applying phase modulation at the laser (requires extra hardware), since a broader spectrum can be achieved.

Acknowledgements

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