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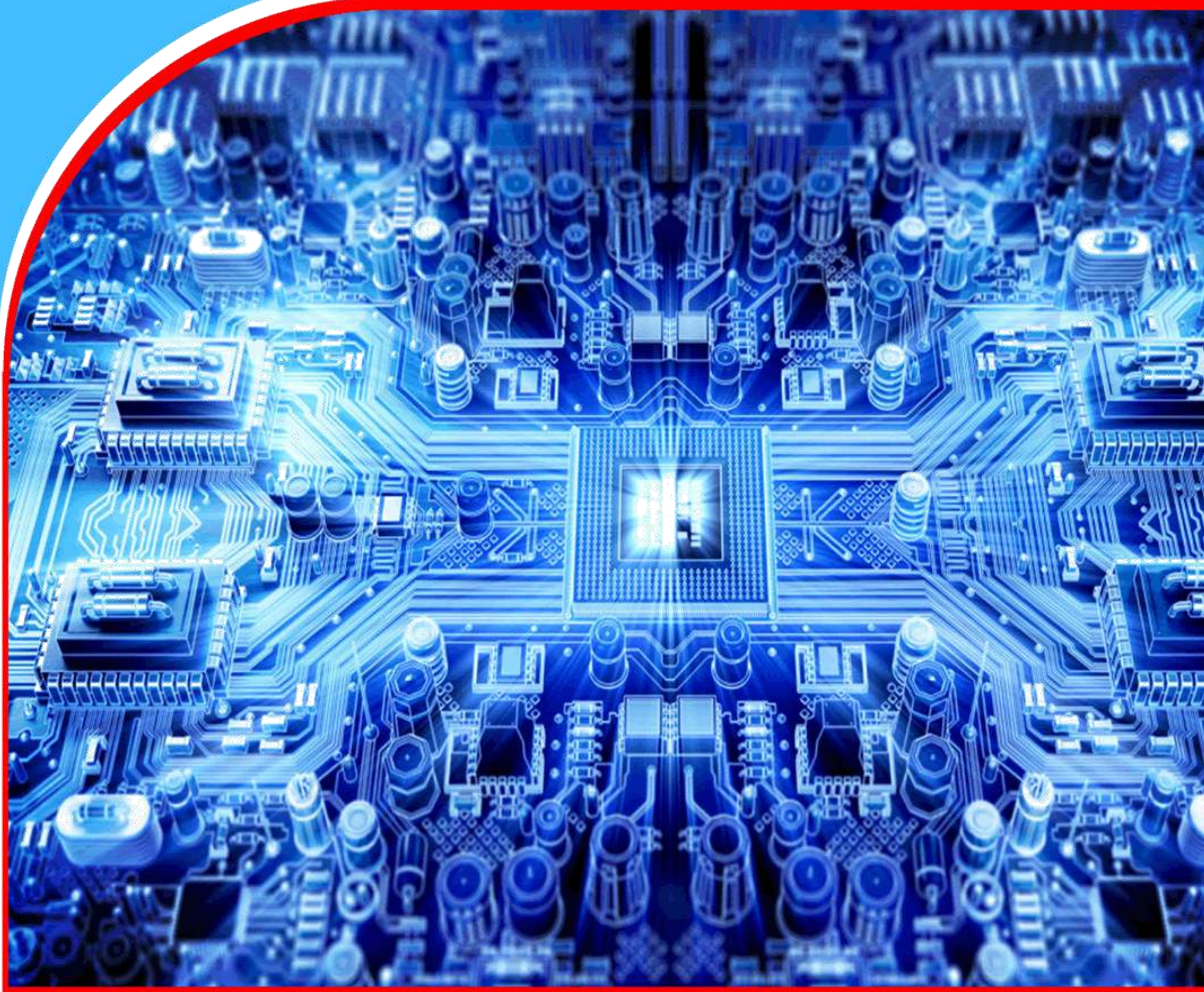

Optimization of Hybrid Optical Amplifiers (Raman-EDFA) with a Standard Fiber (SMF) and a maximum pump power of 200mw in access networks: WDM-PON

Bimogo Joseph Armel

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Bimogo Joseph Armel
Essiben Dikoundou J.F
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Corresponding Author's Email : barelbimogo@yahoo.com

Abstract

In this paper , we demonstrate the possibility of Raman -EDFA association in access networks. For this purpose, we evaluate the respective performances of these two types through a numerical method for 16 channels. Interesting results can be exploited; it is shown that with EDFAs, a target gain of 20dB can be reached for a wavelength range of 980 to 1440nm but with several perturbations in the received signal due to SNR and OSNR. These problems are solved with the integration of Raman amplification which pushes the gain limit to 27dB, with a better flatness.

1. Introduction

Telecommunications operators have made passive optical networks (PONs) the technology of choice in access networks; currently, it is difficult to design new infrastructures without the integration of PONs, especially when it comes to integrating new services such as FTTX, video conferencing, the internet of connected things and many others. Some scientific studies set the limits of PONs at 50 km of optical fiber for 1024 users [1 11]. Studies conducted by the IEEE.802.3 group demonstrate the possibility of transmission with a speed between 10 and 50Gb/s in accordance with the project of standardization of access networks associated with studies done long before by FSAN [1 2].Previous research already confirmed a higher density in 2021, ten times higher than in the past; certainly due to factors as the demographic growth of the number of users added now to the quality, power and bandwidth available for hosting all these services in urban areas.

As a solution, a hybrid optical transmission system has been considered over a distance of 25.24 km, for FTTA [5]. Its main advantages lie in its enormous bandwidth, high transmission power, low cost and good mobility [6]. The results of this study make hybrid systems an interesting solution for the implementation and operation of new services even though their research has been restricted to video.

On the other hand, the optimization of the bandwidth in optical fibers, passes by a multiplexing of the traffic of several users [7]. For this purpose, the WDM-PON technology (Wavelength Division Multiplexing in Passive Optical Network) is more often used in the access network, in order to satisfy the unceasingly increasing demand in bandwidth [8, 9]. However, this technology can lead to a reduction in inter-channel spacing which can be the cause of inter-symbol interference [9].

Finally, the performance of the Raman amplifier associated with that of the EDFA can enhance the optical transmission capabilities in any type of network; their ability to provide gain over the entire bandwidth is an interesting asset in optical transmissions, it is just a matter of choosing a type of pumping adapted to the wavelength [10]. This is one of the reasons why in this paper we are going to associate a hybrid amplification (Raman-EDFA) to WDM in order to address the different concerns of access networks. For this purpose, we consider as a reference the table I, which summarizes the losses of an optical link in an access network. Well before and considering the fact that EDFAs have become unavoidable in access or urban networks [11], we will model each amplifier so that we can better analyze the performance of the hybrid amplifier. Our main objective is to optimize the performance of this amplifier in already deployed SMF fibers in order to improve the transmission in access networks.

Table 1: Budget (losses) of the optical link of the Super-PON access network[1].

Component	Count	Typical loss(dB)	Worst loss(dB)	Total loss(dB)
Fiber	50	0.24	0.24	12
Connector	6	0.2	0.5	1.5
Splices	17	0.05	0.2	1
CAWG	1	4	4	4
1:64 Splitter	1	20.5	20.5	20.5
Margin	1	2	2	2
				41

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2. Experimental overview

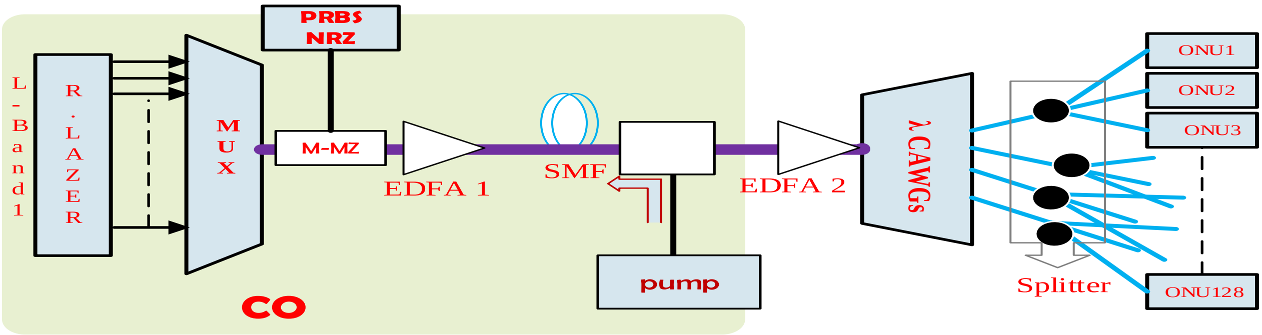

Figure 1: Experimental layout of the proposed WDM-PON

The above experimental model shows the overall configuration of an optical transmission system in access networks. In our case, we want to operate 16 channels, with the wavelength range shown in Table 2 [1]. For this purpose, the transmission signal is pulsed by the laser diodes and then multiplexed. We specify here that we limit this transmission only to the downward direction with a counter-propagative pumping provided by our pump laser. Still in the emission part, we have a data source which produces a pseudo-random sequence (PRBS) with a rate of 10 Gbit/s. The electrical pulse generator (NRZ) converts the basic data into electrical pulses that modulate the laser ignition via the external Mach-Zehnder modulator (M-MZ). The signal conditioning is managed by an EDFA preamplifier, it then transits in a 50 km SMF. Its shaping is ensured by a last amplifier stage before the demultiplexing, to be then distributed in the various ONU. In our study we will adapt this experimental configuration to several amplifiers. The simulation software used is OptiSystem.

Table 2: Specification of wavelengths [1]

Fréquency(THz)	189.807	189.906	190.004	190.103	190.202	190.301	190.400	190.499
Wavelength(nm)	1579.46	1578.64	1577.82	1577.00	1576.18	1575.36	1574.54	1573.73
Fréquency(THz)	190.597	190.696	190.795	190.894	190.993	191.092	191.191	191.289
Wavelength(nm)	1572.91	1572.09	1571.28	1570.47	1569.65	1568.84	1568.03	1567.22

The average launch power of each channel is -8dBm or 1.268 mW for 1.032dBm output of the external modulator. The Raman gain curve of the used fiber is given by figure 2. We observe a gain peak is obtained at 13THz.

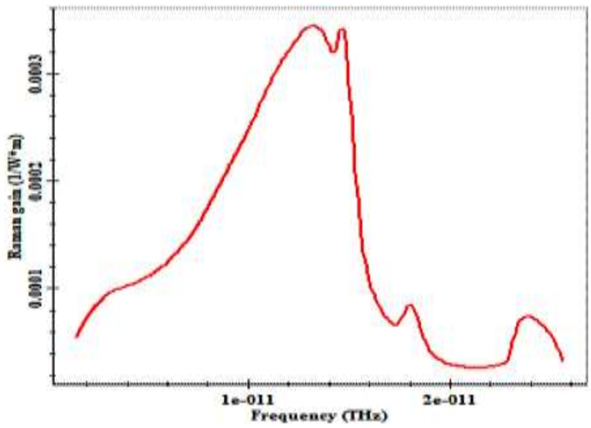

Figure 2: Evolution of the Raman gain in an SMF

In our study, the need for a power budget is necessary to assess the reliability of the system. We will use the detailed scheme of figure 3 only for the emission.

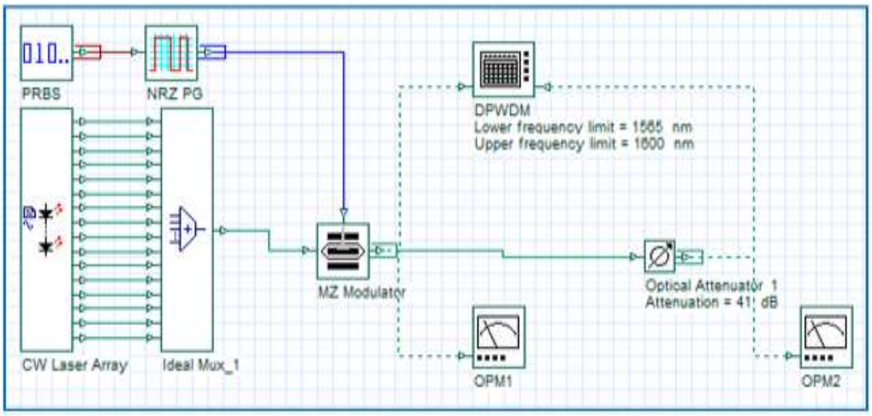

Figure 3: Power budget configuration of the system

In order to extend the gain range of the amplifiers, we have proposed the solution of Hybrid amplifiers (EDFA/Raman) [12]. We configure our model by placing the EDFA before the Raman stage for the simple reason that the powers of the WDM channels are low and the latter could serve as a preamplifier. To do this, we will first simulate a configuration without optimization to observe the flatness of the gain Figure 4. And then, propose two configurations: one for EDFA optimization (Figure 6) and the other for Raman (Figure 7).

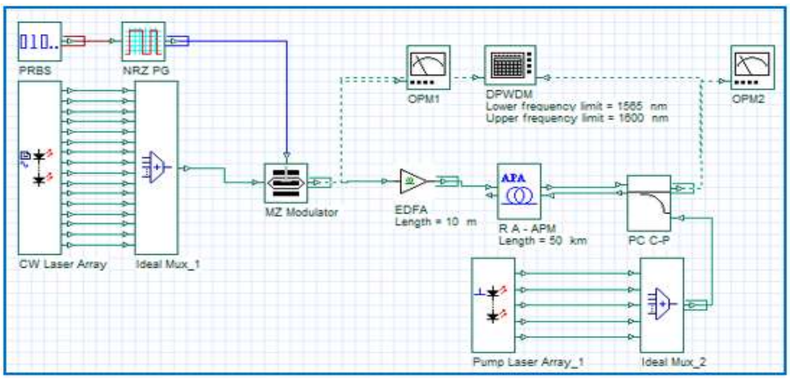

Figure 4: System configuration

2.1 Optimization of the EDFA amplifier

The configuration is the one given in figure 5 above. The parameters that can be changed in order to observe a better flat gain are the wavelength and the back pump power (980 and 1480, 100mW to 200mW), the length of EDFA (5 to 15m), the erbium ion density (1.1025 to 2.5.1050) the target gain being 20dB.

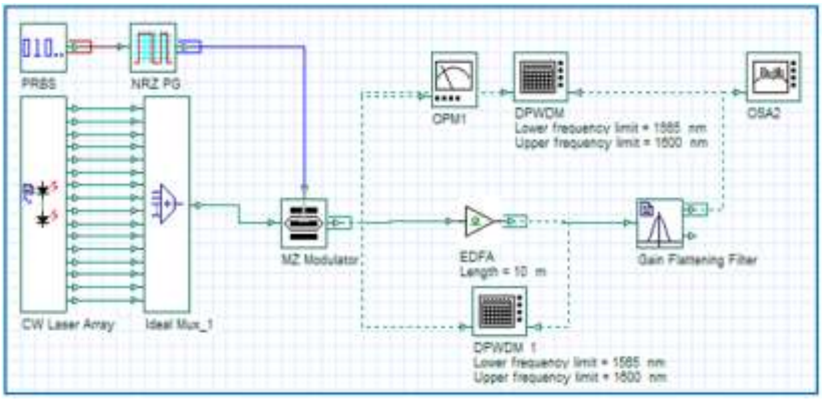

Figure 5: Configuration for the EDFA gain optimization

2.2 Optimization of the Raman amplifier

In order to amplify our signals by the Raman effect, we proposed the optimization configuration in figure 6. The parameters of our amplifier are: the length of the fiber (L=50Km), the absolute temperature of the amplifier (T=300K), the polarization factor (PF=2). The background loss and the Raman gain efficiency are defined by files and these parameters are introduced in the tabs of the Raman component. The effective fiber area is 82µm2, the fiber loss is 0.2dB/Km. The amplifier cross section is set to 50. For the optimization process, we assigned initial values to the pump powers for the wavelengths shown in Table 2. The parameters that can be changed to The parameters that can be changed to bserve better flat gain are those of the pump powers: the minimum and maximum pump powers are selected to be 50 to 250 mW, respectively. The target gain is set to 2 dB with a flatness of 0.001 dB.

Table 3: Initial values of pump wavelengths and powers.

$\lambda_P (nm)$	1424	1438	1452	1466	1500
$P_P (mW)$	375	167	150	120	100

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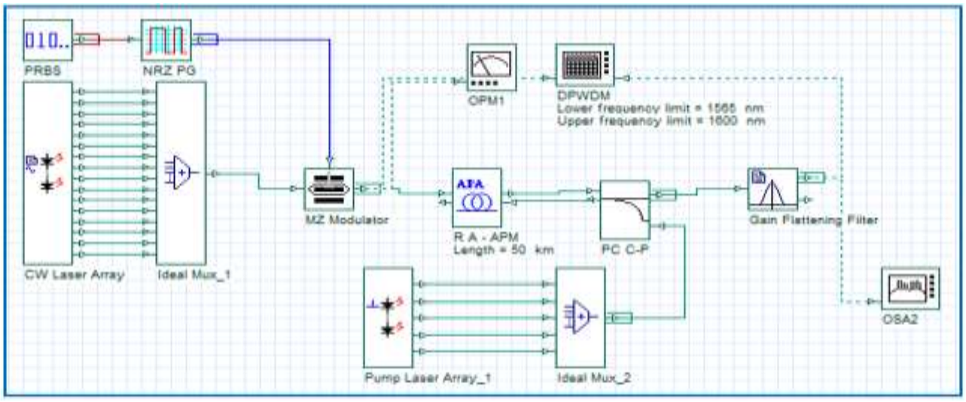

Figure 6: Configuration for Raman gain optimization.

3. Results and Discussions

Figure 7 shows the result of the power budget simulation without any amplifier. It shows us a power of 0.781 dBm at input and -40.23 dBm at output for the total system attenuation which is 41 dB. This output power value cannot be detected. It must be amplified.

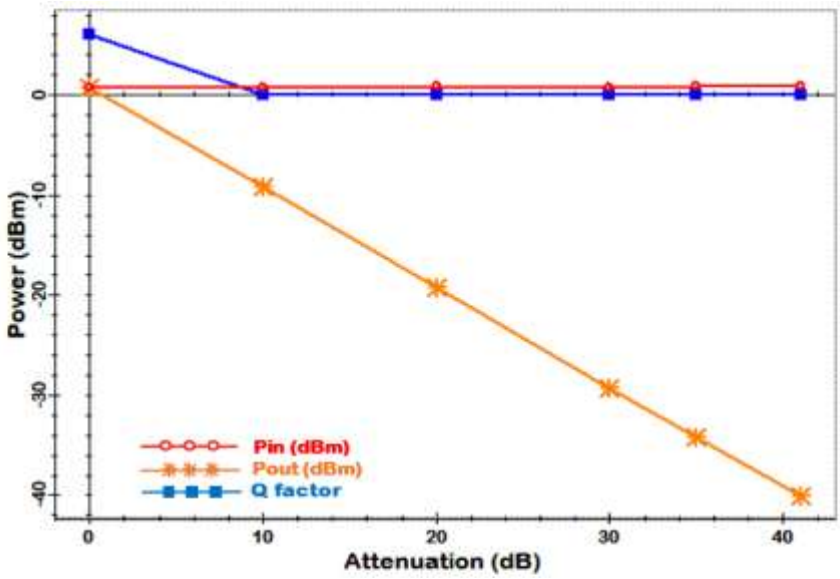

Figure 7: Input power, output power and signal quality factor as a function of total system attenuation

In figure 8, the gain evolves in a decreasing way with the wavelength. Whether Raman or EDFA, we observe the drop in gain tending towards 0.However the importance of the hybrid amplifier is felt in the value of drop; the gain obtained through the normalized values [1], is between 27 and 21dB against 25 and 17 for EDFA. Taking into account the normalized values, the operating frequency is 1573nm, we observe a gain of 21.53 dB without the Raman amplifier with an excursion of 7.943 dB. By integrating the Raman amplifier, the Gain is 24.44 dB with an excursion of 6.35 dB.

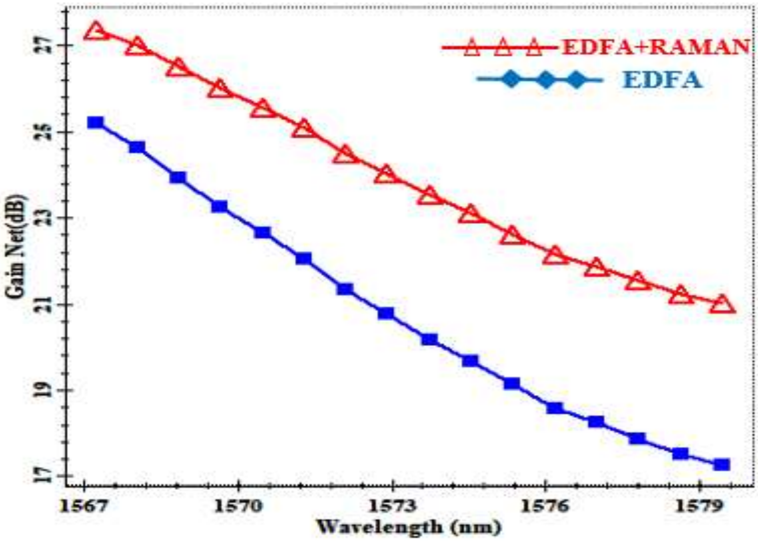

Figure 8: Net gain of the amplification system without optimization

In order to reduce the rise in excursion in figure 8 above, we fix our pump at 200mw, then we consider a pump wavelength of 1480nm close to that of 1550nm .Indeed, according to [12], at 1550nm we have a minimum of attenuation; as for our EDFA, we fix its distance at 10 m with a density of the erbium ion 10.1024. Thus, a better gain flatness is obtained in figure 9 with an average value of 17.5758 dB with only an excursion of 0.7864 dB. The gain is flat over the specified wavelength.

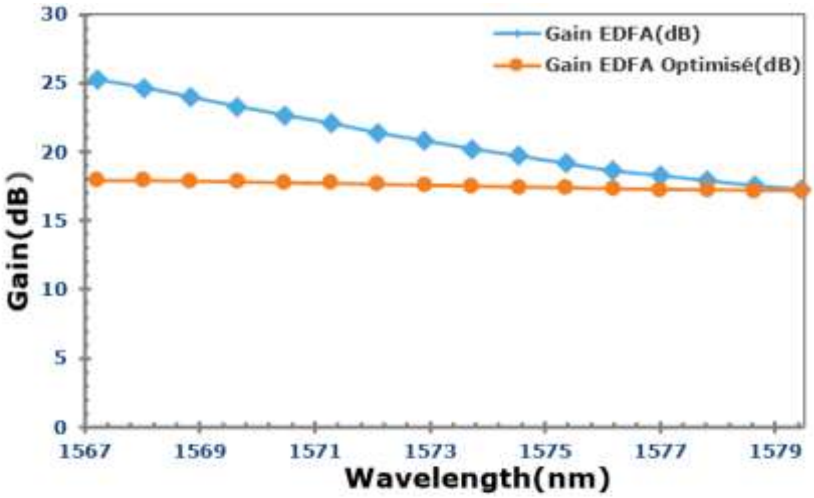

Figure 9: Net gain of the EDFA amplifier

Figure 9 shows the results of Net Gain and the output powers of the system. The output signal power of the EDFA before optimization shows an excursion of 7.9414 dBm. The optimization process led to a reduction of this excursion by 0.7843 dBm for a total average power of 18.1563 dBm. The output power excursion of the hybrid system is only 0.02771 dBm for a total power of 19.5962 dBm. We observe on this figure, a Gain (EDFA+RAMAN) in average value of 18.9639 dB so the flatness is 0.0257 dB.

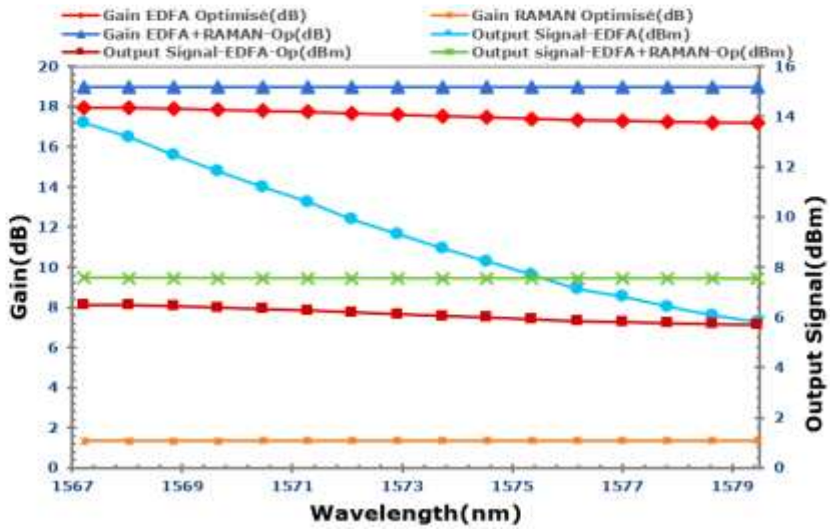

Figure 10: Gain and output power after compared to the wavelength

We observe an output power that goes from 14 dB on a wavelength of 1567 nm to 6 dB on 1579nm; theoretically this is understandable given that the fiber will affect the power of the signal regardless of the type of amplifier used. On the other hand, the hybrid amplifier provides a solution to this problem since it keeps the signal power constant at 6.8db. Another observation is that, when we use the normalized values in [1], we have a gain value 19db higher, hence the importance of the hybrid amplifier. Figure 11 shows the evolution of the SNR and OSNR as a function of gain. The noise figure (NF) remains around -18.96 dB. OSNR induced by the amplifiers being 18.96 dB.

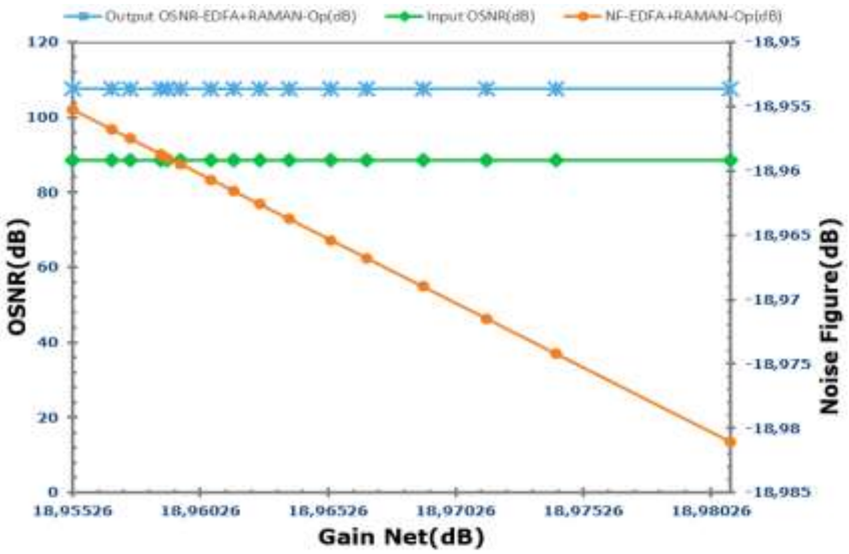

Figure 11: OSNR and Noise Figure of the system

On figure 11, the evolution of the OSNR in relation to the gain indicates a stability of noise for the hybrid amplifier whatever the value of gain, the OSNR remains stable this observation is the same for the EDFAs. On the other hand, the noise figure decreases significantly and always follows the negative value of the gain. For a gain of 18.95 its peak is at -18.955; similarly for all other values, we can therefore conclude that the more the gain evolves positively, the less the noise has an effect on the quality of the signal.

4. Conclusion

In this paper, we have evaluated the performance and contribution of a hybrid amplifier (EDFA and RAMAN) in access networks, particularly on WDM-PON. Analyses based on the numerical method have shown that it is possible with our hybrid amplifier to push the limits of conventional transmissions with a maximum gain of 24.44dB over a distance of 50Km in an SMF, with a maximum excursion of 0.78dB. On the other hand the evolution of the powers showed the alteration that the signal can undergo according to the distance covered indeed more the signal evolves, more the value of its power decreases one left for example of 0.781 dBm in entry and -40.23 dBm in exit for the total attenuation of the system which is 41 dB. The problem posed by the spontaneous emission in the amplifiers found a solution with the integration of the Raman amplifier and finally the type of pumping used allowed to maintain a better inversion of population observed through the flatness of the gain obtained. From our studies, we can predict a better adaptation of the access networks to the different services offered by the telecommunications operators.

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