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Experimental, Characterization and Optimization of the Pumping Power of an EDFA by a QPDSF Configuration

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Abstract: In this article, an experimental system based on the Quadruple Pass Double Stage with a tunable pass filter configuration, is used to amplify the output signal of the Erbium-doped fiber amplification and eliminate the noise due to the amplified spontaneous emission backwards.

The pumping power of the second stage is set at 220 mW, and the input power at -50 dBm, a maximum gain of 68 dB at a minimum noise threshold is achieved.

Keywords: gain, noise figure, ASE, erbium-doped fiber, QPDSF

1 Introduction

Important services and applications have been developed over the last decade in the optical communication area, the emergence of the wavelength division multiplexing (WDM) and the Erbium-doped fiber amplification (EDFA), have improved the quality of data transmission with a high data rate.

However, the presence of splices and other optical components, cause reflection and generation of noise by spontaneous emission. This is due to the absorption a part of incident photons, causing signal quality degradation when reconstructing data at reception [1, 2].

Several important factors can be used to optimize the EDFA: the length of the erbium-doped fiber (EDF) section, the pumping wavelength and the optical pumping power [3, 4].

A new configuration technique has been suggested to achieve maximum gain by minimizing the noise figure [5–7], also useful in reducing the sensitivity of the EDFA to extra reflections caused by imperfections of splices and

other optical components. Other optimization techniques have been proposed, developed and used by S. Singh et al all [8–10].

In this paper, we present an experimental configuration and characterization kit by using a Quadruple Pass Double Stage with Filter configuration (QPDSF) configuration based on the mirrors integrated in the tunable pass filter (TBF) [11]. In order to optimize the pumping power, we have used the means square method which giving a solution with a maximum likelihood. Therefore, to obtain a high gain with a minimum noise according to the variations of the input signal power, the effect of the amplified spontaneous emission power was suppressed.

This configuration requires the use of two types of circulators; one is a three-port circulator, with a TBFs and a coupler are integrated. The second type is a four-port circulator. Thus, the use of a silica fiber doped with erbium in the C band [1,525–1,565 nm] [12].

2 Experimental set up

The experimental kit consists on the QPDSF configuration as illustrated in Figure 1. This configuration contains two amplification stages with four-port optical circulator, as shown in Figure 2.

The input signal is sent from port 1 of the four-port circulator and then transmitted via 10 m EDF. Coming to WDM1 of the first amplification stage, it multiplexed with the pumping signal ($P_1 = 10$ mw) at 980 nm wavelength.

The multiplexed signal is filtered by TBF filter placed between the ports 3 and 1 of the circulator 2, characterized by 1.5 dB of gain and 1 nm bandwidth. This filter suppresses ASE noise coupled to an OSA optical loss analyzer with 0.01 nm of resolution.

The port 3 of the circulator 1 collects the signal from the port 2 and injects it into the second stage over a 15 m EDFA length.

At the WDM2, the signal is multiplexed with variable pumping power P_2 from 10 to 220 mW, and then transmitted to the circulator 3. Then, the TBF suppresses the

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Figure 1: Experimental kit (LD: laser diode, EDF: erbium-doped fiber amplifier, WDM: wavelength division multiplexing, OSA: optical spectrum analyzer, VOA: variable optical attenuator, TLS: tunable laser source, TBF: tunable band pass filter).

Figure 2: Experimental configuration of QPDSF.

spontaneous emission power amplified ASE. At the end of the transmission, the signal is sent on the same fiber to the port four of the circulator 1.

The present configuration allows to optimize the pumping power and to increase the amplification gain, by eliminating the effect of the amplified spontaneous emission power using the TBF [1, 13–15]. This minimizes the noise figure and improves the quality of transmission.

3 Results and Discussion

The experimental results of the variations of the gain and the noise figure presented in Figure 3 as a function of the variations of stage pumping power in the second stage of the input signal power for -50 and -45 dBm, respectively. Whereas, the pumping power of the first stage is fixed at 10 mW.

Figure 3: Experimental gain and noise figure using QPDSF configuration.

According to the curves, it appears that for a pumping power of 10 mW, the gain reaches values at 44.5 and 30 dB for the input power of -50 and -45 dBm respectively. Then, the gain gradually increases by increasing the pumping power by a step of 10 mW, where a high gain of 68 and 60 dB are measured for the input powers mentioned above. We note that a diminution is recorded of the gain at 80 mW pumping power.

On the other hand, the noise results remain a constant during the variations of the pumping power in the region of 8 dB at -50 dBm an input signal power. Nevertheless, for an input power of -45 dBm, a slight noise variation for powers from 140 to 160 mW to reach a threshold of 10.5 dB, then decreases to 10 dB for 220 mW power.

The decrease of the noise value is linked to the implementation of the TBF at the two circulators.

Figure 4 illustrates the behavior of the gain as a function of the input signal power from -50 to 0 dBm, setting the power of the first stage at 10 mW. It can be seen that the gain curve decreases progressively, by increasing the input signal for the different pumping values.

Note that for a power of -50 dBm, the gain reaches a value of 68 dB then decreases to 17.64 dB by increasing the input power to 0 dBm. On the other way, for a pumping power of 10 mW, a value of a 33.5 dB of a gain is achieved.

As a result, a gain of 68 dB arises for 220 mW pumping power, this result is an improvement gain of the work of Sellami et al [16], in witch, they obtained a value of 45 dB a gain.

The variations of the noise figure as a function of the pumping powers for different input signal is depicted in Figure 5. It indicates that the noise figure increases with

Figure 4: Experimental gain against the pump power.

Figure 5: Experimental noise figure against the pump power.

the increasing of the input power signal. Whereas for 220 mW pumping power, a 7.8 dB of the noise figure is achieved for a -50 dBm input signal power, better than the previous results for optimal pumping power.

These results can be explained by the theoretical relationships between the noise figure and the signal input power, in which the gain is proportional to the power of the output signal [16].

Figure 6 presents the curves of the variations of the amplified spontaneous emission power ASE as a function of the variations of the pumping powers of the second stage, for different powers of the input signal. It is found that values of 6.7 and 2.5 dB of ASE are obtained at 220 mW pumping power for -50 and -45 dBm input signal, respectively.

The variations of ASE as a function of the output signal power, for different pumping powers (10, 50, 100, 150 and

220 mW), by setting the pumping power of the first stage at 10 mW as illustrated in Figure 7. Where we find that the ASE value increase by increasing the output signal power.

We observe that for a pumping power of 10 mW, the power is not important at the end of the EDFA. However, when the pumping power set 220 mW, the output power reaches a 9.6, and 6.7 dBm threshold of ASE.

By varying the gain under the same conditions (Figure 8), it decreases from 68 to 35 dB and from 17 to 3.4 dB, by increasing the input signal power at 220 and 10 mW pumping power, respectively. Therefore, an increasing of the noise figure for above powers as revealed in Figure 9. There is an important output power of 17.64 for 7.85 dB noise figure, followed by saturation at a threshold power 10.85 dBm, in optimal pumping power.

It founds that the increasing of pumping power to 220 mW, gives a high gain of 68 dB and an output signal

Figure 6: Experimental ASE against the pump power.

Figure 7: Experimental ASE against the output signal power.

Figure 8: Experimental gain against the input signal power.

Figure 9: Experimental noise figure against of the input signal power.

power of 9.6 dBm while the saturation power was done at 17.64 dBm (Figure 10).

Comparing with the other results summarized in the Table 1, it concluded that the optimal pumping power is

220 mW, is characterized by a high gain for a considerable output power. It should be added that the saturation points have a high output power and threshold pumping power compared to the results obtained at 10 mW pumping power.

Figure 10: Experimental gain against the output signal power.

Table 1: Experimental gain against the output signal power as a function of the pumping power.

Pump power (mW)	Gain (dB)	Output power (dBm)	Output power saturation (dBm)	Gain saturation (dB)
10	33.5	-16.77	-3.2	-3.4
50	52.3	1.9	9.7	9.79
100	56	57	13.68	13.89
150	58.2	7.5	15.91	15.74

4 Conclusion

In this paper, a new approach to configuring an EDFA using the QPSDF configuration was performed experimentally and tested. This technique uses TBF band pass filters to implement on the three-port circulators, with integration of a mirror in the two amplification stages, which eliminates the ASE noise of the amplification.

By using a means square optimization method, a gain of 68 dB was achieved for a minimum noise figure at 220 mW pumping power and -50 dBm. In addition, a comparison was performed with 10 mW pumping power, a minimum gain was measured.

From these results, an important gain is achieved for pumping power optimized by the least squares method, comparing to the work done by M. Sellami and all and X. Dong [16, 17].

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