Experimental Demonstration of Broadband Erbium-Doped Fiber Amplifier (EDFA)

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Abstract.
In this paper, novel design of erbium doped fiber amplifier (EDFA) is demonstrated experimentally. High and broad gain is covered in C and L bands. The used technique combines, in one configuration, two double pass with split band structure for the amplification of two traveled signals one for the C band and the other for L band. This new topology is to investigate the trends of high gain and wide amplification at different status of pumping power, input wavelength and input signal power. The presented paper is to study the performance of the augmented gain of the EDFA configuration using what it can be called double pass double branch wide band amplification. The obtained results show high gain and wide broadening range of 44.24 dB and 80 nm amplification respectively.

Keywords: Erbium doped fiber amplifier, erbium doped fiber laser, optical amplification.

Introduction

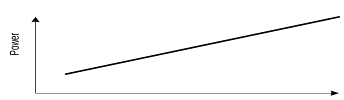
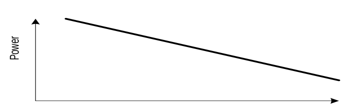
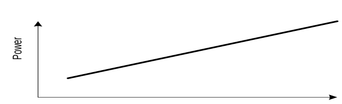
Laser and amplifier today have their dominant role in many scientific and technological areas [1]. After the discovery of fiber optic low loss [2] the laser becomes a real solution for real common problems. The broadband communication fiber optics with its multiple terabits transmission capability forms the backbone of the next generation of communications systems [3]. EDFA amplification tool played a central role in the recent communication breakthrough at different design structures and behaviors [3, 4]. It demonstrates the light signal amplification after traveling thousands of Kms.

Since the theoretical and experiment results prove and complete each other and provide a better image and understanding, a successful effort is required to put the theoretical and experiment results in one box to simplify the ambiguity and the complexity of EDFA. New methodologies to deal with experimental configurations are proposed and demonstrated in this paper. The main focus is to analyze experimentally the amplification phenomena and relate it clearly with the configuration components. The experiment configuration shows a new result, this novelty is based on the combination of the C and L band in double pass and double pass double linear configuration where the two bands can be elaborated and illustrated as broadband amplification with high gain. Various performance characteristics of EDFA have been studies in this paper such as: gain versus the pumping and gain versus wavelength and input signal power.

The need for wide broadband amplification is a must, due to tremendous and explosive revolution of optical communication system. Experimentally, using the C and L bands in series has been shown a huge attenuation. In this domain, Bell lab [5] developed a parallel configuration, it has shown that the amplification can be on both bands but the use of two couplers and single pass

amplifier will keep gain low also. Various techniques have been proposed to extend the band and flatten the gain [6] and expand the DWDM amplification window these studies attempted to widen the amplification band as broad as possible [7-9]. Focusing on high, wide and flatten gain and lower noise figure is the target of the most working research groups in the EDFA field. Dealing also, with the amplification in the C and L bands the EDFA shows an intrinsic difference of the amplification behavior. In general, the amplification performance is related also to fiber attenuation that will increase in S and L band and decrease in the C band. So if the designer is targeting the flattening amplification in broadband EDFA, he has to put in consideration the gap variations of the ripple, where filter equalizer can be one solution for this difference. The gain flattening is a serious issue in the case of using wider EDFA amplification; it becomes intense with the increase of the amplification range. The problem depends on the intrinsic inhomogeneous broadening characteristic of EDF as appearing in the amplified spontaneous emission (ASE) shape with high power in 1532 nm range for C band and a high power in the 1562 nm range for L band. In high concentration of erbium ions at 1000 ppm the high peak is shifted to 1562 nm as recorded in this paper. Using the double pass wide band amplification technique, the broadband of the new configuration has been demonstrated. A high gain and wide amplification range have been proved experimentally for both C and L band.
The proposed configuration has high gain of 44.24 dB and broader range of amplification which reach 80 nm. The technique used in this paper shows the efficient use of optical components inside the EDFA topology. The combining of two double pass technique based on the coupler band splitter gives cutting-edge results. The modification of the design structure make a deep change to produce a very special results that use C and L bands at an efficient way and amplify two wavelengths simultaneously. It can maximize the performance; increases the networks qualities and reduces the cost. The structure can be extrapolated to three bands S, C and L using the same technique. This paper presents new double pass wide band EDFA amplification operating in C and L bands with high gain. To the best of our knowledge no published paper has included this new configuration with such efficient results.
Table 1 shows the general behavior and trends of power inside the EDF it summarizes the input and output power of the EDFA. Where P_{in}^{S} is the signal power, P_{in}^{P} is the pump power and P_{in}^{ASE} is the amplified spontaneous emission power.

Table 1: Input and output power of the EDFA

Power In	Trends	Power Out
P_{in}^{S}		P_{out}^{S}
P_{in}^{P}		P_{out}^{P}
P_{in}^{ASE}		P_{out}^{ASE}

Experimental Design and Discussion of Results

Two EDFs length of 2 m for C band and 6m for L band, were used in this experiment. The erbium ions concentration is 1000 ppm. The loss was measured to be 7dB absorption between the input and output amplifier without EDF. The constructed configuration is shown in Fig. 1. The input signal power is generated from tunable laser source (TLS) it travels through CIR1 from port1 to port2, it was affected by 0.5 dB loss from the band splitter coupler. The signal will be amplified by EDF1. A Tunable Band Pass filter (TBF1) is positioned between port1 and port3 of the CIR2 to suppress the amplified spontaneous emission then travels through the EDF1 for the second pass. At the CIR1 port 3 an optical spectrum analyzer (OSA) is connected to characterize the output signal power. The WDM is used to multiplex the 980 nm pump power wavelength with the input signal power wavelength in the case of forward pumping and counter pumping. For the L band another branch is constructed where 6 m EDF length was used. The input signal power travels through CIR1 to the band splitter of C and L bands, if the signal falls in the L band it travels through WDM2 amplified by the EDF2 to port2 of the CIR3. Between port 3 and port1 the signal will be filtered by TBF2. The signal travels back for the second amplification. Fig. 1 shows the new EDFA configuration at wide band and high gain.

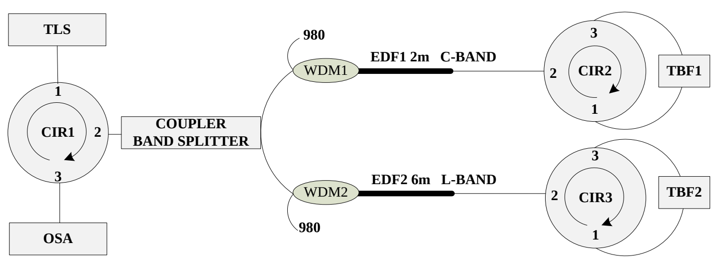


Fig. 1: Experimental configuration of broad and high gain EDFA

Fig. 2 shows the ASE bands of the 2 m and 6 m EDF. It is clear that ASE is high for C band and lower at the two extreme sides of S and L bands. The ASE spectrum was recorded at 150 mW. The ASE span is around 100 nm. This result shows a wide band EDFA for the new configuration.

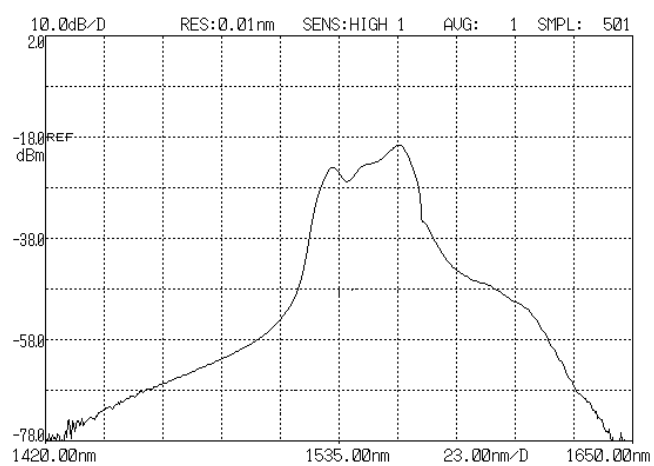


Fig. 2: Experimental ASE of the new configuration without TBFs and without input signal power.

To characterize this new configuration, gain versus pumping powers, wavelength and input signal power were recorded in Fig. 3, 4. Fig. 3 shows the experimental results of gain versus pumping power and the amplified wavelength in nm unit. Following the gain trends versus the change of the wavelength it is clear that the gain is increased when the wavelength is changed between 1520 and 1570 nm, the gain records its maximum at 1560 nm at all pumping powers. Then, the gain starts to reduce in L band to reach its minimum at the 1600 nm and at 1520nm.

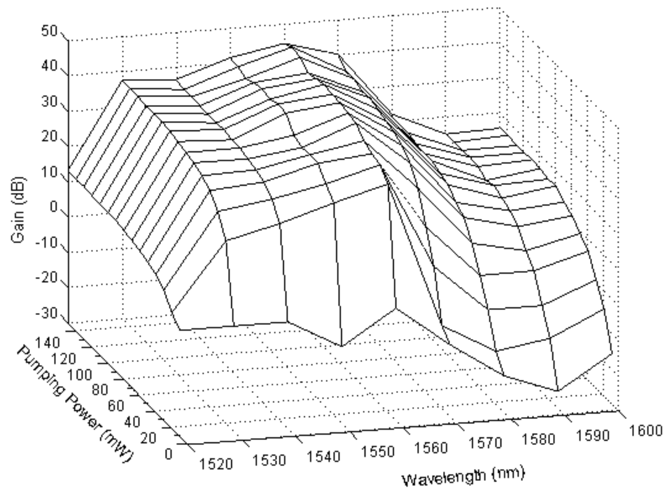


Fig. 3 Experimental gain versus pumping power and wavelength at -40 dBm input signal power

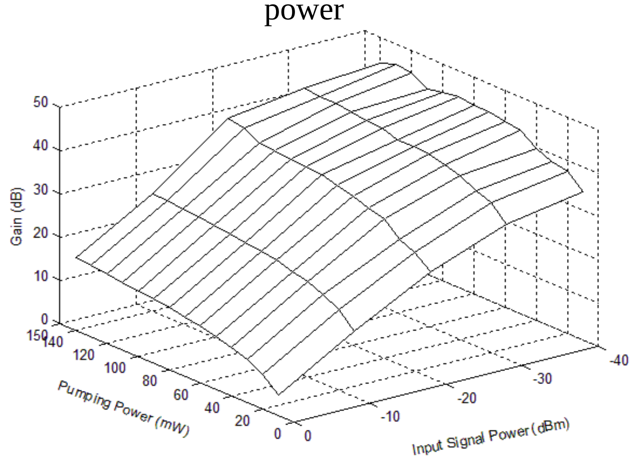


Fig. 4 Experimental gain versus pumping power and input signal power at 1560 nm

In the second step of the results discussion, Fig 4 shows the gain trend versus the pumping power. It is evident that the gain is increasing proportionally to pumping power starting from 20 mW to 150 mW. The gain records its highest value at the highest pump power for each wavelength and shows its maximum at 1560 nm wavelength with 150 nm pump power.

Same figure shows also the gain trends versus input signal power where 1560 nm wavelength is used in this measurement. It is evident the effect of the input signal power on the gain, it reaches its maximum at the lowest input signal power. The gain at -40 dBm will change between 35 dB and 45 dB for the pumping power between 20 mW and 150 mW respectively.

Conclusion

Comprehensive experimental demonstration was investigated and verified using practical design and experimental evidence. Novel double pass double branches broadband EDFA configuration was conceived, designated and experimentally demonstrated for investigation and interpretation. The gain recorded shows that this configuration can be used for wide range in C and L bands as well as high gain. A maximum wide band of 80 nm covering both C and L bands, with gain of 44.24 dB value were achieved using the new EDFA topology.

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