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The Influence of EDFA's Configurations on the Behavioral Trends of Gain and Noise Figure

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Abstract

Various configurations have been conceived and tested for improvement of the gain and noise figures in Erbium doped fiber amplifiers (EDFA's). Single pass (SP), double pass (DP), triple pass (TP) and quadruple pass (QP), are employed in the investigation. The highest gain and highest noise figure (NF) of 54dB and 7dB respectively are obtained at -50 dBm input power with 90 mW pump power using the QP configuration, while and the lowest gain of 23dB and lowest NF of 3dB are obtained at -50 dBm input power with 90 mW pump power for SP configuration.

1. Introduction

Since the first experimental demonstration of a high-gain erbium doped fiber amplifier (EDFA) [1, 2], tremendous progress has been made in the development of erbium-doped fiber amplifiers (EDFAs), which form the backbone of low attenuation fiber optic communication systems. However, optical fiber systems are suffering from the loss due to the different intrinsic characteristics of the fiber material, despite the increased research for new materials and detailed optimization [3]. Many great efforts have been attempt towards a perfect amplifier with ultra high gain, ultra low noise and widest bandwidth possible, with a minimum cost. To enhance an amplifier the main tasks are to improve the performance parameters of EDFA such as effective bandwidth [4], gain [5] noise figure [6] and efficiency, by optimizing parameters (concentration, length, position and component used..) of amplifier. These huge number of design parameters have been the main concern of many research groups. Recently, all the reported papers defined the highest gain between 30dB and 55dB. Various configurations have been implemented and experimentally realized, to investigate the behavior trends of gain and NF vs the input signal power and pumping power. A few published works have attempted to study the single pass single stage, Single pass double stage, and double pass single stage [8] and triple pass double stage [9], but these works were separated and not combined and compared.

In this paper, we report four EDFA's configurations, SP, DP, TP, and QP. A thorough analysis of behavioral trends of gain and noise vs pump and input signal power were demonstrated. In addition, the results were interpreted in sake to investigate the influence of these configurations on gain and NF trends, and way to reduce the gain and NF.

2. Results and Discussions

The experimental setups are shown in Figures 1. A 980nm semiconductor laser was used as the pump source (maximum power of 100mW). The pump was launched into a EDF through a wavelength division multiplexing coupler. The EDF is characterized by 440 ppm of Er^{+3} ions concentration, numerical aperture of 0.27, a cutoff wavelength of 840 nm, and the peak absorption of 6 dB/m at 1527 nm. The tunable bandpass filter (TBF) has 1-nm bandwidth with insertion loss of 1.5 dB at the central wavelength. Figure1 (a) shows the experimental configuration of the SP backward pumping EDFA. It illustrated the input signal power passing through the optical isolator which is then multiplexed with 980nm by the WDM. The signal is amplified by passing it through the EDF.

Figure1 (b) shows the experimental configuration of the DP EDFA. A circulator was used at both ends of the amplifier. The circulator at the bottom was used to provide the input (port 1) and output (port 3) with port 2 connected to the EDF. The circulator at the top was

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used for signal feedback purposes. Port 2 was connected to the EDF; port 3 is connected to the filter input while port 1 was connected to the filter output. The amplified signal from the first pass propagated through port 2 into port 3, passing through the filter into port 1 and back to port 2 to be amplified during the second pass. The total (double pass) insertion loss of the set-up (without EDF) was 6dB (two circulators, 6 connectors, one TBF filter).

TPDS amplifier with TBF is shown in Figure1 (c). The name is given with respect to the signal propagation in the system, whereby, the first-stage amplifier provides a double-pass amplification utilizing a fiber loop mirror and the second-stage amplifier provides single-pass amplification in a backward-pumped configuration (referring to the signal entrance into the EDFs). In the end, the signal travels three passes in the amplifying medium: EDF. The lengths of EDF in the first and second stage amplifiers are 10 and 7 m, respectively. The first and second TBFs have to be spectrally synchronized in order to achieve the most efficient of ASE filtering.

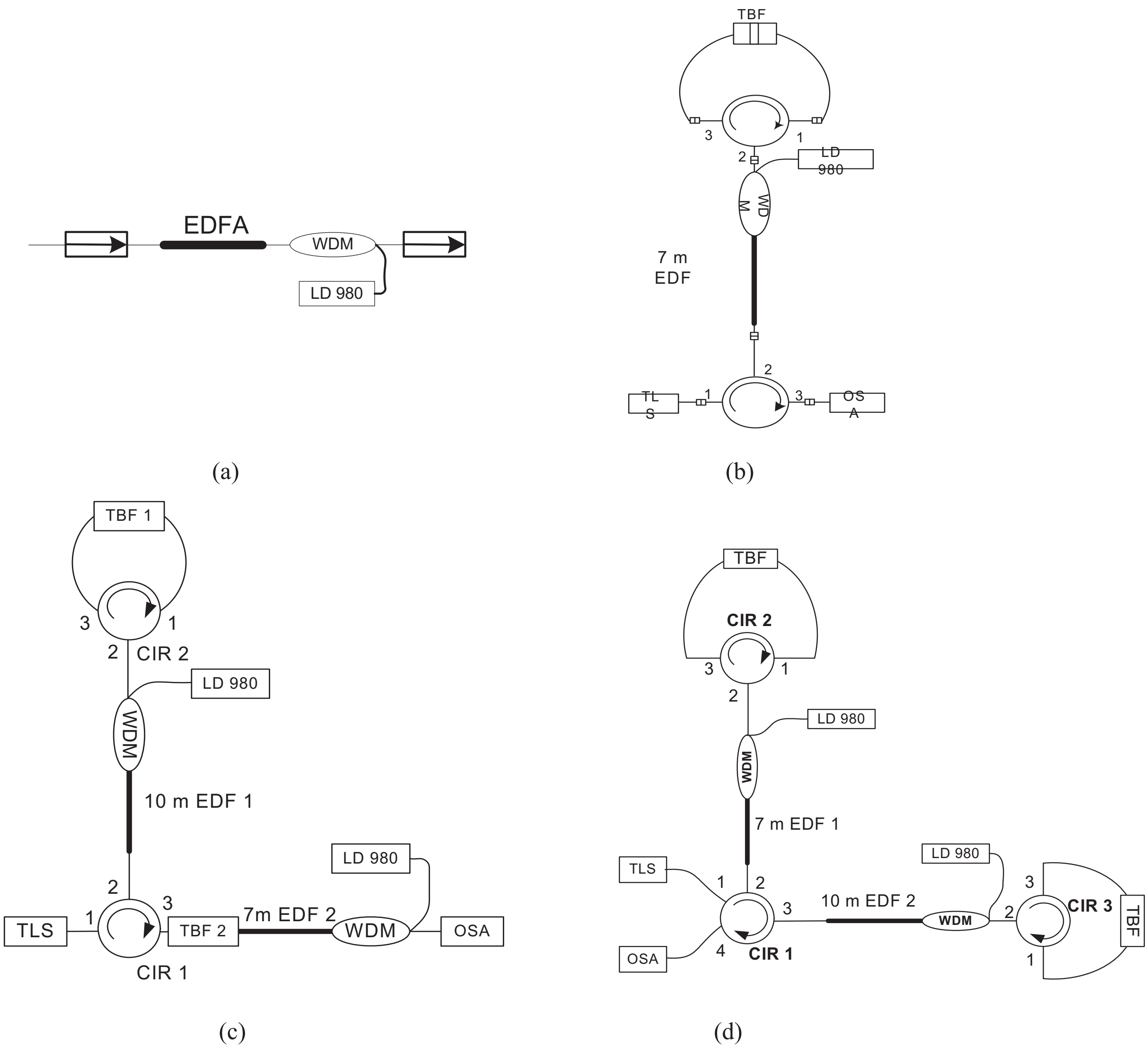

Figure 1 (a): Single pass backward pumping EDFA. (b) Experimental configuration showing the double pass technique (c) TPDS amplifier (d) QPDS.

Figure1 (d) shows the new configuration structure where one circulator with four ports CIR1 and another two circulators with three ports have been used. The first circulator (CIR1) with four ports was used for the input signal power (port 1) and output signal power (port 4), the other two circulators CIR2 and CIR3 were used for signal feedback purposes. Two TBF filters were incorporated between port3 and port1 of both circulators CIR1 and CIR2. EDF1 with 10m length and EDF2 with 7m length where used in the first stage and second stage respectively. The signal was influenced by Quadruple Pass amplification of the two stages.

Figure 2 shows gain against pump power at 1550nm signal wavelength with signal powers of -50dBm for SP, DP, TP and QP configurations. The gain increases sharply just starting the pump with 10 mW and increases slightly after pumping power of 35 mW until getting saturation state for all configurations. The range of the gain is between 40 dB and 60 dB for TP and QP between 20 dB and 40 dB for SP and DP. The highest gain of 54dB is obtained at 90 mW pump power for QP configuration and the lowest gain of 23dB is obtained at 90 mW pump power for SP configuration.

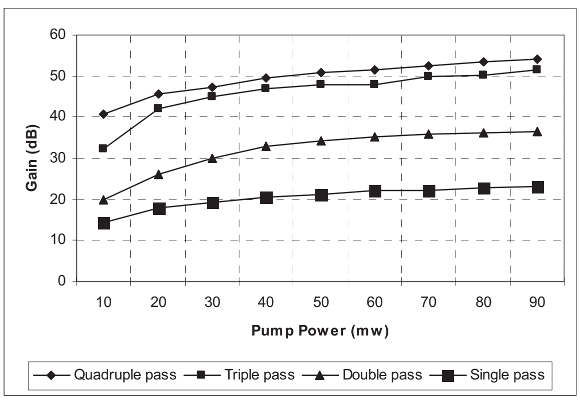

Figure 2: Experimental gain against pump power at λ= 1550nm

Figure 3 shows that NF is plotted against the pumping power, it decreases slightly during the increase of pumping power for all configurations. The NF records the lowest value at 90 mW pump power for SP configuration about 3dB, and the highest value at 90 mW pump power for QP configuration about 7 dB.

Figure 4 illustrates gain against input signal power at 1550nm signal wavelength with pumping power of 90 mw for SP, DP, TP and QP configurations. From the plotted graph It is clear that by decreasing the input signal power the gain for all the four configurations will increase. What is recorded in this graph was the highest gain for QP and lowest was for the SP this can be clearly explained by the efficient new technique that have been used in QP. Although an extra component were used in the QP configuration a very great gain difference between SS and QP was achieved (30dB).

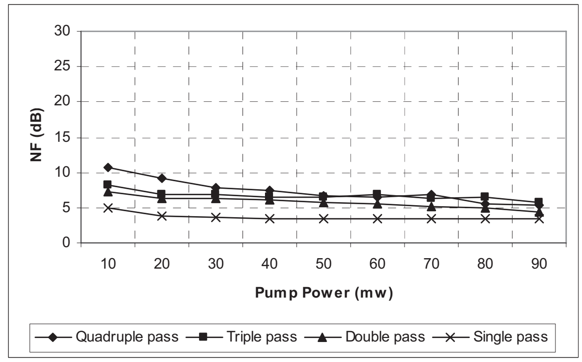

Figure 3: Experimental noise figure against pump power at λ= 1550nm

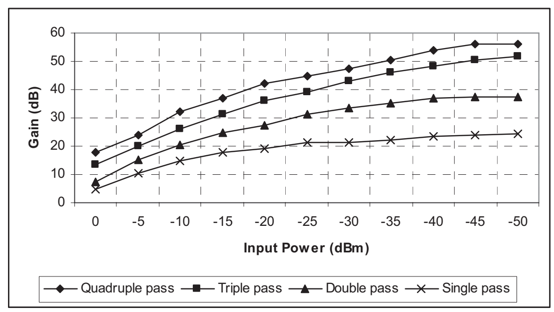

Figure 4: Experimental gain against pump power at λ= 1550nm

The impact of signal power on NF with pump power of 90 mW is depicted in Figure 5. The noise figure decreases by decreasing input power for all configurations. The highest noise figure of 7dB is recorded at -50 dBm input power for QP configuration and the lowest gain of 3dB is recorded at -50 dBm input power for SP configuration

The gain and NF versus the pump power at λ= 1550nm with -50 dBm input power are plotted in Figure 6 and Figure 7 respectively. The gain and NF increase in linear trend with increasing pass number of less than 4 pass. The gain and NF increase slightly more than 3 pass.

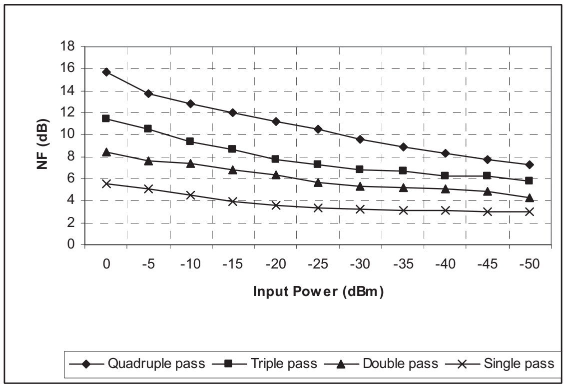

Figure 5: Experimental noise figure against pump power at λ= 1550nm

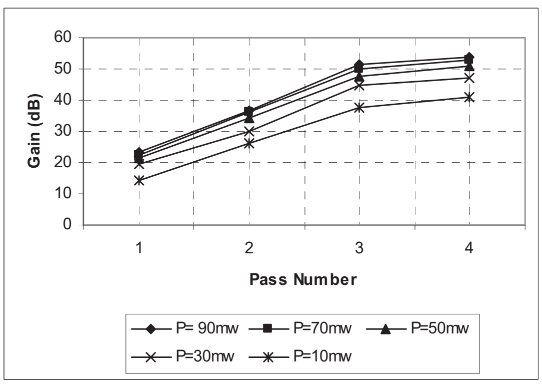

Figure 6: Experimental gain against pass number at λ= 1550nm

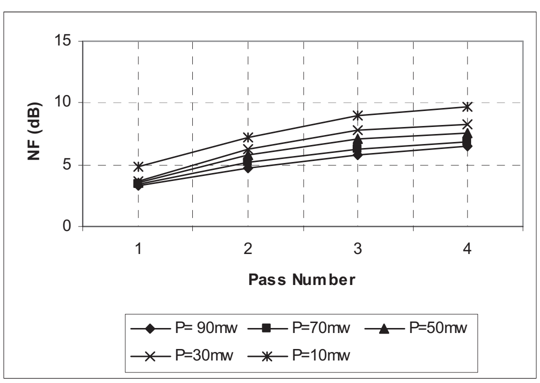

Figure 7: Experimental noise figure against pass number at λ= 1550nm

3. Conclusion

Characterizing and investigating the Si-EDF is demonstrated using new amplifier configurations. Several types of configuration were, investigated, implemented and experimentally realized. The influence of different configurations, such as SP, DP, TP and QP, on the behavioral trends of gain and NF was interprited deeply. A comparative study was demonstrated in this paper in sake suitable gain and noise figure. On one hand, the highest gain and NF were obtained by QP. On the other, the lowest gain and NF were obtained by single pass configuration.

4. References

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