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A New Erbium Doped Fiber Amplifier

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Abstract: In this study, a new configuration of an Erbium Doped Fiber Amplifier (EDFA's) is proposed. Double-pass amplification in a dual-stage using a fiber loop-back is incorporated with a Tunable band pass filter. Spontaneous emission is filtered-out in the mid-section to ensure efficient amplification of the signal as it propagates along the fiber. High gain of 61 dB is achieved for -50 dBm signal power at 1550 nm. The two stages were pumped by laser diodes operating at 980 nm with 10 mW and 220 mW, respectively.

Key words: EDFA, tunable filter, quadruple-pass amplification, optical communications

INTRODUCTION

Erbium Doped Fiber Amplifiers (EDFA's) have attracted much attention for use in the third telecommunication window at wavelengths in the 1540-1560 nm band (Horiguchi and Takata, 1979; Osanai *et al*., 1976). Although, much progress since then has been made, the development of high gain EDFAs has continued to form the backbone of high-capacity optical communications. However, fiber systems still suffer from losses due to different intrinsic characteristics of fiber materials. Hence, much research effort is directed towards new materials and system optimization. Various configurations (Masuda and Takada, 1990) have been proposed to increase amplifier gain and reduce Noise Figure (NF). To our knowledge, there has been no report of results that go beyond a gain of 54 dB. A technique that reduces the effect of ASE self-saturation was proposed by Osanai *et al*. (1976). However, this configuration suffers extra strenuous reflections caused by imperfections of the splices and other optical components (Lester *et al*., 1995). Other reports have shown that filters can be used together with the midway isolator to suppress the forward ASE and improve the signal gain (Laming *et al*., 1992; Way *et al*., 1992). Other approaches to obtain high gain incorporate a double-pass (DP) in the EDFA were also proposed by Bouzid *et al*. (2003) and Hossain *et al*. (2007).

The proposed architecture in this study, results in better gain enhancement and NF by using a relatively short erbium-doped fiber. The configuration is formed by a circulator CIR1 with four ports: port 1 for input signal, port 4 for output and other the two are connected to circulators CIR2 and CIR3, each with three ports for the loop-back signal and two for TBFs. This architecture also allows for further possibilities to experiment with a variety of configurations.

RESULTS AND DISCUSSION

The double stage quadruple pass was achieved by the use of DS-DP configuration as shown in Fig. 1. The two TBFs were incorporated into the system between ports 3 and 1 for each of the two circulators CIR1 and CIR2. A 980 nm semiconductor laser was used as a pump with a maximum power of 300 mW. The first and second stages were formed by EDF1 and EDF2, which are 10 and 15 m long, respectively. Both EDF1 and EDF2 are characterized by NA of 0.27, cutoff wavelength of 840 nm and peak absorption of 6 dB m^{-1} at a signal wavelength of 1527 nm, from which the erbium concentration was

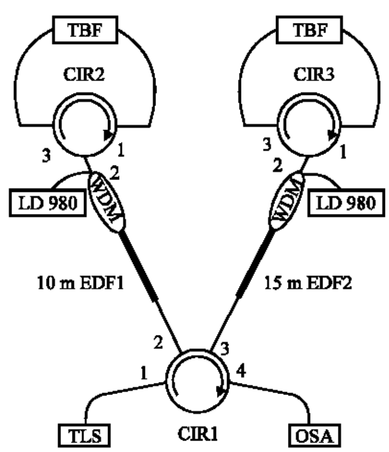

Fig. 1: Experimental configuration of DSQP

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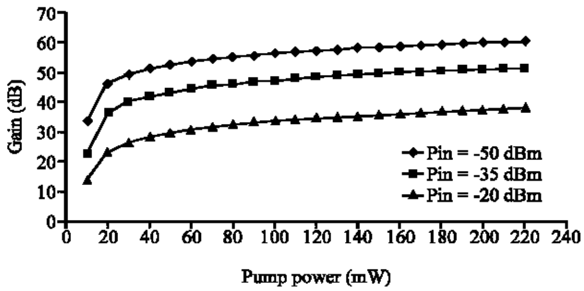

Fig. 2: Experimental gain against pumping power at λ = 1550 nm obtained using DSQP

estimated to be 440 ppm Er^{3+} core: silica/germania. Calibration experiments showed that each turn consistently gave a signal attenuation of 12 dB (three CIRs and two TBFs). Thus the amplified signal propagates through CIR1 port1 to port2, then through EDF1. As it propagates, it is amplified first by EDF1, then through port 2 into port 3 of CIR2 it passes through the first TBF filter into port 1 and back to port 2 where it gets amplified again during the second pass through EDF1 into port 2 of CIR1. It goes on then to the second stage passing through EDF2 and CIR2. The Optical Spectrum Analyzer (OSA) is connected to port 4 of CIR1 (Fig. 1). This technique allows the signal to be amplified by undergoing a quadruple pass through the two amplifier stages.

Figure 2 shows a plot of gain against pump power for a signal of 1550 nm wavelength. The plot is made for signal powers of -20, -35 and -50 dBm, respectively. The pump power has been optimized such that; the first stage was fixed at 10 mW and the pump power in the second stage was varied from 10 mW to 220 mW in steps of 10 mW. The gain value reached 41 dB with only 10 mW pump power for both stages, recording a gain coefficient of 4.1 dB mW^{-1} for the -50 dBm. The gain increased gradually for all three signals until pump power reached 80 mW there was less increase in the value of the gain. The highest gain was obtained 61 dB at 220 mW pump power for the -50 dBm signal.

Figure 3 is a plot of NF against pump power. It shows a constant behavior with increasing of pump power. This can be explained in terms of the relation between NF and pump power, which may be due to the influence of the filter that locks the NF at to a fixed value. The NF records the lowest value for about 7 dB of -50 dBm and highest value of -20 dB. The NF was unaffected by the pump power which was increased from 10 to 220 mW.

Figure 4 shows the relation of gain and NF against input signal power at 1550 nm. The second stage pump power was set to 220, 150, 100 and 50 mW, while the first stage was still fixed at 10 mW. The gain value passes the

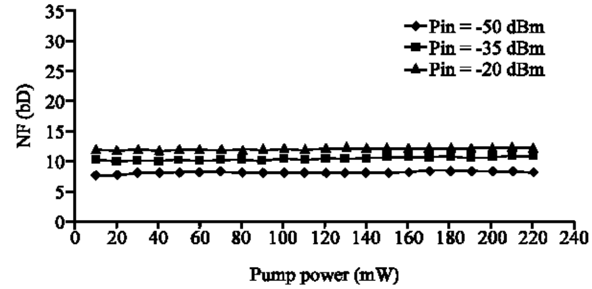

Fig. 3: Experimental noise figure against pumping power at λ = 1550 nm obtained using DSQP

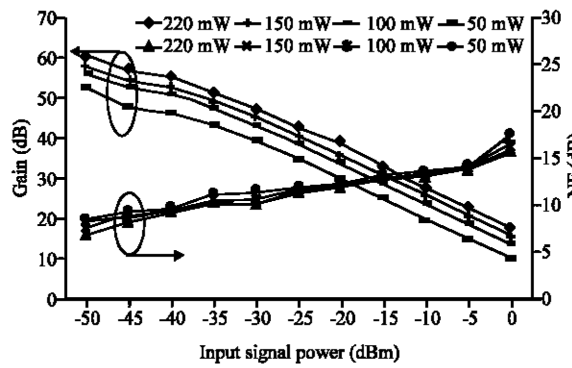

Fig. 4: Experimental gain and noise figure against input signal power at λ = 1550 nm obtained using DSQP

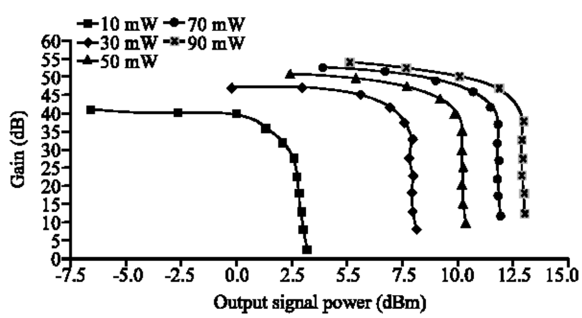

Fig. 5: Experimental gain against the output signal power at λ = 1550 nm obtained using DSQP

40 dB level at -30 dBm signal power with 50 mW minimum pump power, so that the highest gain region recorded was above 50 mW for a signal power of less than -30 dBm. No significant sign of gain saturation was observed in the small signal regime (< -40 dBm). It is expected that the gain value can exceed 70 dB for lower signal powers (-60 dBm). The NF of the amplifier was recorded, which increases with increased signal power. For a signal power of less than -30 dBm the NF reaches its lowest value between 7 and 10 dB.

The gain varies as a function of the output power, as in Fig. 5. It is clear that both the output signal power and

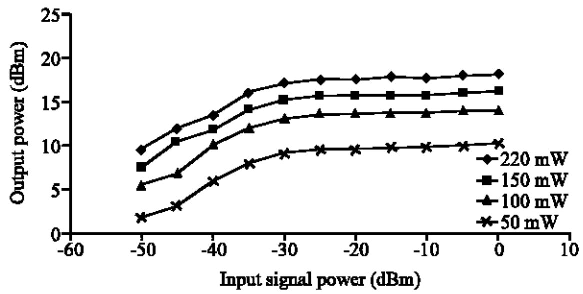

Fig. 6: Experimental output signal power against input signal power at λ = 1550 nm obtained using DSQP

the gain increase with the increase in the pump power and both are constant on the two sides of the graph. For pump powers of 10, 30, 70 and 90 mW, saturated output power of 3, 8, 10.5 11 and 13 dBm are obtained. The unsaturated gain values were 41, 47, 51, 53 and 54 dB, respectively. A maximum power of 13.01 dBm (90 mW) was obtained for 0 dBm input signal power at 1550 nm and a maximum gain of 61 dB was obtained with -50 dBm at 1550 nm.

Figure 6 depicts the output signal power characteristics against input signal power for various pump powers (50, 100, 150 and 200 mW). The graph shows that the output signal power increases with an increase in input power. The graph shows the dependence of the output power on the input signal power. The DSQP system shows a high output power of 18 dBm for a signal power of -30 dBm. It is observed that reducing the signal power from 0 dBm to about -30 dBm, the output signal power remains almost constant. Below -30 dBm the output starts to decrease rapidly. It becomes less that 10 dBm for signal levels between -45 and -50 dBm.

CONCLUSION

The investigation of the EDFA in this study has been demonstrated the viability of a new amplifier configuration. After experimenting with several types of configurations, such as single pass single stage, double pass single stage and double pass double stage, the present design was realized. The Dual Stage Quadruple Pass (DSQP) has proved to be a high gain EDFA. It utilizes two pump lasers of 980 nm and tunable bandpass filters to suppress noise and amplified spontaneous emission. Finally a high gain of 61 dB and a noise figure of 7 for a -50 dBm signal at 1550 nm were achieved.

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