VOL. 11, NO. 5, MARCH 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

PERFORMANCE ANALYSIS ON DOUBLE PASS AMPLIFICATION USING ZR-EDF AND BROADBAND FIBER MIRROR (BFM)

N. S. Rosli[1], A. M. Markom[2], S. W. Harun[2, 3] and A. Hamzah[1]
[1]Department of Electronic Systems Engineering, Malaysia-Japan International Institute of Technology, Universiti Teknologi Malaysia Kuala Lumpur, Jalan Sultan Yahya Petra, Kuala Lumpur, Malaysia
[2]Photonics Research Center, Universiti Malaya, Kuala Lumpur, Malaysia
[3]Department of Electrical Engineering, Faculty of Engineering, Universiti Malaya, Kuala Lumpur, Malaysia
E-Mail: azurahamzah@utm.my

ABSTRACT

A double-pass amplification is demonstrated by using a newly doped fiber named as Zirconia based erbium doped fiber (Zr-EDF) and a broadband fiber mirror (BFM). The performances of the double pass Zr-EDFA are compared with single pass Zr-EDFA at high and low input signal powers, -10 and -30 dBm, respectively. The double pass amplification is observed to give a better performance compared to single pass amplification. This is due to the double propagation of the forwarded and amplified spontaneous emission (ASE) signal into the gain medium and thus will increase the attainable gain in the entire C- and L band wavelength region. BFM is used as the signal reflector to ensure the reflected signal will propagate twice into the gain medium. It is observed that the double pass performance at lower input signal power of -30 dBm shows the better amplification compared to the high input signal power of -10 dBm. With the lower input signal power of -30 dBm, the maximum gain of 40.3 dB is obtained for double pass amplification at wavelength of 1560 nm. The gain enhancement between the maximum gain of double and single pass amplification is observed to be around 11.7 dB for this lower input signal power.

Keywords: double pass amplification, zirconia based erbium doped fiber, broadband fiber mirror.

INTRODUCTION

The remarkable evolution of internet and data traffic has created an ever decreasing demand for long haul transmission and high bit date rate in dense wavelength division multiplexed (DWDM) optical communication systems [1,2]. However, the long-haul transmission brings a drawback which is high attenuation. To overcome this big issue, an optical amplifier is required and Erbium-doped fiber amplifier (EDFA) is proposed [3, 4].

EDFA has widely being utilized in telecommunications networking systems due to its properties and advantages which are insensitivity to light polarization state, no distortion at high bit rate, low insertion loss, low noise figure (NF), high gain and wide gain bandwidth. Because of these properties, EDFA can operate in the 1550 nm and can amplify in many wavelengths simultaneously making the EDFA as a primary choice for most applications in optical communications [5, 6].

There are two types of EDFA which is single and double EDFA. Many researchers have proved that double EDFA shows the better performance compared to single EDFA [3, 7, 8]. The concept of double pass EDFA is the reflected input and amplified spontaneous emission (ASE) signal back into the gain medium by the signal reflector and thus will increase the attainable gain. To achieve this condition, a good reflector should be used. There are a lot of reflectors or fiber loop mirror has been used by researchers in double pass EDFA experiment such as broadband fiber mirror (BFM) [3], tunable band pass filter [7], optical circulator [8], chirped fiber Bragg grating [9, 10] and Hi-Bi fiber loop mirror [11].

From the previous research, there is a very limited number of research by using BFM as the reflector in double pass amplification experiment. Thus, this paper will study the performance of double pass EDFA by using the BFM as the reflector. The double pass EDFA will utilizing a newly doped fiber named as Zirconia-based Erbium Doped Fiber Amplifier (Zr-EDFA). Zirconia (ZrO2) is extensively used as a coating in various applications due to its mechanical strength and chemical corrosion resistance. It is also nonhygroscopic, does not demonstrate photochromic behavior and exhibits excellent transmission in the visible and near infrared. These qualities alone make zirconia as excellent applications in the optics [12]. In addition, the performance of double pass Zr-EDFA will be compared with single pass Zr-EDFA.

EXPERIMENTAL SETUP

Figure-1 shows the configuration setup for single pass amplification by using 1 m Zr-EDF as a gain medium. A forward pumping method is used to pump the Zr-EDF by using a 980 nm laser diode via a 980/1550 nm wavelength division multiplexing (WDM) coupler. A WDM coupler is used to multiplex and de-multiplex the input and pump signal. An isolator is used to propagate light in only one direction and prevent any unwanted backward signal into the cavity. The Zr-EDFA performances are characterized using tunable laser source (TLS) and variable optical amplifier (VOA) in order to give specific reference for each wavelength. An optical spectrum analyzer (OSA) is used to analyze the amplification performance of single and double pass Zr-EDFA.

VOL. 11, NO. 5, MARCH 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

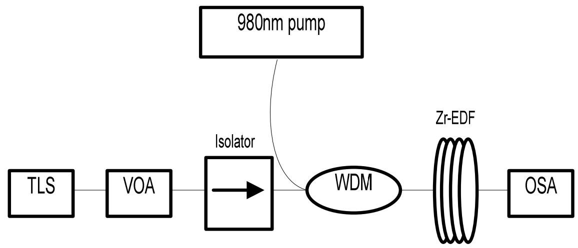

Figure-1. Configuration for single-pass Zr-EDFA

Figure-2 shows the configuration setup for double-pass amplification. In this configuration, the BFM is used as the signal reflector or fiber loop mirror to reflect back a forward and ASE signal into the cavity. Instead of that, the broadband fiber mirror is used in double pass amplification to ensure double propagation of the signal. This double signal propagation will increase the gain in both the C-and L-band region.

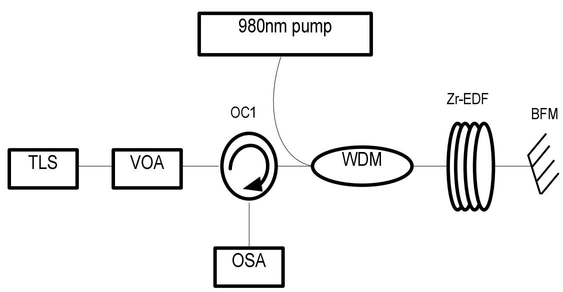

Figure-2. Configuration for double pass Zr-EDFA

RESULTS AND DISCUSSIONS

Figure-3 shows the gain and noise figure (NF) performances of the single and double pass Zr-EDFA where the input signal power is fixed at the -30 dBm (lower input signal power). In this experiment, the signal wavelength is varied from 1520 to 1620 nm (C- and L-band wavelength region). The gain medium, Zr-EDF is fixed at length of 1 m with 980 nm pump power is fixed at the 130 mW. The average gain from 1520 to 1620 nm wavelength for single and double pass amplification are 18.3 and 25.3 dB, respectively.

As shown in the figure, the gain is observed to give a better performance in the double-pass Zr-EDFA compared to the single-pass Zr-EDFA. For instance, at input wavelength of 1560 nm, the maximum gains of 28.6 and 40.3 dB are achieved with the single and double pass amplification, respectively. The gain enhancement of 11.7 dB is observed in the double-pass Zr-EDFA. The gain enhancement is the difference between the maximum gain for double and single pass amplification. This gain enhancement is due to the double propagation of the signal in the gain medium. This double propagation of the signal in the gain medium will increases the effective length of the amplifier and thus the gain.

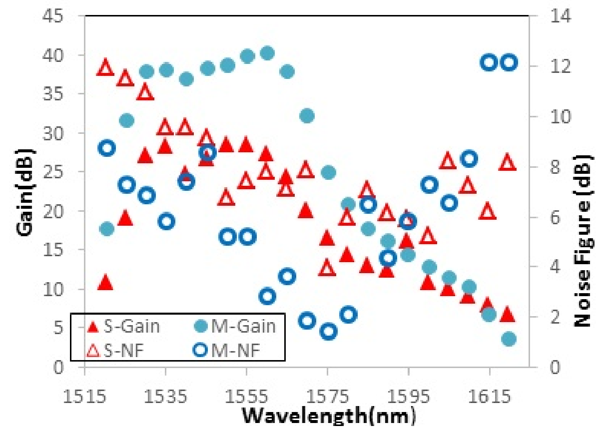

Figure-3. Gain and noise figure spectra for the single and double pass Zr-EDFA at the lower input signal power of -30 dBm.

The gain in single and double pass amplification are showed to increase at the C-band region and decrease at the L-band region. This is due to the emission characteristic of the gain medium when pumped with 980 nm which will decrease the amplification in L-band region. Instead of that, we can conclude that the gain saturation effect in the gain medium is occurred. The NF in single pass amplification is observed to be higher compared to the double pass amplification. This is due to the ineffective population inversion that occurred especially when there are not enough atoms have been pumped to the excitation levels.

Figure-4 shows the gain and NF of the single and double pass Zr-EDFA where the input signal power is fixed at the -10 dBm (high input signal power). The signal wavelength is varied from 1520 to 1620 nm (C- and L-band wavelength region). In this experiment, the length of Zr-EDF is 1 m and 980 nm pump power is fixed at the 130 mW. As shown in the figure, the high input signal gain shows the better performance in term of gain improvement with the double pass amplification compare to single pass amplification. The average gain from 1520 to 1620 nm wavelength for single and double pass amplification are 14.8 and 15.9 dB, respectively.
The gain enhancement for this high input signal power is 1.1 dB. This gain enhancement is lower compared to the gain enhancement with the lower input signal power. This is because of the small gap between the amplifier output and input power of the Zr-EDFA. This is proof by Eqn(1):

$$\text{Gain (dB)} = \text{Pout (dBm)} - \text{Pin (dBm)} \quad (1)$$

where Pout and Pin are the amplifier output and input power, respectively.

The NF in single pass amplification is observed to be higher compared to the double pass amplification. As mentioned earlier, this is due to the ineffective population inversion. This mechanism will lead to insufficient stimulated emission process and thus increase the NF.

VOL. 11, NO. 5, MARCH 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

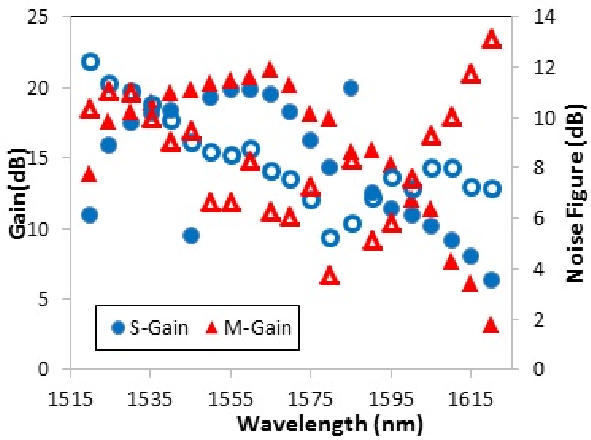

Figure-4. Gain and noise figure spectra for the single and double-pass Zr-EDFA at the high input signal power of -10 dBm.

CONCLUSIONS

The performances of the Zr-EDFA with single and double pass amplification are successfully demonstrated at -10 and -30 dBm for high and low input signal power, respectively. The double-pass Zr-EDFA by utilizing the Zr-EDF as the gain medium and BFM shows the better gain performance compared to the single pass Zr-EDFA in both input signal powers. This is due to the double propagation of forward and ASE signal back into the Zr-EDF (gain medium). The gain in lower input signal power is observed to produce a better gain performance compared to high input signal power in terms of maximum and average gain. At lower input signal power of -30 dBm, the maximum and average gain of 40.3 and 11.7 dB are achieve at wavelength of 1560 nm for double pass Zr-EDFA, respectively. The gain enhancement around 11.7 dB is observed with this lower input signal.

ACKNOWLEDGEMENTS

This work was supported in part by UniversitiTeknologi Malaysia under Grant Nos Q.K130000.2743.01K17.

REFERENCES

[1] X.S. Cheng, R.Parvizi, H. Ahmad, S.W. Harun. 2009. Wide-Band Bismuth-Based Erbium-Doped Fiber Amplifier with a Flat-Gain Characteristic. IEEE Photonics Journal. 1(5): 259–264.

[2] S. D. Emami, P. Hajireza, F. Abd. Rahman, H.A. Abdul Rashid, H. Ahmad, S.W. Harun. 2010. Wide-Band Hybrid Amplifier Operating in S-band Region. Progress in Electro-Magnetics Research 102.pp. 301–313.

[3] B. A. Hamida, A. A. Latif, X. S. Cheng, M. A. Ismail, W. Naji, Khan, S. W. Harun. 2012. Flat-Gain Single-Stage Amplifier Using High Concentration Erbium Doped Fibers in Single-Pass and Double-Pass Configurations. Symposium on Photonics and Optoelectronics (SOPO). pp. 1-5.

[4] M. A. Mahdi, A. W. Naji, B. A. Hamida, X. S. Cheng, S. W. Harun, S. Khan, H. Ahmad. 2011. Review of Erbium-Doped Fiber Amplifier. International Journal of Physical Sciences. 6(20): 4674-4689.

[5] R. Laming, M. N.Zervas, D. N. Payne. 1992. Erbium-doped Fiber Amplifier with 54 dB gain and 3.1 dB Noise Figures. IEEE Photonics Technology Letters. 4(12): 1345-1347.

A. Basak, M. M. Hossian, M.R.Islam. 2013. Performance Analysis of Erbium-Doped Fiber Amplifier in Fiber Optic Communication Technique. Global Journal of Researches in Engineering, 13(6): 15-22.

B. Bouvid, B. M. Ali, M. K. Abdullah. 2003. A High-Gain EDFA Design using Double-Pass Amplification with a Double-Pass Filter. IEEE Photonics Technology Letters. 15(9): 1195-1197.

[6] S. S. Osman, S. W. Harun, R.Parvizi, H. Ahmad. 2009. An Efficient Double-Pass Bismuth-based Erbium-Doped Fiber Amplifier. International Conference for Technical Postgraduate (TECHPOS). 1-3.

[7] M. Z. Jamaludin, M. K. Abdullah, F. Abdullah, F. A. Rahman, M. A. Mahdi. 2008. Double-Pass Chirped Bragg Grating Erbium-Doped Fiber Amplifier: Improved Transmission Distance. IEEE International Conference on Telecommunication Technologies and IEEE Malaysia Conference on Photonics. pp. 45-47.

[8] M. R. Haleem, M. H. Al-Mansoori, M. Z. Jamaludin, F. Abdullah, N. Md. Din. 2011. High Gain Double-Pass L-band EDFA with Dispersion Compensation as Feedback Loop. 21(2): 419-422.

[9] H. Zhang, L. Yu, Y. Liu, C. Wang, Y. Li, Q. Dou, L. Liu, S. Yuan, X. Dong. 2005. Noise Figure Improvement of a Double Pass Erbium-Doped Fiber Amplifier by using a HiBi Fiber Loop Mirror as ASE Rejecter. Optics Communications. 244(1-6): 383-388.

A. Hamzah, M. C. Paul, S. W. Harun, N. A. D. Huri, A. Lokman, M. Pal, J. K. Sahu. 2011. Compact Fiber Laser at L-band Region using Erbium-Doped Zirconia Fiber. Laser Physics. 21(1): 176-179.