Letter to the Editor

PERFORMANCE ENHANCEMENT IN L-BAND EDFA THROUGH DUAL STAGE TECHNIQUE

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Abstract: An experiment on gain enhancement in the long wavelength band erbium doped fiber amplifier (L-band EDFA) is demonstrated. It uses a dual stage technique with dual forward pumping scheme. Compared to a conventional single stage amplifier, the small signal gain for 1580nm signal can be improved by 5.5dB without paying much noise figure penalty. The corresponding noise figure penalty was 0.3dB due to the insertion loss of the optical isolator. The optimum pump power ratio for the first pump is experimentally determined to be 33%. The maximum gain improvement of 8.3dB was obtained at a signal wavelength of 1568nm while signal and total pump powers were fixed at -30dBm and 92mW, respectively. The employment of dual stage amplifier system seems to play an important role in the development of practical L-band EDFA from the perspective of economical usage of pump power.

Key Words: *erbium doped fibre; optical amplifier; L-band EDFA; dual stage EDFA; amplified spontaneous emission*

1. INTRODUCTION

Ultra-wideband erbium-doped fiber amplifier (EDFA) now represents one of the promising future network elements, for the ever-increasing high capacity wavelength division multiplexed (WDM) system application [1]. Among many attempts suggested so far, the silica based EDFAs in parallel configuration (C-band: 1530 ~ 1560nm plus L-band: 1570 ~ 1610nm) [2-3] have been considered to be the most immediate viable candidate for real system applications, due to the maturity of the supporting technologies. There has been a lack of research effort on L-band EDFA compared to C-band EDFA. The L-band require longer erbium-doped fiber (EDF) lengths to obtain the same gain as a conventional band (C-band) EDFA due to its operating wavelengths are very far from the emission peak of silica-based EDF at 1531nm. Therefore, many researches for L-band focused on the efficiency improvement, to relax the need for higher pump power compared to C-band EDFA.

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One of the approaches to power conversion efficiency in L-band EDFA is to recycle a unwanted backward ASE as a secondary pump source to pump an under-pumped EDF section [4]. Other approaches are C-band injection seeding [5] and using a double pass technique [6]. In this letter, two stages L-band EDFA is proposed to improve the gain using optical isolator to split the EDF into two segments. In this amplifier, both segments are pumped separately using forward pumping scheme and the optical isolator is inserted between the first and second stages to eliminate any backward propagating amplified spontaneous emission (ASE).

2. EXPERIMENTAL SET UP

The experimental set up is shown in Fig. 1. Figure 1(a) shows a single stage amplifier configuration. Figure 1(b) shows a configuration of the proposed dual stages L-band EDFA, in which an optical isolator splits the EDF 1 into two segments of EDF 2 and EDF 3. EDF with an erbium the peak absorption of 5.6dB/m at the 1531nm was used for both configurations. EDF 1 was 50m long and it was split into 20m for EDF 2 and 30m for EDF 3. EDF 1, EDF 2 and EDF 3 are pumped by 980nm laser diode at 92mW, 35mW and 57mW, respectively using forward pumping scheme. The gain and noise figure for the proposed two stages amplifier are measured using optical spectrum analyzer (OSA) and are compared with the single stage amplifier.

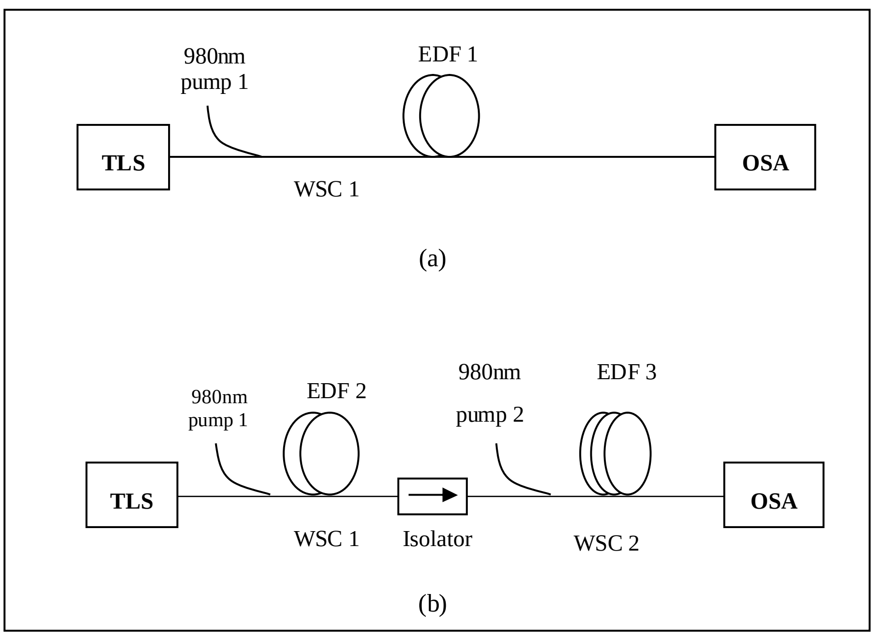

Fig. 1: Configuration of the L-band EDFA (a) single stage (b) dual stage

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3. RESULT AND DISCUSSION

Figure 2 depicts the ASE spectra of both single stage and dual stage amplifiers with a total pump power of 92mW where the thin line represents the ASE spectrum of the proposed dual stages amplifier. As seen, the spectrum of the proposed amplifier is much higher than the single stage amplifier, represented by the thick line. By splitting the pumping to two positions along the EDF length as a dual stage amplifier, the ASE level is increased due to large forward ASE from first stage that has not been depleted by backward ASE of second stage. The power level of this ASE spectrum is not very high due to insufficient pump powers to generate the ASE. This can be solved by deploying 1480nm laser diodes that provide better power conversion efficiencies and consequently higher ASE powers. The pump power of the first stage is fixed at 35mW that is 33% of the total pump power because this is the optimum value as shown in Fig. 3. Fig. 3 also shows the gain and noise figure as a function of the power ratio of pump 1. The maximum gain is obtained at 33% before decreasing slowly until the ratio reached 85%. On the other hand the noise figure shows a constant value of 3.2dB at pump 1 ratios of 28% to 85%.

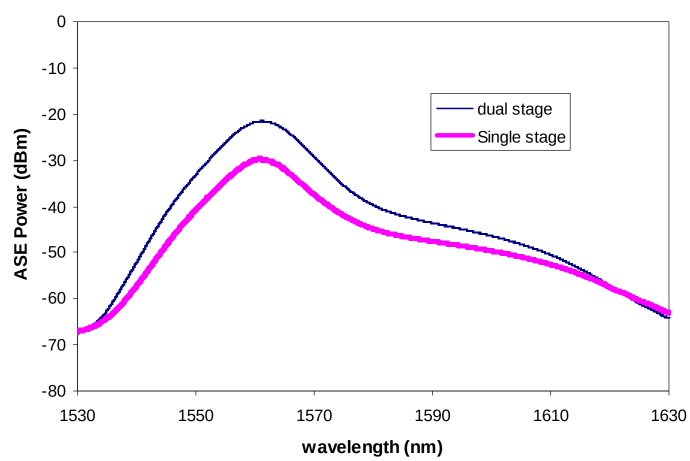

Fig. 2: ASE spectra of the L-band EDFA while the total pump power is fixed at 92mW. For dual stage amplifier, pump 1 and pump 2 are fixed at 35mW and 57mW, respectively.

The gain and noise figure characteristics of the 1580nm signal against input signal power were measured by varying the input signal power from –40 to 0dBm for both cases as shown in Fig. 4. A gain enhancement of about 5.5dB is obtained at small signal levels for the dual stage amplifier compared to single stage amplifier. This is attributed to the dual forward pumping scheme that increased the forward ASE level and thus the amount of energy available for transfer from short to long wavelength also increases. The first stage amplifier works as a pre-amplifier with a relatively high inversion, while the second stage acts as a power amplifier with high pump efficiency. The saturation power of the single and dual stage amplifiers are obtained at –12dBm and –14dBm, respectively. On the other hand, the noise figure of the proposed dual stage amplifier is slightly higher by 0.3dB compared to the single stage amplifier for all input signal powers. This noise figure degradation is caused by the inserted component loss. The optical isolator is used to separate the EDF into two sections to prevent the backward ASE from entering the first stage section and degrades the noise figure terribly.

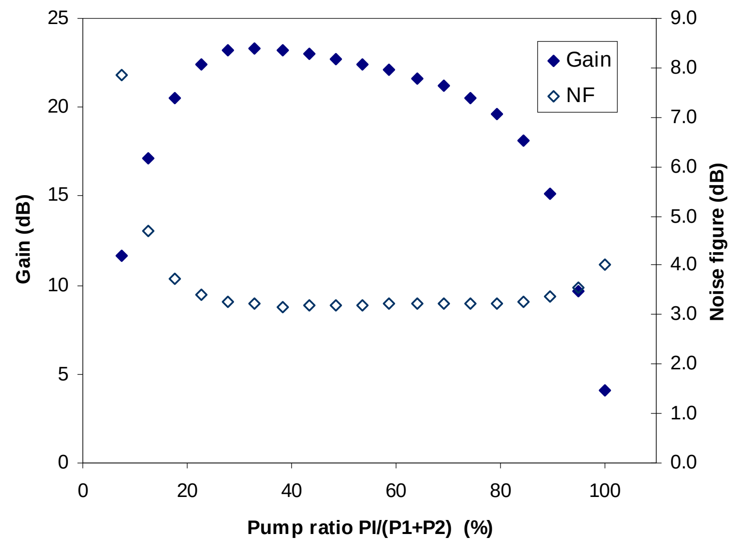

Fig. 3: Gain (closed) and noise figure (clear) as a function of power ratio of pump 1.

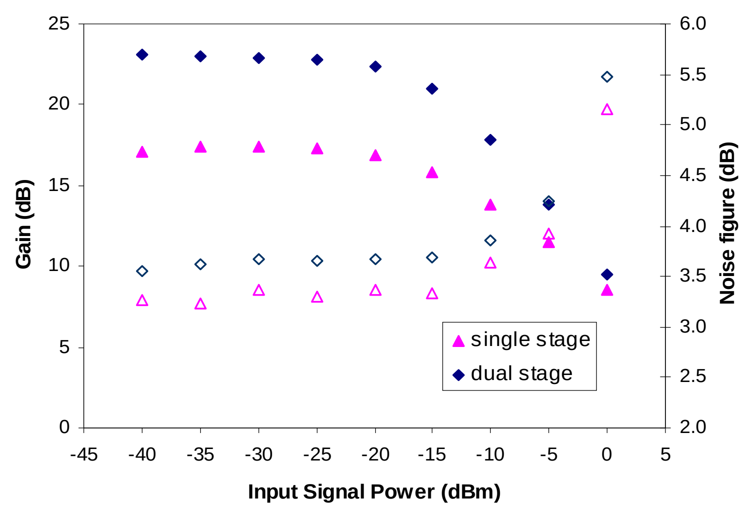

Fig. **4:** Gain (closed) and noise figure (clear) as a function of input signal power.

Fig. 5 shows the gain and noise figure spectra for an input signal power of –30dBm and total pump power of 92mW. As seen, the gain of the dual stage amplifier is higher compared to the single stage amplifier especially at shorter wavelengths. This improvement is obtained by amplifying and employing the forward ASE from the first stage to the second stage. The first 10~15 meters of the forward-pumped EDF experiences a very high pump power with correspondingly high population inversion rates in the C-band in both the forward and backward directions. However, insertion of the isolator blocks the backward ASE from the second stage, which has a higher pump power allocation. Suppression of this high power backward ASE, enables built-up of forward ASE in the first stage since there is no other mechanism to deplete the inversion. This results in a very high power forward ASE which can be used to transfer from the higher energy C-bands to the lower energy L-band wavelengths. It also can be seen in Fig. 5 that the maximum gain enhancement value of 8.3dB is obtained in the dual stage amplifier compared with the conventional single stage amplifier at wavelengths of 1568nm. The corresponding noise figure penalty is 0.5dB. The noise figure penalties were obtained especially at longer wavelengths due to the same reason as explained above.

Fig. 5**:** Gain (closed) and noise figure (clear) as a function of input signal wavelength.

4. CONCLUSIONS

An L-band EDFA with improved gain characteristic, which uses dual forward pumping scheme, has been proposed and demonstrated. The amplifier has improved the small signal gain for 1580nm signal by 5.5dB at the expense of 0.3dB noise figure penalty compared to a conventional single stage amplifier. The noise figure penalty is due to the insertion loss of the optical isolator. The optimum pump power ratio for the first pump is experimentally determined to be 33%. A maximum gain improvement of 8.3dB was obtained at a signal wavelength of 1568nm while signal and total pump powers were fixed at -30dBm and 92mW, respectively. These results show that the employment of dual stage amplifier system will play an important role in the development of practical L-band EDFA from the perspective of economical usage of pump power.

$\tau = \frac{6.5}{k_s C_{NO_o}}\left(\right.$

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REFERENCES

[1] A. K. Srivastave, "Wide bandwidth high capacity systems," Opt. Fiber Comm. Conf. 1999, and the International Conf. on Integrated Optics and Opt. Fiber Comm. OFC/IOOC '99. Technical Digest, pp. 59-60, 1999.

[2] M. Yamada, H. Ono, T. Kanamori, S. Sudo and Y. Ohishi, "Broadband and gain-flattened amplifier composed of a 1.55μm-band and a 1.58μm-band Er^{3+}-doped fiber amplifier in a parallel configuration," Electron. Lett., 33, 710-711, 1997.

[3] Y. Sun, J. W. Sulhoff, A. K. Srivastava, J. L. Zyskind, T. A. Strasser, J. R. Pedrazzani, C. Wolf, J. Zhou, J. B. Judkins, R. P. Espindola and A. M. Vengsarkar, "80nm ultra-wideband erbium-doped silica fiber amplifier," Electron. Lett., vol. 33, pp. 1965-1967, 1997.

[4] J. Lee, U.-C, Ryu, S. J. Ahn, and N. Park, "Enhancement of power conversion efficiency for a L-band EDFA with a secondary pumping effect in the unpumped EDF section," IEEE Photon. Technol. Lett., 11, 42-44, 1999.

[5] M. A. Mahdi, F. R. Mohamd Adikan, P. Poopalan, S. Selvakennedy, W. Y. Chan and H. Ahmad, "Long wavelength EDFA enhancement through 1550nm band signal injection," Opt. Comm., 176, pp. 125-129, 2000..

[6] S. W. Harun, P. Poopalan and H. Ahmad, "Gain enhancement in L-band EDFA through double pass technique," IEEE Photon. Technol. Lett, 14, pp. 296-298, 2002.

BIOGRAPHY

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