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Optimization of Raman Pumping in the Serial Hybrid Fiber Amplifier

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***Abstract* –**A serial hybrid optical amplifier composing of two amplification stages of erbium-doped fiber (EDF) amplifier covered C-band window and Raman fiber amplifier (RFA) covered L band window demonstrated. In this paper, the optimizations were done to obtain the optimum pump power and optimum pump wavelength for Raman amplifier in order to achieve a flat gain bandwidth at wideband amplification. The DCF (dispersion compensation fiber) that used in Raman amplifier pumped by two Raman pump units (RPU). RP1 at 1410 nm with 700 mw is used for S band region, and the RP2 is 1490nm with 350mw is chose to get an amplification at L-band region. The system performance was analyzed in term of overall gain, noise figure, gain variation and gain bandwidth using optisystem7.The proposed design of serial hybrid fiber amplifier (SHFA) provides a flat gain bandwidth of 85 nm ranged from 1525 to1610 nm within 3-dB gain flatness. Over 18.5dB average gain is achieved, and the corresponding noise figure is 5.04dB. The performance evaluated at the optimum parameters with a small input signal power of -30dBm.

Keywords - Serial hybrid fiber amplifier, flat gain bandwidth, Fiber amplifiers, Raman amplifier, Wideband Hybrid Fiber Amplifier, optimum pump condition

I. Introduction

With the rapid growth of Internet technology, there is an urgent need to develop the means of transferring information across huge distances in communication systems. a lot of studies and research works have been focused on the optical fiber devices, One of the main interesting efforts is on the optical amplifiers to promote the weak signal During transport over long distances in the communication systems [1-3].The hybrid optical amplifier (HOA) is a combination of multi amplifiers such as Raman fiber amplifier (RFA) and erbium doped fiber amplifier (EDFA), have featured as a promising solution in broadening the span and transmission capacity of the WDM system [4]. EDFA is emerged firstly at the first generation to covering the C band with the range of wavelengths from 1530 to1565 nm and L-band with the range from 1570 to1610 nm [5-6]. However, the EDFA has its limitations in terms of; they need specially doped fiber, both of the absorption and emission spectrum determined by the erbium levels and slow energy transfer [7].Then, Raman fiber amplifier came to cover these limitations and enhance the performance system without need to special doping. RFA can amplify the power signals at any coming wavelength by adjusting the pump wavelength which is shifted down by 100 nm from the signal wavelength [8].DCF is dispersion compensation fiber uses in Raman fiber amplifier as a proper type to compensate for the losses of fiber [9].HFA has designed by several techniques with different configurations so as to obtain better performance in term of high gain levels, low noise figure, increasing the pump efficiency and extending the bandwidth of transmission system [10-14]. Multi-pump technique of Raman fiber amplifier able to fulfill wideband gain spectrum through selecting a proper pump-wavelength and pump-power of these pump units [15].
Masuda et. al reported a wide bandwidth of 76 nm by using multi pump design of ED/Raman fiber amplifier. They have used in four pump sources for RFA with different operating wavelengths [16]. As well as, Matheus O. L. Benincaet. al. achieved an On-off gain of 17 dB with ripple up to 2 dB over a 65 nm bandwidth at pumping Raman Amplifier (RA) via three counter-propagating pump sources provides over 1W [17].In this paper, serial hybrid fiber amplifier of two amplification stage is simulated utilizing OptiSystem7.The first stage is 3m of EDFA cover C-band and second stage is 7km of RFA cover S+L band. The proposed design resulted in wide Flat-gain bandwidth about 95 nm extended from 1525 nm to 1620 nm.

II. Materials and Method

Figure 1 shows a simulation setup of wideband hybrid Erbium-doped/Raman fiber amplifier utilizing the multi-pumpfor Ramanamplifier.The hybrid gain is a combining of gain mediums for C-band amplification by EDFA and for both of S+L band amplification by RFA.The proposed design is composed of 3 m EDF having anEr^{3+} ion concentration, core radius and Er doping radius of 1000 ppm, 1.65µm and 1.65µm, respectively. EDFA backward pumped by erbium pump unit (EPU) placed at1480nm at 10 mw was injected through wavelength division multiplexing (WDM) to EDFA.The output signal of the first stage of EDFAemployed asthe inputto the second stage of DCF in the serial scheme

[12].RFA consisted of a DCF with 7 km length, total loss and an effective area of,0.44 dB and 20 µm2, respectively.RFA is pumped via two Raman pump units RP1 and RP2 that coupled bypump combiner and injected to the DCF viawavelength division multiplexing (WDM).RP1 with high power of 700 mW at 1410 nm was chosen for S-band region, while RP2 is 350 mW at different wavelengths of 1480, 1485 and 1490nm nmwas implemented to achieve good gain flatness at L bands. Furthermore, a dual port WDM analyzer is employed to measure the gain and noise figure. In addition, an optical spectrum analyzer (OSA)was used to monitor the output spectrum of the optical hybrid amplifier scheme.The input signal power that achieved by tuneable laser source (TLS) within linewidth of 150 kHz was fixed at –30dBm in order to make sure that both of EDFA and RFA is working under the saturation point.

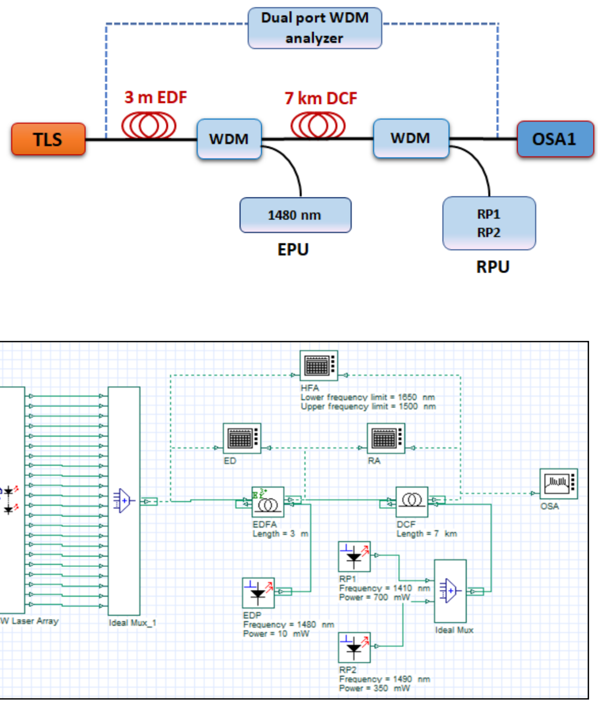

Fig. 1 simulation setup

III. RESULTSAND DISCUSSION

The optimization of the proposed design implemented in terms or pumps power optimization and pump wavelength optimization for each pump.

In this section,Raman pump optimization in L-band region first was presented. the characterization of gain spectrum of pump parameter optimized RFA has been evaluated at different wavelength as well as the noise figure. The input signal power is fixed at –30 dBm, while the signal wavelength range is tuned from 1520 nm –to– 1625 nm with a step of 5 nm. An optimization of RP2which related to the L-band region was presented. It is swept from 200 mW to 350 mW with a step of 50 mW at different pump wavelengths of 1480 nm, 1485 nm, and 1490 nm. These three wavelengths range were chosen to find the optimum overall gain flatness. At first 1480nm is optimized by varying its power within the range of 200 to 350 mW as shown in Fig.2 (a). it is clear from this figure that relatively low flatness gain bandwidth of 20nmat 200mW was achieved and a maximum gain flatness of 25nm (1545-1570) was achieved formaximum power of 350mW. Trade off to the low flatness gain, high gain level of 21 dB was presented. On the other side wider gain flatness was illustrated using 1485nm at the same pump power ranges. Up to 30nm (1545-1575) gain flatness with lowest average gain level of 20dB was illustratedas depicted in fig.2 (b). More improvement realized in gain flatness for all pump power ranges at 1490 nm.Up to 85nm (1525-1610) as a gain flatness was achived at highest pump power of 350mW. Again atrade off is taken for the average gain level. İn this time up to 18.5dB as an average gain is achieved as shown in fig.2 (c). İn general related to Fig.2, inceasing the pump power at the certain pump wavelength, wider gain flatness was ahieved. İn addition, shifting the wavelength of the pump power more in L-band region, resulted in expanding gain flatness range.

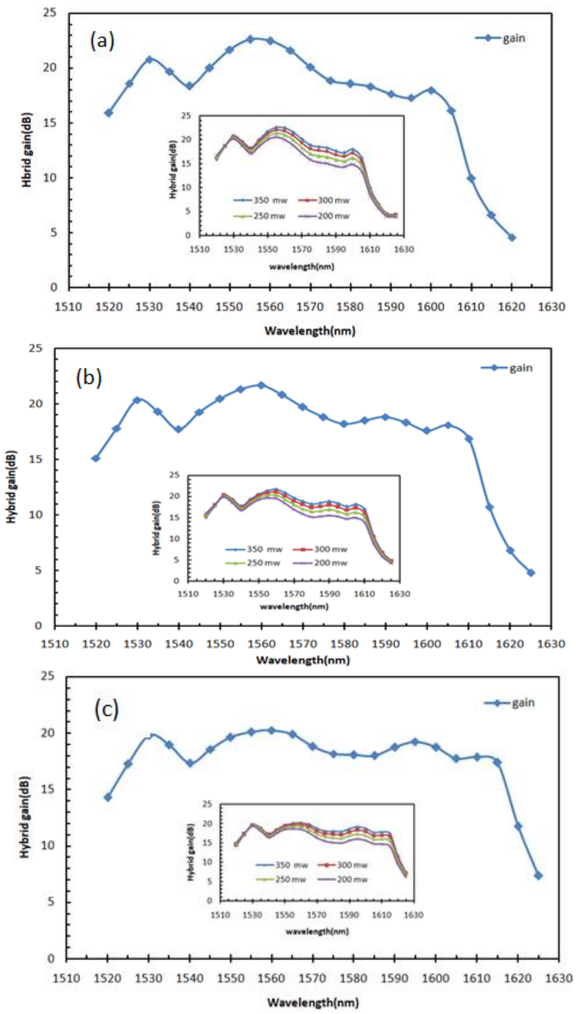

Fig.2 Average gain versus signal wavelength for S–HFA at signal power of –30 dBm and pump power is changed from 200 mw to 350 mw with a step of 50 mW, for the pump wavelength of: (a) 1480 nm, (b) 1485 nm, (c) 1490 nm and.

İn this context, these three differne RP2 wavelengths were compared at the maximum pump power of 350mW in terms of over all gain spectrum and noise figure as dipected in Fig.3 (a) and (b). To clerify the results, table 1 was used to illustrate the SHFA performance for these three pump at the maximum pump power of 350mW. It is clear from Fig.3(b) that the noise figure was amlost same for all of the pump wavelengths, that was due to the RFA was not satureated at such low signal power of = -30dBm.

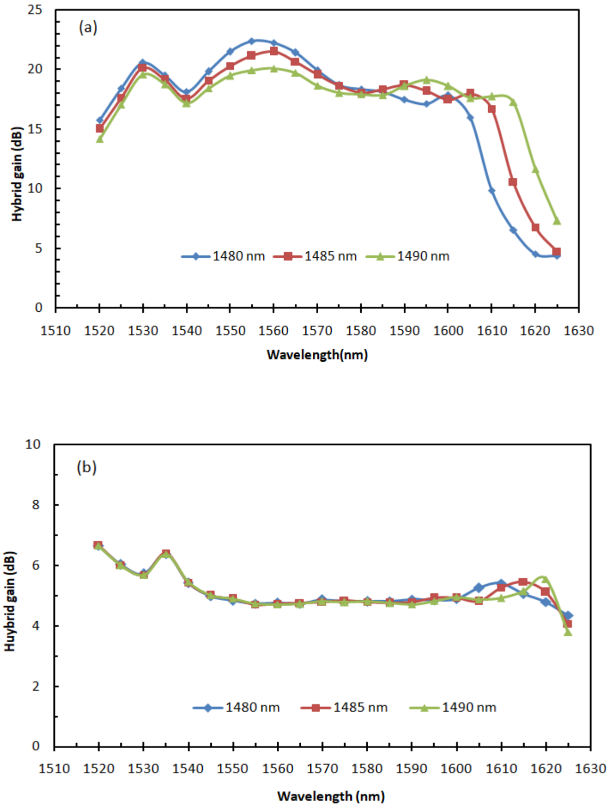

Figure 3. Gain characteristics and NF of S–HFA versus signal wavelength at several RFA pump wavelengths at OPP for signal power of –30 dBm.

Table 1. Results of the main parameters during the optimization process

RP2(nm)	Gavg. dB	Gvar. dB	NFavg. dB	GBW. (nm)
1480 350 mw	21.18	2.57	5.145504	25
1485 350 mw	20.09	2.82	5.131629	30
1490 350 mw	18.56	2.91	5.102596	85

IV. COMPARISON

The overall performance of the proposed design can be evaluated by compared it with a result from previous works in ref. [17] [19] [20], as illustrated in Table 2. The results show a significant improvement in the gain bandwidth is about 85 nm compared to other studies. Furthermore, there isa preference in terms of the number of pumping sources, where the lowest number is used in our design.

V. CONCLUSION

Raman pump unit (RP2) optimization in terms of pump power and wavelength has been demonstrated in this study. The result illustrated that wider gain flatness can be achieved for longer pump wavelength. In contrast lower average gain and high gain variation level is presented. An average gainlevel of 18.5 dB over 85 nm flatness with again variation of 2.91 dB has been presented using 1490nm. Lower flatness gain bandwidth of 30nm and 25nm was achieved using 1485nm and 1480nm respectively under the same pump power condition.

Table 2. Comparison between the proposed design withdifferent previous studies

Main parameters	Ref.[17] ED+RA	Ref.[18] RA+ED+RA	Ref.[19] RA+TD TF	Our work
Gain avarage	17dB	25dB	39.2dB	18.5dB
Gain ripple	>2dB	2.5dB	1.5dB	2.91dB
Gain bandwidth	65nm	80nm	45.5nm	85nm
Noise figure	4dB	....	5dB	5.04dB
No.of pump units	1(EDF) 3(RA)	1(EDF) 3(RA)	2(TDTF) 2(RA)	1(EDF) 2(RA)
Band region	C+L	C+L	C+L	S+C+L

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