JOURNAL OF OPTOELECTRONICS AND ADVANCED MATERIALS Vol. 17, No. 11-12, November – December 2015, p. 1880 – 1884

Hybrid EDFA/SOA amplifier design for CWDM network

M. A. MUTHALIB[ab], N. ARSAD[a,c*], A. A. EHSAN[c], S. SHAARI[c]
[a]*Department of Electrical, Electronic and System Engineering, The National University of Malaysia, Selangor, Malaysia*
[b]*Departmen of electrical Enginerring, Malikussaleh University, 24351, Lhokseumawe, Aceh Utara, Indonesia*
[c]*Photonics Laboratory, Institute of Microengineering and Nanoelectronics, The National University of Malaysia, Selangor, Malaysia*

In this experiment we propose a coarse wavelength division multiplexing (CWDM) transmission system that uses a new hybrid, two-stage EDFA/SOA amplifier. The hybrid amplifier is a combination of cascaded erbium-doped fiber amplifiers (EDFAs) and semiconductor optical amplifiers (SOAs). This amplifier design is capable of providing a nearly flat gain of over 80 nm. The hybrid amplifier had been modeled using an OptiSystem version 9 modeling tool produced by OptiWave and is integrated into a CWDM transmission system with two spans of 100 km transmission distance.

(Received September 22, 2015; accepted October 28, 2015)

Keyword: Coarse wavelength division multiplexing; Semiconductor optical amplifier; Erbium doped fiber amplifier; Optical fiber.

1. Introduction

A transmission system will experience losses when it travels a long distance of 100km or more. In order to transmit signals over such distances (≥100km), it is important to compensate for the attenuation losses in the fiber [1]. Usually a signal drop in the telecommunication system will affect the operation of the system. Thus, an optical amplifier [2, 3] is needed in the system. Optical amplifier is a device capable of increasing the capacity, lengthen the span, and multiply the connectivity of optical communication networks. Previously, losses in the system were minimized by placing a repeater at every 30 to 50 km distances. A repeater is a device used to increase or boost the signal by firstly converting the light signal into an electrical signal, and subsequently re-clocking and re-transmitting the signal by converting the electrical signal back into its optical state.

Coarse Wavelength Division Multiplexing (CWDM) is a multiplexing scheme where multiple wavelength signals are combined into a single fiber optic cable without any interference [4]. By using the CWDM technology, the optical fiber becomes a simpler transport alternative and cost-effective solution to add more services over a single exiting without interrupting other services to existing customers. The CWDM operates at a higher bandwidth as compared to the Wavelength Division Multiplexing, where the operation wavelength span from 1271 nm up to 1611 nm which covers 18 CWDM channels with a channel spacing of 20 nm [5]. In this experiment, a basic 8-channel CWDM system having a wavelength range of 1470 nm to 1610 nm with 20 nm spacing, 80 km transmission distance, an a bit rate of 100 Mb/s using SMF fiber optic is investigated [6]. We use two amplifiers namely EDFA and Semiconductor Optical Amplifier (SOA) to amplify the system.

2. Experimental set-up

We thrive to compare the performance of EDFA and SOA for the application in CWDM system. Union of EDFA and SOA in a hybrid amplifier design are suitable for presenting an amplification spectrum covering the s, c, and l band [8]. SOA possesses the advantages of wide bandwidths, cost-effective multi-channel system, and also suitability for metro space that makes it favorable to the CWDM system [9,10].

The standard usage of EDFA amplification band within the range of 1530 nm to 1560 nm (or simply known as C-band) is vastly applied in long-haul optical fiber communication systems due to the resulting gain being more than 20 dB [11].

For an amplifier to effectively be one of the elements that will increase the performance of any communication systems, it needs to own three major characteristics; i) high gain, ii) low noise, and iii) flat amplification profile [7].

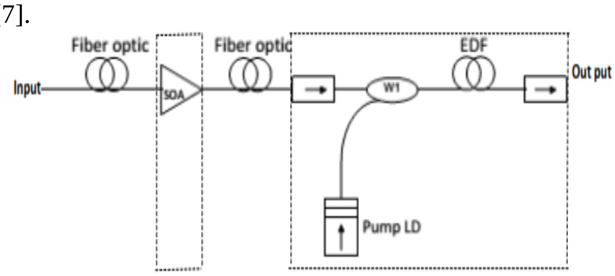

Fig 1: The proposed S and C- band amplifier modules composing of an SOA and EDFA.

Fig. 1 shows the proposed hybrid optical amplifier using EDFA and OSA will encompass the range of S to C bands, with its designing and modeling processes are done using the OptiSystem version 9 optical network simulator tool produced by Optiwave.

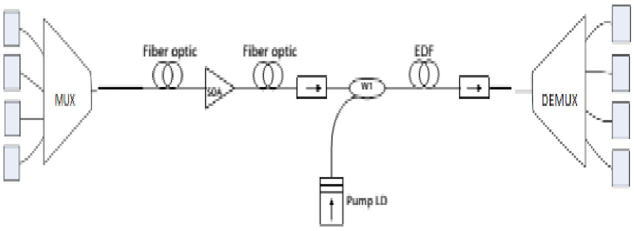

Fig 2: Network layout of CWDM system with the hybrid SOA-EDFA amplifiers.

This experiment is done using an 8-channel CWDM system having a wavelength range of 1470 to 1610 nm and uses a hybrid EDFA/SOA amplifier within the system. Figure 3 shows the set-up of the EDFA/SOA hybrid amplifier in two phases for the CWDM system using OptiSystem.

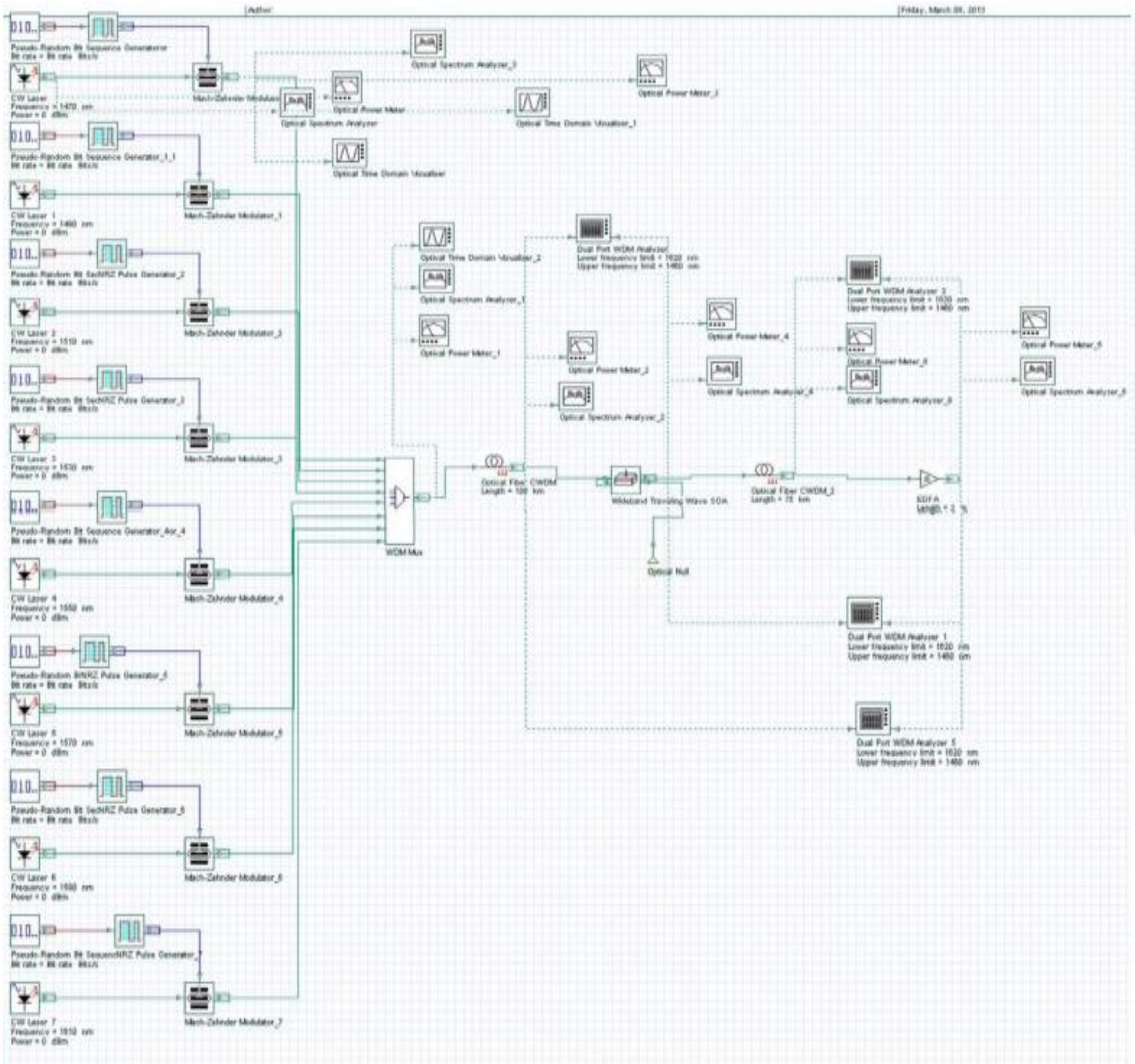

Fig. 3. Network layout of CWDM system with hybrid optical amplifiers are designed and modeled using an optical network simulator tool, OptiSystem version 9 by Optiwave.

In the system, the set up of the hybrid amplifier is divided into two parts; the first one deals with the strengthening of the S band and the C band, while the second part focuses on strengthening the L band. The S band and C band are supported by the SOA and EDFA respectively, while the L band strengthening is performed in a cascade manner by the hybrid amplifier. However, the given gain cannot reach the whole area of the L band causing the strengthening gain to be less pronounced in the band, thus reinforcement is needed on the service area of the L band. In the simulation mode setting, the SOA amplifier is set to operate at a bias current of 0.13 A, an energy band gap wavelength with a maximum center wavelength of 1510 nm, and a center unit frequency noise of 1490 nm. The EDFA on the other hand is set to a length of 10m, with a wavelength of 980 nm and a pump power of 50 mW.

3. Result and Discussion

Fig. 4 shows that the data and voice are sent from a distance of 100 km with a wavelength range of 1470 nm to 1610 nm and a varying bit error rate between 100 Mb/s and up to 2.5 Gb/s.

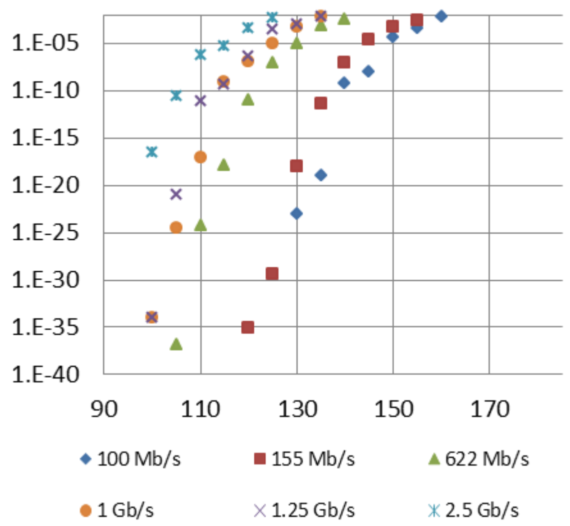

Fig 4: CWDM implementation with different rates for FTTH networks application.

Table 1. Data Simulation according to CWDM system.

OLT	Wavelength (nm)	Tx Power (dBm)	Mux Power (dBm)	Fiber Power (dBm)	Rx Power (dBm)
Ch 1	1470	-2.17	1.35	-10.68	-28
Ch 2	1490	0.5			-22
Ch 3	1510	-3.79			-25.42
Ch 4	1530	-3.3			-23.9
Ch 5	1550	-3.3			-24.1
Ch 6	1570	-1			-23.05
Ch 7	1590	-2.3			-23.9
Ch 8	1610	-3.28			-24.8

To improve the quality of a long-haul telecommunication system, it requires not only a proper amount of power source, but also the integration of amplifiers to boost the signal and minimize loss. Table 1 shows the output power of all 8 channels in the CWDM system. It can be seen that each channel produces different output power, but they all experience huge power reduction as compared to the power source that will greatly affect the quality of the system. By adding amplifiers into the system, mistakes caused by weakness and high noise level within the signal can be reduced, hence guarantee that the user will get the signal in its best form. During the experiment, the values in the simulator were set to match the real system.

From the experiment, it is observed that increasing the power source or bit rate without the support of the network will cause the system to reach its saturation point expeditiously. This causes the results generated from the system to be unreliable. Hence, we try to improve the system by adding a hybrid amplifier consisting of EDFA and SOA with each amplifier exhibits dissimilar characteristics and way or working. The receiver can receive input power from the system at a minimum value of -25 dBm. However, in this experiment we try to cover three bands namely s, c, and l bands, aiming to increase the gain and lower the noise levels for the purpose of providing a good service to the user. We use of the amplifiers in a cascading order to improve the service gain of the CWDM system.

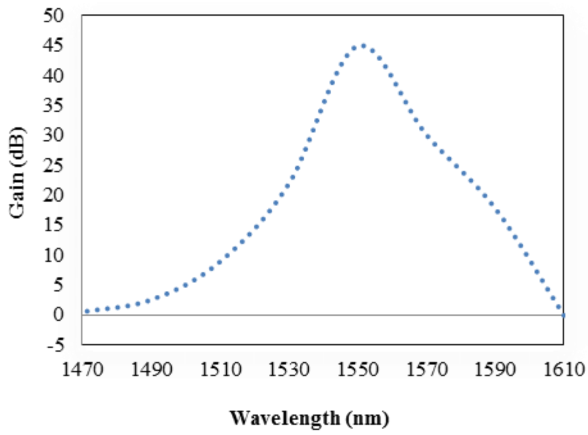

Fig 5: Gain spectra of EDFA amplifier over the bandwidth of 1530 to 1570 nm.

Fig. 5 shows the gain spectra of the EDFA having 1000 mA input power in the experimental setup. The gain that can be provided by the EDFA may reach up to 45 dB. EDFA support the second part of the system by amplifying output gain from the SOA and hence allows from a transmission length that can reach up to 100 km.

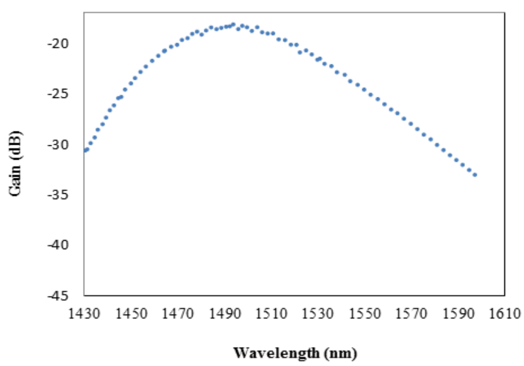

Fig 6: Gain spectra of SOA amplifier with input power 400 mA current level over the bandwidth of 1470 to 1510 nm by real system.

Fig. 6 shows the spectra gain of SOA with an input power of 400 mA and a center wavelength of 1490 nm.

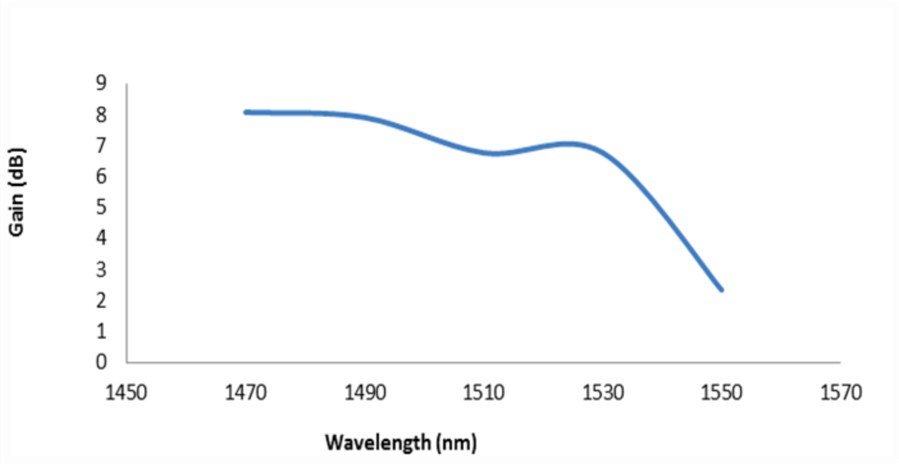

Fig. 5. Gain versus wavelength for cascaded SOA-EDFA configuration by simulator.

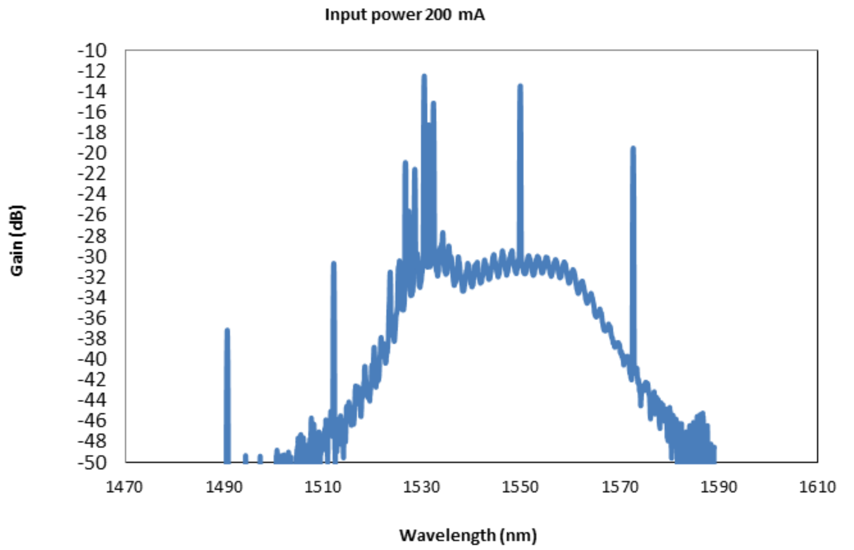

Fig 8: Gain versus wavelength for cascaded SOA-EDFA configuration by real system.

Hybrid amplifier is proven to be capable of giving effective output gain in the system, subsequently allowing the system to greatly lengthen its transmission distances. Figure 7 depicts the hybrid amplifier's simulation result. It shows that there is a decrease in the overall power gain due to the difference in characteristics between EDFA and SOA.

Gain is produced starting from the wavelength of 1470 nm and up until the wavelength of 1535 nm. In term of the flatness of the gain, the gain flattening occurs at different points from the total gain of the hybrid amplifier. At the area where the service gain of EDFA and SOA overlaps, the gain will experiences drop in accordance to the nonlinear characteristic of the amplifiers. Although the gain in the system is not uniform, the overall optical amplification in the hybrid amplifier can increase the performance of the CWDM system for operation distance of up to 100 km in particular.

Fig. 8 shows the result obtained from the hybrid amplifier experiment which uses two amplifiers, EDFA and SOA in a cascading manner. The system is expected to provide service gain in the wavelength range of 1470 nm until 1610 nm, as this is the range where gain flatness will take place. However the service gain in the c band between 1470 nm until 1490 nm appears to be very weak due to a drop in the gain strength over a distance of 40 km but still stays within the adequate signal strength level. Between 1510 nm until 1570 nm, the signal strength is good as a result of output signal from SOA being re-amplified by the EDFA. While between 1580 nm until 1610 nm, the re-amplified signal by the EDFA once again experience drop in strength as it passes the 40 km distance mark in the l band. All the issued output signals are then forwarded to the user.

4. Conclusion

In this experiment we demonstrate a CWDM system that uses a hybrid amplifier consisting of cascading EDFA and SOA that span over the length of 100 km, with uniform performance of 0 dBm power penalty in the simulation system and 80 km in the experimental setup respectively. The proposed hybrid amplifier design enables a nearly flat gain over a broad transmission spectrum, and some of the saturated output powers are produced at the wavelength of 1550 nm or higher.

Acknowledgement

The main author (Muchlis abdul muthalib) is grateful to the project leader for the financial support and authors also are grateful to Photonics Lab for providing the laboratory facilities to carry out the research.

Reference

[1] G. P. Agarwal. (2010). Fiber Optic Communication System.
[2] D. R. Zimmerman, L. H. Spiekman, Lightwave Technology, Journal of, **22**, 63 (2004).
[3] E. Desurvire. (March 1994). Erbium-Doped Fiber Amplifiers: Principles and Applications.
[4] A. A. E. Muchlis Abdul Muthalib., Sahbudin S., Norhana A., Australian Journal of Basic and Applied Sciences, **8**(19), 2014.
[5] A. A.-D. a. H. A.-R. S. Al-RUBAYE, International Journal of Communications, Network and System Sciences, **2**, 636 (2009).
[6] J. D. Downie, et al., "10.7 Gb/s CWDM system transmission with 8 channels 140 nm bandwidth over 120 km using two SOAs," in Optical Fiber Communication Conference, 2006 and the 2006 National Fiber Optic Engineers Conference. OFC 2006, 2006, p. 3 pp.
[7] J. B. Rosolem, et al., "Comparative analysis of optical amplifiers for CWDM networks," in Microwave and Optoelectronics Conference, 2007. IMOC 2007. SBMO/IEEE MTT-S International, 2007, pp. 34-37.
[8] Kamelian. (January 2003). Semiconductor Optical Amplifiers (SOAs) as Power Boosters, [online].
[9] P. Seoijin, et al., Photonics Technology Letters, IEEE, **17**, 980 (2005).
[10] H.-J. Thiele, et al., "Linear Optical Amplifier for Extended Reach in CWDM Transmission Systems," in Optical Fiber Communication Conference, Atlanta, Georgia, 2003, p. MF21.
[11] A. A. E. Muchlis Abdul Muthalib., Sahbudin S., Norhana A., Australian Journal of Basic and Applied Sciences, vol. 8, pp. 186-189, 2014.

*Corresponding author: Muchlis_3@yahoo.com
sahbudin@eng.ukm.my