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Gain Equalisation of Hybrid Fiber Amplifiers

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Abstract--- EDFAs have a high gain, operating at low pump power and their performances are better in comparison with other similar amplifiers and optical devices. Also, the EDFA have a large bandwidth, a low noise figure and polarization insensitivity. However, in case of EDFA based WDM systems a serious problem of un-flattened gain spectrum is observed. Hybrid doped fiber amplifiers with different gain bandwidths have attracted a large interest for increasing the transmission capacity of long haul wavelength division multiplexed (WDM) optical communication systems in C-band and L-band. In this paper, the gain spectrum of EDFA is broadened and flattened by cascading EDFA with TDFA using Dynamic Gain Equalizer. On using this configuration we have obtained an amplification bandwidth of 100 nm ranging from 1460nm to 1560 nm with a ±1.5% gain deviation.

Keywords--- Hybrid Fiber Amplifier, EDFA, TDFA, WDM, Dynamic Gain Equalizer

I. INTRODUCTION

The optical fiber can be doped with any of the rare earth element, such as Erbium (Er), Ytterbium (Yb), Neodymium (Nd) or Praseodymium (Pr). The host fiber material can be either standard silica, a fluoride based glass or a multicomponent glass. The operating regions of these devices depend on the host material and the doping elements. Fluorozirconate glasses doped with Pr or Nd are used for operation in the 1300nm window, since neither of the ions can amplify 1300nm signals when embedded in silica glass. The most popular material for long haul telecommunication applications is a silica fiber doped with Erbium, which is known as EDFA [1-5]. In some cases as Yb is added to increase the pumping efficiency and the amplifier gain. The operation of EDFA by itself normally is limited to the 1530-1560nm region. EDFA has a narrow but high gain peak at 1532 nm and at 1550nm a broad peak with a lower gain is observed. In order to take the advantage of the whole amplification band provided by EDFA gain spectrum, filtering or equalization techniques have to be applied. It is a well-known fact that the EDFA requires lesser power for the pump source and these pump power requirements can easily met by laser diodes. Hybrid fiber amplifiers with different gain bandwidths are the key components for the Wavelength Division Multiplexed systems in C-band and L-band. For taking the benefits of whole amplification bandwidth of hybrid amplifiers, the broadening as well as flattening of gain spectrum of EDFA is preferably required. There are different ways to increase the gain bandwidth of optical amplifiers [6-17]. The broadened and flattened spectrum will allow enough number of multiplexed channels to be amplified which is the basic need of WDM systems.

II. CASCADED HYBRID AMPLIFIERS WITH DGE

Erbium is a rare earth element having atomic number 68(Z=68). Now a day Erbium is used as a dopant into a glass host fiber and then this doped fiber is used as an amplifying medium. An amplified output around 1550nm is obtained in EDFA. As EDFAs are reliable and economic so they are revolutionizing the light wave systems [18]. EDFA can be used as Booster amplifier or In-line amplifier or as pre-amplifier. The gain spectrum of EDFA is very irregular and un-flattened as shown in Fig. (1).This irregularity is due to the stark splitting of the ground and meta-stable levels in the Erbium doped glass [13]. The

EDFA is one of the key devices used for wavelength division multiplexed (WDM) transmission systems. The problem with EDFA is that it has non-uniformity of the amplifier gain. As a result, different channels of a WDM system are amplified by different amounts and this problem become more severe in long-haul systems where cascaded EDFA chain is used. On the other side, Thulium Doped Fiber Amplifier (TDFA) is used in S-band [19]. It is experimented that by cascading TDFA with EDFA, the gain spectrum of EDFA is broadened [20]. Fig. (3) shows the gain spectrum of TDFA. Fig. (5) shows the broadened gain spectrum of hybrid amplifier by cascading TDFA and EDFA. In our earlier work, we proposed TFF (Thin Film Filter) in hybrid amplifier to flatten the gain spectrum [21].In this paper we have proposed a novel method to flatten the gain bandwidth of hybrid amplifiers. It is to be noticed that gain spectrum of EDFA is flattened using a Dynamic Gain Equalizer (DGE). The gain characteristics of hybrid amplifier cascading TDFA with EDFA for WDM systems is studied using opti-system. The basic idea behind gain flattening is very simple yet important. A DGE is used to minimize the attenuation of individual wavelengths within a 1469nm to 1569nm spectral band of hybrid amplifier. The function of DGE is similar to filtering out individual wavelengths and then equalizing these wavelengths on a channel by channel basis. This property of DGE is used here to flatten the gain spectrum of hybrid amplifier. It also helps to compensate for fluctuation in transmission losses. In WDM system, as the gain profile within given spectral band having many wavelengths normally changes, so needs to be equalized when one of the wavelengths is suddenly added or dropped on a WDDM system.

III. METHODOLOGY

The implementation of WDM network system requires a variety of passive as well as active devices to combine, distribute, isolate and amplify optical power at different wavelengths. Optical amplifiers, tunable optical filters and tunable sources constitute WDM systems. Following fundamental relationship is used $c=\lambda\nu$. In this paper a novel technique is proposed to flatten the gain bandwidth of a Hybrid amplifier. The gain bandwidth is extended by cascading EDFA with TDFA. This spectrum is then flattened by using a DGE When we cascaded EDFA with TDFA in series, the total gain of hybrid amplifier is given by product of individual gains of each amplifier. With this configuration we get a wide bandwidth spectrum of nearly 100nm i.e. from1460nm to 1560nm wavelength range. This also includes the 1510nm-1520nm range where EDFA as well as TDFA has no large gain for themselves. This is also observed that this gain is un-flattened mainly from 1520nm to 1540nm region. This whole wavelength range is flattened by using DGE. This device operates by having individually tunable attenuators. Within a 4-THz spectral range it attenuates the optical power of 40 channels spaced at 100 GHz. The control of DGE is done with the help of microprocessor and here interaction with the hardware by a program is made using C. There are four different methods to interact with hardware as shown in Fig. (7). For example, to interact with hardware DOS/BIOS functions can be used in a program or library functions can be called which in turn can call DOS/BIOS functions. But, we here prefer to use program that is needed directly to interact with hardware. The program so designed is based on the fact that control of DGE is based on the feedback information received from a performance monitoring card that provides the gain values. This gain is the main parameter which is to be adjusted. The function of DGE can be cleared from Fig. (8).This allows a high degree of agility in responding to gain fluctuations that may result from changing network conditions. By implementing this novel configuration we are able to achieve a gain having deviation ±1.5dB as shown in Fig. (9).

IV. RESULT AND ANALYSIS

After carrying out multiple Simulations on the Implemented Setups various Results for GAIN Flattening Spectra and Performance evaluating Parameters (BER, Q-Factor and Eye Opening) were obtained.

A. EDFA Amplifier

The optical spectrum obtained for EDFA amplifier as shown below in Fig. 1 with 16 input channels being used shows a variation in the gain of respective channels. The eye-diagram obtained shows a good quality factor but BER obtained has always a scope of being improved.

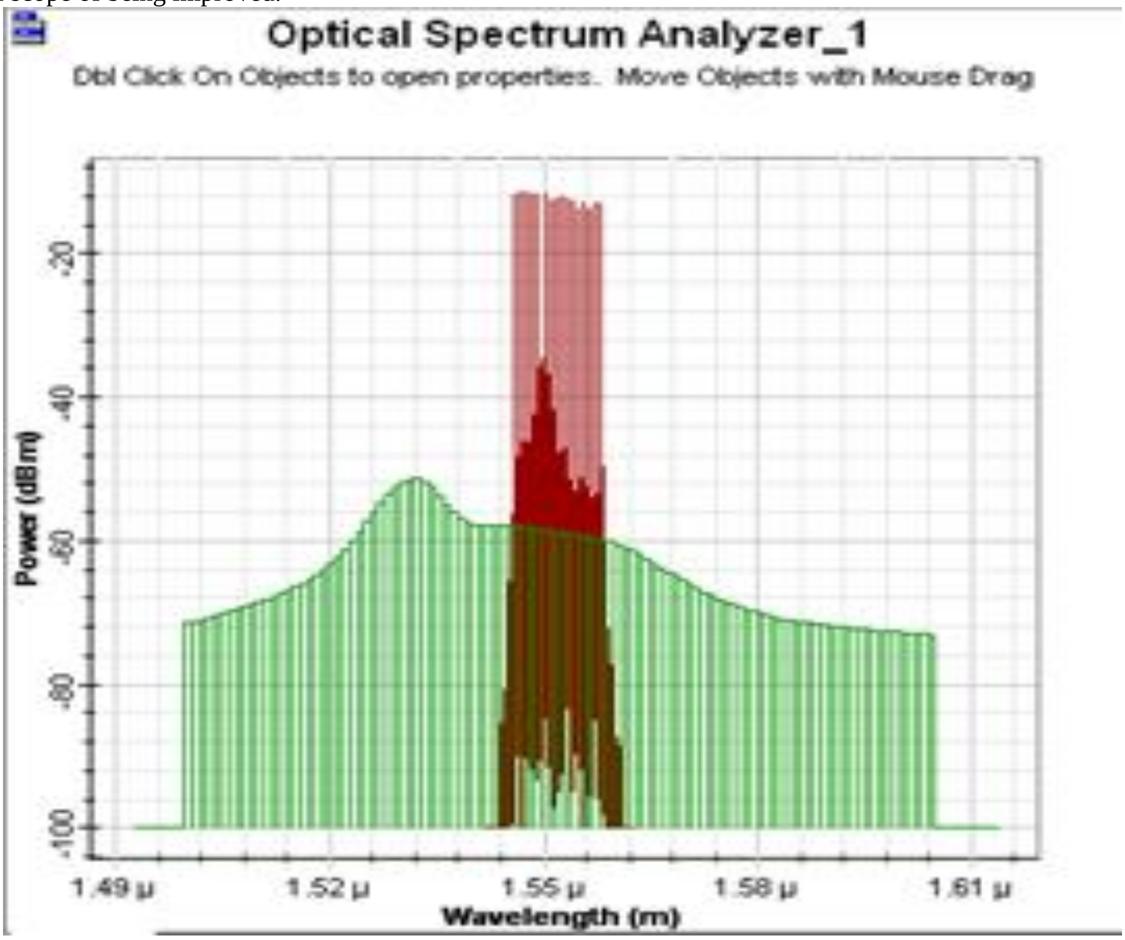

Fig. 1 : Gain Spectrum of EDFA

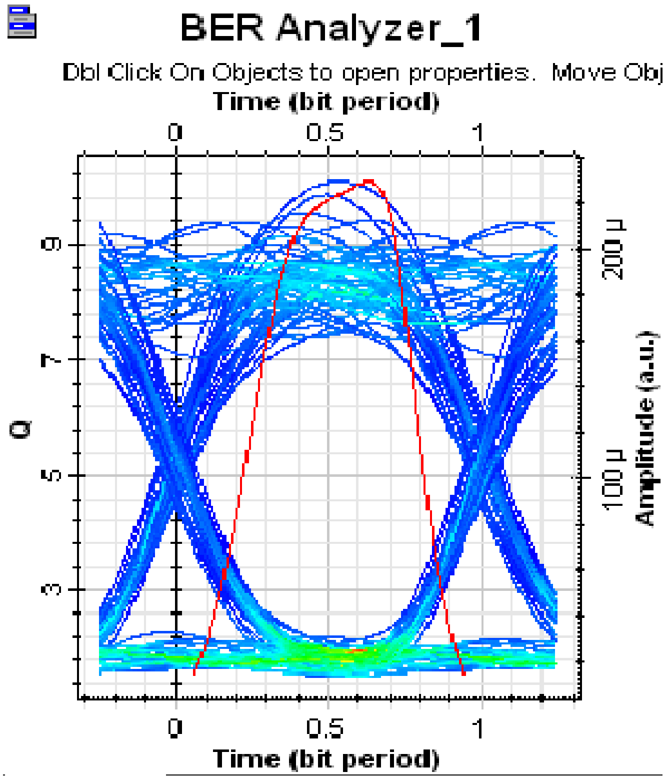

Fig. 2 : BER Analyzer of EDFA

B. TDFA Amplifier

The optical spectrum obtained for TDFA amplifier as shown below in Fig. 3 with 16 input channels being used shows a similar trend of variation in the gain of respective channels. The eye-diagram obtained does not show a good quality factor but BER obtained is improved as in comparison to that obtained for EDFA.

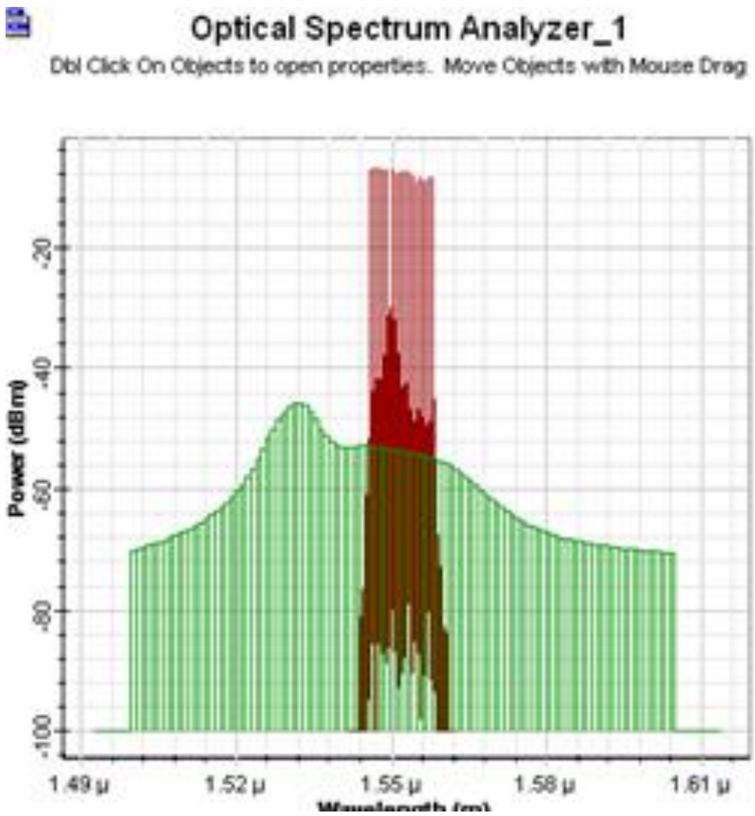

Fig. 3 : Gain Spectrum of TDFA

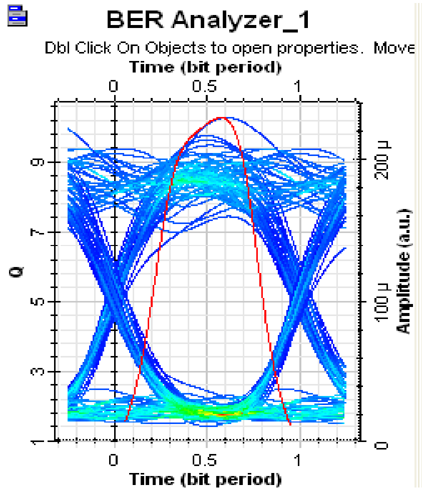

Fig. 4 : BER Analyzer of TDFA

C. Hybrid Amplifier

It is experimented that by cascading TDFA with EDFA, the gain spectrum of EDFA is broadened [20]. Fig. 5 shows the broadened gain spectrum of hybrid amplifier by cascading TDFA and EDFA. The optical spectrum obtained for hybrid amplifier as shown below in Fig. 5 with 16 input channels is widened over the entire range of the input channels. The eye-diagram obtained shows a good quality factor and BER obtained is improved as well.

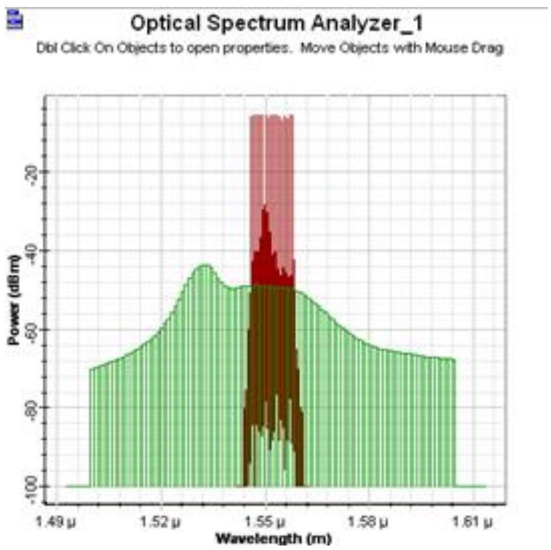

Fig. 5 : Broadened Gain Spectrum of Hybrid Amplifier

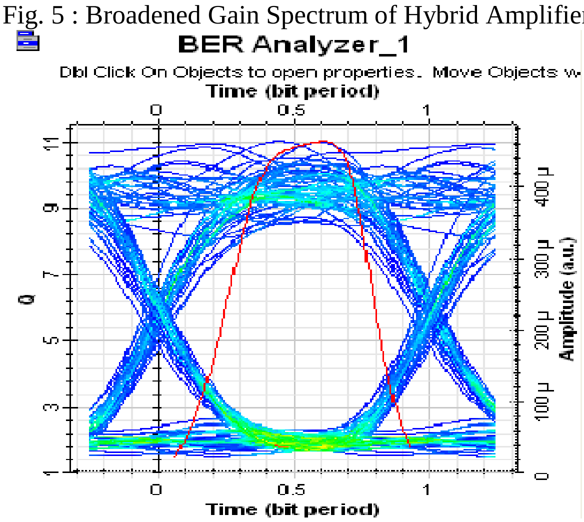

Fig. 6 : BER Analyzer of Hybrid Amplifier

D. *Hybrid Amplifier with DGE Set-up*

The gain bandwidth is extended by cascading EDFA with TDFA. This spectrum is then flattened by using a DGE When we cascaded EDFA with TDFA in series, the total gain of hybrid amplifier is given by product of individual gains of each amplifier

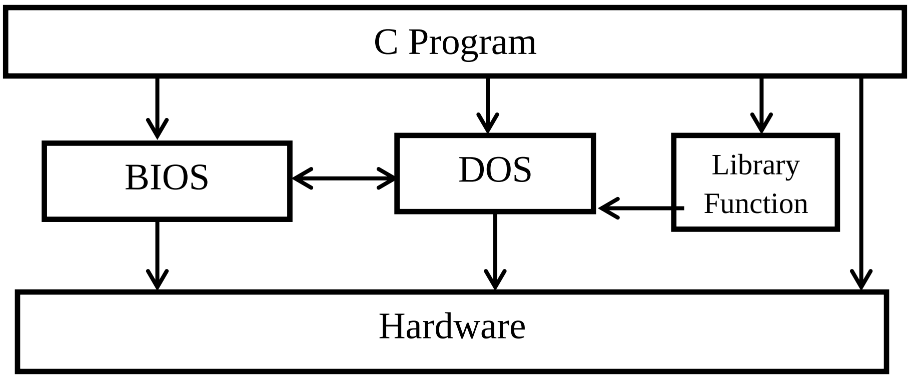

Fig 7: Block Diagram for Different Methods For Interacting With Hardware

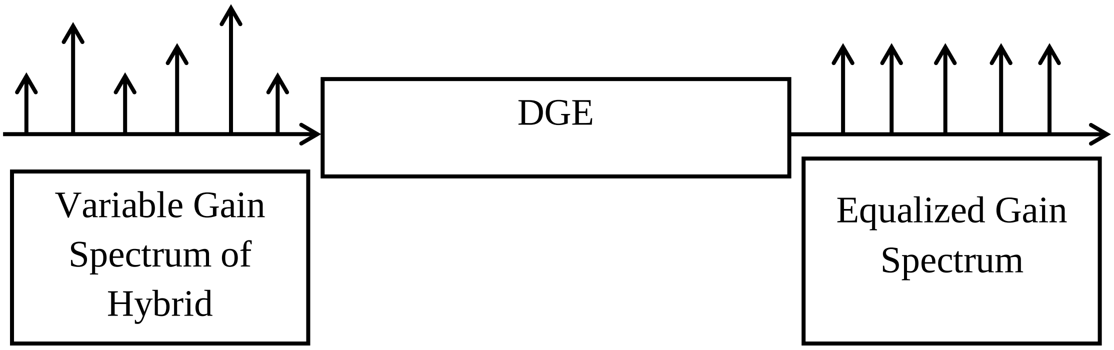

Fig. 8 : Working of DGE

It can observed from the Fig. 8 shown as above that with the implementation of DGE the overall gain has the least variation for the input number of channels being used.

E. *Gain Spectrum of Hybrid Amplifier with DGE*

As shown below in Fig. 9, it is observed that that the gain bandwidth is extended to the entire range of 1460nm to 1560nm wavelength and gain spectrum obtained is almost flat for the entire range.

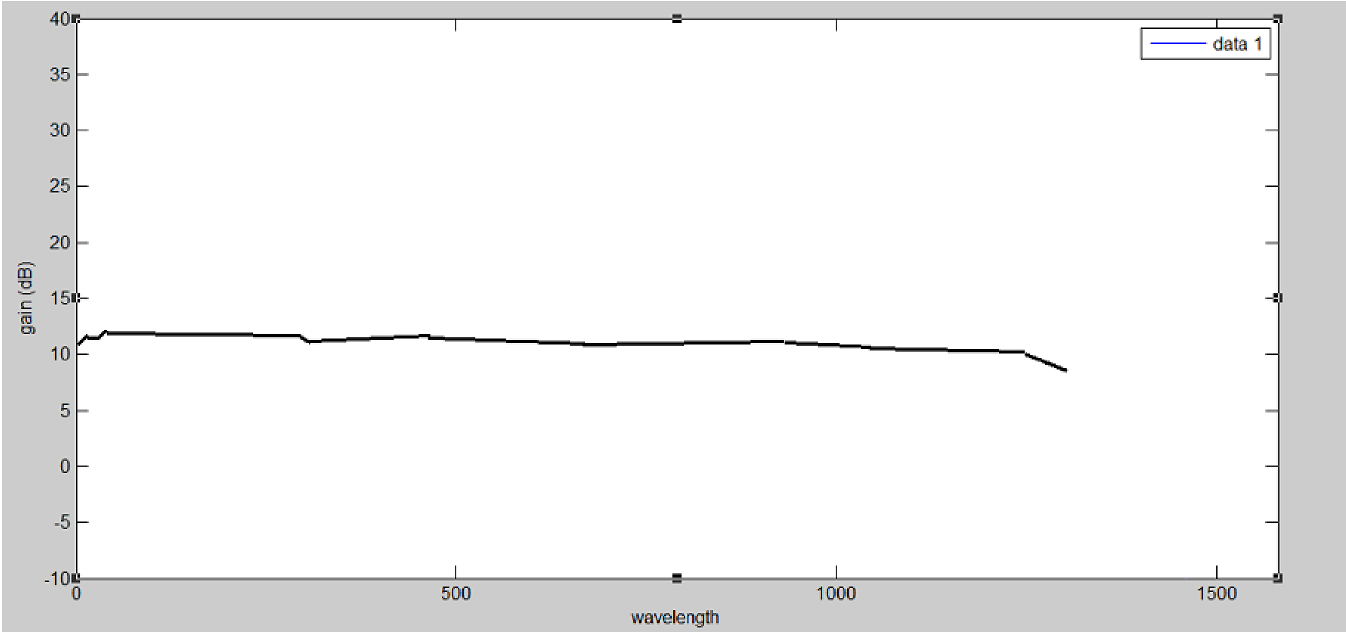

Fig. 9 : Flattened and Broadened Gain Spectrum of Hybrid Amplifier with DGE

V. CONCLUSION

With this proposed design it has been found that when we cascaded TDFA with EDFA in series then gain spectrum is broadened. The gain variation is less than ± 1.5% in the wavelength region of 1460-1560 nm. The DGE is so designed that transmission loss occurs around the maximum gain of hybrid amplifier i.e. at 1531nm.

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