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Gain Flattening Improvements With Two Cascade Erbium Doped Fiber Amplifier In WDM Systems

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Abstract

The new optical communication systems utilize WDM technology. The optical amplifiers are one of the most important parts of optical communication networks. These amplifiers have been used at three states of Booster, Pre-amplifier, and In-line by amplifying optical signal. With regard to much expanses of equipment and optical communication systems, the design of amplifiers with higher gain and lower channels gain flattening applys lower equipments. A WDM system by two cascades, EDFA optical amplifier with two separate pump lasers have been designed. Then, pump laser power parameter has been considered as the variable and the best fiber length Erbium doped with respect to gain flattening between channels and the highest channels gain and the output noise figure of system.

Keywords: Gain Flattening, Fiber Length, Pump Laser, EDFA

Introduction:

Repeaterless transmission systems have been deployed to support longer distances of signal propagation between transmitters and receivers. The use of repeaterless transmission system has eliminated the need for optoelectronic conversion which produces overhead in terms of cost and complexity and is not bit rate transparent.[1]

Erbium Doped Fiber Amplifier (EDFA) is an optical amplifier that uses a doped optical fiber as a gain medium to amplify an optical signal. A single EDFA is used for simultaneously amplifying many data channels at different wavelengths within the gain region. The signal which is to be amplified and a pump power are multiplexed into the doped fiber then the signal is amplified because of the interaction with the doping ions. EDFA is the best known and most frequently used optical amplifier suited to low loss optical window of silica based fiber. The EDFA is a key component in long haul multichannel light wave transmission systems such as Wavelength Division Multiplexing (WDM). One difficulty in implementing a WDM system is that the EDFA gain spectrum is wavelength dependent. In a WDM system, the EDFA does not necessary amplify the wavelength of the channels equally. EDFA in a WDM system are often required to have equalized gain spectra in order to achieve uniform output powers and similar signal to noise ratios. There are several methods in designing a flat spectral gain of EDFA such as by controlling the doped fiber length and the pump power, proper choosing of optical notch filter's characteristic, by using an acousto-optic tunable filter and by employing an homogeneously broadened gain medium. In this paper the gain flatness of EDFA is achieved by controlling the doped fiber length and the pump power for a given input power of- 26dBm and a desired output power of more than 8 dBm.[2]

WDM is the basic technology of optical networking. It is a technique for using a fiber (or optical device) to carry many separate and independent optical channels.

The most important characteristics of an amplifier are its gain, its power output and (for WDM systems) its range of amplified wavelengths. It is important to choose an amplifier with the right characteristics for the application. The "natural" amplified range of a simple EDFA is about 1535-1560 nm. This can be expanded by the use of co-dopants and amplifiers with an amplified range of around 40 nm are currently available.

In general there are three types of EDFAs:

(1) Power amplifiers are placed immediately after the mixing stage at the transmitter end of the system. The input power level will be relatively high. The limitation here is likely to be total output power of the amplifier. For example if we want to amplify a mixed WDM stream of 10 channels from -5 dBm by 8 dB the total output power of the amplifier will be 10 channels at 3dBm (that is, 2 mW). Total amplifier power needed in this case is 20 mW.

(2) Line amplifiers receive a relatively low level signal and must amplify it by as many dB as possible (30 is a good number). The limitations here are gain, noise and total output power.

(3) Preamplifiers needs to be quite sensitive, have a low level of noise and reasonably high gain but typically they don't need a high level of signal power at the output. Depending on the system a figure of (say) -20 dBm per channel may be sufficient output power.[3]

Dense Wavelength Division Multiplexing (DWDM) utilizes a large aggregate bandwidth in a single fiber by taking advantage of advanced optical technology that is able to launch and multiplex many wavelengths in one fiber, switch wavelengths optically with channels having spacing of 0.8 nm or less, and at the receiving end, de-multiplex and read each wavelength separately. In DWDM, each wavelength constitutes a separate channel capable of carrying traffic at a bit rate that may not be the same on all channels. DWDM systems take advantage of advanced optical technology to generate many wavelengths in the range around 1550 nm.[4]

The erbium doped fiber amplifier (EDFA) is the most deployed fiber amplifier as its amplification window coincides with the third transmission window of silica-based optical fiber. An optical fiber is

doped with the rare earth element erbium so that the glass fiber can absorb light at one frequency and emit light at another frequency. An external semiconductor laser couples light into the fiber at infrared wavelengths of either 980 or 1480 nanometers. This action excites the erbium atoms. Additional optical signals at wavelengths between 1530 and 1620 nanometers enter the fiber and stimulate the excited erbium atoms to emit photons at the same wavelength as the incoming signal. This action amplifies a weak optical signal to a higher power, affecting a boost in the signal strength.[3]

System's structure and design

Optisystem software has been used in order to design system consisted of 16 optical channels, an optical multiplexer, an isolator, two EDFA, two pump laser, WDM transmitter and Optical power meter, Optical spectrum analyzer, dual port WDM analyzer as it shows in figure1. Wavelength is 1546 nm and transmitter power is -26 dBm and pump laser frequency is 980 nm.

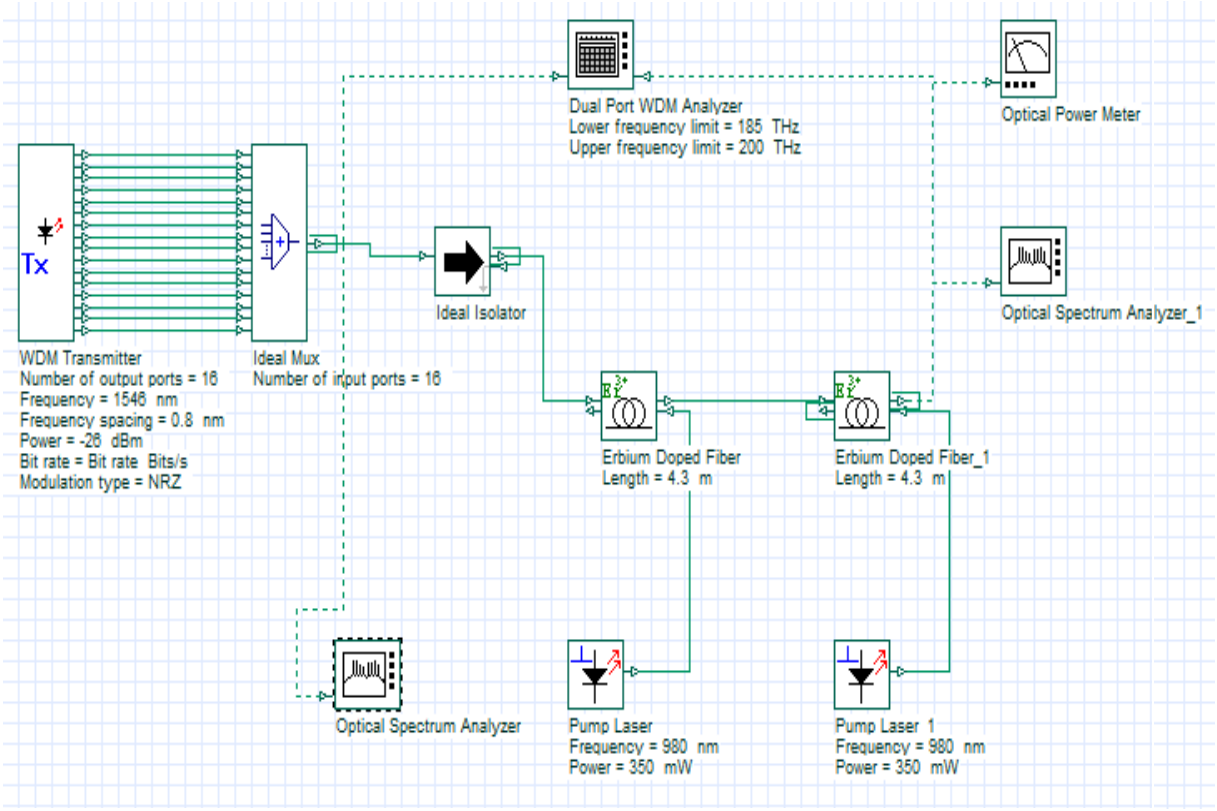

Figure 1: System Design

Simulation results

Optical spectrum analyzer has been used for measuring gain and noise figure in final.[5] The optimum fiber length in state of one EDFA with one pump laser power of 24.13 mW is about 5.22 m, that channels gain and gain flattening is 23 dB and 0.29 dB respectively.[6] Fiber length in state of two EDFA along with two laser pump powers of 100 mW is about 9.9 m which channels gain and gain flattening is 34 dB

and 1.6 dB respectively.[7] With pump laser power of 350 mW, EDFA length must be 8.6 m that parameters could be optimized respect to two previous states. In this state, channels gain and gain flattening is 41 dB and 0.48 dB respectively.[8]
Here, we obtain the best fiber length Erbium doped based on gain flattening parameters of channels, the maximum channels gain and noise figure by using pump laser power variations.

Pump laser power variation

Pump laser power variation has been considered between 50 mW to 800 mW.
Table 1 shows the parameters variation of pump laser power and figures 2,3, and 4 respectively show channels gain flattening diagram, the maximum channels gain and noise figure based on fiber length Erbium doped in different pump laser powers.

Table 1: Parameters variation of Pump Laser Power

Pump Laser Power (mW)	Fiber Length (m)	Gain Flattening (dB)	Maximum Gain (dB)	Noise Figure (dB)
50	6.7	0.37	32.43	3.87
100	7.4	0.41	35.82	3.88
150	7.8	0.43	37.72	3.94
200	8.1	0.46	39.08	4.05
250	8.3	0.47	40.09	4.09
300	8.4	0.49	40.86	4.05
350	8.6	0.48	41.57	4.11
400	8.7	0.49	42.13	4.09
450	8.8	0.5	42.68	4.15
500	8.9	0.5	43.12	4.13
550	9	0.5	43.57	4.2
600	9.1	0.51	43.99	4.28
650	9.2	0.53	44.34	4.26
700	9.2	0.52	44.63	4.25
750	9.3	0.52	44.97	4.33
800	9.3	0.54	45.18	4.23

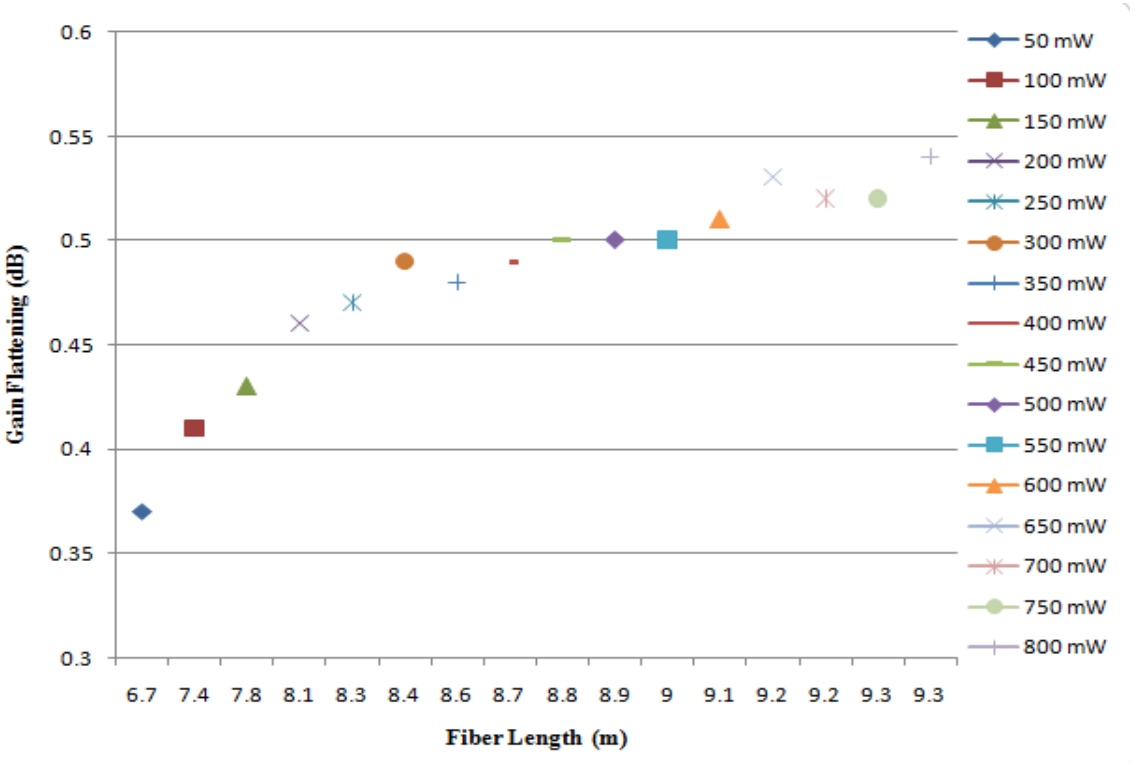

Figure 2: Gain Flattening Based On Fiber Length In Different Pump Laser Powers

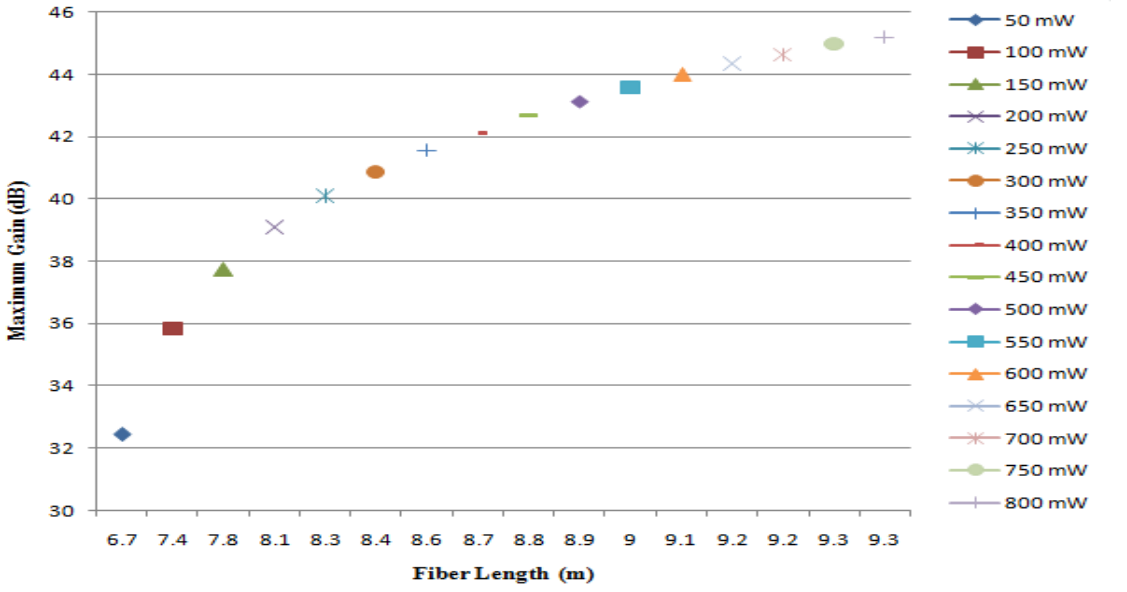

Figure 3: Maximum Gain Based On Fiber Length In Different Pump Laser Powers

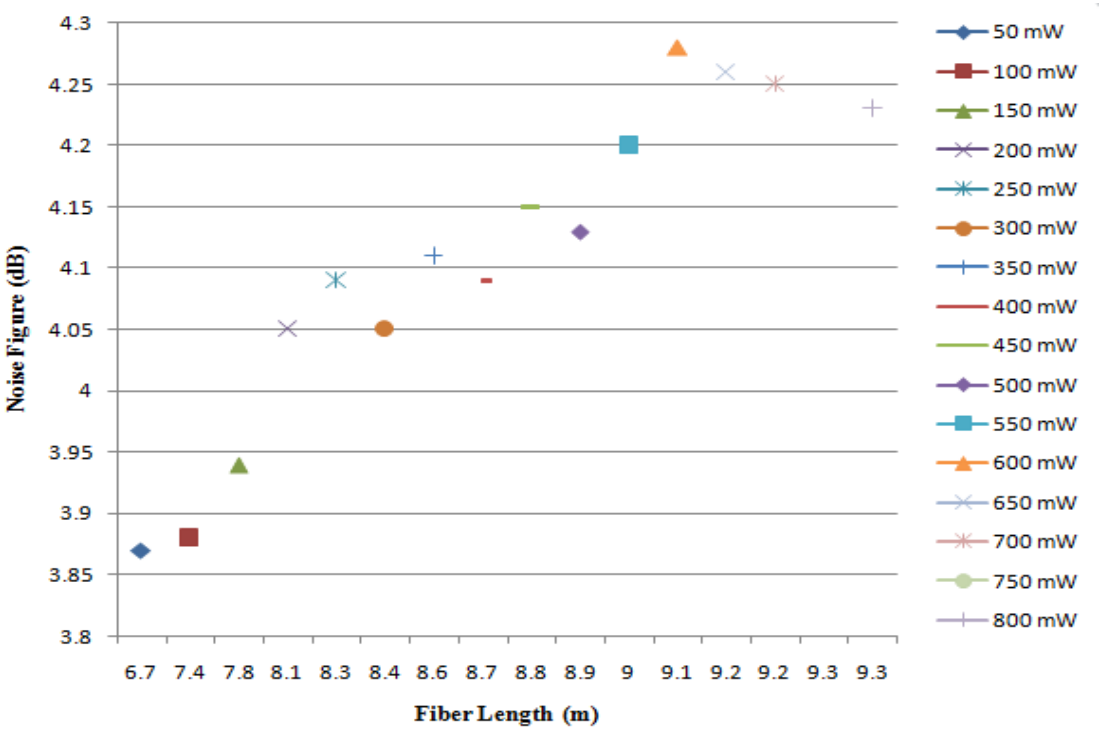

Figure 4: Noise Figure Based On Fiber Length In Different Pump Laser Powers

Conclusions

In this article, we used two EDFA amplifiers with two separate and equal pump lasers with 16 optical channels and wavelengths of 1546 to 1558 nm with channel distance of 0.8 nm in order to achieve higher gain and better noise figure in optical transmission systems. The system has been simulated with Optisystem software. We have considered pump laser power parameter as the variable and observe its effect on channels gain and channels gain flattening and noise figure between 16 channels.

The results show that as the pump laser power increased, fiber length Erbium doped, channels gain, noise figure and channels flattening also increased that we can use the average pump laser powers based on design and optical communication system's situations.

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