A REVIEW OF OPTICAL AMPLIFIER

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Abstract: This paper is centered on four important parts of Erbium doped fiber amplifier (EDFA) optical amplifier; first is the atomic part, where it is evident and meaningful to give deep and details information of erbium spectra structure and its energy level splitting. The atomic spectra, is very crucial part in defining and understanding the amplification phenomena. The second part is based on the theoretical background of EDFA analysis, and to understand the parameters that are used for formulating the amplification rules related to spontaneous and stimulated emission. The third part is the design, where a full investigation is given to various configurations from the single pass to the quadruple pass. Vast and new designs were invented showing high-gain and low-noise-figure (NF) utilizing a new techniques. The fourth is the critical-review part, where many research papers have been reviewed to show and clarify their strong and weak points at different interpretations. This part is to specify the weakness of the classical understanding of EDFA and to describe and conceive the next generations and its characteristics.

***Index Terms* – Very large scale integration, EDFA optical fiber amplifier.**

INTRODUCTION:

In optical communication network, signals travel through fibers for very large distances without significant attenuation. However, when distances become hundreds of kilometers, it becomes necessary to amplify the signal during transit. Optical fiber amplifiers provide in-line amplification of optical signals by effecting stimulated emission of photons by rare earth ions implanted in the core of the optical fiber. Erbium is the preferred rare earth for this purpose though amplifiers using Praseodymium are also in use. EDFAs are used to provide amplification in long distance optical communication with fiber loss less than0.2 dB/km by providing amplification in the long wavelength window near 1550 nm. The principle of rare earth doped fiber amplifier is the same as that of lasers excepting that such amplifiers do not require a cavity whereas a cavity is required for laser oscillation. Advantages of EDFA are as follows:

(1) It provides in-line amplification of signal without requiring electronics i.e., the signal does not need to be converted to electrical signal before amplification. The amplification is entirely optical.

(2) It provides high power transfer efficiency from pump to signal power.

(3) The amplification is independent of data rate.

(4) The gain is relatively flat so that they can be cascaded for long distance use. On the debit side, the devices are large, there is gain saturation and there is also presence of amplified spontaneous emission (ASE).

(i) Semiconductor optical amplifier (SOA): Optical amplifier, with the introduction in 1990s, conquered the regenerator technology and opened doors to the WDM technology. It is mainly used to amplify an optical signal directly, without the need to first convert it to an electrical signal. There are many types of optical amplifiers, namely Raman amplifiers, erbium doped-fiber amplifiers (EDFAs), and semiconductor optical amplifier (SOA). This article will make a clearer introduction to SOA amplifier, and analyze its advantages and disadvantages. SOA optical amplifiers use the semiconductor as the gain medium, which are designed to be used in general applications to increase optical launch power to compensate for loss of other optical devices. Semiconductor optical amplifiers are often adopted in telecommunication systems in the form of fiber-pigtailed components, operating at signal wavelengths between 0.85 µm and 1.6 µm and generating gains of up to 30 dB. Semiconductor optical amplifier, available in 1310nm, 1400nm, 1500nm, 1600nm wavelength, can be used with singlemode or polarization maintaining fiber input/output. The basic working principle of a SOA is the same as a semiconductor laser but without feedback. SOAs amplify incident light through simulated emission. When the light traveling through the active region, it causes these electrons to lose energy in the form of photons and get back to the ground state. Those stimulated photons have the same wavelength as the optical signal, thus amplifying the optical signal.

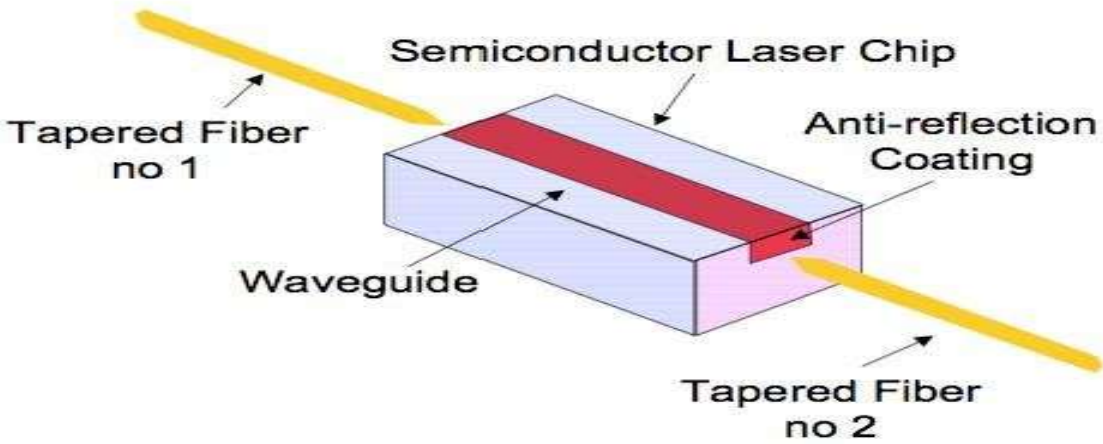

Figure: 1.1 Semiconductor Optical Amplifier

(ii) <u>Raman Amplifier:</u> As the limitations of EDFA amplifier working band and bandwidth became more and more obvious, Raman amplifier was put forward as an advanced optical amplifier that enhances the signals by stimulated Raman scattering. To meet the future-proof network needs, it can provide gain at any wavelength. At present, two kinds of Raman amplifiers are available on the market. One is lumped Raman amplifier that always uses the DCF (dispersion compensation fiber) or high nonlinear fiber as gain medium. Its gain fiber is relatively short, generally within 10 km. The other one is distributed Raman amplifier. Its gain medium is common fiber, which is much longer, generally dozens of kilometers. When the Raman amplifier is working, the pump laser may be coupled into the transmission fiber in the same direction as the signal (co-directional pumping), in the opposite direction (contra-directional pumping) or in both directions. Then the signals and pump laser will be nonlinearly interacted within the optical fiber for signal amplification. In general, the contra-directional pumping is more common as the transfer of noise from the pump to the signal is reduced, as shown in the following figure.

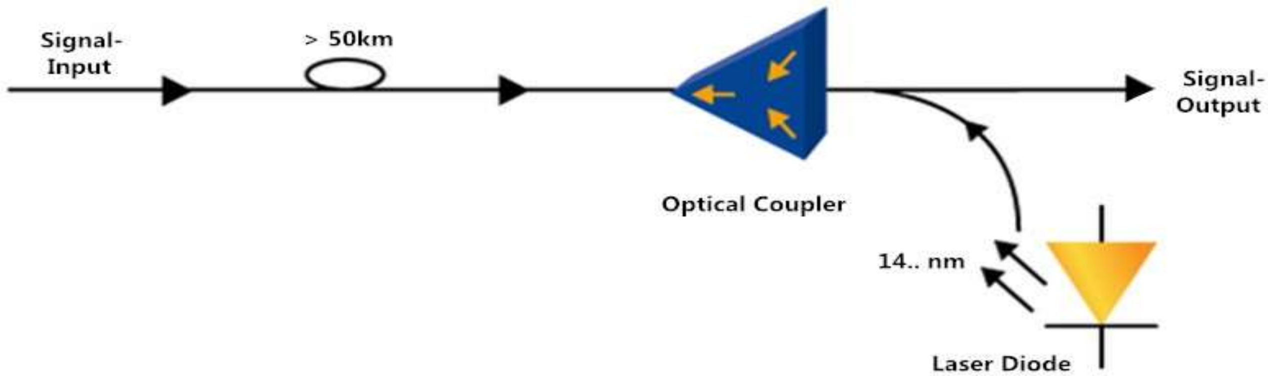

Figure 1.2 Raman Optical Amplifier

(iii) <u>EDFA AMPLIFIER:</u> EDFA amplifier is generally used for very long fiber links such as undersea cabling. The EDFAs use a fiber that has been treated or "doped" with erbium, and this is used as the amplification medium. The pump lasers operate at wavelengths below the wavelengths that are to be amplified. The doped fiber is energized with the laser pump. As the optical signal is passed through this doped fiber, the erbium atoms transfer their energy to the signal, thereby increasing the energy or the strength of the signal as it passes. With this technique, it is common for the signal to be up to 50 times or 17dB stronger leaving the EDFA than it was when it entered. Here is an example of an EDFA. EDFAs may also be used in series to further increase the gain of the signal. Two EDFAs used in series may increase the input signal as much as 34dB.

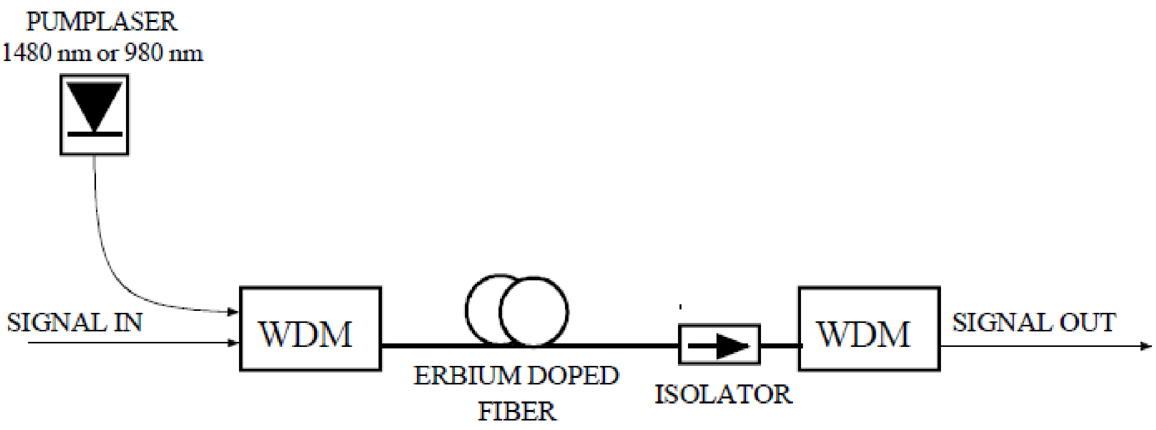

Figure 1.2 Erbium Doped Fiber Optical Amplifier

TABLE 1.1 DIFFERENT PROPERTIES OF OPTICAL AMPLIFIER`S

Property	EDFA	Raman	SOA
Gain (dB)	> 40	> 25	>30
Wavelength (nm)	1530-1560	1280-1650	1280-1650
Bandwidth (3dB)	30-60	Pump dependent	60
Max. Saturation (dBm)	22	0.75 × pump	18
Polarization Sensitivity	No	No	Yes
Noise Figure (dB)	5	5	8
Pump Power	25 dBm	>30 dBm	< 400 mA
Time Constant	10^{-2} s	10^{-15} s	2×10^{-9}
Size	Rack mounted	Bulk module	Compact
Switchable	No	No	Yes
Cost Factor	Medium	High	Low

Conclusion.

Among the various technologies available for optical amplifiers, EDFA technology proves to be the most advanced one that holds the dominate position in the market. In future, the WDM system integrated with high performance EDFA, as well as the demand for more bandwidth at lower costs have made optical networking an attractive solution for advanced networks.

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