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Review of EDFA Gain Performance in C and L Band

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ABSTRACT: A review on Erbium doped fiber amplifier (EDFA) system capable of amplifying incoming signal light between 1525-1610 nm. Understand its basic configuration, materials and their effects in transmission channel. Also learn how to handle amplification of high speed incoming light signals entire C+L band wavelengths in single mode fibers as well as multimode fiber. There are two major issues incorporated to EDFA for example to achieve high gain (≥ 40 dB) & lower noise figure (≤ 6 dB) at various parameters like input power and ASE to transmit signals longer distances.

KEYWORDS: WDM, EDFA, ASE, Noise Figure, Fiber.

INTRODUCTION

With the rapid growth of the Internet and data traffic, the conventional band (C-band, 1530 to 1560 nm) cannot satisfy the explosive bandwidth demand on optical communications. To improve the channel capacity of wavelength division-multiplexing (WDM) systems, the short wavelength band (S-band, 1460 to 1530 nm) and the long wavelength band (L-band, 1565 to 1610 nm) erbium-doped fiber amplifier (EDFA), even broadband (S+C+L-band) EDFA by utilizing a seed light injection or parallel configuration have been proposed. Among them, L-band erbium-doped fiber amplifiers (EDFAs) perform with relatively low pump efficiency on the gain, as the operation wavelengths are far from the peak emission band of Er3+ ions. Generally, to obtain a high L-band gain, a laser diode with a high power pump and a longer EDF length is needed [1],[2],[3]. To improve the pump efficiency of the L-band as much as possible, several methods have been consider, such as feed backing unwanted amplified spontaneous emission (ASE) power into EDF to serve as the secondary pump through a circulator or incorporating a fiber Bragg grating, C-band light assisted pumping, and using a double-pass technique[4]. Among these methods, the double-pass L-band EDFA is an efficient and cost-effective scheme, which uses a circulator or fiber loop mirror to recycle the L-band ASE into the EDF, again for the enhancement of the L-band gain [5],[6].

LITERATURE SURVEY

In this paper, author investigate the performance of high gain wideband erbium-doped fiber amplifier that operates in conventional as well as long wavelength using short-length high-concentration erbium doped fiber (EDF). A tuned optical filter and C/L coupler are used to sharply reduce the self-saturation effect and suppress the C-band amplified spontaneous emission noise. The amplifier achieves a signal gain of 52 dB with a low noise figure of 3.8 dB for L band but in conventional band gain at -50 dBm input signal power gain goes to below 25 dB due to using many circulator because circulator produces many loses.

Author using double-pass dispersion compensators in a loop-back scheme. Dispersion slope mismatch is compensated precisely for all C+L band channels employing fiber Bragg gratings (FBGs) at sharp ease. Gain variation among multiple channels can be reduced to ±O.2 dB. The pump efficiency is improved by recycling the residual pump power.

In this paper author using C and L band Erbium Doped Fiber Amplifiers (EDFA) with 70 nm bandwidth, 36.53 dB gains with an noise figure of 5.8 dB achieved. To get this using 16 channels Wavelength Division Multiplexed (WDM) system with channel spacing of 5.3 nm is taken into account. -30 dBm powers at the input signals (1530 nm- 1610 nm) are applied to three port filter and then input signals are separated into C and L bands. Each band signals are separately amplified in double pass configuration.

In this paper author employing two separate amplifier with different lengths 1.5 m and 9 m long EDF optimized for C-band and L-band operations respectively, in a double-pass series configuration. The CFBG is used in both stages to allow a double propagation of signal and thus increases the attainable gain in both C- and L-band spectra. At an input signal power of -30 dBm, a flat gain of 22 dB is achieved with a gain variation of ±3 dB within a wide wavelength range from 1530 to 1600nm. The corresponding noise figure varies from 4 to 8 dB within this wavelength region.

PROBLEMS & FORMULATION

The optical amplifiers are used to amplify signals at very high data rates hence there is chance of interferences, so we will need tunable filter to choose the desired signal (wavelength) but this mechanism considered drawback due to low security and expensive. Apart of this many reference papers used in this review paper used single pass, double pass and triple pass but in all cases larger gain variation occurs. To compensate gain variation and achieved high gain, a tuned Gain Flatting Filter (GFF) are used before & after the EDFA amplifier. GFF filter is a combination of FBG & band pass filter, which sharply removes noises & minimize gain variation over huge bandwidth.

PRINCIPLE OPERATION OF EDFA

In its most basic form the EDFA consist of a length of EDF (typically 10-30 m), a pump laser, and a component (often referred to as a WDM) for combining the signal and pump wavelength so that they can propagate simultaneously through the EDF. In principle EDFA's can be designed such that pump energy propagates in the same direction as the signal (forward pumping), the opposite direction to the signal (backward pumping), or both direction together. The pump energy may either by 980 nm pump energy, 1480 nm pump energy, or a combination of both. Practically, the most common EDFA configuration is the forward pumping configuration using 980 nm or 1480 nm pump energy, as shown in Figure 1. This configuration makes the most efficient use of cost effective, reliable and low power consumption 980 nm semiconductor pump laser diodes, thus providing the best overall design with respect to performance and cost trade-offs [1],[2].

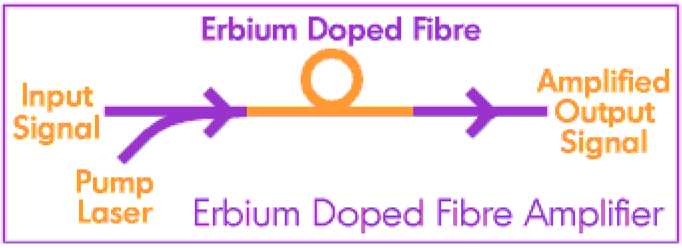

Figure.1. schematic of basic pumping in EDFA

Erbium has several energy levels, until now 1480 nm & 980 nm are preferred due to its greater gain and lower noise figure. The ions can be excited with a 1480 nm pump laser into the first excited state as shown in figure 2. When falling back to the ground state, the ions have some extra energy to get rid of, which they each give out as a photon (a single "particle" of light). This is called spontaneous emission because the ions fall back to the ground state and give out photons without any aid whatsoever. Such spontaneous emission can build up in the amplifier and is known as "amplified spontaneous emission" or ASE. ASE is an undesirable effect and adds "noise" to the amplifier [3],[4].

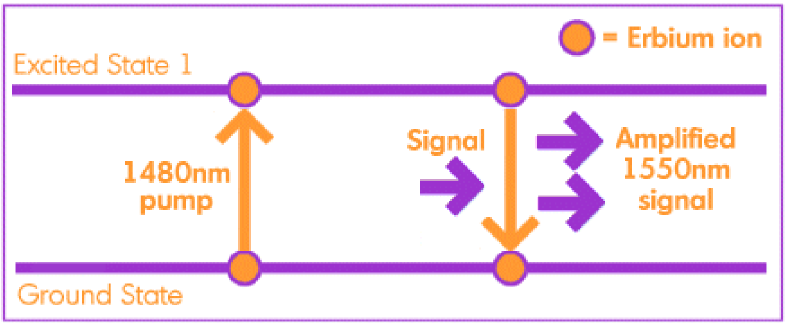

Figure.2. Representation of 1480 nm pump power in EDFA

If an optical signal is incoming at around 1550 nm however, it can cause some of those excited ions to fall down to the ground state and give out a photon each. This is stimulated emission because the signal is directly causing the photons to be emitted. The emitted photons are at the exact same wavelength as the signal and so are now parts of the signal. The signal now has more photons representing it than before, so it has been amplified.

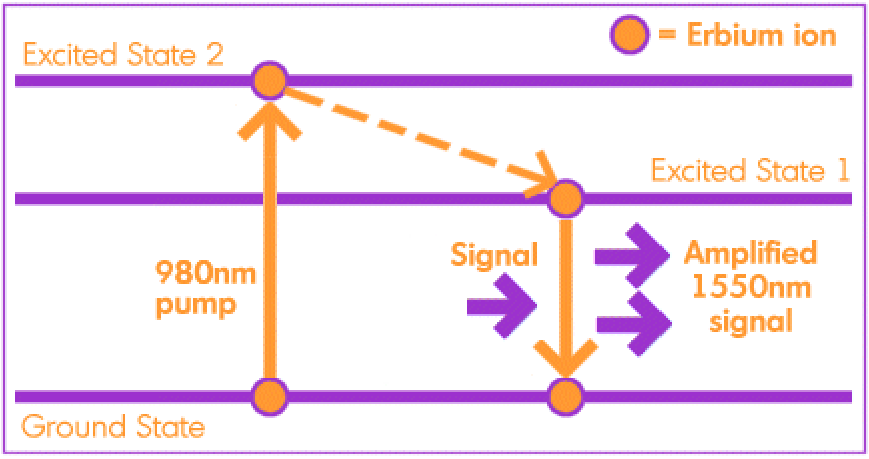

FIGURE.3. Representation of 980 nm pump power in EDFA

Consider a 980 nm pump power as shown in figure 3, and then 980nm pump excites the erbium ions into a much higher state than the 1480 nm pump. However, the ions only stay in that higher state for a very short period of time (maybe nanoseconds) before moving down to the next state. Once there, they stick around for several milliseconds, which is much longer than ions excited by the 1480nm pump. The longer they remain in the excited state, the more likely it is that the signal will come along and cause stimulated emission [5],[6]. This also reduces the unwanted spontaneous emission that adds to the noise in the system. Therefore 980 nm pumps give greater amplification efficiency and are the preferred pump method for EDFAs.

DESCRIPTION OF DIFFERENT TECHNIQUES IN EDFA

(A) TWO EDFA WITH ISO

This technique consists of input signal source, an optical attenuator, two optical circulators (C1, C2), pump laser, wavelength division multiplexer (WDM), two erbium doped fibers (EDF1, EDF2), 3dB optical coupler, an optical isolator (ISO), C/L optical coupler and optical filter. A 980 nm pump laser is used to pump the gain medium with fifty percent of the pump power is distributed to the first stage while the remaining portion of pump power is distributed to the second stage by using a 3 dB optical coupler. The first and second stages of the amplifier are pumped in forward direction through a WDM which is used to multiplex the 980 nm pump power and the signal power. The ISO is placed at the input port to eliminate any back reflection, a tunable band-pass filter with 1 nm bandwidth is inserted between port 1 and 3 of the second circulator (C2) to filter out the forward amplified spontaneous emission (ASE) noise from saturating the gain of the double-pass stage [1]. The amplifier achieves a signal gain of 52 dB with a low noise figure of 3.8 dB at -50 dBm input signal power using a single pump source with only 8 m of EDF length.

(B) EDFA WITH GFF

In this technique two-stage EDFA with coupled AGC optical circuit to be consider. It consists two co-propagate EDF As with 980 nm pumps with an intermediate gain flattened filter (GFF) and variable optical attenuator (VOA). To provide spectral gain flatness for all set point gain range, both amplifiers stages were designed to operate at nominal gain (totalizing the maximum set point gain), the operation point which GFF curve was designed, and then the VOA attenuation is controlled to provide all the set point gain range with flattened spectrum. Author achieved a flattened gain spectrum with maximum equivalent noise figure ranging from 1.12 to 6.53 dB for the complete power mask operation for the proposed GFF-EDFA amplifier, compared to 6.22 to 9.26 dB obtained for EDFA-VOA-EDFA [3].

(C) HYBRID C+L EDFA

A new C+L band hybrid amplifier scheme using single-wavelength pump source. All C+L band channels reach the 3-port optical circulator (OC) after covering a distance over SMF transmission and are then divided into two groups using a C/L WDM coupler. The C band signals enter the C band branch at the upper side and are then amplified by a pump source. A pump reflector is positioned at the EDF end which reflects the residual pump power for further EDF segment pumping. On the other hand, the L band signals enter the dispersion compensation module (DCM) via the L band branch of the C+L WDM coupler and then pass through the same DCM in the opposite direction. They will then be reflected by the corresponding FBGs then travel back along the same DCM. The DCM composes of several DCF segments and several FBGs. Each FBG has a central reflected wavelength matching its corresponding signal. Different signals travel through different DCF lengths, before being reflected by the corresponding FBG to achieve precise dispersion management. The NF value of each channel is 6.9, 7.3, 7.1, 7, 6.9, 7.3, 7.28, and 7.2 dB from 1530 to 1565 nm with 5 nm interval. Based on similar procedures, the calculated values for NF are 6.55, 6.0, 5.8, 5.67, 5.5, 5.58, and 5.63 dB, respectively, from 1570 to 1600 nm with 5 nm interval [6].

(D) DOUBLE PASS C+L BAND EDFA

A conventional and new double pass C+L band EDFA configuration schemes are taken into consideration. This C+L band double-pass scheme has two optical circulators (OC) which have 3 ports in each arm (C and L band). The input signals are applied into a multiple laser source (MLS) and passing through port 1 to port 2 of optical isolator which blocks back reflections, then the input signal applied to 3-port filter and finally C and L band signals are separated. C band signals passing through port 1 to port 2 of OC1 are combined with the pump signal through a pump coupler, and then, these signals are entered as inputs of the C band EDF. The double pass EDFA configuration, 4.15-25.29 dB gain improvement is obtained for C+L band signals with an input power of -30 dBm, and the decrease in noise figure is between 4.66-27.76 dB for the same band [7].

(E) DUAL-STAGE SERIAL AND PARALLEL DOUBLE-PASS USING CFBG

In this technique author demonstrate a new dual-stage serial and parallel double-pass configuration in which a highly doped fiber with Erbium ion concentration are taken. Wide-band EDFA employing dual stage EDFs in a serial double-pass configuration. The C-band chirp fiber Bragg grating (CFBG) is placed midway the two stages to act as a reflector for the C-band EDFA. It reflects C band signal for double-pass operation and pass-through the L band signal to be transmitted so that it can be amplified by the second stage of the amplifier. The amplified signal is then reflected back into the system by the L-band CFBG [8].

CONCLUSION

In this paper, several technologies have been discussed to design optical amplifiers that are suitable for the low-cost, moderate performance and covering a huge bandwidth from 1460 to 1610 nm. These amplifiers must be small in size and easy to control to allow their use in many places in the network. The different technologies, EDFA have different properties making them suitable for a variety of applications. Gain, noise figure, and output power of more than enough for currently made in these technologies seem to be suitable for single- and multichannel metro and access operation. The best choice among them is double pass amplification architecture best suited for current networks scenario.

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