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Gain Optimization of EDF Optical Amplifier by Stages Enhancement and Variation in Input Pumping Power

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Abstract- The scope of this paper is to analyze the performance of augmented gain EDF amplifier systems by enhancing the stages of EDF amplifier & further by variation in pumping power on designed EDF amplifier system. The design evaluates the performance of the network for a given pattern specifies the design accessibility for the speed enhancement. The Performance of an Optical Communication system can be improved by the use of EDFAs as an Optical Amplifier. Erbium doped fiber amplifier (EDFA) is an important element in DWDM networks. For the present work, we have used EDFA design software tool. The proposed model consists of an input source, isolator, pump source, erbium fiber and WDM coupler. It simulates various characteristics such as amplified spontaneous emission, minimum gain, maximum gain, average gain, noise figure, gain flatness, gain tilt etc. in efficient manner. It confirms the excellent agreement between simulations and results obtained in real EDFA design. And also changing the design parameters on four stages EDF amplifier such as Input Pump Power, the different performance parameters (gain and noise figure) can be optimized without changing the values of isolator, erbium fiber length and WDM.

I. Introduction

Optical amplifier

An optical amplifier is a device that amplifies an optical signal directly, without the need to first convert it to an electrical signal. An optical amplifier may be thought of as a laser without an optical cavity, or one in which feedback from the cavity is suppressed. Optical amplifiers are important in optical communication and laser physics. There are several different physical mechanisms that can be used to amplify a light signal, which correspond to the major types of optical amplifiers. In doped fiber amplifiers and bulk lasers, stimulated emission in the amplifier's gain medium causes amplification of incoming light. In semiconductor optical amplifiers(SOAs), electron-hole recombination occurs. In Raman amplifiers, Raman scattering of incoming light with phonons in the lattice of the gain medium produces photons coherent with the incoming photons. Parametric amplifiers use parametric amplification.

The optical fiber can be doped with any of the rate 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 multi component glass. The operating regions of these devices depend on the host material and doping elements. Fluorozirconate glasses doped with Pr or Nd are used for operation in the 1300 nm window, since neither of these ions can amplify 1300 nm 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 a EDFA. In some cases, Yb is added to increase the pumping efficiency and the amplifier gain .the operation of an EDFA by itself normally is limited to the l530-1560 nm region. The active medium in an optical fiber amlifier consists of a nominally 10-30-m lenght of optical fiber that has been lightly doped with a rare earth lement ,such as erbium(Er),ytterbium (Yb),thulium (tm).the host fiber material can be standerd silica,a fluoride-based glass,or a tellurite glass.

Doped fiber amplifiers

Doped fiber amplifiers (DFAs) are optical amplifiers that use a doped optical fiber as a gain medium to amplify an optical signal. They are related to fiber lasers. The signal to be amplified and a pump laser are multiplexed into the doped fiber, and the signal is amplified through interaction with the doping ions. The most common example is the Erbium Doped Fiber Amplifier (EDFA), where the core of a silica fiber is doped with trivalent Erbium ions and can be efficiently pumped with a laser at a wavelength of 980 nm or 1,480 nm, and exhibits gain in the 1,550 nm regions.

An erbium-doped waveguide amplifier (EDWA) is an optical amplifier that uses a waveguide to boost an optical signal. Amplification is achieved by stimulated emission of photons from dopant ions in the doped fiber. The pump laser excites ions into a higher energy from where they can decay via stimulated emission of a photon at the signal wavelength back to a lower energy level. The excited ions can also decay spontaneously (spontaneous emission) or even through nonradioactive processes involving interactions with phonons of the glass matrix. These last two decay mechanisms compete with stimulated emission reducing the efficiency of light amplification.

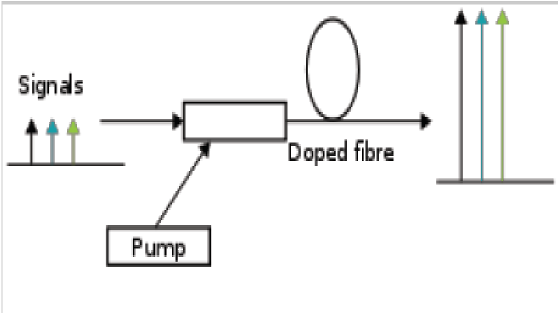

Fig. 1 Schematic diagram of a simple Doped Fiber Amplifier

The amplification window of an optical amplifier is the range of optical wavelengths for which the amplifier yields a usable gain. The amplification window is determined by the spectroscopic properties of the dopant ions, the glass structure of the optical fiber, and the wavelength and power of the pump laser

Basic principle of EDFA

A relatively high-powered beam of light is mixed with the input signal using a wavelength selective coupler. The input signal and the excitation light must be at significantly different wavelengths. The mixed light is guided into a section of fiber with erbium ions included in the core. This high-powered light beam excites the erbium ions to their higher-energy state. When the photons belonging to the signal at a different wavelength from the pump light meet the excited erbium atoms, the erbium atoms give up some of their energy to the signal and return to their lower-energy state. A significant point is that the erbium gives up its energy in the form of additional photons which are exactly in the same phase and direction as the signal being amplified. So the signal is amplified along its direction of travel only. This is not unusual - when an atom "lases" it always gives up its energy in the same direction and phase as the incoming light. Thus all of the additional signal power is guided in the same fiber mode as the incoming signal. There is usually an isolator placed at the output to prevent reflections returning from the attached fiber. Such reflections disrupt amplifier operation and in the extreme case can cause the amplifier to become a laser.

Gain saturation

Gain is achieved in a DFA due to population inversion of the dopant ions. The inversion level of a DFA is set, primarily, by the power of the pump wavelength and the power at the amplified wavelengths. As the signal power increases, or the pump power decreases, the inversion level will reduce and thereby the gain of the amplifier will be reduced. This effect is known as gain saturation – as the signal level increases, the amplifier saturates and cannot produce any more output power, and therefore the gain reduces. Saturation is also commonly known as gain compression. To achieve optimum noise performance DFAs are operated under a significant amount of gain compression (10 dB typically), since that reduces the rate of spontaneous emission, thereby reducing ASE. Another advantage of operating the DFA in the gain saturation region is that small fluctuations in the input signal power are reduced in the output amplified signal: smaller input signal powers experience larger (less saturated) gain, while larger input powers see less gain. The leading edge of the pulse is amplified, until the saturation energy of the gain medium is reached. In some condition, the width (FWHM) of the pulse is reduced.

II. SOFTWARE USED

In the desiging of the EDF optical amplifier required software is Gain Master

III. EDF- OPTICAL AMPLIFIER DESIGN

EDFA optical amplifier designing is done with help of the Fiber Optical Simulation Program & the Gain Master. Design tools are used .In this design we show that the optical amplifier gives all the parameter of the erbium fiber & that gives the idea how the signal is to be transfer from one location to the other location. In this design we find the gain,wavelength & noise parameter. The software allows for schematic representations of an optical amplifier to be input via a graphical user interface which mimics the symbolic language often used by engineers to outline a design on paper. The program tracks the optical power through the design, integrating the differential equations to solve the propagation of signal, pump, and amplified spontaneous emission (ASE) bands through all erbium fiber sections. Once a simulation is complete, the user may look inside the design by graphing the power propagating through any fiber in the design, as well as through the length of all erbium fiber sections. . Also, by use of the probe component, the user may make common two-point measurements of interest, such as gain, noise figure, conversion efficiencies, etc. Optical parameters of any component may be changed and the simulation re-run to observe the effects on amplifier performance.

In this paper we have shown the variation of gain & noise with respect to the wavelength for the second stage of optical amplifier. The range consider the 1550 nm-1620nm.the software use is gain master of erbium doped fiber amplifier

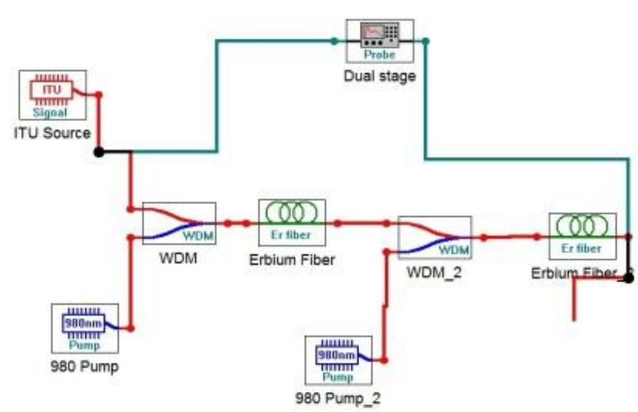

Fig 2. Dual stage EDF Optical amplifier design

optical amplifier up to the threshold value the gain increases after that the gain decreases with wavelength & becomes zero at the peak value of wavelength on the similar pattern the noise also 1st increases & then decreases & finally becomes zero at the peak wavelength.

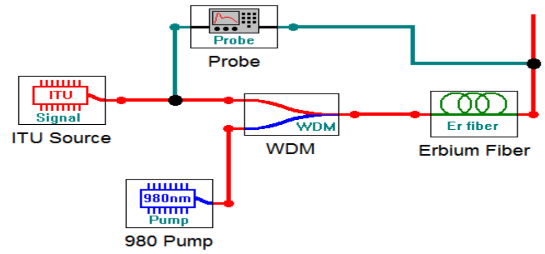

Fig. 3Single Stage EDF optical amplifier design

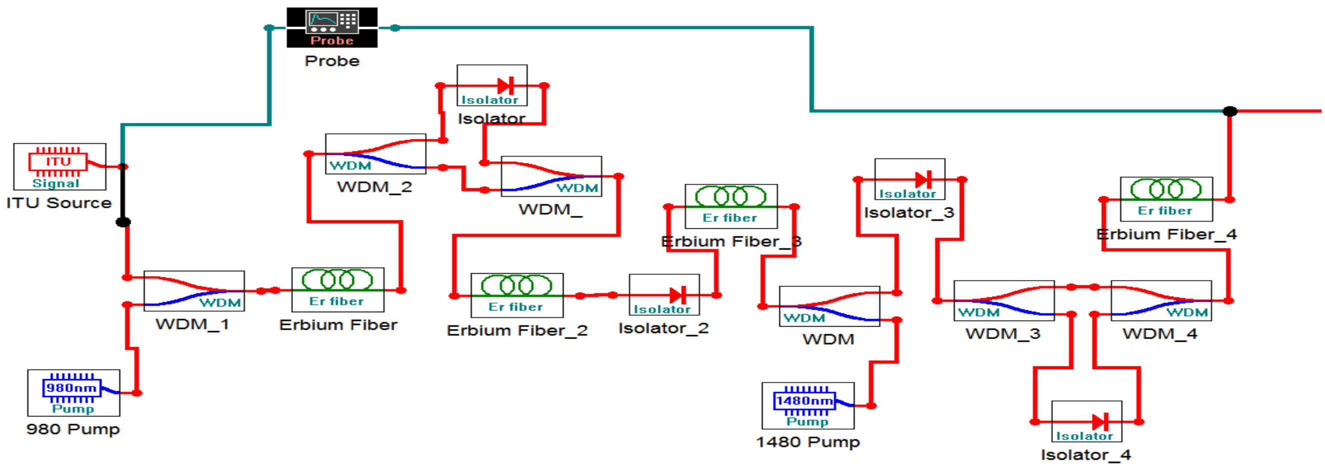

Fig. 4 Four- stages EDF Optical amplifier design

IV. RESULT ANALYSIS, GAIN AND NOISE FIGURE SPECTRA

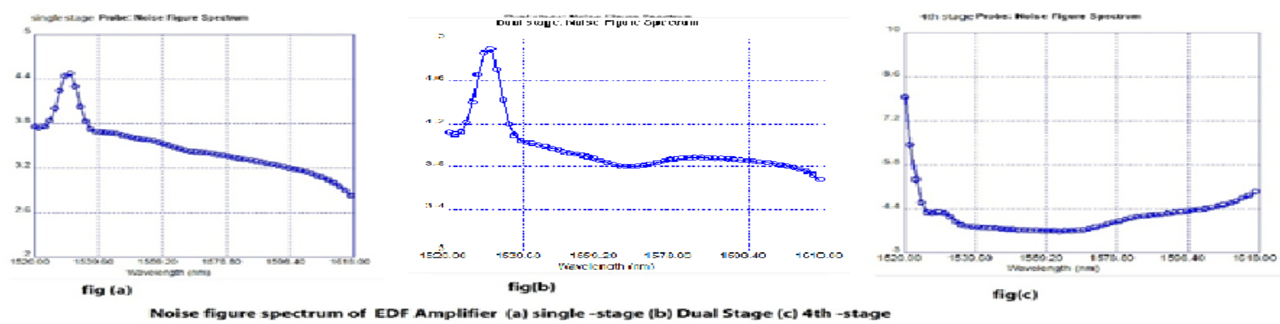

Fig. 5 Noise figure spectrum of EDF Optical amplifier (a) Single-stage (b) Dual –Stages (c) Four-Stage

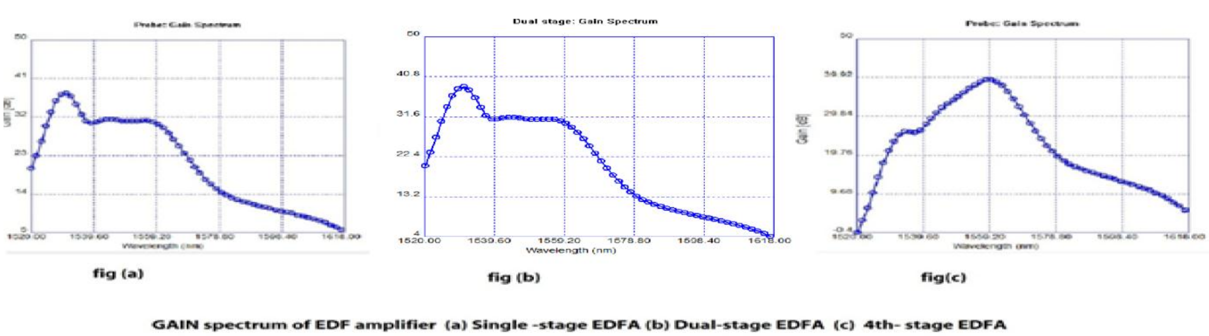

Fig. 6 Gain spectrum of EDF Optical amplifier (a) Single-stage (b) Dual –Stages (c) Four-Stages

SR. NO	EDFA Parameters	Single Stage EDFA	Dual-Stages EDFA	Four-Stages EDFA
1	Average gain	28.091 dB	30.884 dB	31.182 dB
2	Max gain	37.279 dB	36.976 dB	39.253 dB
3	Min gain	3.788 dB	7.130 dB	0.358 dB
4	Gain –Flatness (P-P)	33.491 dB	39.846 dB	39.611 dB
5	Gain-Flatness (RMS)	10.589 dB	10.098 dB	10.837 dB
6	Gain Tilt	17.824 dB	9.846 dB	5.844 dB

Table 1: Analysis of EDFA gain, noise figure with single-stage, dual-stage & four-stage EDF optical amplifier.

V. EFFECT OF PUMPING POWER ON EDF AMPLIFIER

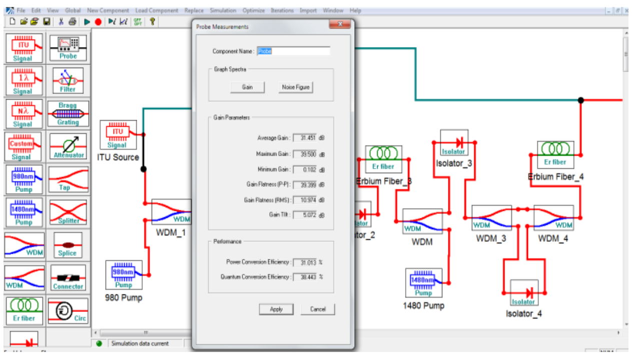

Fig 7 Simulation results of Four-stage EDF Optical amplifier by Gain Master

Sr no.	Pumping Power	GAIN			Gain Flatness		Noise Figure
		Average	Maximum	Minimum	P-P	RMS	
1	0.12 W	31.451 dB	39.500 dB	0.102 dB	39.399 dB	10.974 dB	7.70952 dB
2	0.35W	33.366 dB	41.389 dB	2.537 dB	38.852 dB	11.420 dB	6.465982 dB
3	0.55W	37.414 dB	45.308 dB	5.934 dB	39.374 dB	12.571 dB	5.016773 dB
4	0.85W	39.298 dB	47.082 dB	6.165 dB	40.916 dB	13.177 dB	4.649022 dB

Table 2: Analysis of EDFA gain, noise figure by variation of pumping source power

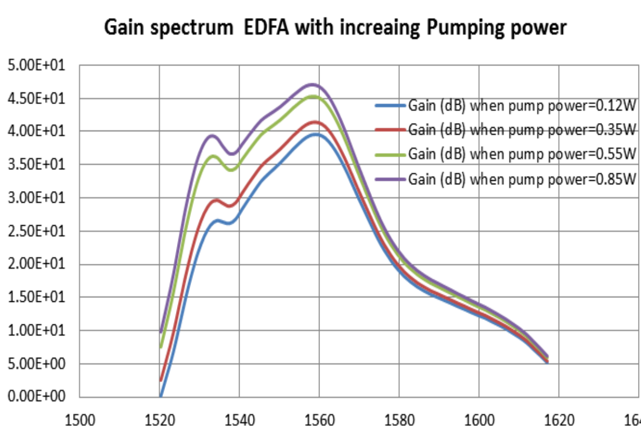

Fig. 8 Gain spectrum of EDF optical amplifier on effect of input pumping power (0.12W, 0.35W, 0.55W, 0.85W)

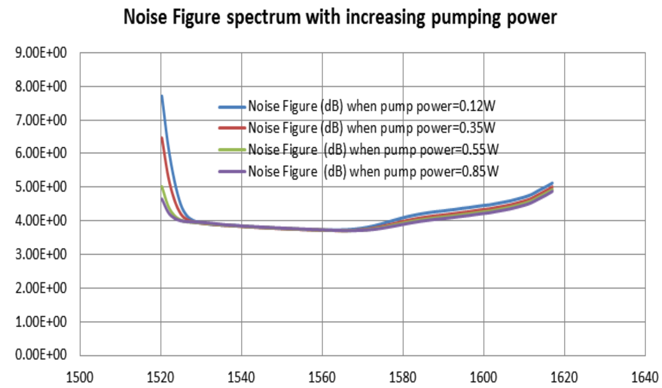

Fig. 9 Noise figure spectrum of EDF optical amplifier on effect of input pumping power (0.12W, 0.35W, 0.55W, 0.85W)

VI. CONCLUSION

This paper shows that the optical amplifier is to be used for amplify the signal and basically designed an optical amplifier to increase the level of the input signal and found that the optimum parameters for the transmission of the data. The input wavelength is taken in between 1520-1617nm. Moreover it also shown the noise spectrum of the erbium doped optical amplifier. Wavelength division multiplexing (WDM) technique is used for the multiplexing of the signal between the two stages of the optical amplifier. Moreover it is also concluded that the range of the optical amplifier is 1520 -1620 nm. It can be used only up to the 10-30m. It shows the results of the fourth stage of the optical amplifier and the different optimum parameters of the optical amplifiers (table 1). Pumping power effect on EDF amplifier is analyzed Simulation Results indicate that Gain and noise figures are affected by pump power. It may be observed that the Gain is optimized and Noise Figure initially decreases with increase in Pump Power and then attains the same value. (Table 2)

REFERENCES

[1] M. A. Mohammed," Theoretical Analysis of a Double Stages Erbiumdoped Fiber Amplifier" 978-1-4244-6235-3/10/$26.00 ©2010 IEEE

[2] H. Masuda, "Review of wideband hybrid amplifiers," in *Tech. Dig. OFC'00*, 2000, pp. 2–4.

[3] P. B. Hansen, L. Eskildsen, S. G. Grubb, A. J. Stentz, T. A. Strasser, J. Judkins, J. J. DeMarco, R. Pedrazzani, and D. J. DiGiovanni, "Capacity upgrades of transmission systems by Raman amplifier," *IEEE Photon. Technol. Lett.*, vol. 9, pp. 262–264, 1997.

[4] M.-S. Kao and J.Wu, "Extending transmission distance of high-density WDM systems using post transmitter fiber Raman amplifiers," *J. Lightwave Technol.*, vol. 9, pp. 394–399, 1991.

[5] D. N. Christodoulides and R. B. Jander, "Evolution of stimulated Raman crosstalk in wavelength division multiplexed systems," *IEEE Photon. Technol. Lett.*, vol. 8, pp. 1722–1724, Dec. 1996.

[6] L. F. Mollenauer, J. P. Gordon, and M. N. Islam, "Soliton propagation in long fibers with periodically compensated loss," *IEEE J. Quantum Electron.*, vol. QE-22, no. 1, pp. 157–173, Jan. 1986.

[7] M. N. Islam, "Raman amplifiers for telecommunications," *IEEE J. Sel. Topics Quantum Electron.*, vol. 8, no. 3, pp. 548–559, May/Jun. 2002.

[8] J. Bromage, "Raman amplification for fiber communications systems," *J. Lightw. Technol.*, vol. 22, no. 1, pp. 79–93, Jan. 2004.

[9] D. Garbuzov, R. Menna, A. Komissarov, M. Maiorov, V. Khalfin, A. Tsekoun, S. Todorov, and I. Connolly, "1400–1480 nm ridgewaveguide pump lasers with 1 watt CW output power for EDFA and Raman amplification," in *Proc. Optical Fiber Communications Conf.*, Anaheim, CA, 2001, pp. PD-18-1–PD-18-3.

[10] John N. Senior "Optical Fiber Communications principles and practice" New Delhi, 2005.

[11] H. S. Seo, Y. G. Ghio, and K. H. Kim "Design of transmission optical fiber with a high Raman gain, large effective area, low nonlinearity, and low double Raleigh back scattering "IEEE photonic technol.lett.vol.16,January 2004.

[12] Parekhan M. Jaff, "Characteristic of Discrete Raman Amplifier at Different Pump Configurations",World Academy of Science, Engineering and Technology 54 2009

[13] Akhter Fowzia et al, "Modeling and characterization of all possible triple pass EDFA configurations", International Journal of Physical Sciences Vol.7 (18), pp.2656-2663, May 9, 2012

[14] Semmalar S., Poonkuzhali, Devi.P, "Optimized Gain EDFA of different lengths with an influence of pump power", IEEE Paper, 2011

[15] Semmalar S., Gujral Jyoti, "EDFA with Optimized Gain using Tri-Counter Directional Pumping",International Journal of Applied Engineering Research, ISSN 0973- 4562,Vol.6 No.5,April 2011.

[16] Naji W.A et al, "Review of Erbium–doped fiber amplifier", International Journal of Physical Sciences Vol.6(20), pp 4674-4689,September 23, 2011.

[17] Naji W.A et al, "A Computer based Simulator for Erbium-Doped Fiber Amplifier", May 11-13, IEEE Paper 2010

[18] Berkdemir Cuneyt et al, "On the Temperature-Dependent Gain and Noise Figure Analysis of CBand High- Concentration EDFAs with te effect of Cooperative Upconversion", IEEE Journal of Lightwave Technology, Vol.27, No.9 May 2009

[19] Awaji Yoshinari et al, "Challenges towards Burst- Mode EDFA", IEEE Paper 2009

[20] Tamer Adolph, Ould Saadi H. and Boutaleb A., "Simulation based analysis of erbium doped fiber amplifier (EDFA)", Journal of applied science, ISSN 1812-5654, Asian network for scientific information 2006

[21] Tae Joon et al, "All-Optical Gain-Clamped Erbium-Doped Fiber Amplifier with Improved Noise Figure and Freedom from Relaxation Oscillation", IEEE Photonics Technology Letters, VOL.16, No.1, Jan 2004

[22] Harun S.W et al, "Gain Clamping in Two-Stage LBand EDFA Using a Broadband FBG", IEEE Photonics Technology Letters, VOL.16, No.2, February 2004

[23] Izyani M.A Mas et al, "Flattened Dual-Stage GCEDFA Using Fiber –Ring Laser Technique",IEEE Paper 2003

[24] Novak Stephanie et al, "Analytic model for gain modulation in EDFA", IEEE Journal of Light wave Technology, vol.20, No.6, June 2002.

[25] Novak Stephanie et al, "Simulink Model for EDFA Dynamics Applied to Gain Modulation", IEEE Journal of Light wave Technology, vol.20, No.6, June 2002.

[26] Optical amplifier - Wikipedia, the free encyclopedia http://en.wikipedia.org/wiki/Optical_amplifier

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