OPTIMIZATION AND PERFORMANCE EVALUATION OF HYBRID AMPLIFIERS

DISSERTATION-II

Submitted

By

RAGHAV VASHISHTH

Department of ECE

In partial fulfillment of the Requirement for the

Award of the Degree of

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In

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Miss. SAMEKSHA BHASKAR

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Name of the Student: Raghav Vashishth | Registration No: 11005596

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Details of Supervisor: | Designation: Asst. Prof.

Name: Sameksha | Qualification: M.Tech (ECE)

U.ID: 17004 | Research Experience: -3 yrs

SPECIALIZATION AREA: Optical Comm. ED01 (pick from list of provided specialization areas by DAA)

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DECLARATION

Iherebydeclarethatthedissertation proposal entitled, "**OPTIMIZATION AND PERFORMANCE EVALUATION OF OPTICAL AMPLIFIER**"submittedforthe M.TechDegree is entirely my original work and all ideas and referenceshavebeendulyacknowledged.Itdoesnotcontainanyworkfor theawardofanyotherdegreeordiploma.

Date:

RaghavVashishth

Reg. No. -11005596

CERTIFICATE

This is to certify that **RaghavVashishth** having registration no**. 11005596** has done his report for dissertationII- titled, "**Optimizatoinand Performance Evaluation of hybrid optical amplifier**" under my guidance and supervision. To the best of my knowledge, the present work is his original study. No part of this report has been submitted for any degree at any other university.

This report is good for submission and partial fulfilment of condition for award of **Master of Technology**.

Miss. SamekshaBhaskar
Asst. Prof Lovely Professional University
Phagwara, Punjab

Date:

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ABSTRACT

This Report evaluates the performance of hybrid EDFA and RAMAN amplifiers which are used in dense wavelength division multiplexing systems. Hybrid amplifiers are used to increase the transmission distance and to reduce the non-linearity in the fiber thread. In EDFA the major problem is amplified stimulated emission(ASF) which is generated at the time of the amplification of input signal due to stimulation emission. Optical fiber Communication is the secured and capable technology used in most of existing networks in today's world. Because of its larger bandwidth and low losses it is able to send the data over the long distances without much degradation in the signal. With the help of DWDM technique it is easy to process the signals in the single thread of the fiber. In optical fiber communication, the attenuation is the major limiting factor imposed by optical components or by fiber itself which degrades the system performance and limits the reach of the signals. To compensate these effects opto-electronic regenerators are used to reshape, retime or retransmit the signal, but simultaneously it increase the cost of the system. On the other hand, optical amplifiers boost the signals without going through the costly conversions from optical to electrical signal and vice versa. But due to the various non-linear effects and phase noise present in the optical amplifier, its use is restricted to limited applications in optical communications.So, there is demand of optical amplifiers which provide better performance (in term of transient performance, power crosstalk, gain flatness, larger gain bandwidth etc.) for DWDM systems.

In order to achieve these objectives it is utmost important to design, characterize and investigate an appropriate optical amplifier for high capacity DWDM systems. As such, new ways to extend the bandwidth, improve the noise and dynamic properties of present-day amplifiers are constantly pursued. This thesis facilitates this process by tracking several system level challenges while acknowledging the limitations of existing devices.

The hybrid optical amplifier is an enabling and promising technique for future DWDM multi-terabit systems to minimize the impairments due to fiber nonlinearities and to enhance the gain bandwidth and or gain flatness.This thesis mainly design, characterize and optimize the new hybrid optical amplifiers for DWDM system and further various important aspects has been addressed, such as gain flatness , gain bandwidth,Quality factor for the Systems at different modulation format and

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LIST OF ABBREVIATIONS

BER Bit Error Rate

DCF Dispersion Compensation Fiber

DFB Distributed Feedback Laser

DWDM Dense Wavelength Division Multiplexing

EDFA Erbium Doped Fiber Amplifier

FP Fabry-Perot Laser

HFA Hybrid Raman and Erbium Doped Fiber Amplifiers

MMF Multimode Fiber

NF Noise Figure

OSNR Optical Signal Noise Ratio

SMF Single Mode Fiber

Chapter 1
INTRODUCTION

1.1 Motion in fiber optic system development

Optical fiber systems are used as a backbone for sending and receiving the data at ultra high speed and at longer distances. Commercial users demands for the very high speed network for sending and receiving media rich messages in less time and the corporate user demands for ultra high speed so that they can connect their local area network to the internet at high data rate and efficiently. To fulfil the demand of the user the network with high data rates and lower cost is required. Optical Fiber communication systems fulfil these demands because of their higher bandwidth and lower costs over the conventional data transmission systems.

Fiber optics technology uses the thin glass threads to transmit data from one place to another in the form of light. Fiber optical communication systems send data over fiber glass thread by turning electronic signals into light signal.The Recent researches on fiber optical glass cable have shown result of transmitting over 100 petabits of data per second over network.Fiber optic cable thread works basically on three main properties i.e. dispersion, absorption, scattering and non-linearities.In the long haul transmission systems these properties bring some of the drawbacks because they cause power losses, attenuation losses, scattering etc. When light wave travelling inside the fiber cable it spreads out and become too longer in their wavelength domain and slowly dissipates on the cladding part, absorption occur due to the impurities in the cables like hydroxyl ion which are present in the fiber due to moisture.

In the optical fiber communication systems , the humiliation in signalalong with the transmission distance is there due to the various non-linearities in optical system and other dominating errors as discussed above .The number of users can be improved by increasing the power levels or by reducing losses in the network by the use of opto electronic regenerator circuits.But such regenerators are quite complex in circuitory , time consuming and costly for DWDM systems because of the various processing levels in their system design i.e. demultiplexing,optical electrical optical (O-E-O) conversion and multiplexing. This reduces the reliability of the system or network as regenerator is an active device. Therefore, upgradation of the multichannel WDM network will require optical amplifiers which directly amplify the transmitter optical signals without going through O-E-O conversion.The optical amplifiers are mainly used in WDM application as all the adjacent channels with different wavelengths can be amplified at once. By placing it just after the transmitter optical amplifier increase the lightsignal power as pre-amplifier and by placing it just before the receiver as post- amplifier. As the requirement of higher capacity and long haul unrepeated transmission distance increases, the conventional transmission methods has to be studied to full-fill the demand of current technology. There are so many non-linear effects such as cross phase modulation (XPM) , self-phase modulation (SPM), four wave mixing (FWM),gain saturation,etc. and phase noises which are present in the optical amplifiers which limit it to be used for theseveral applications in optical communication systems. So, there is therequirement of optical amplifiers which provide better performance in term of transient performance nonlinearities,power crosstalk,larger gain bandwidth, gain flatness and much more for DWDM optical systems. In order to attain these objectives it is necessary to design, optimize and characterize an suitable optical amplifier for the high capacity of DWDM fiber optical systems.

For today's ultra high speed broadband applications and to improve the system performance without using expensive techniques the hybrid amplifiers are promising and broadly used technology. Like most of the technologies, HOA's also comes with some drawbacks that should be taken in care. These drawbacks includes, crosstalk, transience response as well as some other sources of noise that are picky to fiber Raman amplifiers (FRAs), such aspump-mediated relative intensity, noise transfer , double Rayleigh backscattering and some problems with nonlinearities, due to the high average power in the fiber itself. The main goal behind proposing the HOA is to:

(i) maximize the gain bandwidth of WDM optical system with the lowest gain variation over the effective bandwidth of system,

(ii) To reduce the losses due to induced nonlinearities in the systems

(iii) To avoid the problem of the high cost gain flattening filters and multiple pumps for the large gain flattened systems.

Hybrid Erbium Doped Fiber Amplifier and RAMAN are used for dense wavelength division multiplexing (DWDM) systems. Hybrid amplifiers are used to increase the transmission distance and to reduce the non linearity in the optical fiber system.In EDFA the major problem is amplified stimulated emission(ASF) which is generated at the time of the amplification of input signal due to stimulation emission at the exited state. In other words we can say that ASE is the background noise and these noise signals are amplified with the input signals are amplified with the input signal where they are passed through some other amplifier which is one of the drawbacks of the EDFA In this work the optimization and the performance of hybrid EDFA and RAMAN amplifier is performed using optisystem software.

1.2 DWDM Technology:

In a system consisting of DWDM, many optical signals with different wavelengths are sent on the single thread of fiber. If we use repeaters then it is required to de-multiplex the optical signals and then have to repeat every individual signal after the (O-E-O) conversion. On the other hand, the optical amplifier directly amplify all the signals which pass through it simultaneously. In this way the development of the optical amplifier that has enhanced and enabled the practical DWDM systems with better performances.

Conventional WDM begins in the late 1980s using the two broadly spaced wavelengths in the 1310 nmand 1550 nm regions, Sometimes also called wideband WDM . In theearly 1990s saw a second generation of the WDM systems , sometimes called narrow band WDM, at that time two to eight channels are used in the systems.These channels were spaced at the spacing of about 400 GHz inthe 1550 nm window. By the mid of 1990s, dense WDM (DWDM) systems were discovered which uses 16to 40 channels and interval from 100 to 200 GHz. By the late 1990s DWDM systems haveevolved to the area where they were capable of 64 to 160 parallel channels,which were densely packed at50 Ghz or even 25 GHz spacing, as shown in figure 1.1.

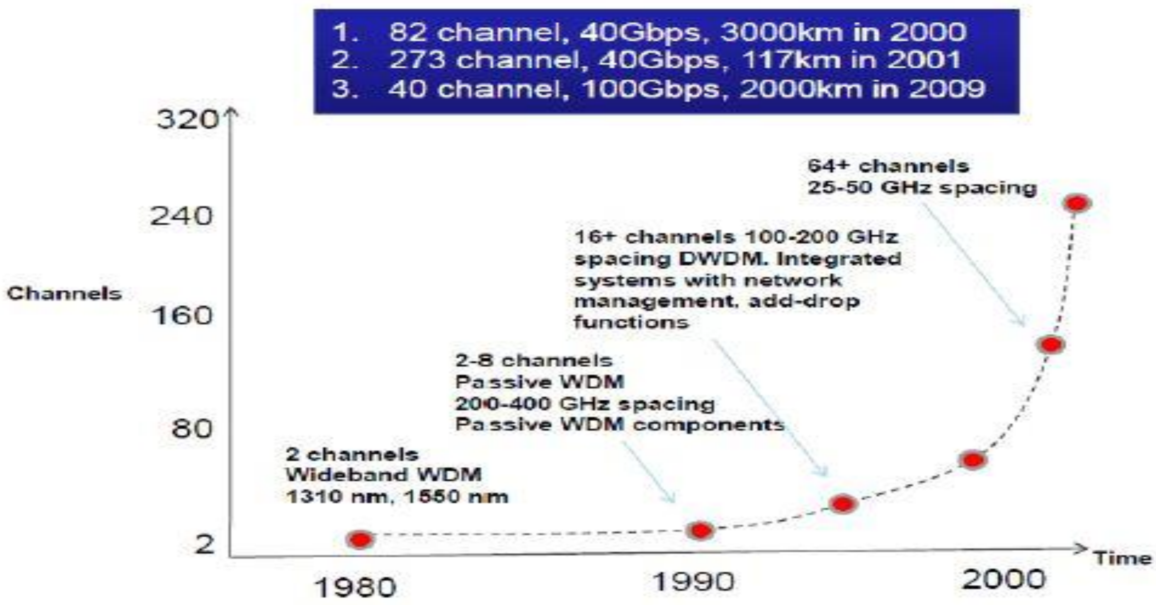

Fig 1.1 DWDM Technology.

1.3Transmission of light inside the fiber

Optical fiber uses the phenomenon of total internal reflection for transmitting the light in the form of data over the long distances. Optical fiber is uses the optimal visible light transmission for digital links or analog links.Optical Fiber can transmit large quantities of data for telecommunications applications at higher speeds.

Optical fiber are strands of pure glass material as thin as a human's hair that carry digital information over much long distances. Optical Fiber uses the light pulses to transmit the data or information over the network.

Total internal reflection principle in fiber optics cable states that when the angle of incidence exceeds the critical angle value, light can not get out of the glass fiber . Instead the light reflects back in to the fiber . When this principle is applied to the construction of the fiber optic strand. It is possible to transmit information down fiber lines in the form of the light pulses.

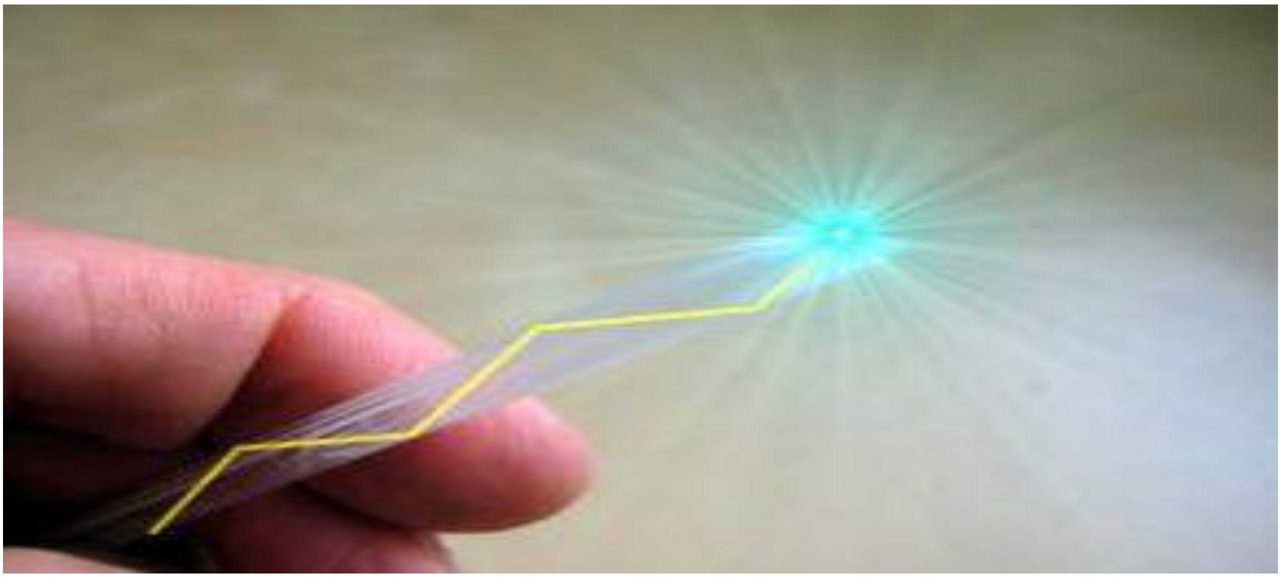

Fig 1.2 Inside the optical Fiber

Fiber optic cables work at high speeds up into the gigabits per seconds. These are having much large carrying capacity.Optical fiber Signals can be transmitted further without needing to be "refreshed" or strengthened. Optical fiber can resist to the electromagnetic noise such as motors or other nearby cables, radios. Optical fiber maintenance cost is very less as compared to the copper wires maintanace.Optical Fibres are the appropriate means of communication signal transmission as compared to the copper wire cables.

1.4 Types of optical Fiber Cables

1.4.1 Single Mode Fiber:

Single Mode fiber has very small cores of about 9 microns length in diameter and transmits the infrared light. Single stand of fiber with the diameter of 8.4 to 10 microns that has one mode of transmission properties.Single mode fiber has much more smaller core radius than that of the multimode fiber.

Single mode fiber gives the higher transmission rate and up to 50 times more distance transmission than multimode fiber, but itis also a cost more than the multimode fiber. Single-mode fiber has a very much smaller core than that of a multimode. The single light wave and small core virtually eliminate any of distortion that could result from overlapping the light pulses, providing the least signal attenuation in the circuitory and the highest transmission speeds of any of fiber cable type.

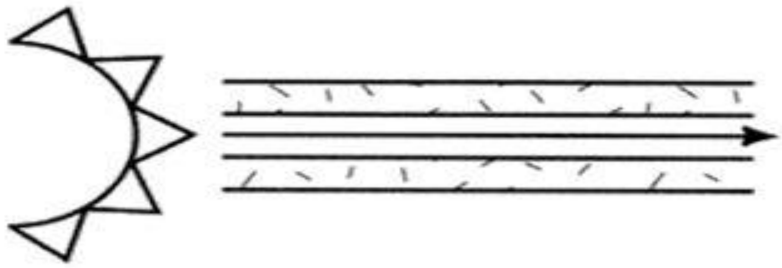

Fig 1.3 Single Mode Fiber

Single mode optical fiber is an optical fiber in which only the lowest order bound mode can propagate at the wavelength of interest typically 1300nm to 1320nm.

1.4.2 Multimode Fiber:

The core diameter of multimode fiber is much bigger than that of wavelength of the transmitted light.A number of mode can be simultaneously sent over this type of fiber. Fiber modes are related to the possible ways by which lights travels inside the fiber.

Multimode fiber gives high bandwidth at high speeds over medium distances. Light waves are dispersed into numerous paths or modes as they travel through the cable's core typically around 850nm or 1300nm. Typical core diameters of multimode fiber are 50, 62.5, and 100 micrometers. However, in long cables nearly greater than 3000 feet or 914.4 meters multiple paths of light can cause signal distortion at the receiving end in the circuitory , resulting in an imprecise and incomplete data transmission so designers now require for single mode fiber in new applications using Gigabit and beyond gigabit.

It is generally used as the backbone applications in buildings.Increasingly number of users are taking the benefits of fiber closer to the user by running the fiber to the desktop or to the network zone.

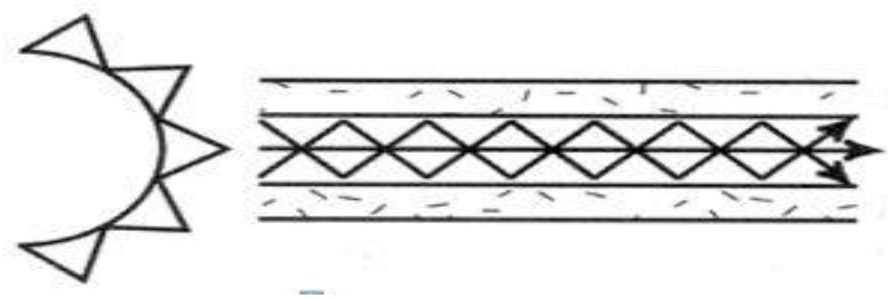

Fig 1.4 Multi-Mode Fiber

1.5The Importance/Role of Optical Amplifiers:

As compared to conventional regenerators, the optical amplifiers can much efficiently amplify all the signals simultaneously without going to any time consuming, complex and expensive O-E-O conversions. The large gain bandwidth of the optical amplifiers has enabled the high capacity of the WDM technology, which is used to increase the fiber capacity by propagating many of the parallel channels situated side-by-side on a wavelength grid of optical system. Furthermore, the lesser noise figure of this amplifier has emitted the need for costly periodic electro-optic regeneration circuitry. Also a single state of the earth erbium doped fiber amplifier (EDFA) can simultaneously amplify close to a nearly a 10 Gbps WDM channels, corresponding to the 1Tbps worth of traffic, without electro-optic conversion or by any use of high-speed electronics circuitry.

However, as the result of the large bandwidth of today’s single-mode silica fibers (SMF), the capacity of modern optical communication network is restricted by the bandwidth of used amplifier. Similarly the reach of currently used optical systems is also limited by various non-linearity effect and noises induced by the optical amplifiers circuitry.

1.6 Basis Principle for the Operation of Optical Amplifier:

The emission and absorption of light produces atoms inside the semiconductor, which exists in the certain discrete energy states, to create their move from one distinct energy level to the other or vice-versa. The energy of emitted light is related to the difference between the higher energy state E2 and the lower energy state E1 as shown in Figure 1.5. When photons with the energy E are incident on the atom at lower energy state E1 of semiconductor , it is possible that they may get excited to the higher energy state E2 through the absorption of photon called as the absorption process as shown in Figure 1.5(a). As atoms in the energy state E2 does not remain in the stable state, the atom try to jump to the lower energy state in arbitrary manner by generating the photon at output as shown in Figure 1.5(b). This process is called spontaneous emission of photons.

Optical amplification process uses the principle of stimulated emission, similar to the approach used in a laser.The stimulated emission process occurs, when the incident photon having energy of E = hc/ λ incident with electron in higher energy state, causing it to return back into smaller or lower state with creation of the second photon as shown in the Figure 1.5(c), where h is the Plank constant, c is velocity of the light in vacuum and λ is the wavelength of the incident light. The process of light amplification occurs, when the incident and emitted photons are in the same phase and discharge two or some more photons.

To achieve better results in optical amplification, the population of photon at of upper level has to be greater than that of the lower level i.e. N1 < N2, where N1 and N2 are population densities of smaller and higher state, respectively. This condition in the semiconductor is known as the population inversion. It can be achieved by using external sources such as pump which is responsible to excite the electron to the upper energy level.

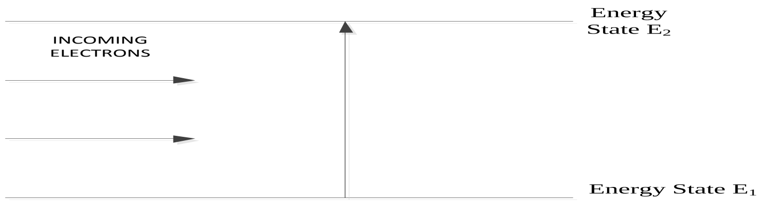

Fig. 1.5(a)

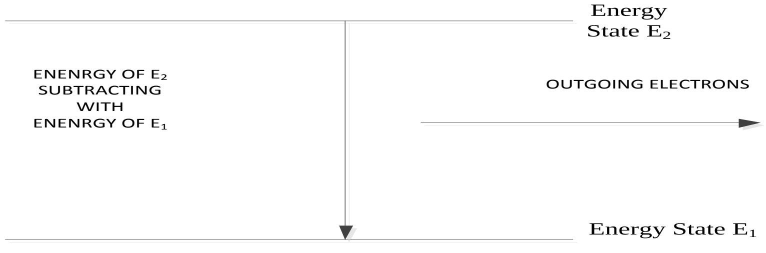

Fig. 1.5(b)

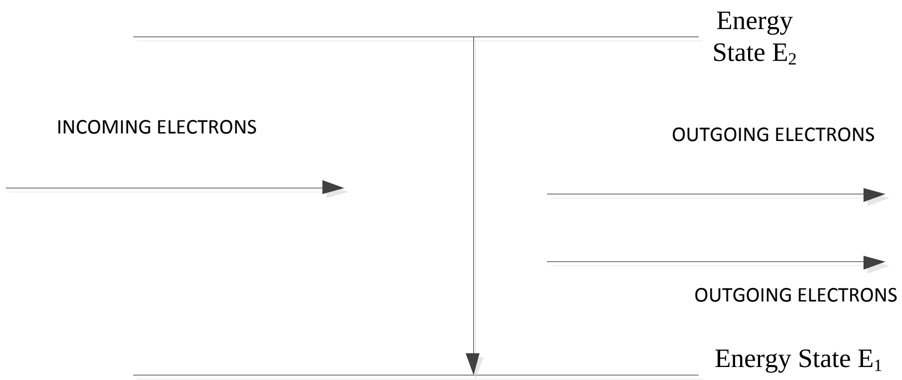

Fig. 1.5s(c)

Figure 1.5Processes of Optical amplification (a) Absorption, (b) Spontaneous emission and (c) Stimulated emission.

1.7 Types of Optical Amplifiers:

Optical amplifiers are studied on the basis of their construction that is whether they are semiconductor based amplifiers (for example Semiconductor optical amplifiers) or fiber based (for example Raman and Brillouin amplifiers, Rare earth doped fiber amplifiers,). Optical amplifiers are also studied as conventional (RAMAN,EDFA, SOA,) and some doped waveguide amplifiers (EDWA, EYDWA etc.) and HOAs of some different configurations of waveguide amplifiers, conventional optical.

1.7.1 Semiconductor Based Optical Amplifier.

The semiconductor optical amplifier (SOA) is a updated version of semiconductor laser devices, as shown in Figure 1.5, which typically has different value of reflectivity and device length.SOA's are very similar to the laser exceptingthe reflecting facets. A signal with lower power is guided through the activated region of the SOA amplifier, whichleads to stronger signal emition via stimulated process.

The SOA is fundamentally a PN-junction diode and the depletion layer that is at the junction behaves as the active region. Both the ends of SOA's are given an non-reflection coating which is dependable to eliminate the gain ripple. The surfaces can also be angled a little to weaken the reflection process. In the process of a semiconductor laser, there is no non-reflection coating is present. The SOAs are quite different from the other doped fiber amplifiers in the way in which population inversion is achieved. In a semiconductor material the populations are not those of the ions which are in various energy states but of the carriers (i.e holes or electrons)

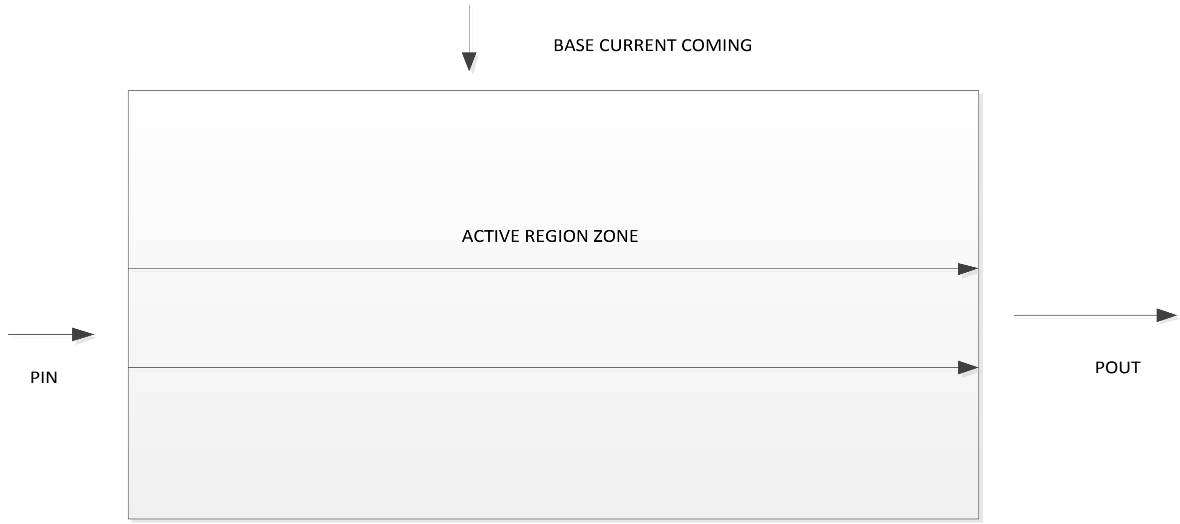

Fig 1.6 Semiconductor Based Optical Amplifier

1.7.2Erbium Doped Fiber Amplifiers:

To prepare fiber amplifiers to work in different wavelengths from 0.5 µm - 3.5 µm the Rare-earth element like erbium, thallium ytterbium and ytterbiummay be doped into the optical fibers.Amplifier’s gain bandwidth, operating wavelength and other relative characteristics can be determined by the dopants instead of the fiber materials. An EDFA’s are, so far, the most widely used fiber amplifier’s , because EDFA’sare capable to amplify all the wavelengths ranging from 1500 nm to 1600 nm [5],

Length of EDF, the pump laserand wavelength selective coupler are the three basic components of EDFA amplifier as shown in the Figure 1.7. The optimal fiber length used can be effected by the quantity of the pump wavelength, Erbium doping ions, pump power and input signal powers [1]

The abundantqualities that have made the EDFA as the requirement in today’s fiber optic applications are such as: (i) polarization independent, (ii) great coupling efficiency and (iii) convenience of compact and high-power pump lasers.

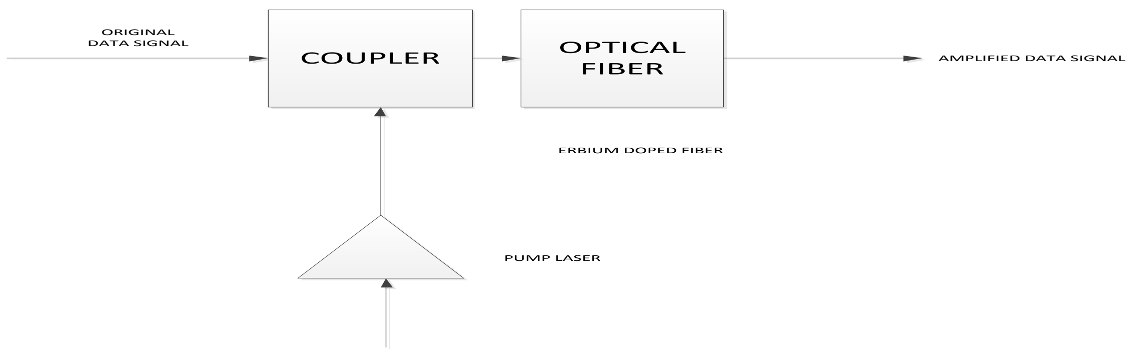

Fig 1.7 Erbium Doped Fiber Amplifiers

1.7.3 RAMAN Amplifier:

To decrease the cost factor, the optical fiber itself can be used as a medium to increase the gain and is called as Raman Amplifier , for the optical amplification process under the elevated pump power phenomena without the use expensive doped ionsDue to fiber non-lonearities this factor takes place due to Raman scattering. This effect can be studied by in viewing of the simple spring. If a lighter load is attached to the spring, the addition of the spring is linear to the load applied and becomes non-linear as the load is very heavy. Similarly the effect of a dielectric medium, such as the optical fiber, to an intensed amount of light wave isnon-linear and Raman scattering is the result of this type of nonlinear process. The concept is shown in Figure 1.8. The pump photon νp is absorbed by the material and the molecules which are energized are excited to the non-resonant state (also called as the virtual level) while after sudden decay of molecules to smaller energy state, a photon of the different energy is free νs . The molecular vibrationlevels of the horde material determine the outline of the Raman's gain line and the frequency shift. Light incident on a medium is changed to a smaller frequency during the Raman scattering process [20].

Stimulated Raman scattering (SRS), which is the gain method in the Raman amplifier occur in the optical fiber's when the pump wave is dispersed by the silica molecules. A block of Raman fiber amplifier in the optical communication network is shown in the Figure 1.8. The signal sent from the optical transmitter travels through the optical fiber thread and detected at the receiver end using the photodiode at the receiver end. For the distributed Raman amplifier (DRA), the pump wavelength is much shorter than that of the signal wavelength and power is provided by pumping up the fiber; where to be the fiber is amplified by an value that corresponds to that of the optical frequency difference of near about 13.19 THz [21]. The signal then experience gainup gradation due to the SRS process. In this process, signal light and pump are coherently coupled by the Raman principle and is changed into the second data photon that is the exact copy of the first data signal , and the residual energy produce an optical phonon which yield the amplification process [22]. Four important points which makes the Raman amplifier cost effective and attractive are

(i) Raman scattering can takes place in any sort of fiber;
(ii) Its gain is of Raman is non-resonant, i.e. which is presented over the whole transparency area of the optical fiber Raman by the proper choice of the pump wavelengths
(iii) Its gain is sensibly flat over a broad wavelength range and
(iv) It has very fast in the process of the amplification because the upper state is a virtual state.

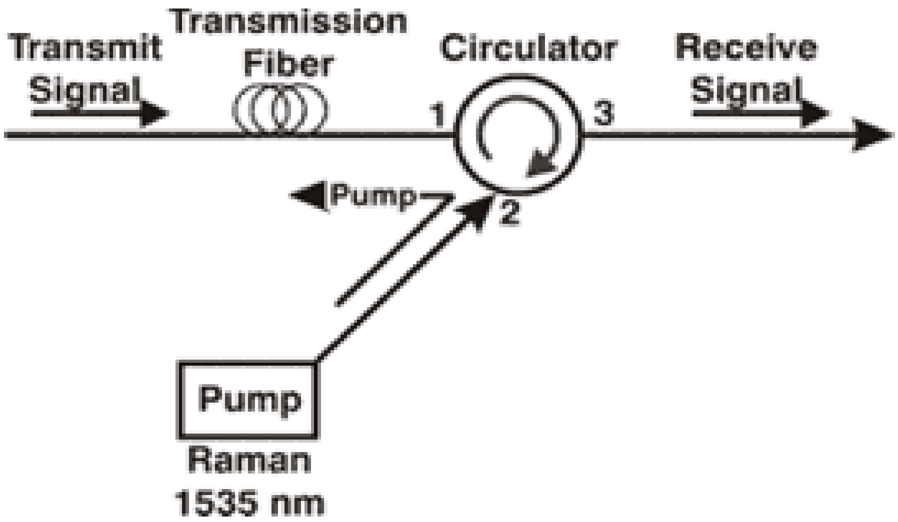

Fig 1.8 Raman Amplifier

1.7.4 Hybrid Optical Amplifier:

The growing demand for the broad bandwidth in present backbone of the networks makes it growingly necessary to enlarge the opera table transmission bandwidth of the deployed fiber systems beyond the broadly used in the C-band specification of about (1530 nm to 1565 nm). As the telecommunication bandwidth is mainly limited by today's amplifier's of the choice, the very new way of theincreasing the amplifier's bandwidth thatshould be pursued. EDFA's are planned to amplify in the range of 1565 nm to 1625 nm i.e in the L-Band and are commercially existing and also have been demonstrated with comparatively lesser noise figure and thehigh gain [22]. Such an amplifier may be united with the C-band of EDFA, to getmerged C+L band EDFAs. though the number of issues which make the optical system pricey are such as: (i) the fiber broadcast length used for the L-band amplifiers are generally many times larger than that of the C-band EDFAs, (ii) the signal band should be divided just prior to amplification, (iii) different amplifiers for each band of amplification are consequently required, and (iv) after the process of amplification, the combiner is needed to combine the band of wavelengths again. The divider and joiner will donate loss to the signal and therefore increases the noise figure perameter of the amplifier. in addition, a"seam" of worthless bandwidth will be generated between the bands, due to lesser gain and the higher noise figure in the region [21]. While the bandwidth of the single EDFAis limited and their power efficiency is much high as compared to that of Raman amplifiers alone. From an effectiveness point of view, it is therefore attractive to make as a large amount use of the EDFA gain as much as possible and use other methods of amplification behind the EDFA bandwidth. As an exemplar,The hybrid combination of EDFA and Raman amplifier have been used to enlarge the unspoiled bandwidth of discrete amplifiers up to the value of 80 nm [30], 100 nm [31] and so on.

In universal way , the grouping of more than single optical amplifier in any construction is called as hybrid optical amplifier (HOA). Mohammed N. Islam stated that the network gain of the Raman and EDFA and HOA as GHybrid is the addition of the two individual gain of the Raman and EDFA [21]. Gain partition in the hybrid amplifier is as shown in Figure 1.9. so in the case of Raman-EDFA HOA the net gain is given by

G-Hybrid = G-EDFA+G-Raman

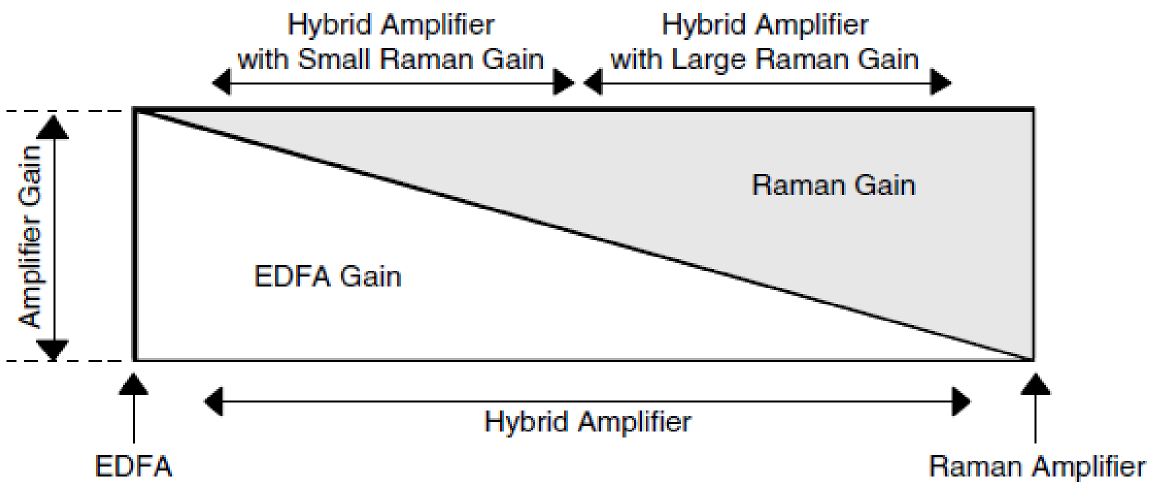

Fig. 1.9 Gain partitioning in hybrid amplifier

From Figure 1.9, it can be observed that, some part of the input wavelength band spectrum is effectively amplified by the EDFA with the higher gain and the other is amplified by the Raman, over the all wavelength available the single amplifier shows large amount of deviation. But if both the Raman amplifier and EDFA are combined in any configuration (parallel or cascaded) then the large amount of gain flatness can be observed also with the highest amount of gain.

Mohammed N. Islam investigates the gain bands of many types of optical and HOA as shown in Figure 1.10. It can be Observed that the hybrid pattern of usual optical amplifiers provide more gain bandwidth i.e. more than 80 nm with better value of the gain flatness.

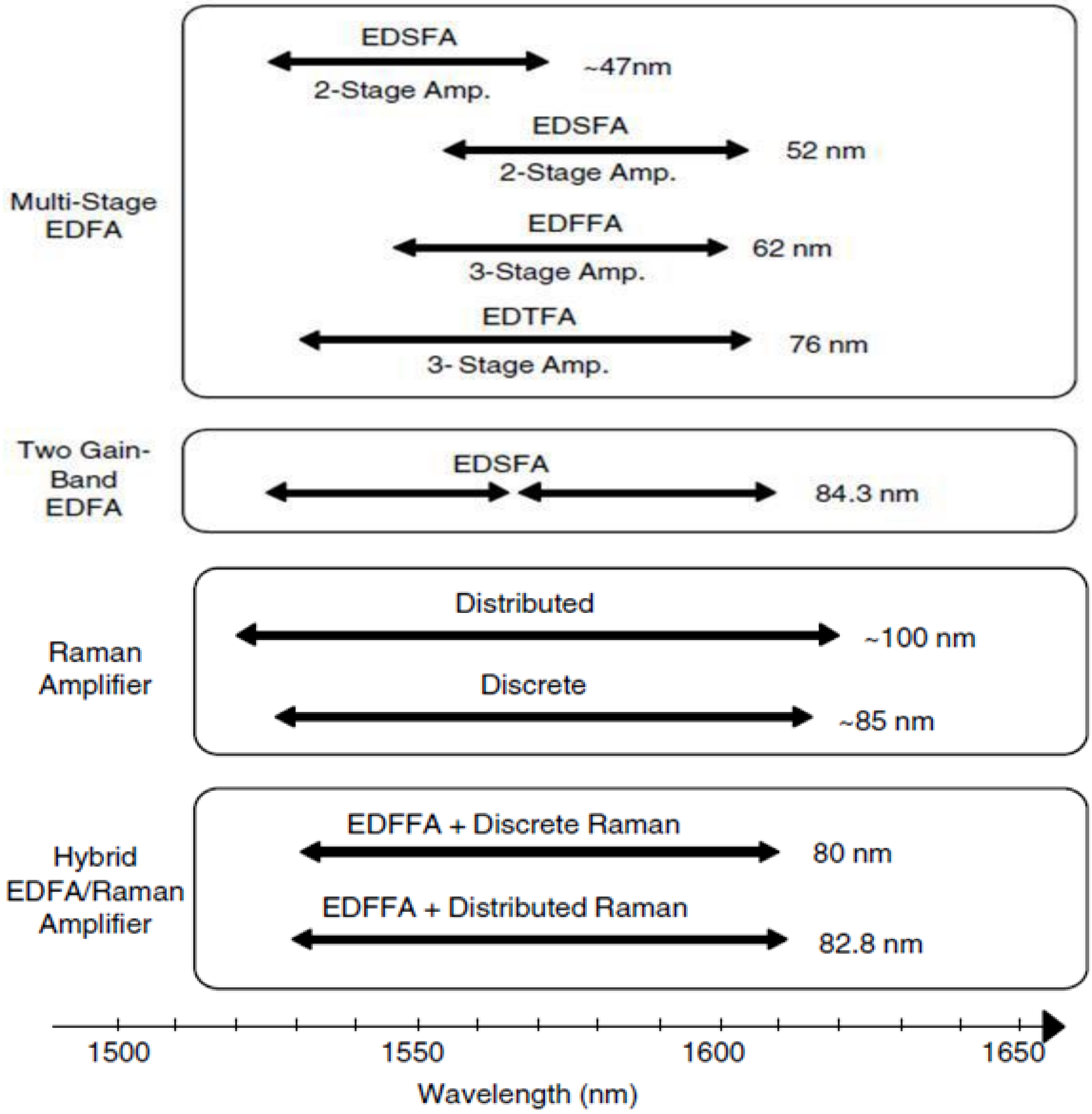

Fig.1.10 Gain bands of broadband fiber amplifiers

1.8 Comparison Between operational principle of Optical Amplifiers:

The fundamental principle of all of the optical amplifiers are approximately same but its survival in particular appliance is depend on their characteristics and constraints. As an conventional on-chips and switches, wavelength converters or the logic gates For their very small size and verey lesser power utilization the SOA's are the best over the EDFA and Raman Amplifiersalso for the HOA configuration consisting of Hybrid of SOA and EDFA give better result in the term og higher gain and lesser power consuptionwith the use of Hybrid Raman and EDFA the System become little expenciveBut the provide best result for Gain flatness and higher gain for the DWDM system efficiently after compairing the various configurations it is studied that for DWDM systems teh combination of EDFA and RAMAN gives for long-haul distances but in the system where lesser input power is available the SOA's gives best results.

1.9 Basic Arrangements of an Inline Optical and Hybrid Optical Amplifiers

In 2000, Masuda [15] studied the several types of hybrid configurations used in serial patteren and further this work is unmitigated by Lee et al. [16] in 2005 and presented various configurations comprising of low cost's HOA using single pump. Figure 1.11 shows some of the basic designs or mixture of an in-line amplifier.

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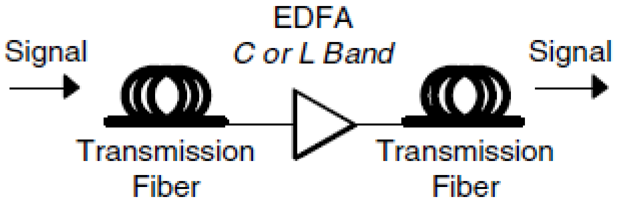


Fig. 1.11(a)

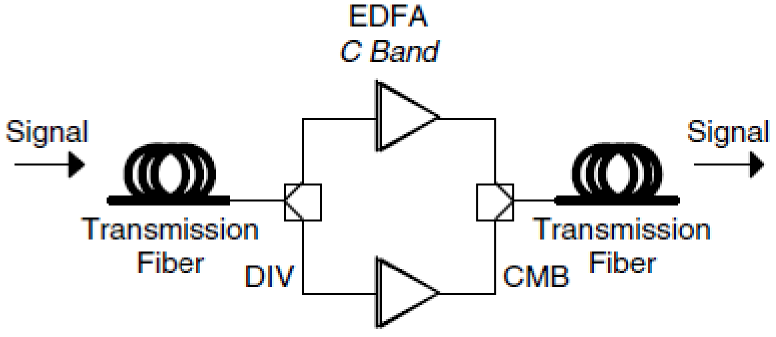


Fig. 1.11(b)

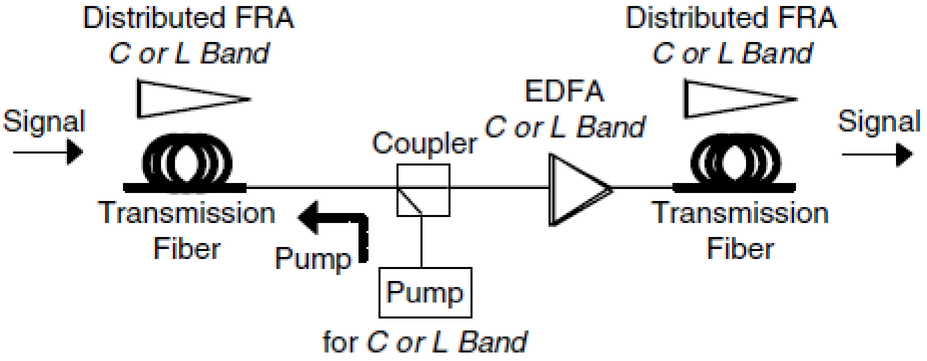


Fig. 1.11(c)

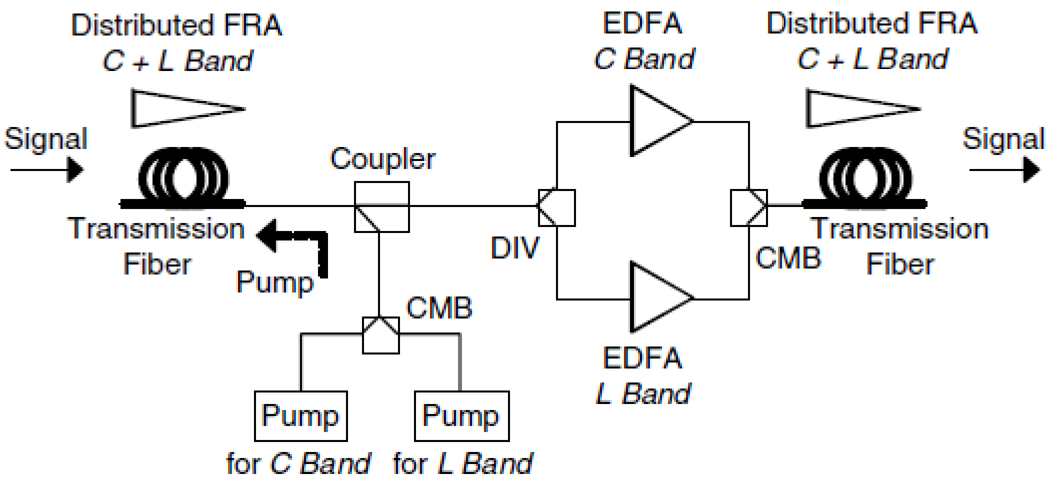


Fig. 1.11(d)

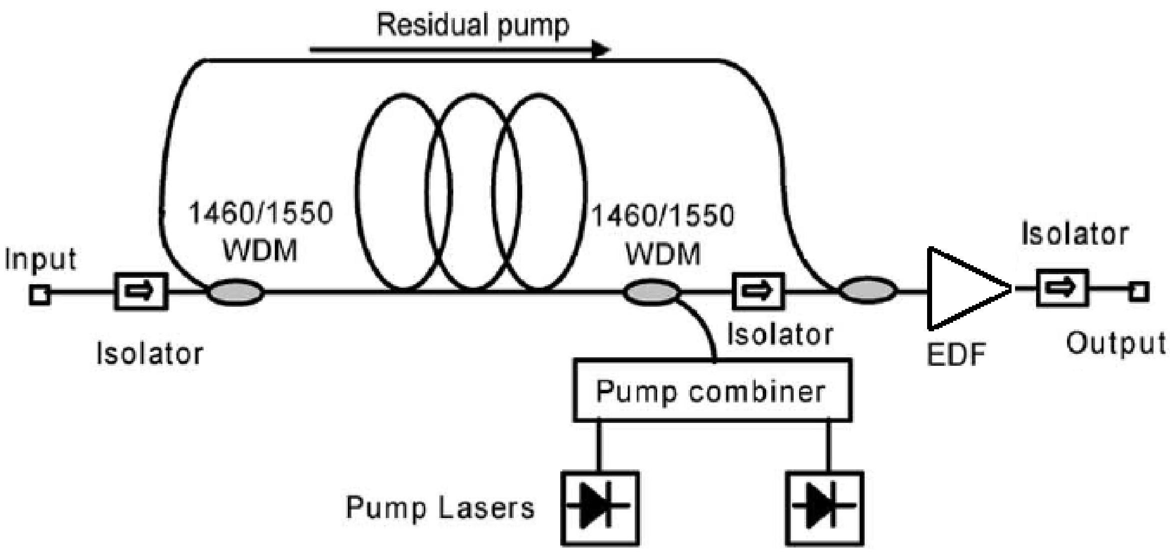


Fig. 1.11(e)

Figure 1.11: Architectures of inline optical and hybrid optical amplifiers: (a) a EDFA; (b) dual C-or L-band EDFAs ; (c) C+L band Raman-EDFA HOA in cascade setup; and (d) Raman-EDFA HOA; (e) HOA Raman-EDFA with lesser cost and residual pump.

In short we can conclude that the fiber optical communication networks and the fiber optical amplifiers are taken into concern with their basic principle theory such as absorption,SRS,stimulated emission, spontaneous emission etc.

Chapter 2
LITERATURE REVIEW

[1] **Simranjit Singhet.al.** In this paper it is investigated that for future dense wavelength-division-multiplexing(DWDM) multitera bit optical systems Hybrid optical amplifiers (HOAs) are an important and promising technology. HOAs are designed to increase the bandwidth and to increase the span length and also to achieve larger gain bandwidth product with better gain flatness using DWDM . DWDM is a technology that assigns to the users of an opticalnet works at specific wavelengths or "colors" and adds them in a single unit of fiber. Instead of increasing the data transfer rate or using more fibers the bandwidth of an optical network is scalable by adding more wavelengths to the input circuitry or in other urds we can say that decreasing the channel spacing between adjacent channels .To increase the transmission capacity, basically there are three techniques: (1) Using the broadband optical amplification (2) Increasing the bit rate of the syatem and (3) Decreasing the channel spacing of the adjacent channels. In the first approach, the hybrid rare earth doped fiber amplifier is the optimum alternative to improve the capacity. The HOA, which cover the lesser loss region of the optical fiber such as 1480 nm,1550 nm and 1580 nm. Most of The HOAs have been proposed to increase gain bandwidth product of the optical system which are responsible for increase in capacity. With second technique, the bitrate per adjacent channel of wavelength division multiplexed optical systems can be increased to 40 Gbps or more, by using electronic circuits at high speed and optical time division multiplexing (OTDM) technologies. Due to high bit rate, there is a need of various compensation approaches to compensate dispersion in the optical system. With third approach, narrow channel spacing is made possible by using a relatively low bit-rate per adjacent channel as compared to the second approach each of the three methods mentioned above have their individual different technical issues to be determined. In this paper author uses first and third method in parallel with the help of which it is possible to achieve larger capacity with better possible broadband amplification in the optical system. Even though, a DWDM system consisting thin channel spacing with broadband amplification is expected to be one of the next generation high capacity global transmission optical systems.

Transmission capacity of optical system =bit rate× number of wavelengths.

Where The number of wavelength N is given by:

Number of wavelengths =optical signal bandwidth× channel density.

Transmission capacity=bit rate× optical signal bandwidth× channel density.

The emission of the very first channel is at 185 THz and is increased in the number of channels are according to 25 GHz channel spacing upto 40th channel. The two stage HOA are placed after the laser which utilize the EDFA and RAMAN as a gain media.At the first stage of hybrid optical amplifier that is EDFA consists of 9m of erbium doped fiber co-directionally pumped by optical unit which consist a laser diode which emits at 1465 nm with pump power of 100 mW. erbium concentration in erbium doped fiber is 5 × 10^24m^−3with the erbium lifetime of 10 ms .At second stage i.e. RAMAN amplifier is connected through an optical filter.Active filter having noise dynamics of 100 dB and bandwidth centre frequency of the optical filter is 1530 nm. Second stage RAMAN amplifier consists15 km of single mode fiber and counter directionally pumpedat the 1500 nm and 1489 nm pump respectively. Both the pumps 1550 nm and1489 nm are having the pump power of 123 mW and 131 mW.

By using the above explained circuitory the hybrid optical amplifier with flat gain characteristics is obtained using two stage configuration as explained above with a midway isolator. Thishybrid optical amplifier is invested for dense wavelength division multiplexed system of 25 GHz channel spacing between each adjacent channel. The gain equalization approach is applied, and the hybrid optical amplifier that has a gain of greater than 16 dB, an Optical Signal to Noise Ratio greater than 13 dB,3 dB of gain flatness, and the noise figure is maintained below 7.4 dB at the flat gain region of the given hybrid amplifier.

[2] **Simranjit Singh et.al** The Raman and EDFA HOA is investigated for 16 × 40 Gbps system which has been modulated using DPSK modulator with different channel spacings of 100,200Ghz.It is studied that, it has been studied that this system gives higher bandwidth utilization and lesser crosstalk even at the higher speed with the use of DCF in the circuitry .It is noticed that DPSK is the best modulation Format to be implemented for DWDM systems with lesser channel spacing as it provides lesser cross talk for higher rate systems.

[3] **Ju Han Lee et.al** here the author investigated a novel Scheme of the dispersion-compensating Raman and erbium-doped fiber amplifier recycling remaining pump for increasing the overall efficiency of the power . The implemented dispersion-compensating hybrid amplifier systems have only one pump source for Raman amplification in the dispersion-compensating fiber (DCF) and the remaining pump power after the DCF is used for resulting signal amplification process joined to DCF. Using the given scheme, Author achieve the important development of both gain of the signal and effective gain-bandwidth by the factor of 15 dB and 20 nm.

[4] **Amanpreet Singh, R.S. Kaleraet.al** this paper is based on WDM system for 16,32 etc channels for 10 Gbps. Transmission distance perimeter has been considered for the performance comparison of EDFA ,SOA RAMAN amplifier. It has depicted that dispersion is 2ps/nm/km and required no. of channels to be lesser than SOA and provide better result due to some reasons like no of channels considered ,saturation problem for gain arises due to cross phase modulation and cross gain modulation .in this paper EDFA is found to be much better than SOA here author Has found that Raman amplifier provides much better result for amplification in L band . research and development are going on in order to increase the medium capacity and log haul optical system simuntaniously internet global success demand for higher system capacity transmission distance of optical fiber is limited by fiber losses sometimes opto electronic repeater are used in the case of loss limitation where optical signal is converted to electric current and re-generated using transmitter . Advantage of optical amplifiers is that it amplifies optical signal without converting it into electrical foam .The author has observed that Raman Amplifier provides low output power than other amplifier and give better result for high wavelength. Transmission distance is varied from (40-200km) and dispersion is varied (2-10ps/nm/km).for dispersion of 2ps/nm/km SOA gives better results as the channels and dispersion is increased then EDFA gives better results in form of Q factor and EYE closure.

[5]**Simranjit Singhet.al** In his work author used four modulation formats ie Nonreturn-to-zero(NRZ),Nonreturn-to-zero raised cosine (NRZ-RC),Return-to-zero(RZ),Return-to-zero raised cosine (RZ-RC).Different hybrid systems are introduced in DWDM Systems and noticed that Raman amplifier’s performance is degraded when NRZ-DPSK,RZ-DPSK are used . DWDM system With RZ and RZ-RC when performed with Raman-EDFA provides better results for long distances 1512 and 1260 km respectively.it is also concluded that hybrid optical amplifier is the good alternative to increase the span length upto 84 km. with acceptable quality factor greater than15 dB and bit error rate less than 10^-9.

[6]**Umesh Tiwari et.al**Author reported that simulation and experimental characterization of a hybrid amplifier consisting of a Ramanamplifier and an erbium doped fiber (EDF) amplifier, with the enhanced performance. The incorporation of a pumped EDF section in a fiber Raman amplifier (FRA) employing a dispersion compensating fiber is demonstrated to provide better results than a single FRA system. The simulated system is characterised in term of Noise Figure and single channel gain. and it is concluded that the setup present in this simulation gives best results for noise figure an d has the lowest gain ripple. with the increase in input signal power the gain spectrum increases and it is observed that multi channel gain

spectrum of hybrid configuration is quite different from single channel .Working on the described system author has found that the Polarization Dependent Gain calculated in the Hybrid System is the smallest.

[7]**Singhet.al** In this paper the Author evaluated the performance of DWDM system for 64×10 Gb ps with Hybrid Optical Amplifier and observed that (RAMAN–EDFA) gives the best output power of 20.18 dB m and eye opening of0.00233at the distance of 160 km for dispersion 2 ps/nm/km. The Effect of modulation formats (NRZ,RZ and DPSK) are observed on the optical/hybrid optical Amplifier and it is observed that 64×10, RZ is more badly affected by non-linearity's, where NRZ and DPSK is more affected by the dispersion parameters. They also compared the EDFA and hybrid fiber amplifier(HFA) and noticed that HFA is an alternative to enhance the performance of line amplifier instead of using EDFA only. They described that the configuration of HFA that has lesser noise figure and higher output power. The OSNR and Q-factor in the case of HFA is morethan by 1.0 dB. Author observed that the performance of different Hybrid amplifiers(EDFA, RAMAN, SOA, RAMAN–EDFA, RAMAN–SOA), the transmission distance vs output power graph shows that as the transmission distance is increased from 80 to 200 km, the degradation in the output power occurs in the system due to continuous raise in ASE as the span distance increases in the given system. The eye opening diagram of different amplifiers vs transmission distance are also observed. Large eye opening meansgood communication and less BER. It is also noted that as the transmission distance is increased from 75 - 180 km the eye opening is decreased simultaneously due to non-linearities and induced dispersion. From the Observed results it is noted that the RAMAN–EDFA Gives better performance as compared to other individual amplifier and cover maximum distance of single span ie 160 km. At 160 km the system provides acceptable output power of 20.18 dB m and eye opening of 0.00233 after this distance the performance of the system degrades.

[8] **Simranjit Singhet.al**in the fiber optical link the post, pre and symmetrical power compenciation methods are investigated for (RAMAN-EDFA) hybrid amplifiers. It is noticed that the post power compensation method is better than pre and symmetrical power compensation method in terms of eye closure penalty bit error rate and received output power. It is observed that RAMAN–EDFA as a post power compensation method gives least bit error rate of 10^−40 and high output power of 12 dBm at−15 dBm signal input power in the fiber link. The graph between the signal input power and bit error rate at the fiber network are observed. For post and symmetrical power compensations, the bit error rate is much low which denotes better performance. It is also noticed from the results that the bit error rate

redubes with the increase in the signal input power at the optical fiber network. It is reported in the literature that due to the nonlinear behaviour of the propagation, the system evaluation depends upon the power levels and the position of dispersion-compensating fibers in the circuitory.in the end of the study the author concluded that the post power compensation method provides better results in term of BER , EYE closure and the received power as compare to symmetrical and pre power compensation methods.

[9] **R.S. Kaler et.al.** multi terabits DWDM system which consist of hybrid optical amplifier RAMAN-EDFA for different data format such as, return to zero(RZ) , non-return to zero (NRZ)and differential phase shift keying (DPSK). It is Observed that in 64×10 and 96×10 Gbps, RZ is more badly affected by nonlinearities, where as NRZ and DPSK are more affected by dispersion parameters .It has been observed that in system consisting of the RAMAN-EDFA amplifier, the RZ raised cosine modulation scheme has the maximum power level with the lowest loss which is indicated by the diminution of the noisy spikes at the output of thereceiver and BER estimator analyzer. Author further investigated that the highest single span distance for different modulation schemes. RZ provides the best results and covered 180 and 175 for 64 and 96 channel DWDM system respectively. Incontext of 64 and 96 channels DWDM link which is amplified by the hybrid optical amplifier (RAMAN-EDFA).here each individual channel has 10 Gbps data speed. They further investigated that the performance comparison of hybrid optical amplifier RAMAN-EDFA with different modulation formats in the terms of Q-factor, eye closure, bit error rate (BER) and output power for different modulation Schemes (RZ, NRZ and DPSK)and optimizes the maximum single span transmitted distance. The variations in the Q-factor for, RZ, NRZ and DPSK are, 24.42–13.88 dB, 21.31–14.95 dB and 22.25–14.62 dB respectively in the given system..When these data formats are compared RZ rectangular provides the improved result as compare to other modulation schemes. Increase the transmission distance shows that the BER increases correspondingly for the distance of 130-190 km .The minimum bit error rate is calculated by the RZ data format ie 1×10^−40 and for the worst-case it becomes around 2.781×10^−9 dB which is acceptable for these type of fiber links.

[10]**Sun Hyok Chang. et.al.** Investigated the characteristic of hybrid optical fiber amplifier (HFA). HFA consists of three basis 1stages small length EDFA pre-stage, Dispersion Compensating Fiber Raman amplifier and the power boosting EDFA. HFA has lesser noise figure, higher output powers, and also broad input power dynamic ranges. Experimentally the Gain control method of HFA is presented and the transient gain venture is suppressed to

less than 0.5 dB.HFA can be used as the line amplifier in optical transmission system even when combined with distributed Raman amplifier due to broad input power and dynamic range. The transmission evaluation of HFA is much better than EDFA by more than 1.0 dB of Q-factor in720 km single mode fiber transmission distances. Author compared the transmission evaluation of Hybrid Amplifier with conventional EDFA. EDFA is used in the experiment consists of two stages gain stage and DCF connected at inter stage in the circuitry. The EDFA has the input pump power of 2 dBm and the output power of 23 dBm with 80 input channels, as those of the HFA. The noise figure of the EDFA calculated is lesser than 7 dB, 2 dB larger than that of hybrid fiber amplifier. In the end of the paper the author observed that HFA has constant output power of 23 dBm with flat gain spectrum while the input power was varied from2 dBm to 15 dBm. Hybrid line amplifier consist of DRAand HFA is sufficient due to the wide input power dynamic range of Hybrid Amplifier. HFA alone showes better transmission results in line amplifier than EDFA's.

[11] **H. H. Lee et.al** investigated that the demand for higher speed internet system and digital TV system is increasing , passive optical networks (PON) have emerge as the access equipment of choice. If we talk about the currently deployed time-division multiplexing (TDM) PON (1:32 split and 20-km reach), large splits, extended reach wavelength division multiplexing (WDM)-TDM hybrid Passive optical networks have been studied. A long haul WDM-TDM hybrid PON can be allocated the feeder fiber between several PONs, while making links between a decreased number of metro/code nodes and large number of optical network units (ONUs). By consolidate central offices, a long-reach WDM-TDM PON operation has the assistance of simplifying the network design and also the real estate costs. Combining a general low-gain Raman stage with the SOA results in flat gain over 80 nm or much more. Author demonstrated an 80-nm flat gain bandwidth and gain clamped SOA-Raman hybrid amplifier for CWDM networks. Four channels of 2.488 Gb/s CWDM signals were amplified and no gain saturationin is diced also bit-error-rate power penalty was observed.

[12]**Kenneth C. Reichmann et.al** Author demonstrated the cascade of broad band semiconductor optical amplifiers and Raman hybrid amplifiers which provide just about flat gain over 70 nm. A coarse-wavelength-division multiplexing(CWDM) transmission system consists of three span of80 km shows linear evaluation and 1-dB of the power .They demonstrated that The hybrid amplifier consist of a SOA and a Raman pump, a pump coupler, and an optical isolator and plots the wavelength vs gain of the hybrid amplifier and

its constituent stages. The triangle represent working of the SOA alone and shows a gain tilt of 6.6 dB between1510 and 1570 nm. The SOA is based on the buried hetero design structure using a dilute mode method .The device had at hin and wide multi quantum well active regions, which facilitates lower noise and maximum power operation over a broad band. Angle's effect and antireflection coatings reduce back reflections excluding the gain ripple impairments. After the study of this paper it is studied that the demonstration of a CWDM transmission system using a cascade combination of SOA Raman hybrid amplifiers. These broad-band amplifiers not only provides nearly flat gain over four CWDM-channels also the spanning of 70 nm, but do so to the long-wavelength side of the SOA gain peak, where saturated output powers are having higher. Uniform performance was observed over the entire band with not more than a 1-dB power penalty after 240 km and no measurable degradation due to variations in polarization. With the proper selection of SOA and Raman pump and wavelength, similar results may have been calculated a over any band within the wavelength range 1300–1650 nm.

[13]**Cristian Riveraet.al** In this paper a numerical model has been implemented for the EDFA-Raman hybrid amplifier which provides a better design that flattens the characteristic of the EDFA gain spectrum, enlarging the link length and useful amplification bandwidth. The numerical model has been evaluated through experimental measurement, for a simple hybrid configuration of amplifiers .The advantages of the using of hybrid amplification have been studied, regarding the use of EDFA or Raman separately, in terms of improving the gain flatness and bandwidth. It is important to note that there are mainly experimental results concerning this type of hybrid amplifiers. The contribution of the model is used in the simulations in this work is especially essential for future research and design of hybrid amplifiers models. The model used in the simulations enables researchers to design and calculate the performance of the hybrid amplifier, for an improvement in many of the optical fiber link already installed till date , which work mainly with EDFA's. The OSNR is 35 dB which is similar to that achieved after the EDFA. The difference between the signal channel value obtained for the experiment and the measurement is due to the WDM coupler losses which are not considered in the simulation results .In the case of the hybrid amplifier, simulations with the complete hybrid model which is developed considering the effects of both of the amplifiers.

Chapter 3
OBJECTIVE AND SCOPE OF STUDY

In the present scenario the research and development are working to increase the overall capacity of the optical network system for long haul communication of the optical signals .also the communication market and internet needs to increase the system capacities .the distance of the optical fiber communication is ultimately limited by the losses present inside the fiber due to non-linearity’s of the optical fiber thread characteristics .For the WDM systems the in long haul communication the opto-electronic repeaters are of no use because in opto electronic repeater the optical signal is first converted into the electrical signal and then again into the optical signal which is a quiet complex process and expensive too. Now a days the optical amplifiers are used with the help of which the optical signal is directly amplified in the optical domain without any conversion of the signal into electrical domain. These amplifiers amplify the signals continuously and also decreases the attenuation in the circuitory of the advanced optical network system.

The major reason behind the decrement of power in the optical network is the attenuation factor of the optical thread.

3.1 Objectives:-

1. To plan, Optimize and evaluate the HOA to broaden the gain bandwidth and gain flatness for the ultra-low dense wavelength division multiplexed network/system.

2. To investigate the architectures of HOA for dense wavelength division multiplexed network and obtain the effect of different parameter for instance pump power, core radius of Er input pump power Raman Pump on these amplifiers.

3) We can vary EDFA and RAMAN amplifiers length; it is interesting to see how gain and noise figure varies with a length of hybrid amplifier.

4.The impact of Different Modulation Patterns are like RZ,NRZ,DPSK can be studied for DWDM hybrid optical Amplifier.

5)The Best modulation scheme can be implemented for High speed system having more no of input channels.

3.2 Scope of the Study:

The Project will mainly focus on the simulation of Hybrid, EDFA and RAMAN amplifiers using opti system software. The Performance of the amplifier is analysed on the basis of amplifiers gain , noise figure (NF) and optical signal to noise ratio (OSNR).

Different Parameters of amplifiers are changed to obtain the gain flatness and to reduce the noise figure at the output of the hybrid circuit.

Optical amplifier can also be used in cascaded form by using different configuration to develop better performance. The hybrid amplifier is also used in long haul DWDM transmission system

Chapter 4
Research methodology

Simulation setup:

To flatten the gain of the first and second stage of the given circuitry shown in fig the effect of various parameters is discussed. In the given circuitry the various parameters like raman pump power, input pump power core radius of EDFA is studied at DWDM system having the channel spacing of 12Ghz. At the first step the laser array model have the first operating frequency at 185Thz and with the increase in no of channel it goes upto 185.756 for the 64 no of channels used in the circuitry.The hybrid structure of the EDFA and RAMAN are used to increase the gain media at first and second stage of the hybrid circuit.

teh EDFA amplifier is co-pumped at 1465 nm having 9m of the erbium doped ions in it the pump of the edfa is pumped at 50mW of pump power. Core radius at this setup is 2.2 after this the signal is passed through the optical isolator and after that the same signal is applied to the Raman amplifier present at the second stage of the hybrid structure. The Raman Amplifier is co and counter pumped at 1550 and 1489 nm frequency respectively .this circuit is simulated for the differ values of the raman pump power that is 250nm, 550nm 750nm

	Previous system	Current System
No. of Channels	40	64
Channel Spacing	25GHz	12GHz
Use of Filter	Yes	No
Gain	>16dB	>19dB
EDFA Pump Power	100mV	50mV
RAMAN Pump Power	123mW & 131mW	Varied Pump Power 250mW , 550mW , 750mW
Core Radius of EDFA	Default 2.2um	Varied 2.2um , 2.4um , 2.8um
Input Power	0 dBm	Varied -26dBm , -10 dBm , 0 dBm

Table 4.1 parameters in current System

respectively the effect of gain is also analysed with the effect of the change in the core radius of EDFA that is at 2.2um, 2.4um , 2.8um .similarly the effect of gain is analysed at the varied pump power at the input of the circuit that is at laser array consisting of 64 channels.

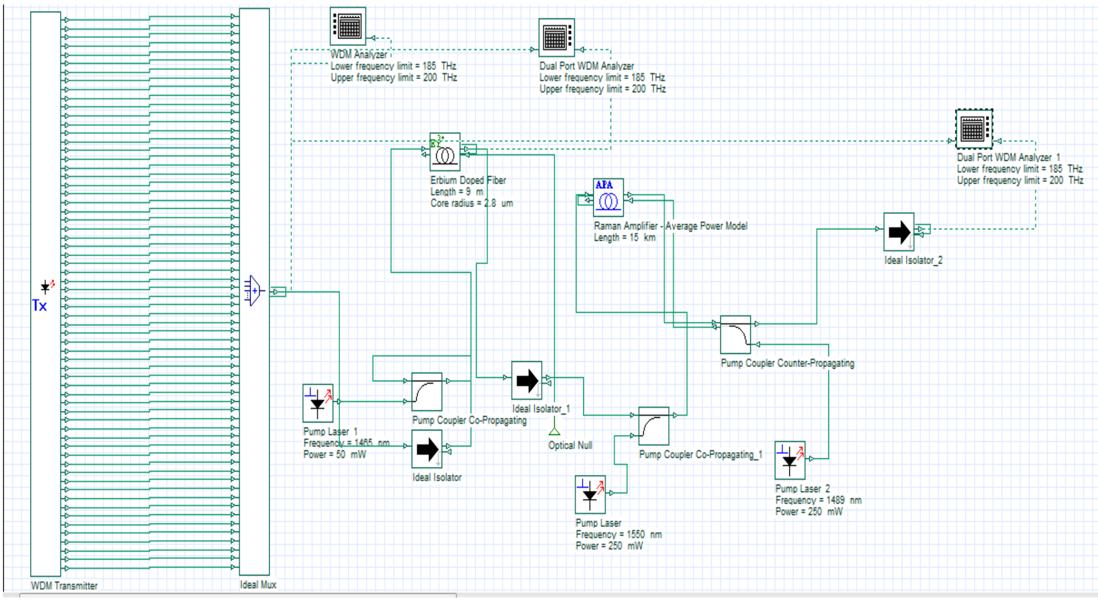


Fig. 4.1 circuit to flat the gain at first and second stage

As shown in the circuitry of the simulated system the given circuit is iterated number of times for calculating the gain (dB) with the change of the several parameters.In the first layout the raman pump power is varied .In this system 64 channels are at ultra-narrow channel spacing i.e. 12GHz is used at -26 dBm input power.to calculate the Gain after the First and the second Stage all the perimeters are kept same as stated above .Sometimes inside the fiber thread the light starts reflecting back to avoid that we use optical isolators so that the flow of the optical signal should remain in one direction .To calculate the Gain at each frequency level the WDM Analyser are used to get the Results as shown in the fig.4.1

In short we can conclude that the following four changes are made in the setup to get the optimized results and also to study the effect of HOA for these Changes

1. Change in RAMAN Pump Power: In this system 64 channel at ultra-narrow channel spacing i.e. 12GHz is used at -26 dBm input power.Where the other parameters are discussed above here only the raman pump power is varied that is 250nm , 550nm , 750 nm and the results are analysed with the help of optical WDM analyser.
2. Gain after first stage and 2nd stage of the HOA: In this system we have kept all the parameter same and only took readings after EDFA(first stage) and Raman (second stage) .Only pump power is 750dBm and the gain flatness and gain (dB) is observed at both first and second stage with the help of WDM analyser.

3. Change in input Pump of the given HOA: In this layout we have varied the input power -26,-10,0 dbm.In this we again observe the results for gain at the second stage and it is ovserved that the gain degrades with increase in the input pump.
4. Change in Core radius:In this system we varied a core radius of EDFA 2.2um,2.4um,2.8 um and analyzed the effect of this after final stage.It is found that as we increase the core radius Gain degrades and it is best at 2.2um.

System consisting of 43×40 Gbps DWDM HOA Network using different Modulation Schemes for instance RZ,NRZ,DPSK.The hybrid Raman and EDFA is studied for a 43 × 40 Gbps (DPSK) modulation format at channel spacing of 100Ghz. It is noticed that the implementedhybrid optical amplifier (HOA) gives better gain, signal quality and induces lesser crosstalk even when 1720 Gbps DPSK signals are sent over 150 km of pumped single mode fiber used along with dispersion compensating fiber.

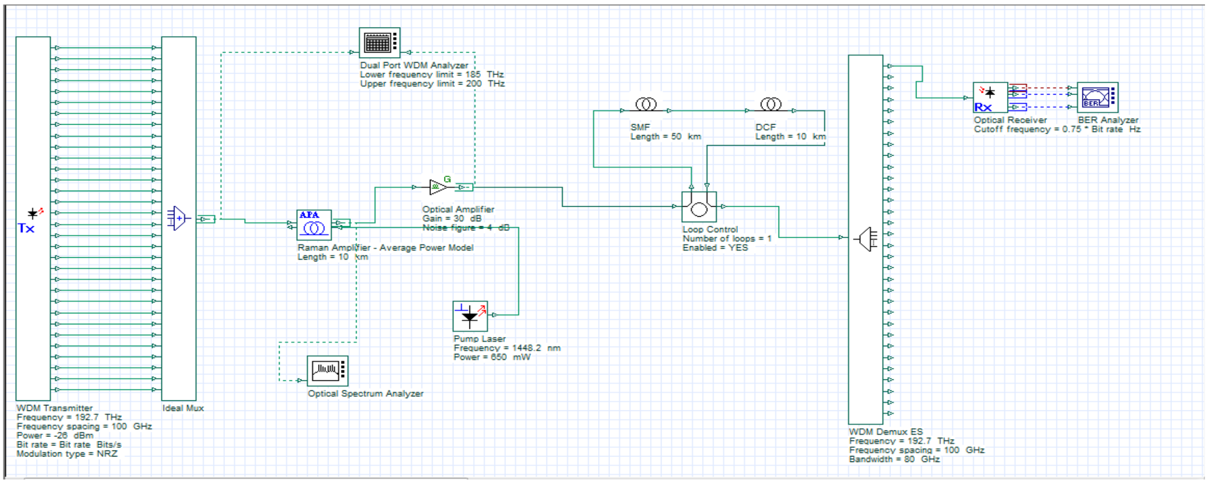


Fig.4.2 Circuit showing different modulation formats

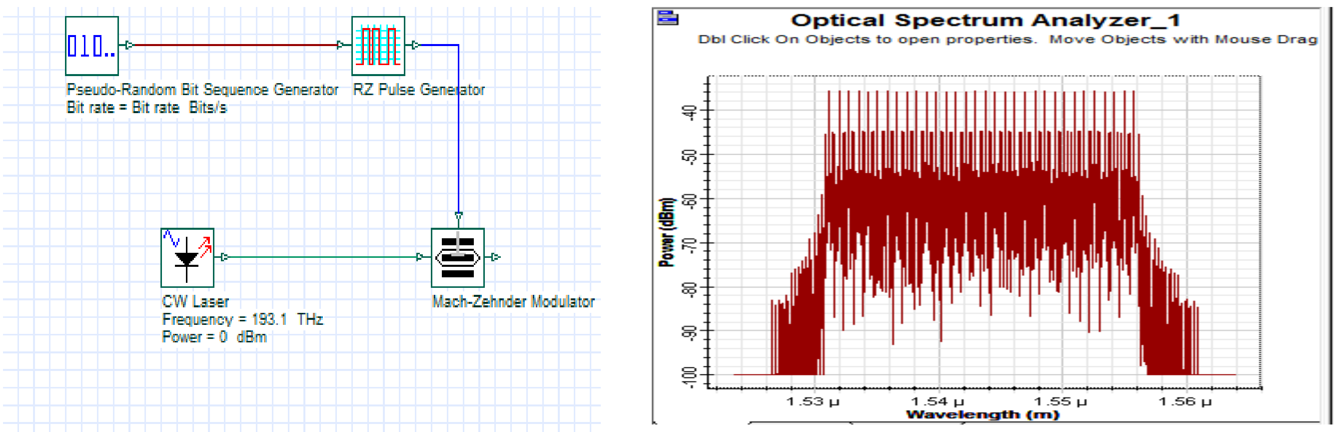


Fig 4.3 RZ modulator and spectrum

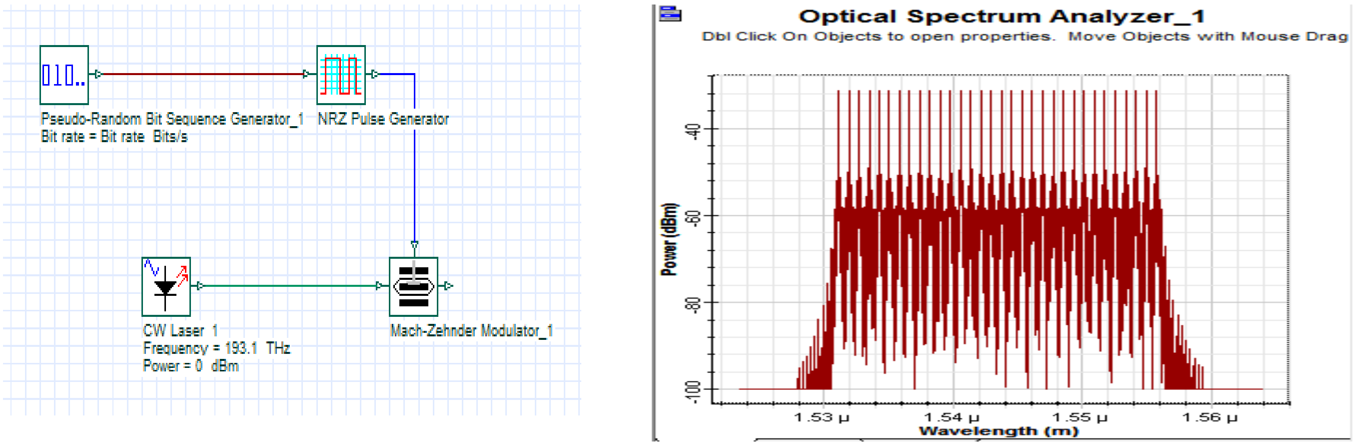


Fig. 4.4 NRZ modulator and Spectrum

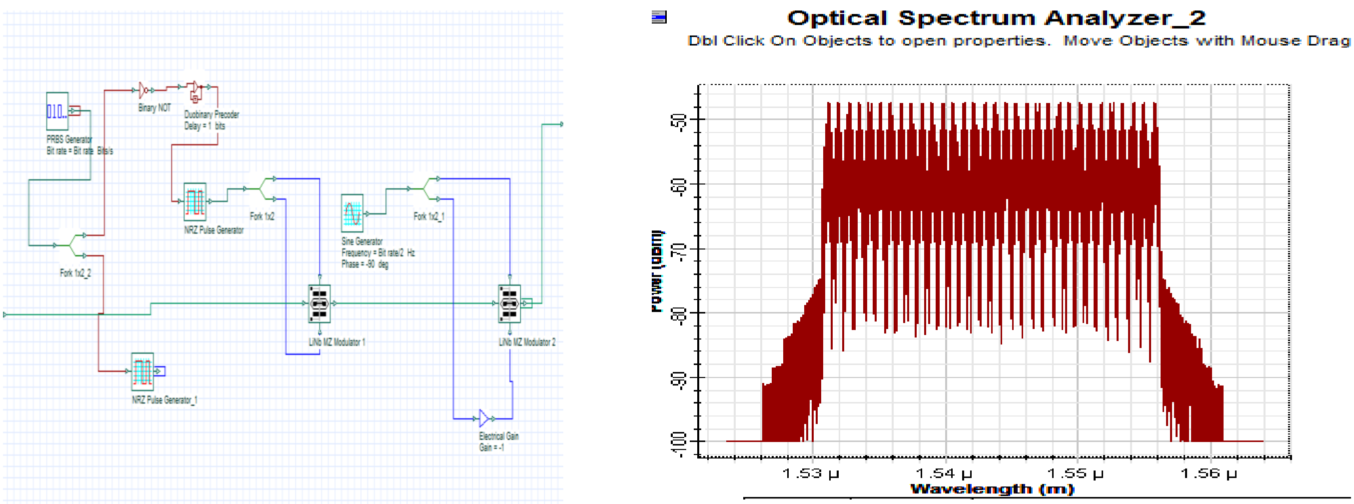


Fig. 4.5 DPSK modulator and spectrum

Performance analysis of high 43×40 i.e.(1.72Tb/s) DPSK using DWDM in HOA System. In this Objective, the innovative area of optical system and communication are recognized where the proposed HOAs, in the above objectives, are used as inline to seek out the better performance in the hybrid optical system. First of all, the hybrid Raman and EDFA are investigated for a 43 × 40Gbps ultra-high speed in the system using DPSK modulated format. The research has been done by assuming different channel spacing's between the adjacent channels. An enhancement has been reported as compared to the current state-of-the-DPSK scheme. Also, to utilize the bandwidth efficiently the new modulation format is used in the given system. It is based on concurrently modulation of non-return-to-zero and polarization-shift-keying. The new planned data format has also been studied for Raman-EDFA Hybrid Optical Amplifier as high speed DWDM applications systems. Further, an optimised and heuristic explanation is introduced for the DWDM systems. The solution is based on the principle of hybrid optical amplifiers for the high transmission of DWDM links and by replacing the usual optical amplifiers over the local links with the endeavour of minimizing the total count of the optical amplifiers needed in the system and hence the cost is reduced as well. The performance analysis of proposed HOA has also been chequered in the scenario of high capacity of long haul DWDM communication networks.

In the current, the DPSK is the capable modulation format which is prone in achieving the better performance for high-speed optical communication system at lower cost. Due to various losses the degradation in the signal power and reduction in amplitude of the signal, the optical amplifiers are essential to be used at the optimal position. Regrettably, the investigation of hybrid amplifiers being used for the optical network with DPSK modulation is not examined yet. The literature has offered various simulations on long- and short distance DWDM systems in the presence of lower cost of hybrid amplifiers. DWDM system in order to the additional increases the data rates. The communication was confirmed for DWDM at 50-GHz channel spacing over 1200 km in literature without assuming any type of inline dispersion compensation within the system. But the current work has been reported for the limited number of channels and also to described the particular data rate per channels is 40 Gbps. Also, in this investigation, only the conventional amplifiers are taken to use. In this Section of the report, the earlier work has been extensive by studying the Raman-EDFA HOA in set-up of ultra-high speed DPSK modulated DWDM system.

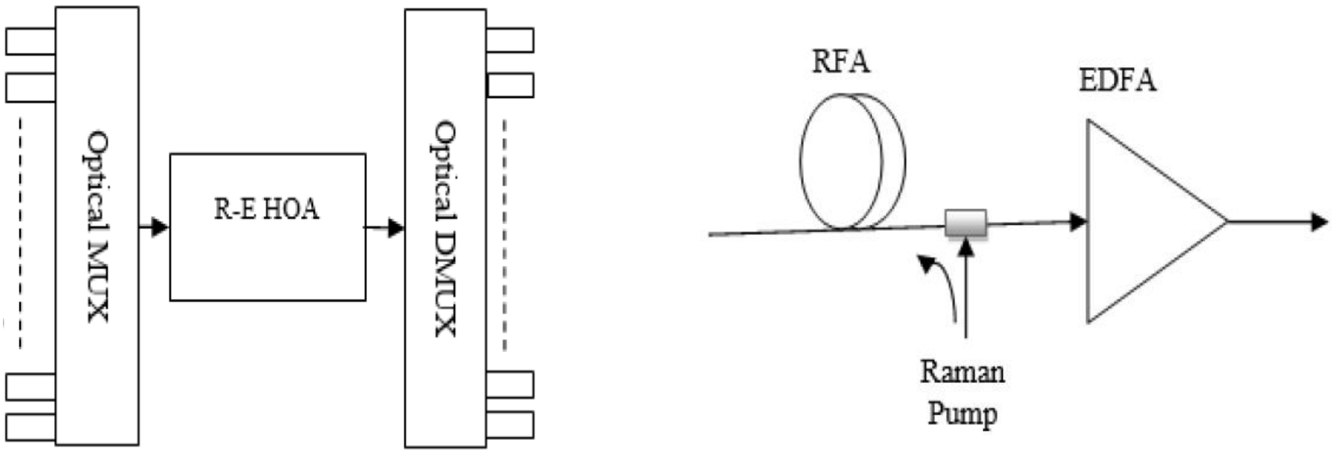


Fig. 4.6 basic block of HOA

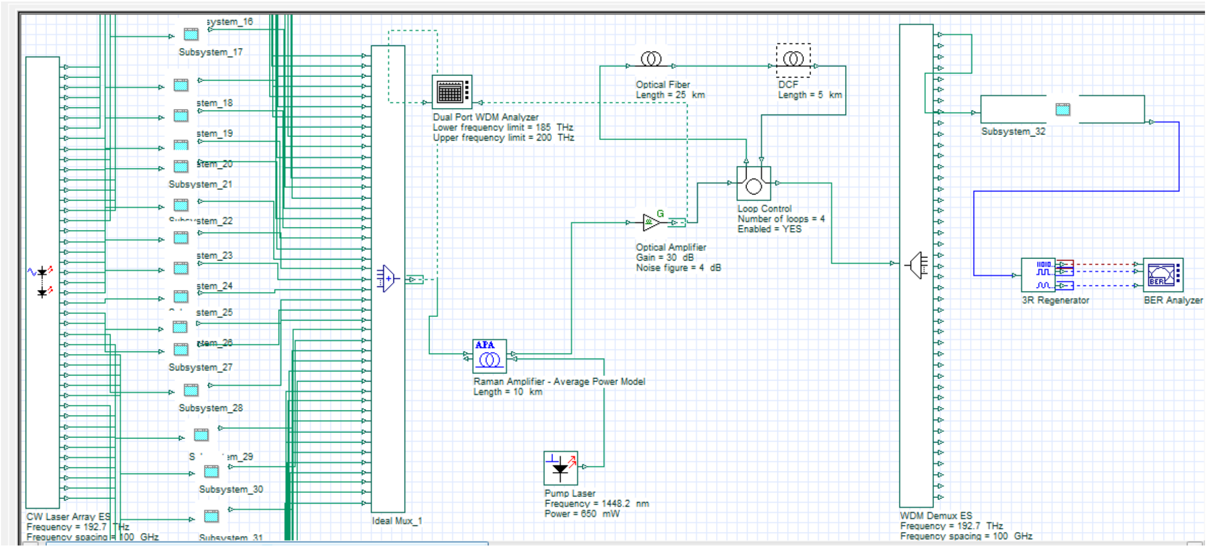


Fig. 4.7 simulation setup of DWDM 43×40 Gbps System

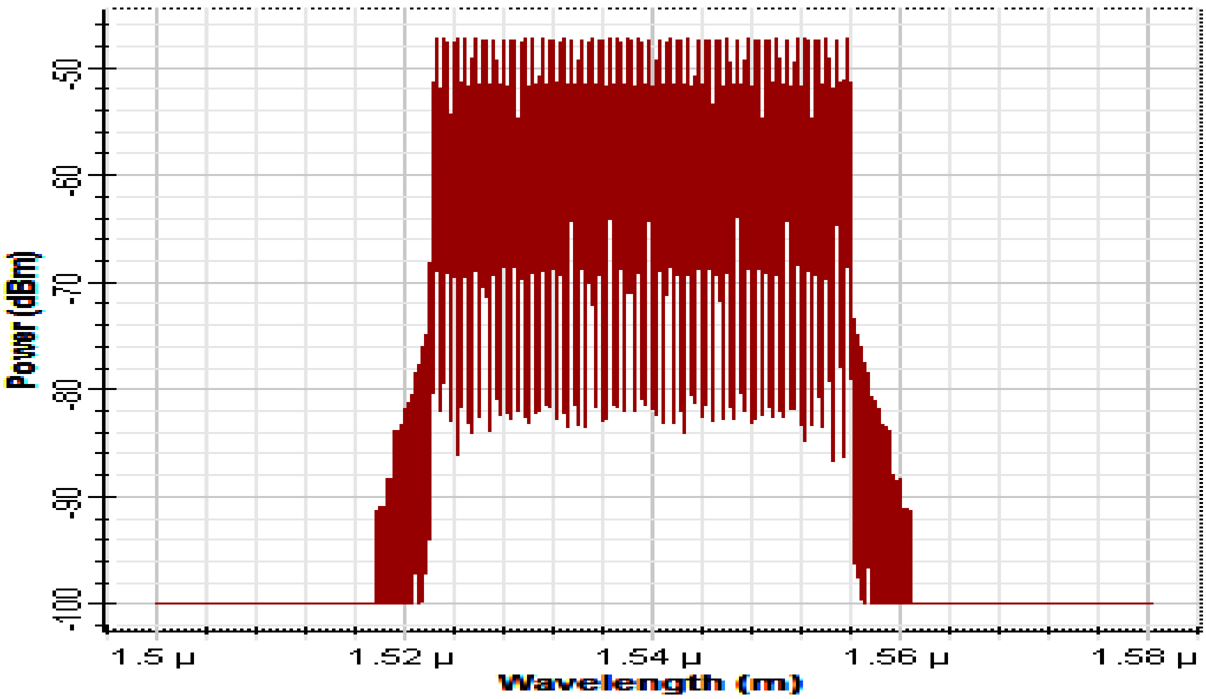


Fig. 4.8 Spectrum analyser at input DPSK

Numerical Simulation Setup

The proposed Raman-EoDFA (R-E) HOA as DWDM Network or system has been shown in Figure 4.7**.** The numerical simulation has been evaluated by using the Raman pump unit of 650 mW having the output power at 1448.2 nm.

In the various R-E configuration of the system, the Raman amplification has been made to operate with the reverse-propagating pump method so that the signal consists of lower pump noise coupling. In this system, the transmitter's source consists of 43 continuous wave lasers have been used by selecting the frequency. Here, the input power of each signal is tuned to −26dBm, as rise in the input power means squalor in the quality of received signal due to induced non-linarites. To drive an optical modulator, a pseudo-coded data bits with the DPSK digital sequence is generated by the pattern generator at 40-Gbps, is used.

Parameter	**Value**
Raman Fiber length	10 km
Raman Fiber attenuation	0.2 dB/Km
Raman Dispersion	2.75dB/km
Operating Temperature	300 K
EDFA Gain	30dB
Pump Power	650mW

Table 4.2 Parameters value in 43*40Gbps system

Chapter 5
RESULT AND CONCLUSION

As we know that HOA with ultra-low channel spacing is implementing to measure gain at first and second stage of hybrid system. It is observed that the HOA has flat gain at the first stage and higher gain is observed at the second stage of the hybrid system with approx. 2.5 dB of gain flatness. At the first stage of the amplifier, the gain flatness is 0.51 dB observed with maximum gain of 9.21 dB. The results are shown in figure 5.1.

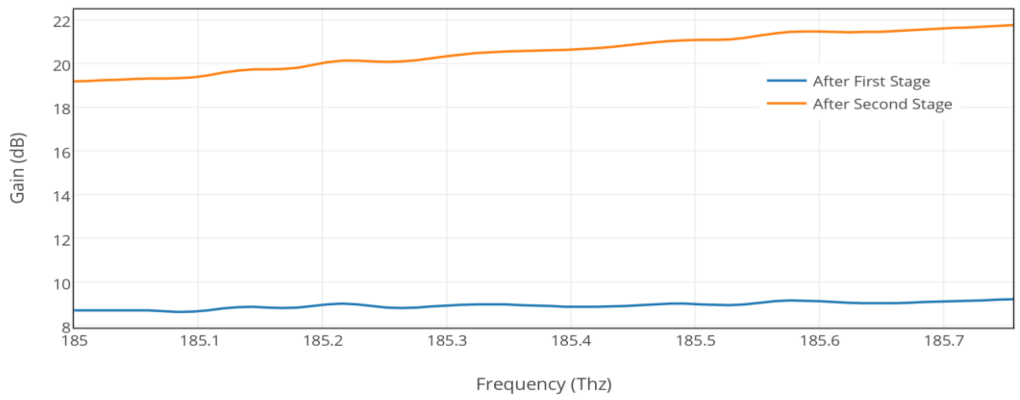


Fig 5.1 gain at First and Second Stage of HOA

The results are also calculated on the bases of varied input pump power. When the input pump power is -26 dB, the maximum gain of 13.06 dB at the second stage of HOA. As we increase the input pump power, we find that the maximum gain of 12.3 dB and 7.99 dB when the pump power is -10 and 0 dB respectively.

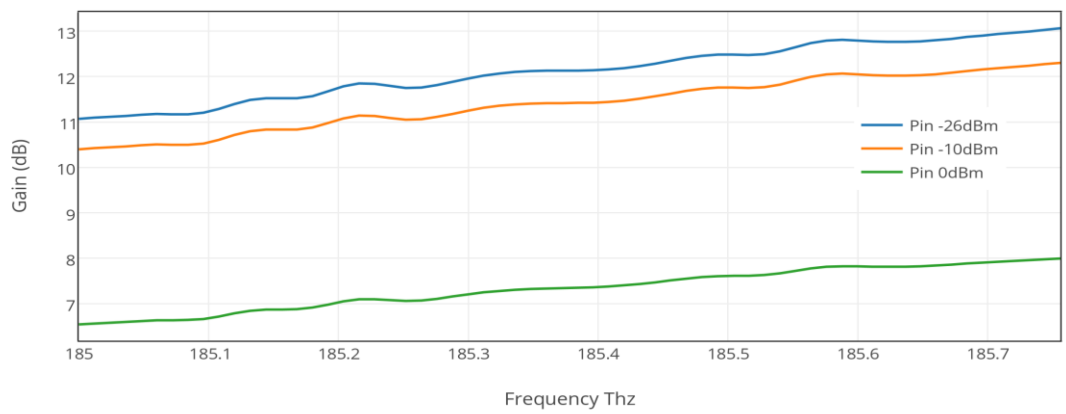


Fig 5.2 Gain at different input Pump Power

Here we have observed the gain at different value of Core Radius of EDFA. When the Core Radius of EDFA is 2.2um, the maximum gain of 13.06 dB is observed at second stage of HOA with gain flatness of 1.9 dB. When Core radius is increase 2.4um and 2.8um the maximum gain of 7.95 dB and 7.83 dB is observed with the gain flatness of 1.44 and 1.45 respectively. The result are shown in figure 5.3 .

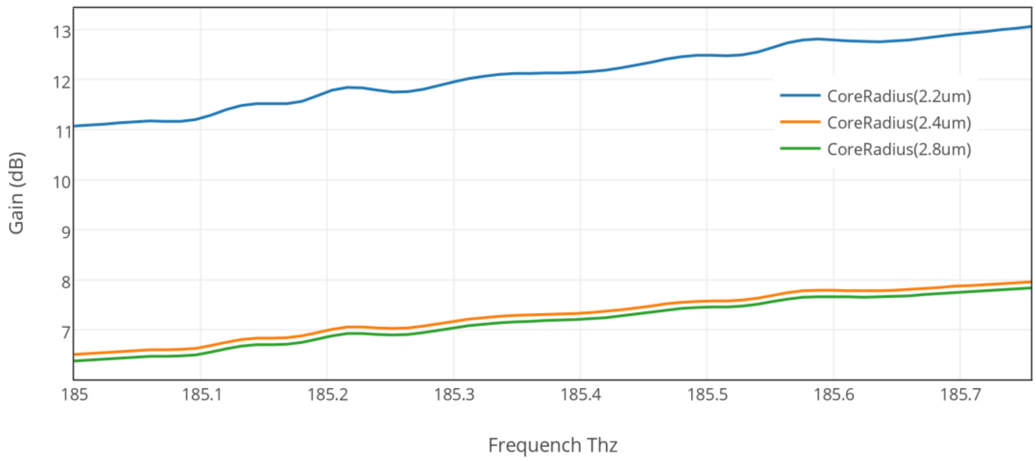


Fig. 5.3 Gain at different Core Radius of EDFA.

In figure 5.4, it is observed that when raman pump power is 250 mW, the maximum gain of 13.06 is observed with the gain flatness of 1.9 dB. When we increase the raman pump power to 550 mW and 750mW the maximum gain of 18.75 dB and 21.75 is observed with the gain flatness of 2.53 dB and 2.57 respectively.

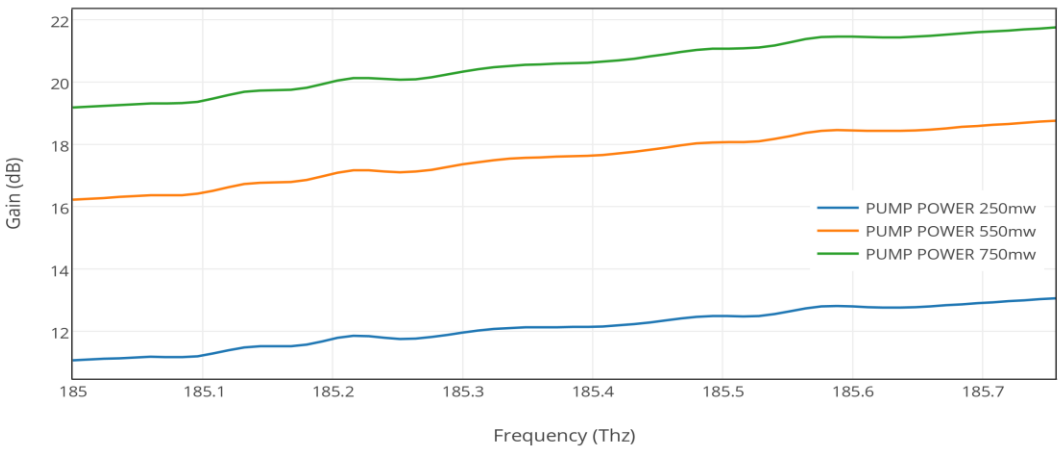


Fig. 5.4 Gain at different Pump power of Raman Amplifier

Conclusion: in the 64channel DWDM hybrid optical amplifier with channel spacing of 12Ghz starting at frequency of 185Thz to 185.756Thz. It is concluded that the highest gain of 9.2 dB and 21.75 dB is observed at first and second stage of HOA. When we increase the Core radius of EDFA the gain decreases to 13.06 dB, 7.95 dB, 7.83 dB is observed at 2.2um, 2.4um and 2.8um respectively. The gain of HOA decreases with increase in CORE Radius of EDFA. On the other hand we observed that with the increase in raman pump power the gain at the second stage of HOA increases. If we talk about the input pump power at the laser the value of gain decreases with the increases in input pump power of HOA.

Second results

In the figure 5.5 it is observed that for the 30×40Gbps HOA system when performed with different modulation schemes i.e. RZ,NRZ,DPSK it is observed that the quality factor of the system decreases with the increase in the length of the fiber. All the modulation schemes are performed for 60Km,120Km,180Km respectively. For 60 Km of length of fiber the quality factor of 4.463,6.064,8.25 is observed for RZ,NRZ,DPSK. For the length of 120 Km the Q factor of 4.382,6.079,6.823 is observed for RZ,NRZ,DPSK respectively and for the length of 180Km the Q factor of 2.5, 3.9 and 3.611 is calculated respectively.

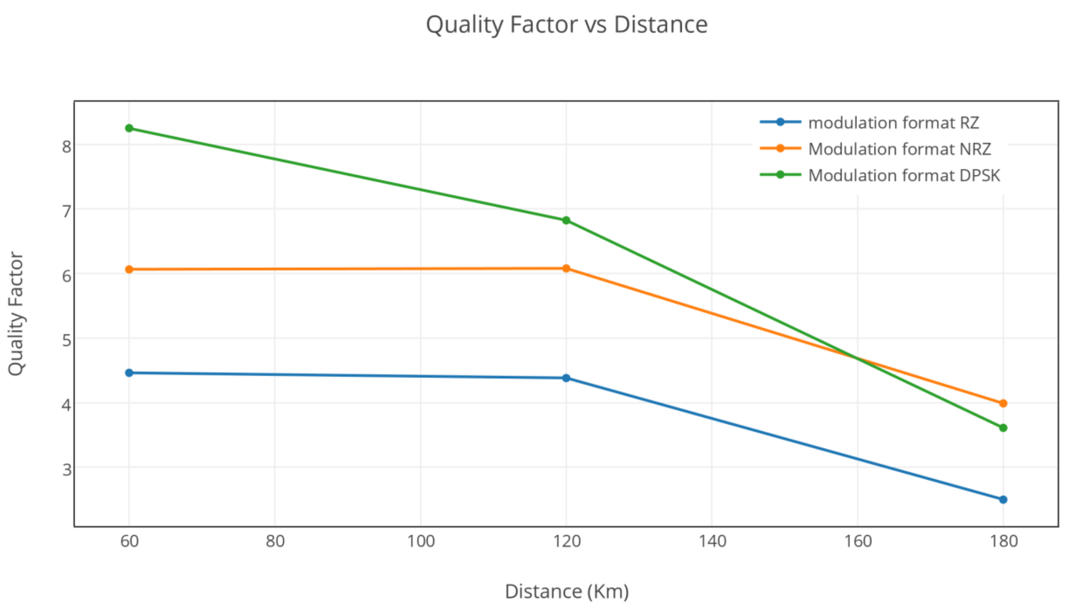
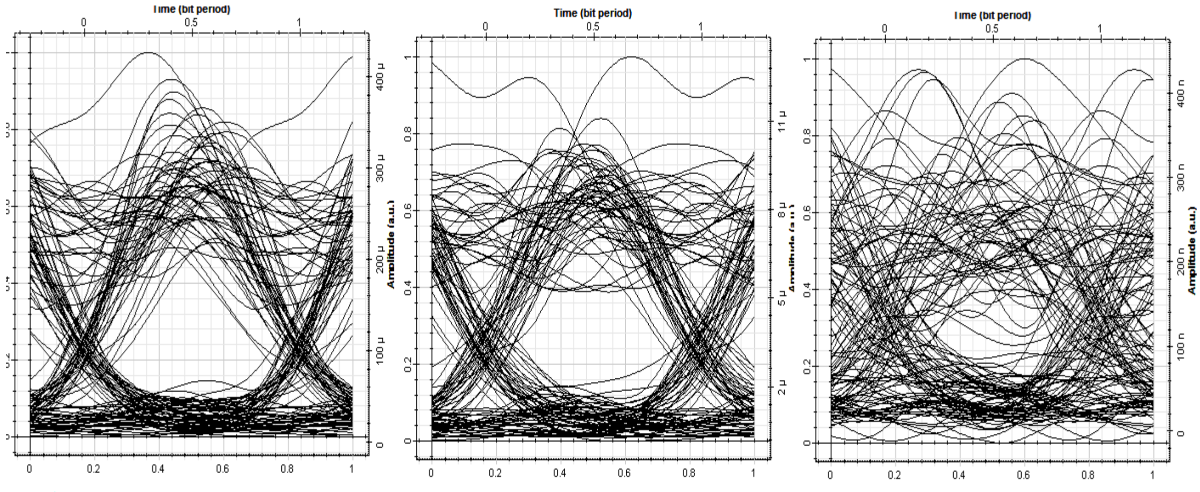


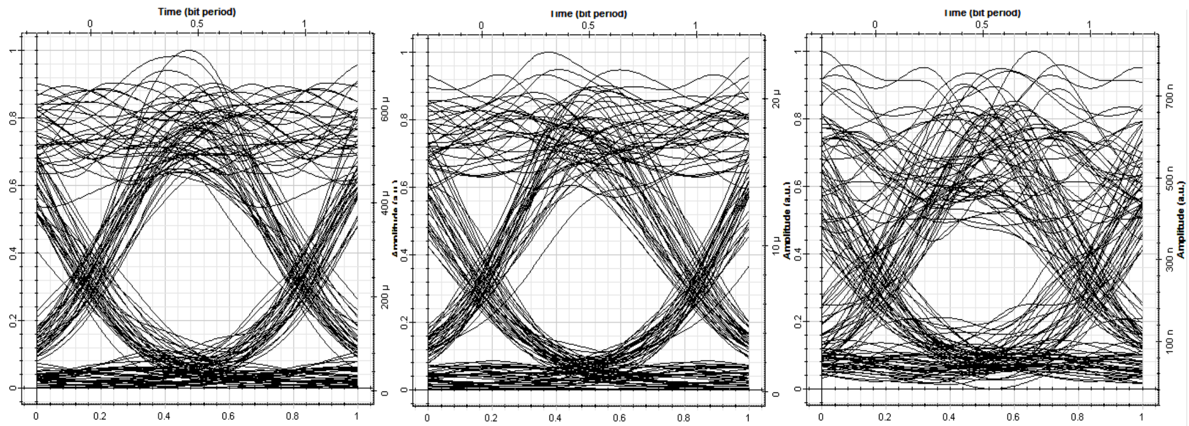
Fig 5.5 Quality Factor for Different Modulation Scheme with increase in distance.

The Eye diagrams for the different modulation formats are plotted below from the Eye Diagrams we can conclude that DPSK modulation scheme gives the best results over the other modulation schemes.



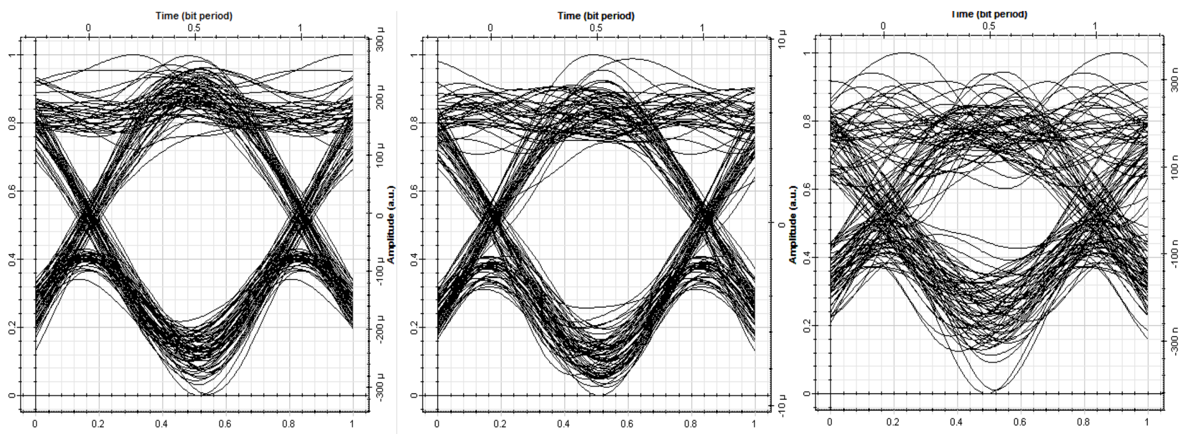
Eye Diagram for RZ at 60 Km **Eye Diagram for RZ at 120 Km** **Eye Diagram for RZ at 180 Km**

Fig 5.6 (A)



Eye Diagram of NRZ at 60 Km **Eye Diagram of NRZ at 120 Km** **Eye Diagram of NRZ at 180 Km**

Fig 5.6 (B)



Eye Diagram of DPSK at 60 Km **Eye Diagram of DPSK at 120 Km** **Eye Diagram of DPSK at 180 Km**

Fig 5.6 (C)

Fig 5.6 Eye diagram for different modulation schemes (A) RZ, (B)NRZ, (C)DPSK

Here the 43×40Gbps system is performed for the Raman-EDFA amplifier and the circuit is iterated for the different distances i.e 30Km,60Km,90Km,120Km,150Km for the starting frequency of 192.7Thz with the input pump of -26dB with the channel spacing of 100Ghz.

It is observed that the Q factor degrades with the increase in the fiber length as the distance increases from 30Km,60Km,90Km,120Km, 150Km the quality factor of 8.167832,7.60767,6.66541,6.12181 and 5.8767 respectively.

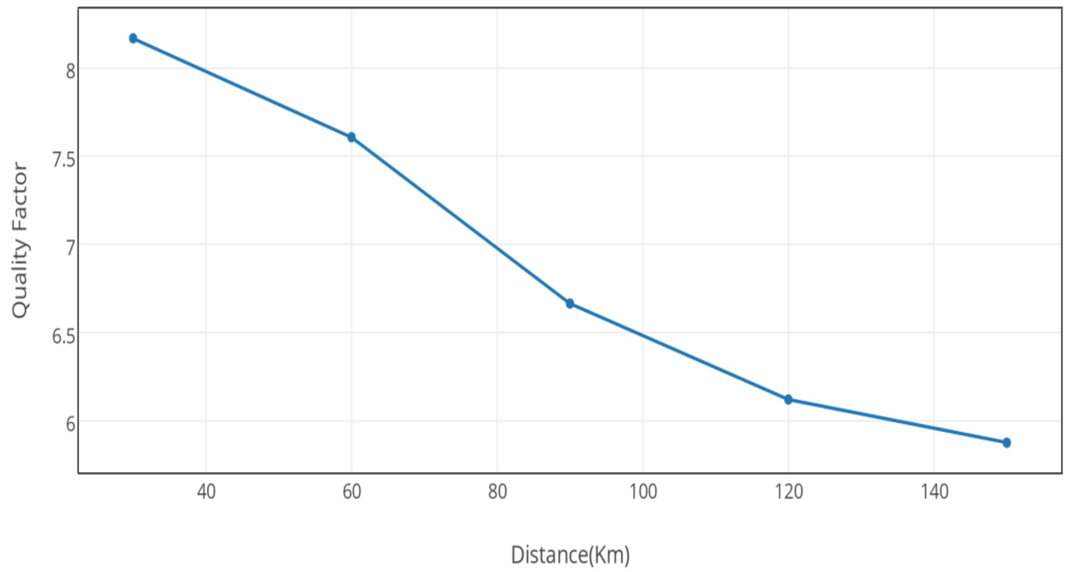


Fig 5.7 Distance vs Q factor for 43×40 Gbps DWDM system

From here we have concluded that with the increase in the length of the DWDM HOA network at 43×40 Gbps system the Quality factor degrades and the maximum acceptable results are obtained at the distance of 150Km with the more increase in the distance the results at the BER analyser degrades .

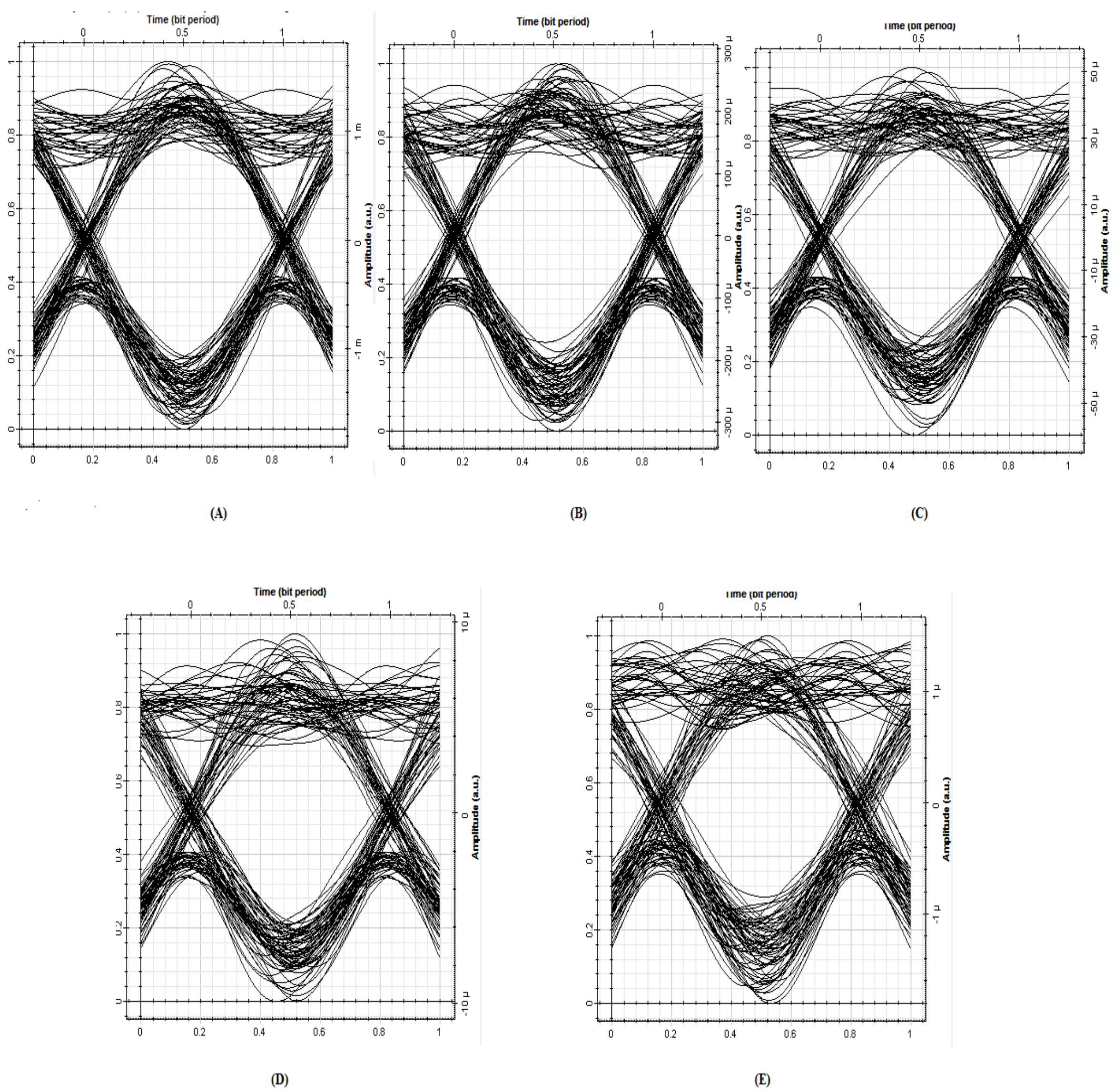


Fig 5.8 (A)System at 30 Km (B)System at 60Km (C)system at 90Km(D)System at 120Km(E)System at 150Km

Chapter 6
Summary

As we have concluded in the report that the Fiber optic network are the backbone of the communication network in the present scenario because they provide in higher bandwidth.

When the optical signal propagates inside the fiber then it gets degraded due to the effects of dispersion, scattering and non-linearity's present inside the fiber because of the presence of hydroxyl ions. To amplify the degraded signals so that they can propagate to the longer distances we use the optical amplifiers that amplify the optical signal directly without any O-E-O conversion.

On the other hand there are various problems in the optical Amplification process because one type of optical amplifier cannot amplify the wide range of frequency to overcome this problem the use of HOA comes into the picture .In this report we have observed the effect of HOA for the gain flatness with the change in various parameters like Raman pump power, input pump power,EDFA core Radius for the DWDM systems at very low channel spacing

The HOA is also studied for the different modulation Format i.e. RZ,NRZ,DPSK modulation scheme and it is observed that DPSK gives best results over all modulation formats and after that DPSK is used for 40×43Gbps system and its Quality factor is measured by applying different loops at different distances. And the given system work well for 150 Km of the distance but beyond this distance the result of the System degrades.

Future Scope:

- The novel mixture of Raman amplifier with some rare doped amplifier should be studied for covering much wider gain bandwidth spectrum
- As we know application in the Hybrid Optical Amplifier in the Broad area transmission network as pre, post, in-line amplifiers. The assignment of best HOAs in different optical network can be evaluated.
- Some other Modulation formats or schemes can be implemented to increase the acceptable quality factor in the optical hybrid networks.

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