DENSE WAVELENGTH DIVISION MULTIPLEXING LINK TRANSMISSION USING HYBRID AMPLIFICATION

DISSERTATION-II

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This is to certify that I Poda Ramanjaneyulu bearing Registration No 11506925 has completed objective formulation of thesis titled, **“**DENSE WAVELENGTH DIVISION MULTIPLEXING LINK TRANSMISSION USING HYBRID AMPLIFICATION” under my guidance and supervision. To the best of my knowledge, the present work is the result of her original investigation and study. No part of the thesis has ever been submitted for any other degree at any University.

The thesis is fit for submission and the partial fulfillment of the conditions for the award of

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I, Poda Ramanjaneyulu, student of M-Tech Electronics and communication under Department of Electronics and communication of Lovely Professional University, Punjab, hereby declare that all the information furnished in this Dissertation-II report is based on my own intensive research and is genuine.

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ABSTRACT

For Several years now, optical fiber communication systems are being substantially used all over the global for telecommunication, video and data transmission purposes. The demand for transmission over the global telecommunication network will keep growing at an exponential rate and only fiber optics could be capable of meet the challenges. Presently, almost all of the trunk lines of the existing networks are using optical fiber. This is because the optical fiber able to permitting the transmission of many signals over the long distances. But, attenuation is the major problem imposed by the transmission medium for long-distance excessive-speed optical systems and networks. So, with the growing transmission rates and needs within the subject of optical communication, the electronic regeneration has become more expensive. The effective optical amplifiers got amplifier come into existence, which eliminated the expensive conversions from optical to electrical signal and vice versa. Due to the need of longer and longer unrepeated transmission distances.

Wavelength division multiplexing (WDM) optical transport networks are expected to provide the capability required to satisfy the growing volume of telecommunications traffic in a cost-effective way. This thesis is investigating the ability of optical amplifier running at 8 × 10 GB/s in optical communication system. Three types of Hybrid optical amplifiers have been investigated independently and compared.

In this thesis, the 8 channel WDM systems at 10 Gbps have been investigated for the various optical amplifiers and hybrid amplifiers and the performance has been compared on the basis of transmission distance, Gain and Quality Factor. The amplifiers EDFA, RA and SOA have been investigated independently and further compared with hybrid amplifiers like RA-EDFA, EDFA-EDFA and EDFA-SOA. It is observed that optical hybrid amplifiers provide the Flat gain at 200 km with the power of -15 dBm. It is observed that upto 100 km the EDFA-SOA provide the better BER than the EDFA-EDFA, EFDA-RA and the after 100 km EDFA-SOA has less power when compared to them.

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LIST OF ABREVATIONS

BER	Bit Error Rate
CD	Chromatic Dispersion
CNR	Carrier to Noise Ratio
DCF	Dispersion Compensated Fiber
DFB	Distributed Feedback
DFA	Doped Fiber Amplifier
DRA	Distributed Raman Amplifier
DS	Dispersion Shifted
EDFA	Erbium-Doped Fiber Amplifier
FRA	Fiber Raman Amplifier
GVD	Group Velocity Dispersion
HA	Hybrid Amplifier
ISI	Inter Symbol Interference
NB-HA	Narrow Band Hybrid Amplifier
NDS	Normal Dispersion Shifted
NF	Noise Figure
OADM	Optical Add/Drop Multiplexer
OAMP	Optical Amplifier
OFA	Optical Fiber Amplifier
OXC	Optical Cross Connect
PON	Passive Optical Network
RF	Radio Frequency
SMF	Single Mode Fiber
SNR	Signal to Noise Ratio

SOA	Semiconductor Optical Amplifier
SRS	Stimulated Raman Scattering
WDM	Wavelength Division Multiplexing
WLAN	Wireless Local Area Network

CHAPTER 1

INTRODUCTION

1.1 Introduction to Optical Fiber Communication

Development of optical fiber (OA) communication has made progressing quickly for the beyond many years. Optical fiber communication frameworks have a protracted history and it became acknowledged all through the second half of the twentieth century that an extra transmission bandwidth might be carried out through making use of optical waves as the carrier. However, these possibilities become not abused up to the innovation of laser inside the 1970s [1]. With that approach of the laser and in this manner the accessibility of an optical coherent resource, some other modern manner for the optical conversation has been made. Initially, the expansive loss has made them appear impractical. At that factor Werts and Hockham observed the huge losses have been an outcome of impurities inside the optical fiber fabric and that the mislaying should reduce through using glass-primarily based optical waveguide. These become acknowledged in 1970, and after that prevailing to creating a Si fiber with the attenuation of approximately 30 dB/km [2]. This make the transmission of couple of kilometers which is commercially achievable. In the meantime, optical semiconductor lasers, GaAsP working continually at the room temperature were proven. Original light wave frameworks working close to 0.8 µm turned out to be monetarily accessible in 1980 and these frameworks were working a bit rate of 45 Mb/s with permitted spacing dividing of 10km. In a traverse of a couple of years, second era light wave frameworks working close to 1.3 µm were created. The merits of working at the wavelength could build increase the dispersion. It was additionally found that the optical fiber loss is beneath 2 dB/km [3] and it shows dispersion at 1.3 µm wavelength area.

Original light signal frameworks working close to 0.8 micrometer turned out to be monetarily accessible in 1980 and these frameworks are working at the bit rate of 45mb/s with the permitting use of distance of 100 km. Second era framework became created by way of utilizing GaAsP detector and lasers, the bit rate became confined to under 100 Mbit/s because of the scattering in multi-mode fibers. With the presentation of single mode fiber until the mid-80s, this problem has become conquer. With the aid of 1987, second era light systems waves have been operating at the bit error rate of 1.7 Gb/s with a repeater dispersing up to 100 km.

However, it became determined that second generation technology frameworks had been confined by way of the fiber misfortune at 1.3 μm, along these lines with a specific end goal to accomplish a higher data rate or the distance it must work close to 1.55 μm where the loss is very less in silica fibers. Here, they found another issue with traditional in GaAsP semi-conductor laser, as they couldn't be utilized as a result of pulse spreading which results to simulation of several longitudinal modes [4]. Two techniques were acquainted with adapt to this spacing issue.

The main principle method was the utilization of a dispersion shifted phase fibers, which can be used to have a base dispersion close to 1.55 μm and the second technique was to confine the laser range to the independent to longitudinal mode. In 1990, third era 1.55 μm frameworks were produced by utilizing those methodologies and the different systems that are working at a bit rate of 2.5 Gb/s. regardless for the good execution of the third era frameworks, they have found first demerit: the want to get better the signal occasionally by utilizing repeaters normally at the spacing 70-80 km separated [5].

The main problem was overcome with the approach of optical fiber amplifiers within the mid-90s. The fourth era frameworks were created utilizing fiber optical amplifiers (OA) to accelerate the repeater desperation and the bit rate. The invention of erbium doped fiber amplifier (EDFA) was a primary advantage for the research studies for the optical fiber technology inside the 1.55 μm wavelength area and it substantially affected ultra-length long haul transmission systems. Erbium doped fiber amplifier has made it attainable to transmit the optical higher than the hundreds of kilometers without using the electric repeaters, simply by falling optical amplifiers and fiber segments in a sequence [6]. The innovation has permitted systems to transmit the information to longer distance and at a faster information charge. By means of 1996, it became accounted that fourth-era frameworks were suit for transmitting more than 12,300 km at the bit rate of 10 GB/s.

Although optical amplifiers need to remedy the loss trouble, they refuse the dispersion issue since the dispersive impacts aggregate over different amplifications phases. Consequently, the fiber dispersion or the spacing remains in fourth era systems while 5th generation frameworks are struggled to find the solution. By using the early piece of the 2000s, nearly the long-haul deal (which is in between 200-900 km) or the ultra-long haul (higher than 900 km) fiber-optic transmitting system by using making use of Raman Effect. Raman amplifiers (RA) had been no longer deploy until the late Nineteen Nineties.

This challenge has slightly changed into a moderately bad efficiency in the Raman amplifiers at lower level signal output power. Erbium-doped fiber amplifiers require the powers inside the range of 5 to 20 mW, even as Raman amplifiers requires the power within the variety of one to five Watts. By this way, to upgrade the gain up to 20 dB or even more it is more required to extent high pump power in Raman amplifiers (RA) [7]. Presently Optical hybrid amplifiers (HOA) high output power gain.

The tremendous development of the rapid Internet and information movement has made a highly growth for high transmission data transfer capacity for the Dense wavelength division multiplexing (DWDM) optical communication frameworks. With the improvement of high optical communication innovation, it is urgent demand for expansive limit, ultra-long-remove transmission system, and then DWDM applications [8].

Optical fiber is utilized to convey extensive number of autonomous data with various channels having their own particular wavelength in single fiber. Here the Dense Wavelength Division Multiplexing (DWDM) is introduced.

Compared with communication systems, DWDM frameworks had the elements of huge data transfer capacity, expanding the transmission limit, current interchanges organize and in addition the extension of basic, reliable and so on. For long-haul optical fiber communication, optical amplifiers are a key for optical transmission with DWDM. Semi-conductor optical amplifier (SOA), Erbium doped fiber amplifier (EDFA) and Raman amplifier (RA) are the regular optical amplifiers that are used in the operation for DWDM system.

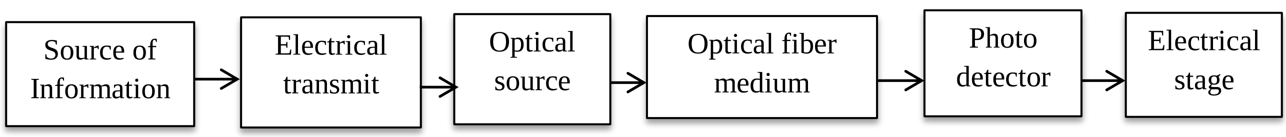

Figure: 1 Block diagram of optical fiber communication [8]

Optical amplifier is the device which amplifies or increases the information of the input signal to output and its works in the stimulated emission process. Pre-amplifier and Post-amplifier are utilized to keep up the quality in the signal now a day. SOA, RAMAN and EDFA are mainly used to boost up the signal.

These amplifiers have the ability of increasing various signals by giving the better information rates. Optical gadgets are used for higher wavelength optical communication system as a result of its having the benefits of high gain, substantial transmission capacity and better execution.

Essentially, there are three primary components in fibre optic communication framework. They are

1) Compact light source
2) Low less Optical fibre
3) Photo detector

Depending upon the application like LAN these light sources are required. In this they incorporate power, speed, noise and so forth light emitting diode and laser diode are the primary parts utilized as a part of the light sources [8]

Optical fiber well known as the cylindrical shaped dielectric waveguide which is comprised of low loss material. It is made up of great expelled glass and it is flexible to the diameter across of this link in 0.25 to 0.5 mm.

The primary standard of photo detector is to change the light signal to electrical signal. Depending upon the client wavelength PN photograph diode and avalanche photo diode is utilized. The bit error rate and provision flat gain is probably depended on the reliability of the communication link. Optical amplifiers unquestionably assume a fundamental part in such situations as opposed to optoelectronic devices and repeaters which are very complex and costly for WDM. In the recent years, Raman amplifiers have the attenuation for long transmission communication and high capacity. While SOA and EDFAs have more use in WDM systems since they are high on–off proportions and increment transmission distance. This network arrangement aimed for decreasing the wavelength dispersion of 0.8 nm which is the currently in operation to beneath than 0.5 nm [9]. Control of the frequency adherence and development of frequency de-multiplexing accessories are analytical to those efforts.

1.2 Optical amplifier

1.2.1 Principal of Optical amplifier

An important optical fiber communication interface incorporates an optical fiber link associating with the transmitter and receiver. Despite the fact that the signal transmitting in the optical fiber go through some distance much less attenuation than the different mediums. For example, copper, there may be nonetheless difficulty around one hundred kilometer on the gap of the signals that can travel earlier than noise and can be easily detected.

Optical amplifiers are broadly utilized in fiber optic information data source links. Optical enhancement makes use of the principle of the stimulated emission, like the approaches utilized as a part of a laser. The stimulated emission takes place, while incident photon having electricity energy $E = hc/\lambda$ communicate with photon in higher strength state making it go back over into lower state with formation of second photon, where h is Plank constant, c is velocity of light and λ is the frequency. The optical amplification occurs, when the emitted photon and incident photon are at the stage and discharge greater photons. This process continuous effectively makes avalanche multiplication and the amplified coherent emission is received.

1.2.2 Different types of Optical amplifiers

Optical amplifiers have been characteristics on the basis of these elements: it is based on the linear characteristics or non-linear characteristics.

1.2.2.1 EDFA

The EDFA comprises of three essential additives: pump laser, duration of erbium doped fiber, and frequency unique coupler to sign up for the pump and signal wavelengths as regarded in figure3. The length of the optical fiber utilizes the pumping wavelength, pump power, quantity of erbium doping and the signal power. Due to the compatibility in the optical fiber Erbium doped fiber amplifiers (EDFAs) may be extensively utilized. An EDFA has an exceptionally huge wavelength scope that amplifies the making of useful as transmission amplifier in wavelength division multiplexing frameworks. Theoretically EDFA is equipped for amplifying all of the wavelengths going from 1450 to 1600 nm. However, for all intents and functions there are two kinds of windows for the wavelength. Those are called C-band and L-band. This permits the information data to simulate the excited atoms to discharge photons. Many of the erbium-doped fiber amplifiers (EDFAs) are pumped by means of lasers with in the wavelength of both 960 nm and 1460 nm [10]. The 960-nm pump frequency has validated the efficiency of around10 dB/mW, and the 1480-nm pump wavelength gives the efficiency of around 5dB/mW. Typical gains are at the request of 25 dB. Generally, noise figure in the EDFA lies between 5-6 dB with ahead pumping power and comparable figures for in reverse pumping are 7-8 dB accepting 1460 nm pumping signal has been utilized.

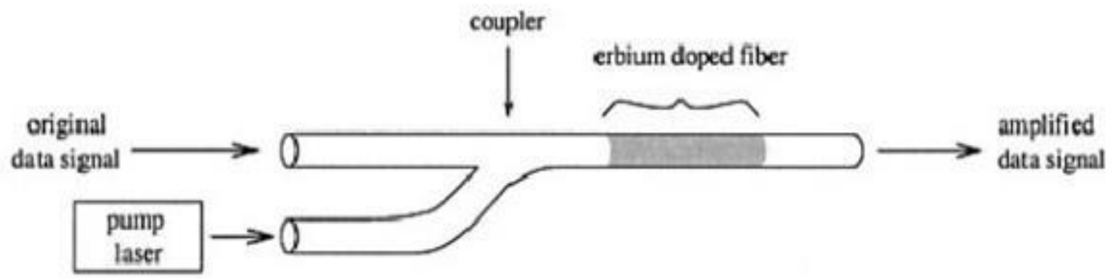

Figure 2: Erbium Doped Fiber Amplifier [10]

1.2.2.2 RAMAN Amplifier

Raman stimulated gain in optical fiber occurs with the exchange of power with one optical beam to any other optical beam through the transfer of energy in a phonon. The phonon emerges when the light emission couples the vibrational strategies in the medium. In case of this, the optical fiber is the amplifying standard making the gain provided by Raman amplifiers reliant on the optical fiber's number.

In Si fibers, the Raman gain transfer capacity is more than 240 nm, with the overwhelming taking place at 85 nm from the pump power wavelength. This power the Raman gain to increase accessible over the complete transmission range of the optical fiber the length of an appropriate pump source is obtainable. The gain displayed with the aid of the Raman Effect which is fused by Si glass is polarization built therefore, only the gain occurs in both the pump beam and the signal of the comparable polarization. To the Raman fiber amplifier (RFA), potential is given by using optical pump for the transmission of optical fiber; the pump wavelength must be very less than the wavelength to be enhanced by the sum that relates to an optical fiber frequency difference of round 12.4 THz [11]. The signal is then experience the gain due to stimulate Raman emission Scattering (SRS), a nonlinear optical procedure in which a pump electron is consumed and right away remitted as a signal photon and phonon, subsequently amplifies the signal as appeared in figure 3.

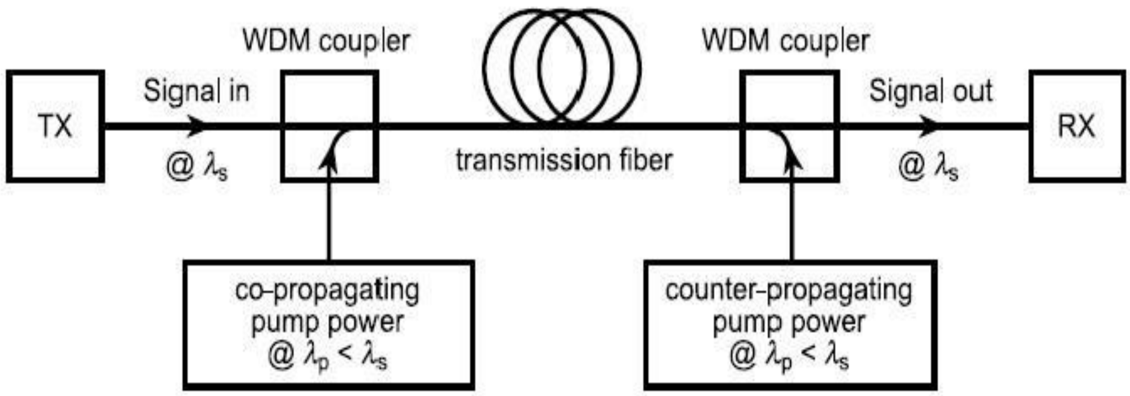

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Fig No: 3 Raman Amplifiers [11]

1.2.2.3 Operation Semiconductor Optical Amplifier

Semiconductor laser is the modified version of the semiconductor laser amplifier, having ordinarily has one-of-a-kind of different device length and characteristic reflectivity. Semiconductor optical amplifier (SOA) was fundamentally similar to a laser with the exception of no reflecting functions. A susceptible signal is sent via the active area of the semiconductor, which, by means of stimulated emission, brings out the strong signal produced from the semiconductor.

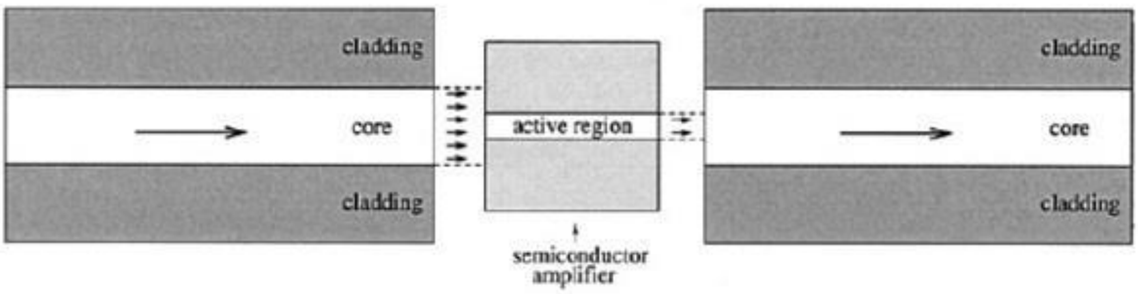

Fig No: 4 Semiconductor Amplifiers [10]

SOA's are normally uses in the following measures:

1) Used as energy boosters to boost the signal following the source.
2) For the long-distance communications, we provide optical amplification (in-line amplification).
3) Photo detector after the Pre-amplifiers.

1.2.2.4 Hybrid Optical Amplifier

The cascading of the two optical amplifiers Raman amplifier (RA) and Erbium-doped fiber amplifier (EDFA) is known as a hybrid optical amplifier (HOA), the EDFA-RA. The cascading a semiconductor optical amplifier (SOA) and the erbium-doped fiber amplifier (EDFA) is known as a hybrid optical amplifier (HOA), the EDFA-SOA. Hybrid amplifier gives high power gain.

$$GHybrid = GEDFA + GRaman$$

Two sorts of elements present in the hybrid optical amplifier (HOA) they are: the narrow band Hybrid Optical Amplifier (NB-HOA) and the other one is wide band Hybrid Optical Amplifier (WB-HOA). The NB-HOA utilizes erbium-doped fiber amplifier (EDFA) in the transmission fiber together with a distributed Raman amplifier (DRA) and gives low transmission of noise in the C-band and the L-band. The noise figure in the transmission line is very less when it is more compared with the EDFA was utilized. The WB-HOA, then again, it employs the EDFA together with the discrete Raman amplifier and give a wideband transmission line and low-noise to the C-band and L-band. The gain transfer bandwidth transmission speed ($\Delta\lambda$) of the Narrow Band-HOA is 40 to 50 nm and the Wide Band-HOA is 80 to 90 nm.

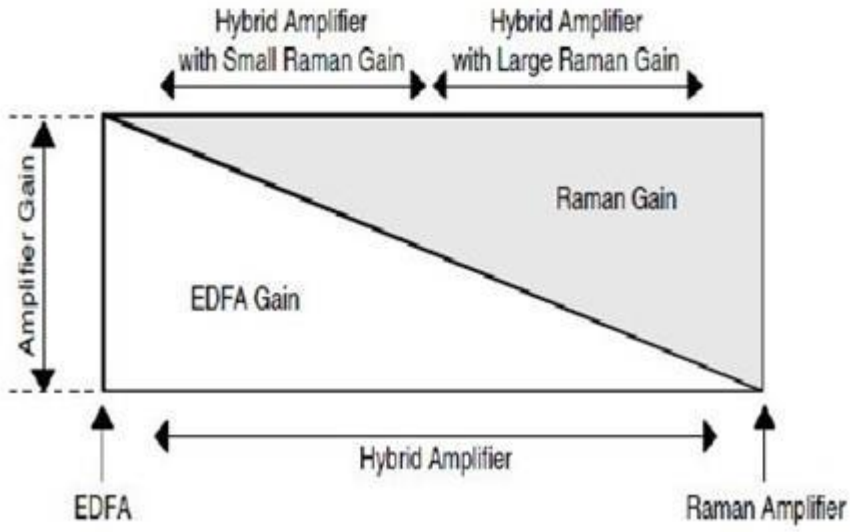

Fig No: 5 Hybrid Optical Amplifier [10]

1.2.2.5 Comparison of Various HOA

Parameters	Gain and NF	Gain Parameters	No of Channels	Gain Bandwidth
RA + EDFA	Gain>10db	4.6 dB	160	3.98 THz
EYCDFA + EDFA	Gain~36db	Flat	-	-
EDFA + SOA	Gain>24db	~0.74 dB	100	25 nm
Raman+ EDFA + HOA	Gain>10db	~1.76 dB	100	20 nm

Table 1: Comparison of different HOA

1.2.2.6 Applications of Hybrid Optical Amplifier

1) Pre-amplifier

-It is an electronic device which is used to amplifies a very weak signal or the Low Noise and improves the sensitivity of receiver

2) In line amplifier

-These are the type of amplifier situated in a Transmission line to strengthen the attenuated signal for transmission onto the next location

3) Booster amplifier

-TV

4) LAN booster amplifier

1.3 Operation of Wavelength Division Multiplexing (WDM)

Wavelength division Multiplexing (DWDM) which can be applied to multiplex various optical provider alerts right into a single optical fiber utilizing different wavelength. In wavelength division multiplexing (WDM) lasers of various wavelength are balanced with the aid of separate information streams and modulated light waves are passively consolidated and dispatched to a comparable fiber at the other side with unique wavelengths are separated individually demodulated and all of the information streams are recuperated. Thus, wavelength division multiplexing creates many channels over a similar fiber [12].

Wavelength division multiplexing (WDM) is a tackle which can exploit the tremendous optoelectronic bandwidth bungle by using requiring that each end user hardware work just the electronic bit rate but different optical signals from the various ends are multiplexed to the same fiber. There is a strategy for using amplifiers for ideal usage of available fiber data transfer capacity i.e. by this way using various methods for utilizing different techniques of optical amplifiers in various frequencies were used. The hybrid optical amplifiers can be associated either in series or in parallel and this setup is named as Hybrid optical amplifier.

In comparable setup, the DWDM signals are first of all demultiplex into a several wavelength band bunches with the coupler, then they're amplified by different amplifiers that have gain within the touching on wavelength band and afterward they're combined with the coupler. The description of the comparable setup is exceptionally basic and relevant to all optical amplifiers [13].

However, with the weaknesses additionally e.g. an unusable frequency area continues among every gain band protect from the guard defend band to the coupler likewise, the noise figure decreases because of the lack of the coupler placed before every amplifier. Despite what might be expected, the amplifiers are associated in sequence have moderately wide gain band width, since they don't require different couplers.

WDM compares to the plan in which dissimilar optical amplifier carrier at different wavelengths are regulated by using autonomous electrical source bit streams and they are then transmitted over a comparable fiber. Optical signal at the receiver end is De-multiplexed into autonomous channels by using the optical system strategy. The advantage of EDFA is that they are prepared for amplifying signals at numerous wavelengths all the while. This gives another way to deal with growing as far as possible. At each regenerator range, a single optical amplifier could replace a variety of costly regenerator, one for every fiber.

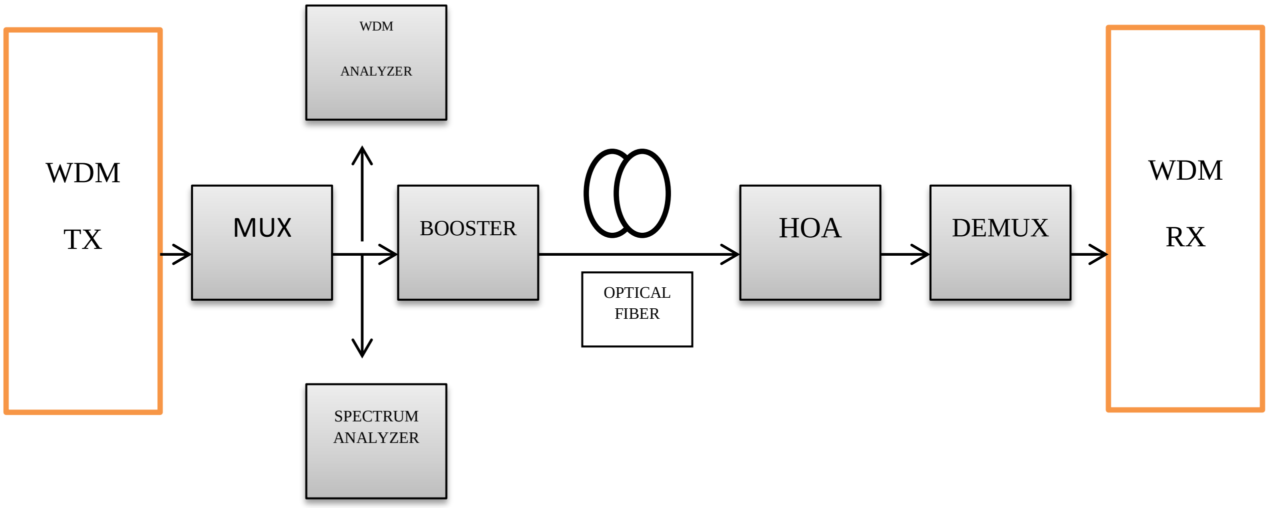

Fig No: 6 DWDM Block Diagram

The first generation of WDM systems gives just the indicate point physical connections, which are point to point either static or physically designed the second generation of WDM is equipped for setting up end-to-end connection oriented light way sin the optical amplifier layer by presenting optical add-drop components (ADM) and optical cross connects(OXC). The mesh topologies and ring can be executed utilizing these OADMs and OXCs. The Diagram for the WDM is demonstrated as follows.

1.4 Optsim

In 1983, optical communication group of Politecnico di Torino has determined the core variant of OptSim. Initially the optical simulation program was known as TopSim. Here they have used the transmission framework simulation package, which was initially created for mobile and satellite communication. TopSim was rapidly improved with the expansion of a library tools for the hybrid optical systems and after the large efforts made by the simulation masters of Politecnico di Torino, the Topsim simulation program was later known as Optsim [9]. OptSim is really the fastest test system since all the operational parts depend on a period area calculation. Here by the OptSim, it is equable to demonstrate nearly "genuine" ultra-whole deal system with the accomplish practical outcomes.

1.4.1 Requirements for Optisim System:

Here we require the optisim of Windows 2000/XP.

1) Requires minimum of 64 Mbytes of RAM for the processing information of 128 Mbytes of RAM for faster processing.

2) Free space of 100 Mbytes to establish the OptSim system.

3) A printer is used to print the schematics or charts made by the OptSim.

4) For the determination of 1024 pixels or more the color graphic is used.

CHAPTER 2

LITERATURE REVIEW

2.1 Motivation

In the fiber optic communication, there will be the growth in distance with the decrease in the transmission signal. The number of clients can be improving through expanding the power budget plan or reducing the different losses in the system by way of utilizing optoelectronic regenerators. In optic electronic regenerators, the optical signals are to start with changed over into electric current and after that recovered by using utilizing a transmitter. However, such regenerators turn out to be very complicate and more expensive for wavelength division multiplexing systems. Here the regenerator reduces the reliability of connectivity of a dynamic device. In this manner, increase of multichannel WDM system would require hybrid optical amplifier. To dispose of the loss obstacles and to amplifying the signal, the hybrid optical amplifiers are used which particularly increase the transmission of the optical signal without exchange to electric powered form as in-line amplifiers. The optical hybrid amplifiers has been frequently utilized for Wavelength division multiplexing (WDM) as the light wave frameworks so that everyone channels can amplify it.

2.2 Literature Survey

Neha Thakral et al. [14] (2016) Described the setup that has worked to research the execution of various HOA with mix of EDFA-SOA-EDFA, EDFA-SOA and SOA-RAMAN with 3 channels utilizing bit rates of 6.27 Gbps, 12.51 Gbps and 18.76 Gbps and It was observed that EDFA-SOA more appropriate for RZ in contrast with other hybrid optical amplifier for the proposed DWDM transmission interface. The Simulation setup for the Different HOA can be performed and the Q-factor, Eye Diagram and BER value can be obtained.

Shivani Radha Sharma et al. [15] (2016) the wavelength utilized for the streamlining ranges from 1559 nm to 1567 nm, which lies in the L-band of hybrid optical communication to obtain the straight uniform gain with low noise figure. By improving these parameters in Opti system programming the greatest estimation value of gain got is 23.81 dB with variations of 2.89 dB and noise figure is kept up underneath 8 dB.

Meenakshi Sharma et al. [16] (2015) we upgrade the length of EDFA, and after that for various estimations of pump wavelength and pump power of the Raman Fiber Amplifier, the working noise figure and the range of the hybrid EDFA/RFA is investigated. It brings about decrease to gain variation to 3.4609 dB with the less noise figure. Another method utilizing gain leveling filter is flattered which the results in decrease of gain variation of EDFA to 1.0015 dB. Simulation setup for the mixture of hybrid EDFA-RFA can be actualized; wavelength and pump for various cases can be obtained.

Kirandeep Kaur et al. [17] (2015) Execution based on Raman-EDFA mixture hybrid amplifiers has been done for 100 channels DWDM transmission framework. The channels with transmission data rate of 10 Gbps were investigated at decreased channel spacing of 0.4 nm and 0.2 nm. The outcome examination of system execution displayed that with booster amplifier, channel transmission rate and dividing of 10Gbps and 0.2 nm respectively, approx. level gain of 25dB along with the transmission distance up to 200 km can be effectively accomplished. However without the booster amplifier the peak gain was around 21dB with moderately no indications of gain flatness over same transmission range.

Peter Kaspar et al. [18] (2015) Here SOA demonstrates a maximum length to length gain of 10 dB and a max inner gain around the 26 ± 2 db. Gadget was created from III–V material wafer-fortified onto a Si on the insulator wafer. In a loop setup containing 20 km of single-mode fiber (SMF), the SOA information signals of different modulation configurations. Transmission along the bit error rate beneath the error correction is exhibited for up to 10 loops utilizing QPSK, 6 loops utilizing 8QAM, and six loops utilizing 16QAM. SOA Design and static Performance schematic diagram is more complex and parameters are inaccessible.

Inderpreet Kaur et al. [19] (2014) Different receiver clearly show that two different designs work attractively for the BER of 10-8 at 1478 nm to 1556 nm transmission capacity range for the span of 50 km optical fiber. Hybrid TDFA-EDFA design demonstrates the outcomes over hybrid EDFA-SOA setup for 40 km period of different lengths in terms of BER and Q factor for 97 DWDM channels dispersed at 0.4 nm in the wavelength scope of 1478 nm to 1556 nm.

Shien-Kuei Liaw et al. [20] (2014) Described the hybrid optical amplifier (HOA) is connected for 100 km and then it can extend for both bidirectional and unidirectional transmissions and single-wavelength pump source is utilized to the pump for both the ends of L band RFA and C band EDFA.

Prince Jain et al. [21] (2014) In this paper we have considered what is the amplifier, different types of hybrid amplifier and Comparison of these hybrid amplifiers. There have sorted of half amplifiers of EDFA, RA, Thulium-Doped Fiber Amplifier, Tellurite Based Fiber Raman Amplifier, SOA fiber Optical Parametrical Amplifiers (FOPA). Hybrid amplifiers have demonstrated the effective in DWDM frameworks to increase long haul transmission distance with the change of bandwidth along the suppressed impairments and nonlinear impacts. The greatest test with optical hybrid amplifiers is to maintain and provide high bandwidth if there is any occurrence of higher number of channels.

Hybrid amplifiers will be displayed for DWDM frameworks utilizing Optical Communication programming in which different mixes of optical amplifiers will be in series in arrangement to make advantage in DWDM frameworks. Displaying of various parameters e.g. gain, spontaneous emission, BER, length of fiber and variations of output power can be performed for proposed hybrid amplifier.

M. E. Marhic et al. [22] (2014) a fiber optical amplifier parametric took after by a conventional amplifier can help to reduce the internal nonlinear crosstalk, while displaying a low noise figure. Exploratory setup for a hybrid OPA-SOA is totally unique when compared with the other Hybrid optical amplifiers.

Simranjit Singh et al. [23] (2014): This paper displays a flat gain for the optical hybrid amplifier proposed under the mixture setup utilizing the Er-Yb Co-doped waveguide optical amplifier. The commitment of this paper is to premise the flat gain optical hybrid amplifier in based on the least expensive standard optical amplifiers. After the examination of the different hybrid amplifiers of dense wavelength and division multiplexing, it was perceived that Raman–EDFA is the best combinations for the enhanced outcomes. It is also précised that the proposed Raman amplifier is issued as a booster for the hybrid distributed Raman amplifier and Er-Yb doped channels. Because of this the gain progression in the hybrid amplifiers this distortion in pulse shaping and crosstalk between the symbols presents. The outcomes that enhanced in the execution as far as the gain, flatness and cost that brings the fantastic execution and will be appropriate for the next era of the DWDM system. In this we can also obtain the lesser gain with the hybrid optical amplifiers.

Simranjit Singh et al. [24] (2013) In this paper we have investigated flat gain of the C-band and L-band proposed hybrid optical amplifiers for the dense wavelength division multiplexing the hybrid optical amplifier (HOA) with the flat gain rectifications is proposed utilizing two phase of DRA-EDFA design the mixture optical amplifier is explored as a dense wavelength multiplexing system with 25ghz channel separating it is also précised that as we increment the input power then the bandwidth increases and it was additionally adhere that the smooth power output spectrum is acquired when power of all different channels is settled at 3Mw this technique is done without using any other gain flattering techniques which provides the better solution.

Manoj Kr.Dutta et al. [25] (2013) In this paper a comparative investigation is done between two distinctive optical amplifiers in particular EDFA and RA, the two most normal and widely utilized amplifiers for WDM innovation has been examined. Before the access of such fiber amplifiers, there was no particular strategy for amplifying different channels. The execution estimation depended on noise figure and gain levelness of the amplifier. The simulation result demonstrates that in the 1.5-μm optical window area Raman amplifier is a solid contender to the EDFA, which benefit from the development of the higher power pump lasers. The simulation result also uncovers that EDFA gain was not flat over the whole spectral range of gain in the optical channels; EDFA presents noise that corrupts the SNR ratio. In general, erbium-doped fiber amplifier (EDFAs) offers high power transformation proficiency and Raman amplifier offers broadband validity joined with low-noise properties which are much helpful for optical WDM transmission framework.

Simranjit Singh et al. [26] (2013) in this investigation has been dine for the pre, post and symmetrical power different techniques for a different places position of hybrid optical amplifier (HOA) RAMAN–EDFA in fiber link. The impact for the increment in signal input power there are three power compensation techniques in terms of BER, eye diagram and the output power.

It is observed that the post power compensation method is better than pre-and symmetrical power technique. The effect of variations in length of the standard single mode fiber (SMF) and to find the dispersion compensated fiber another three power techniques has been added and they have been observed. They investigated RA–EDFA as the post power restitution strategy gives the least bit error rate (10−30) and high output power (12 dBm) at −15 dBm signal output control at fiber signal.

V.Bobrovs et al. [27] (2012) In case of the occurrence of the distributed Raman amplifier (DRA) in long haul reach optical access system of the wavelength division multiplexing (WDM) exploit is not sufficient. Decrease of optical amplifier signals quality is assessed in 15 Gbit/s long reach in WDM optical get to access to the crossover distributed Raman-semiconductor optical amplifier and the distributed Raman-erbium doped fiber amplifier. Simulation of the 15 Gbit/s long haul reach the DWDM optical get to framework can be executed with 1 and 16 transmitters with passive optical networks.

Minwan Jung et al. [28] (2012) here they propose a long-haul reach hybrid DWDM–TDMPON block diagram which was proposed optical hybrid amplifier can be adequately utilized. The attainable of utilizing the proposed hybrid amplifier for the long-reach hybrid optical amplifier in DWDM–TDM-PONs is experimentally researched by performing a progression in the signal transmission experiment with the different things with of PON design having an aggregate reach of 80 km and 6 split clients. Free space bidirectional signals transmission at a bit rate of 10 Gbit/s is effectively illustrated.

T.S. KAMAL et al. [29] (2012) here we introduce the simulation results comes about for DWDM frameworks with an ultra-high limit up to 1.29 Tbit/s and shadowy effectiveness moving toward 0.4 piece/s/Hz. The effect of signal to noise ratio (SNR) on these parameters, for example, length of BER, channel spacing, scattering, and different channels has been explored and the outcomes acquired has been explained on the premise of BER impacts. It has demonstrated that with an, the SNR increments to the most extreme ideal value the channel spacing also increases and after that degrades in the channel. With an expansion of channels, the SNR degrades for low wavelength spacing. For large wavelength spacing, it becomes freer for the large number of channels. Keeping constant channel dividing, the SNR degrades with the expansion in the length of the Bit error rate. SNR additionally increases with a little increment in spacing of the BER and with bit rate increases and received power decreases.

Kamaljit Singh Bhatia et al. [30] (2012) In this paper we know to outline an optical-OFDM framework, considering the essential design parameters. As we probably are aware, the phase fluctuations have an important role in these frameworks. We showed that the laser explained at a bias current of 2 mA had less fluctuations and worked with a most extreme dynamic range comparable to the multimode laser at an bias current of 6 mA. We picked a single mode laser with a bias current of 2 mA as the optical-fiber connects for the optical-OFDM framework.

Simranjit Singh et al. [31] (2012) It was represented hybrid optical amplifier (HOA) provides better results with a biggest secured single traverse of (220 km) at channel dividing of 6.25 GHz. It is offered that to the RA–SOA, RA–SOA–RA, EDFA–RA–EDFA and EDFA–semiconductor optical amplifier–EDFA, the work rate for this has been thought not to be more than 20, 17, 20, and 24 Gbps separately.

Matheus O. L. Beninca et al. [32] (2011) this investigation makes use of an Erbium Doped Fiber Amplifier (EDFA) running as a boosting to get optical gain over the C-band and an allotted distributed Raman Amplifier (DRA) to increase the benefit over the L-band and control the gain ripple. The amplifier execution becomes processed in terms of ripple and on-off gain, Noise determines (NF) and Optical signal to Noise Ratio (OSNR). Our effects appear on-off gain from 17 dB with ripple up to 2 dB over a sixty-five-nm bandwidth. The OSNR become well than 30 dB with Noise Figure decrease at the one hundred twenty km. optical Fiber joins from ninety km up to one hundred eighty km had been obtained.

Tuan Nguyen Van et al. [33] (2010) investigates 3 figuring different techniques of different cascaded EDFAs Fiber for the optical communication links that utilize the Hybrid optical amplifier.

Gao Yan et al. [34] (2009) Differentiated and the utilization of different EDFA amplifier we could get more broad gain and High noise proportion. The examination for the DWDM transmission framework can be executed in the opti system and the results for the optical range analyzer can be created.

Giuseppe Talli et al. [35] (2006) the approach consolidates the backhaul and access the works in the single optical connectivity foundation that connections end clients straightforwardly connected to the systems without the requirement of electronic conversions. The client TX depends on an electronic absorption modulator (EAM) which is monolithically coordinated with two the semiconductor optical amplifiers (SOA), giving adequate bandwidth and net gain that support the upstream and splitting factors bit rates up to 10 GB/s. With an aggregate distance of 100 km and with the upstream bit rate of 10 Gb/s, can supports up to 17 TDM PONs working at various frequencies channel distribution plan is dispensed.

H. S. Seo et al. [36] (2005) exhibited through numerical estimations that the L, S, and C groups has been amplified consistently and at the same time through mediums. The medium was an in-line hybrid optical fiber arranged by a Ge-doped core and Er-doped cladding. The process is easy to arrange the amplifier since there is no reason to slice between mediums. Another merit is that every single optical signal in the whole band is amplified in the meantime along the fiber. In this way, the NF is effortlessly controllable we arrange the amplifier in two phases by inserting an isolator.

Sun Hyok Chang et al. [37] (2005) portrayed the transient phenomena of hybrid RA/EDFA amplifier depend on the channel add/drop is explored. The temporary reactions of different channels are come about because of the combined dynamic flow of EDFA and RA. The transmit-suppressing hybrid RA/EDFA is ended up being sufficient for WDM system together with reconfiguration optical add/drop multiplexer and additionally sincere optical cross connect, if optical exchanging speed was chosen cautious.

T. Matsuda et al. [38] (2004) was demonstrated that the mixture optical amplifiers depicted thus gained the transmission execution in the C-band. They have been experimentally exhibited the 55×42.7 Gbit/s L and C-band WDM signal transmission. Application of EDFA is In-line hybrid amplifiers comprising of C-band EDFAs and L-band distributed Raman amplifiers empower 2.3 Tbit/s WDM signals has been transmitted more than three periods of 65 km DRF. These are experimentally confirmed that C-band transmission is very less than the U-band transmission to the DCF line.

S. Radic et al. [39] (2002) Optical repeater node is built by utilizing L-band Erbium-doped fiber amplifier (EDFA) and bidirectional Raman pumping to accomplish joined gain of 32 db. Dense wavelength-division-multiplexing (DWDM) transmission of 30+30 25-GHz-divided channels is shown utilizing mixture of bidirectional optical amplifier over the nonzero-dispersion shifted over the fiber spans.

K.C.Reichmann et al. [40] (2001) They have done 4-Node metro division wave length and dense multiplexing ring system where the lambda asset at network node and lambda is considered as the virtual ring. Here the downstream and the upstream for the bit error rate is discover utilizing the linbo3neai here we are showing four hub metro WDM ring system in which all of the wavelengths are sourced at the system node and every wavelength can be considered as particular multiuser virtual ring system adjusted upstream signal display insignificant power penalty both the axis node and the end station are designed to profit by the segment integration.

Desurvire E et al. [41] (2000) exhibits capability of erbium-doped fiber amplifiers (EDFA) for the useful in wavelength division multiplexing communicating the systems. It has very low crosstalk, low addition loss, low noise figure, high gain and the polarization insensitive. EDFA has a nearly wide range of amplification making which is more helpful for the transmission of optical amplifier in wavelength division multiplexing (DWM) frameworks.

Hypothetically EDFA is capable for increasing every one of the wavelengths running from 1500 to 1600 nm. However for all intents and purposes there are two signals of wavelength. These are L-band and C-band. The L band ranges from 1520 nm to 1550 nm and C band from 1550 nm to 1620 nm. The conductor laser pumping source at 960 nm wavelength has turned out to be the best regarding effectiveness (high than 10 dB gains per mw power) and better noise execution

Yuichi Takushim et al. [42] (1999) In this paper we have designed the gain spectrum of a gain clamped amplifier under the different working conditions and wavelength must be balanced. gain clamped is leveled by utilizing mach-zehnder gain equalizer the gain is in a ideally clamped and resistant to the input signal in the scope of 70nm EDFA have incredibly contributed there progress in the wave length division multiplexing (WDM) innovations on the account of high optical gain and value the acknowledgment of perfect pick up complimented range with settled increase free to working ventures we understood the pickup realization of gain is complimented operation within the 70nm spectral width around 1555nm by utilizing zehnder gain equalizer the gain spectra is measured when the input power of the saturation from-11dbm to -26dbm.

Hidenori Taga et al. [43] (1996) here talked about that the optical amplifiers were produced, just the little distance (up to a couple of 10 km) WDM framework was the convention, because of these optical repeaters that are used for the WDM transmission were thought were not much useful. The approach of the hybrid optical amplifiers made it possible to develop for the long distance communication. There are 2 sorts of hybrid optical amplifiers has been utilized as a part of communication framework; doped fiber amplifiers (DFAs) and semiconductor optical amplifiers (SOAs).

Durhuus T et al. [44] (1996) demonstrated that wavelength transformation at 2.5 GB/s has punishment of 0.7 dB by utilizing cross gain modulation in SOA. The wavelength converter is based on light of cross gain adjustment in the transmission separation of 50 km by utilizing normal dispersion shift (NDS) fiber with 3 dB punishment for 5 GB/s.

Jay M. Wiesenfeld et al. [45] (1993) have transformed the information at 10 Gb/s from one information signal wavelength to another information signal wavelength, which is either more or shorter, utilizing gain pressure in a 1.6-pm semiconductor optical amplifier (SOA) for wavelength change. They have described that utilizing the moderate powers; frequency transformation is accomplished over an 18 nm (3 THz), with 0.8-3 dB control punishments.

T. Toyonaka et al. [46] (1992) discussed about the utilization of a high NA aspheric focal point for the coupling optical amplifier and have manufactured an increase in gain polarization-insensitive SOA module. The coupling misfortune has the low as 2dB/aspect, a net gain of 20dB, and the sensitivity of under 0.4 dB were additionally illustrated.

CHAPTER 3

Scope of the Study and objectives

3.1 Problem formulation

1. While using the Single amplifier we found that gain is not appropriate to enhance the gain there is needed to use the combinations of optical amplifier (OA) as Hybrid optical amplifiers.

2. The single optical amplifier not able to send the signal more than 200km,so to send the signal for more than 200 km we are using the hybrid optical amplifiers (HOA).

3. The data rates of conventional amplifiers are low so to provide the enhanced data rates HOA are used.

3.2 Thesis Scope

1. There are several main stages that consist in the formulation of thesis. These are shown in the figure 13 as the flow chart representation.
2. First, we have review a theoretical background of the optical amplifiers which was carried out and most of the time spent in reading the papers or articles and extracting the information from different journals.
3. Following this, a literature review on the hybrid optical amplifier has been made.
4. The review on these papers is more useful in understanding the operation of optical transmission using different hybrid optical amplifier.
5. The optical block diagram is being made according to the optical components that are available in the Optsim software and hybrid optical amplifiers has been developed which is having the better visualization of the system structure and the components used.
6. Here the results for the optical amplifier design can be obtained from the Eye diagrams, Bit error rate (BER), output power, Eye opening and the Eye closure.

7. After the results both the optical amplifier (OA) and the hybrid optical amplifier (HOA) can be analyzed and compared.
8. After that in the proposed methodology we are finding the flat Gain at different stages of the hybrid optical amplifier with the different channel spacing of 50 GHZ and 25 GHz.
9. Noise figure is also being calculated for the hybrid optical amplifiers in the proposed technique.

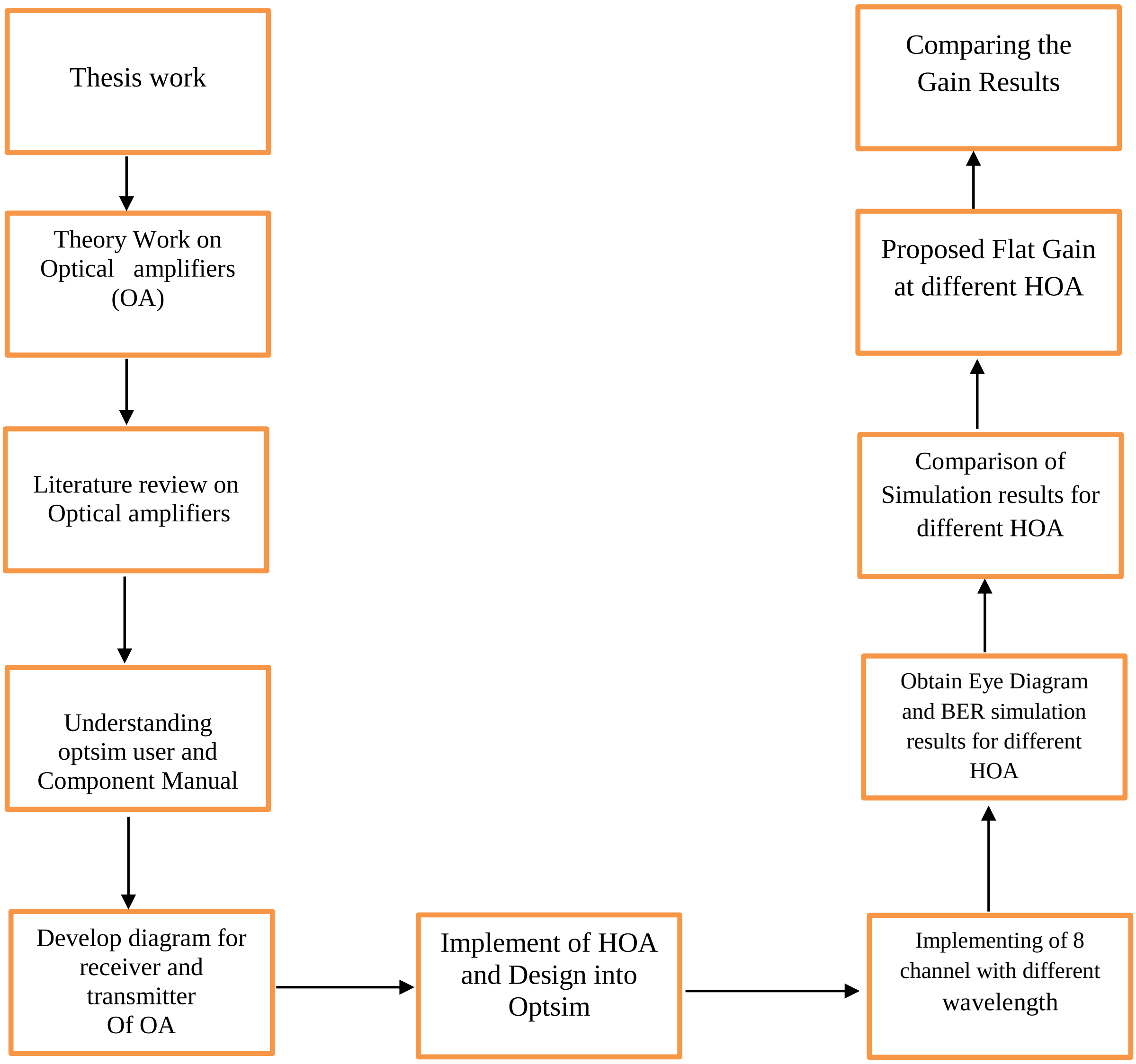

Figure: 7 Flow chart Implementation

3.3 Objective of the thesis

1.To review of literature related to optimizing dense wavelength division multiplexing (DWDM) link over long fiber links by the use of Hybrid optical amplifiers (HOA) techniques.

2.To investigate the extension of gain flatness for DWDM based link with fiber length exceeding 200 km.

3.To analyze the performance of DWDM links for different specifications for channel spacing.

4.To investigate and compare error and gain performance of different configuration of hybrid optical amplifiers (HOA) like EDFA-EDFA, RA-EDFA and SOA and EDFA.

CHAPTER 4

RESEARCH METHODOLGY

4.1 Methodology

1) Here in the stage we are implementing the paper "Performance optimization of SOA, EDFA and Raman and hybrid optical amplifiers in WDM network with reduced channel spacing of 50 GHz".

2) In this model, eight users can transmit their data at 10 GB/s speed with dispersion of 50 GHz. Each of the input signal is pre- amplified with the booster and modulated in NRZ format. The signals which are amplified are sent to the channel where the different signals are transmitted over DS-anomalous fiber of different transmission distance. The WDM transmitter is constructed with the compound component using eight transmitters.

3) In WDM transmitter the different components present are laser source, data source, external Mach-Zehnder modulator and the electrical driver in each transmitter part. The data source is generating signal of 10 GB/s with the pseudo random sequence. Conversion of input signal into electrical signal is done by the electrical driver.

4) The CW laser generates the frequency of 8 laser ray at 192.85 THz to 193.20 THz with the channel spacing of 50 GHz. Ideal laser noise bandwidth and random laser beams has been used. The signals which are generated from the source and the laser are fed to the mach-Zehnder modulator all these signals are modulated to the carrier.

5) From the optical transmitter here it is connected to the optical mux where the role of the mux is to combine the several input to single output and we use optical spectrum analyzer to measure the values and the one output is connected to the single mode fiber (SMF) with the length of 150-200 km and they are connected to the several combinations At the Receiver end we use Rectangular optical filter and the photo detector converts the electrical signal to the Binary signal and to measure the output we used BER analyzer and the EYE Diagram.

6) The simulations setup of different hybrid amplifiers like EDFA, SOA, RA, RAMAN-EDFA, EDFA-SOA and EDFA-EDFA at various different transmission distances are shown in figure 8,9,10.

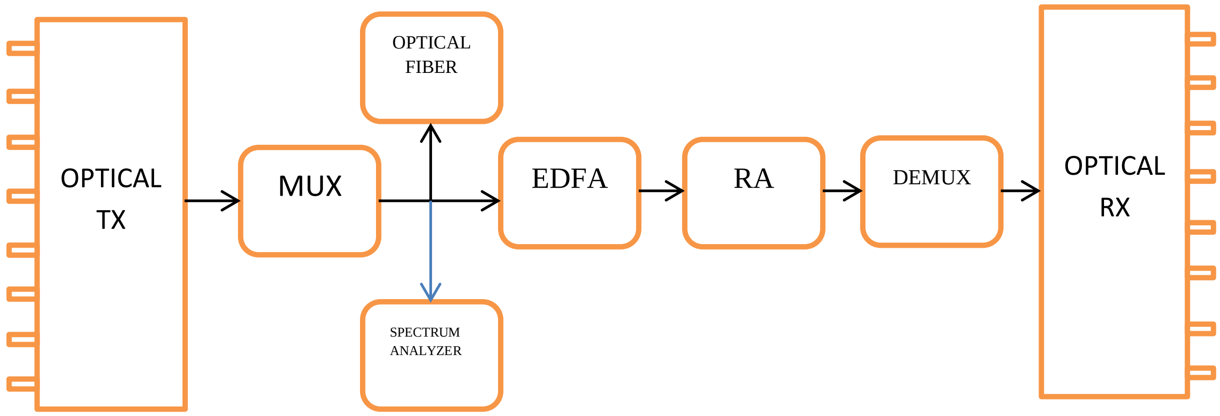

Figure: 8 Block Diagram setup for EDFA-RA

Figure 8 describes the simulation block diagram for the hybrid optical amplifier (HOA) for Raman amplifier (RA) and Erbium-doped fiber amplifier (EDFA).

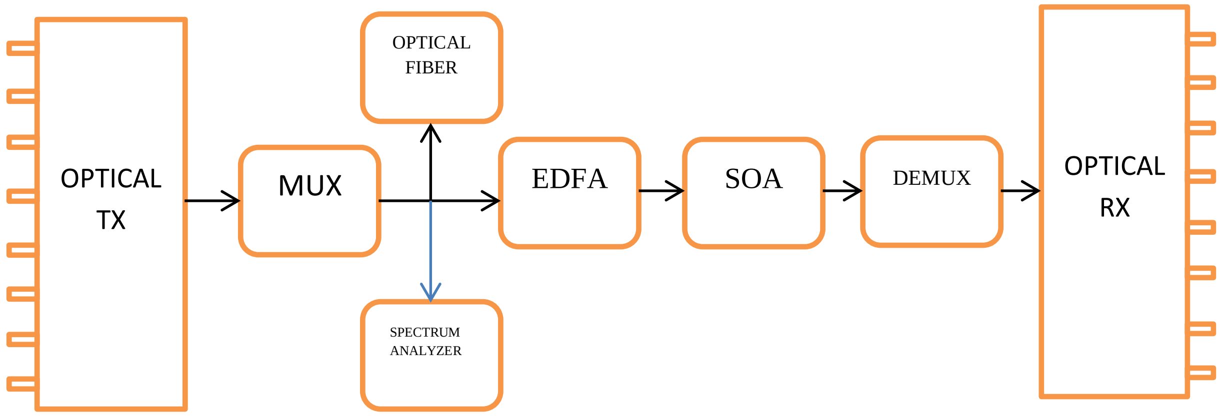

Figure: 9 Block Diagram setup for EDFA-SOA

Figure 9 describes the simulation block diagram for the hybrid optical amplifier (HOA) for Erbium-doped fiber amplifier (EDFA) and semiconductor optical amplifier (SOA).

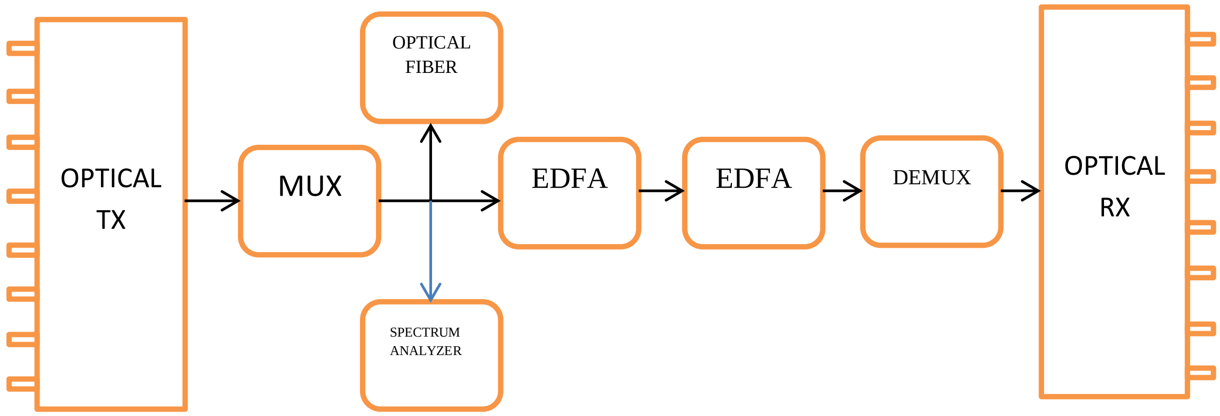

Figure: 10 Block Diagram setup for EDFA-EDFA

Figure 10 describes the simulation block diagram for the hybrid optical amplifier (HOA) for Erbium-doped fiber amplifier (EDFA) and Erbium-doped fiber amplifier (EDFA).

4.2 Parameters for the Hybrid Optical Amplifiers:

Parameters	Values
Length	300 x 10^-6 m
Bias Current	100 ma
Confinement Factor	0.35
Insertion Loss	3 db

Table No: 2 Parameters of SOA

Parameters	Values
Length	10-40 Km
Operator Temperature	300 K
Pump Wavelength	1480 nm
Pump Power	250 mw

Table No: 3 Parameters of RA

Parameters	Values
Output Power	12 db
Noise figure	4.5 db

Table No: 4 Parameters of EDFA

4.3 Simulation setup

Here in this stage we have implemented the block diagram in optical simulation system (software).

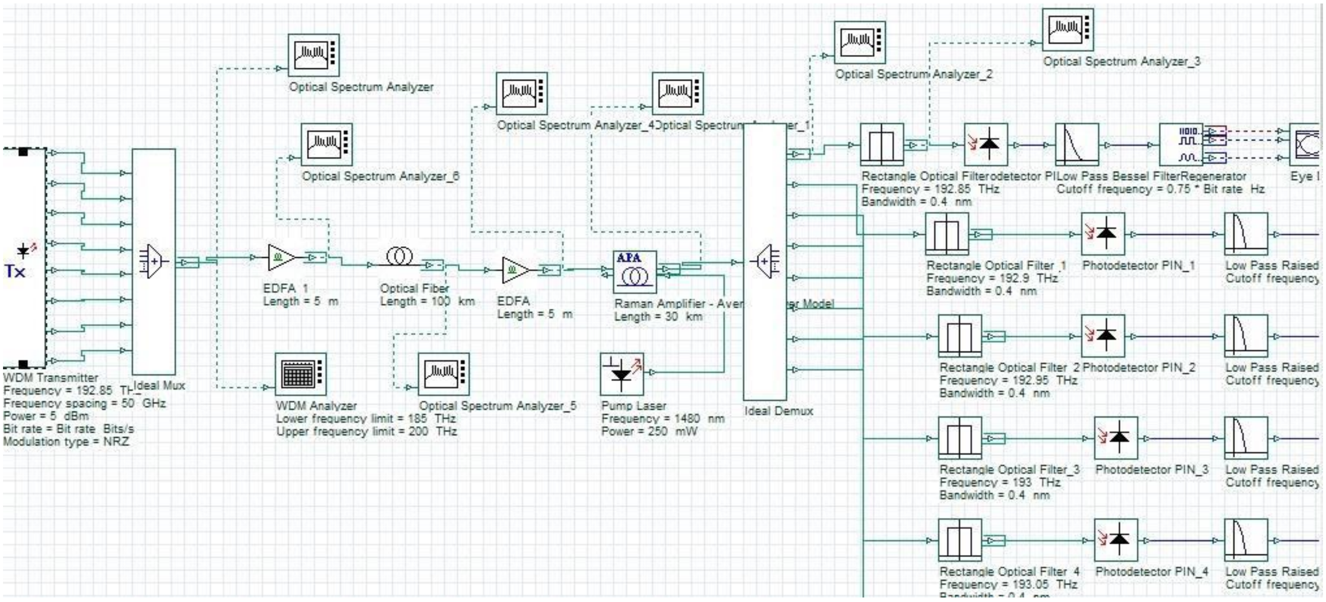

Fig No: 11 Simulation Diagram

The implementation of the schematic block diagram in the Optsim simulation is shown here and main the WDM transmitter and the WDM receiver. In the middle, we are taking the combination of hybrid optical amplifiers.

Proposed Methodology:

This is the simulation set up for the proposed technique that is the Flat Gain at various hybrid optical amplifiers.

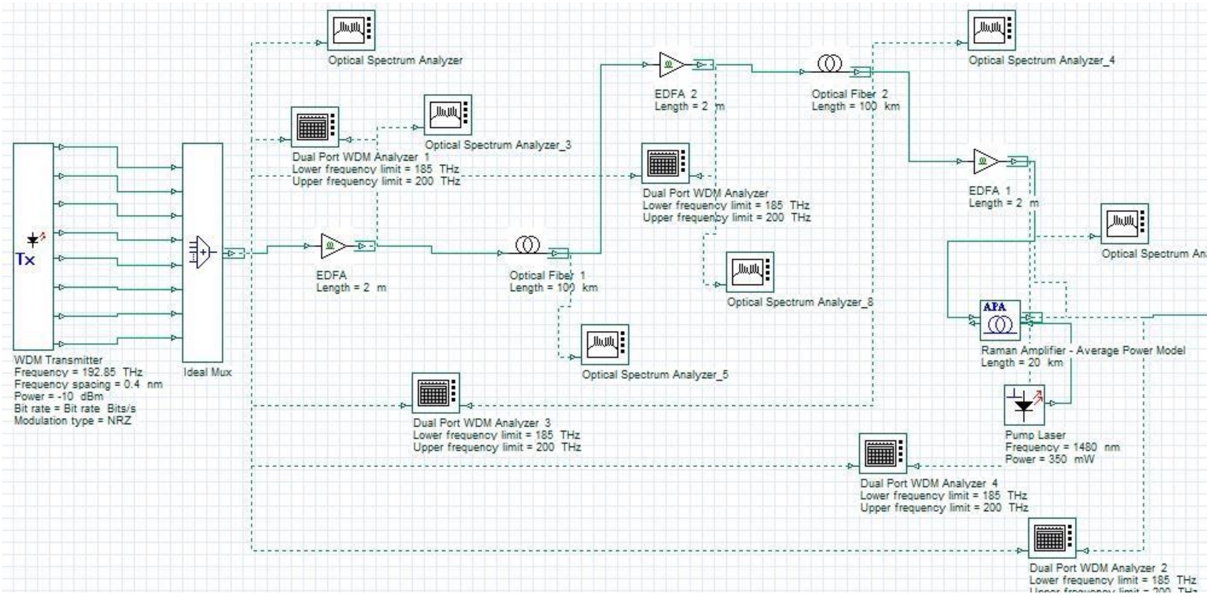

Fig No: 12 Simulation Diagram for proposed technique

Here we are finding the flat gain for the different hybrid optical amplifier like EDFA-RA, EDFA-SOA and EDFA-EDFA for the 20-200 km and this schematic diagram is shown in figure: 18. In this simulation to find out the flat gains we are using the dual port wavelength division multiplexing (WDM) analyzer.

CHAPTER 5

RESULTS AND OBSERVATIONS

The Results for the optimization performance of SOA, EDFA, RAMAN and hybrid optical amplifier in WDM network with the channel spacing of 50 GHz is shown below.

EDFA+EDFA: The Eye diagram for the combination of the hybrid optical amplifier (HOA) for Erbium-doped fiber amplifier (EDFA) and Erbium-doped fiber amplifier (EDFA) at 150 km is shown in the figure 12.

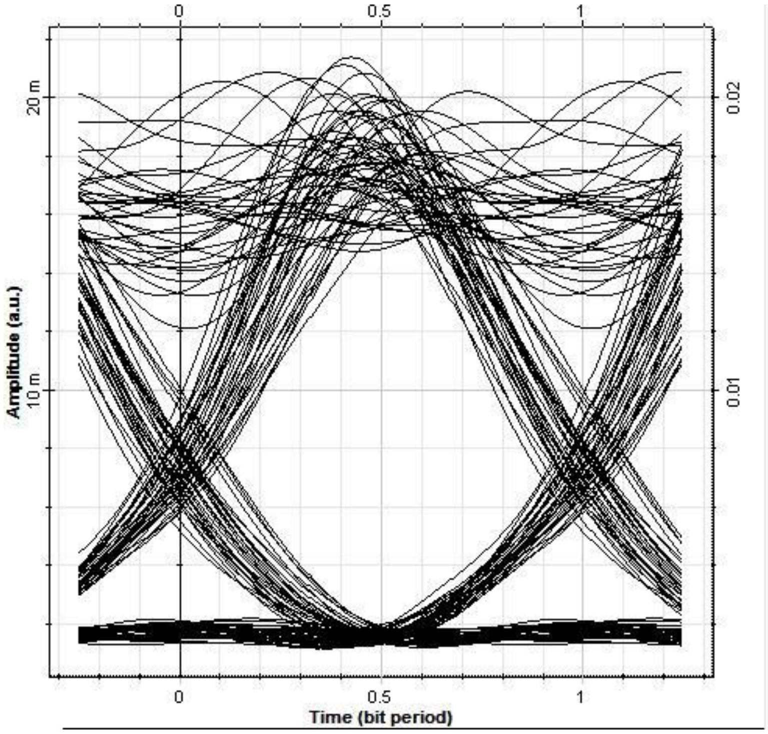

Fig No: 13 Eye diagram for EDFA-EDFA at 150 km

Here the eye opening at 0.00157 and the eye closure at 1.46 dB. The bit rate for the EDFA-EDFA at 150 km is 3.171e-027 and the quality factor is 31 db.

EDFA+RA: The Eye diagram for the combination of the hybrid optical amplifier (HOA) for Erbium-doped fiber amplifier (EDFA) and Raman amplifier (RA) at 150 km is shown in the figure 12.

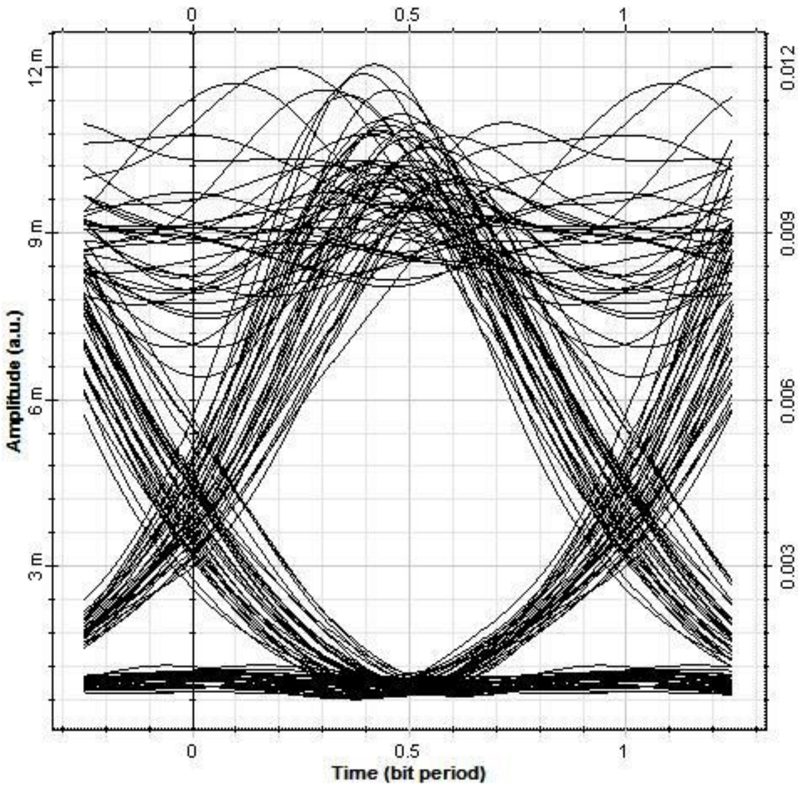

Fig No: 14 Eye diagram for EDFA-RA at 150 km

Here the eye opening at 0.0022 and the eye closure at 0.84 dB. The bit rate for the EDFA-EDFA at 150 km is 2.40161e-026 and the quality factor is 32 db.At 100 km EDFA-SOA provides the best eye opening and which will be the good communication and also the bit error rate for EDFA-SOA is also better when compared to any other combination in the hybrid optical amplifier.

Performance of different optical amplifiers (OA) like EDFA, SOA and RA has been compared in terms of quality factor with respect to the transmission distance and they are showed in figure: 14. The graph represents the transmission distance of the fiber increases with the quality factor (Q-factor) decreases. Here it shows up to 100 km EDFA and RA is similar when compared to the SOA. Raman amplifier having the highest Q-factor of 31 dB and from 100 km onwards the SOA gives us the better performance than EDFA and RA.

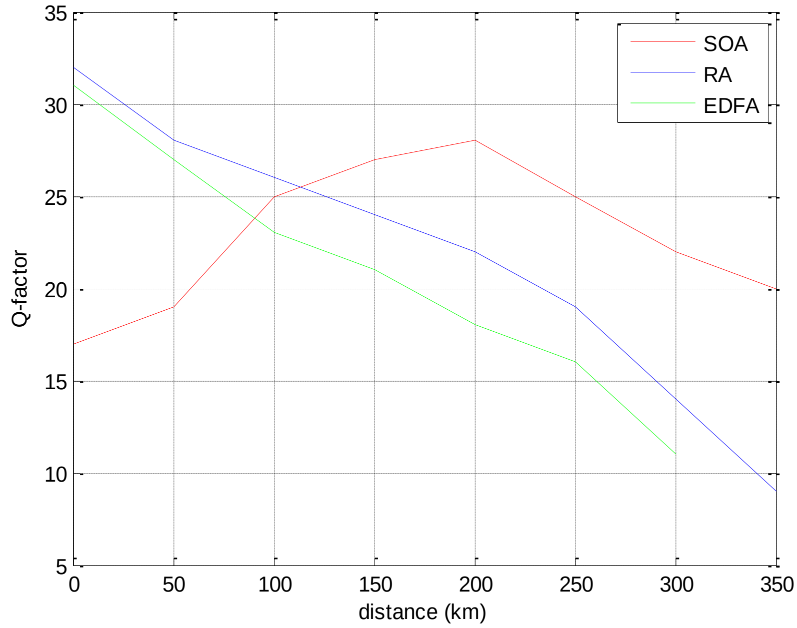

Fig No: 15 Q-factor Vs Distance for optical amplifiers

Performance of different optical amplifiers like EDFA, SOA and RA has been compared in terms of output power with respect to the transmission distance and they are showed in figure: 15. Here also the output power decreases with the increase in the Distance. The Figure: 15 shows at 100 km SOA provides the maximum power of 1.86 dBm.

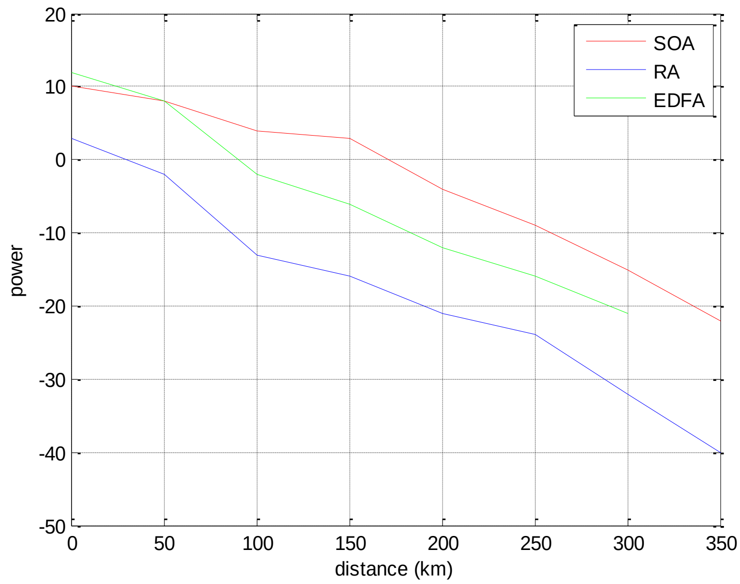

Fig No: 16 power vs Distance for optical amplifiers

Now the performance of different hybrid optical amplifiers like EDFA-EDFA, SOA-EDFA and EDFA-RA has been compared in terms of Quality factor (Q-factor) with respect to the transmission distance and they are showed in figure: 16. Here the due to the non-linear effects in the system after the 100 km the Q-factor starts decreasing which will degrade the system. As the increase in distance the variations in the Quality factor decreases. This means from 100 km onwards SOA-EDFA provides better performance than other hybrid amplifiers before the 100 km other hybrid amplifications like EDFA-EDFA, EDFA-RA is more suitable.

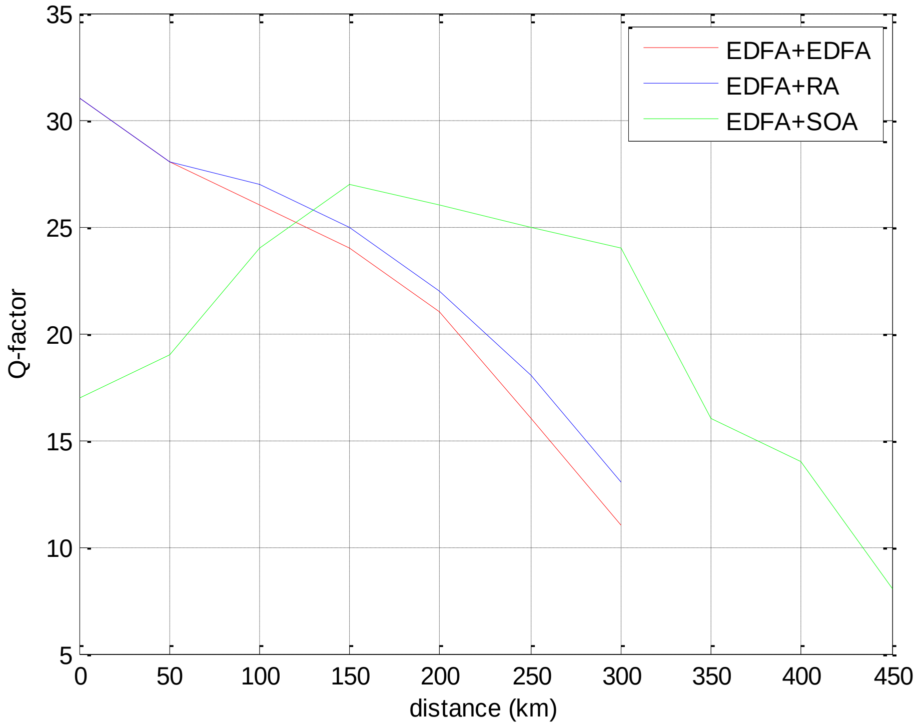

Fig No: 17 Q-factor Vs. Distance for hybrid optical amplifiers

Now the performance of different hybrid optical amplifiers like EDFA-EDFA, SOA-EDFA and EDFA-RA has been compared in terms of output power with respect to the transmission distance and they are showed in figure: 17. Here also as the distance increases the output power decreases and this is due to the attenuation and non-linear elements in the system. The output power for the SOA-EDFA is 21.84-13.08 dBm and it provides the maximum output power when compared to the other hybrid optical amplifiers.

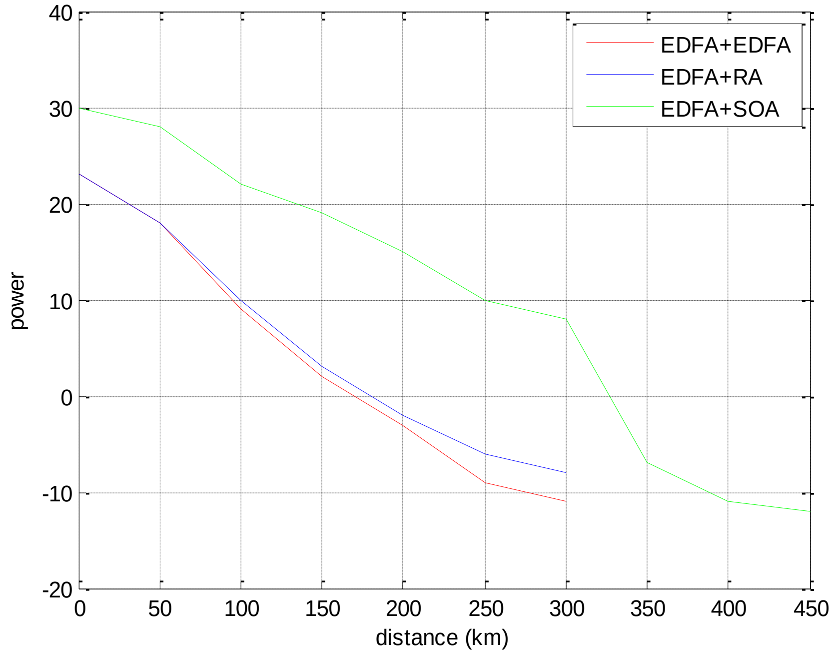

Fig No: 18 power vs Distance for hybrid optical amplifiers

Comparison of Q-factor for HOA at various distances

HOA TYPE	100 km	200 km	300 km
EDFA-SOA	24	17	9
RA-EDFA	39	31	18
EDFA-EDFA	38	31	16

Table No: 5 Comparison of Q-factor for HOA at different length

Comparison of Received power for HOA at various distances:

HOA TYPE	100 km	200 km	300 km
EDFA-SOA	39	30	18
RA-EDFA	32	23	14
EDFA-EDFA	33	23	13

Table No: 6 Comparison of Received power for HOA at different length

Comparison of Q-factor at 200 km

HOA TYPE	100 km	200 km	300 km
EDFA-SOA	24	17	9
SOA	30	17	11
EDFA	43	31	18

Table No: 7 Comparison of Q-factor at 200 km

Here the Figure 19 describes the results for the proposed technique which is the combination of hybrid optical amplifiers (HOA) for the flat gain.

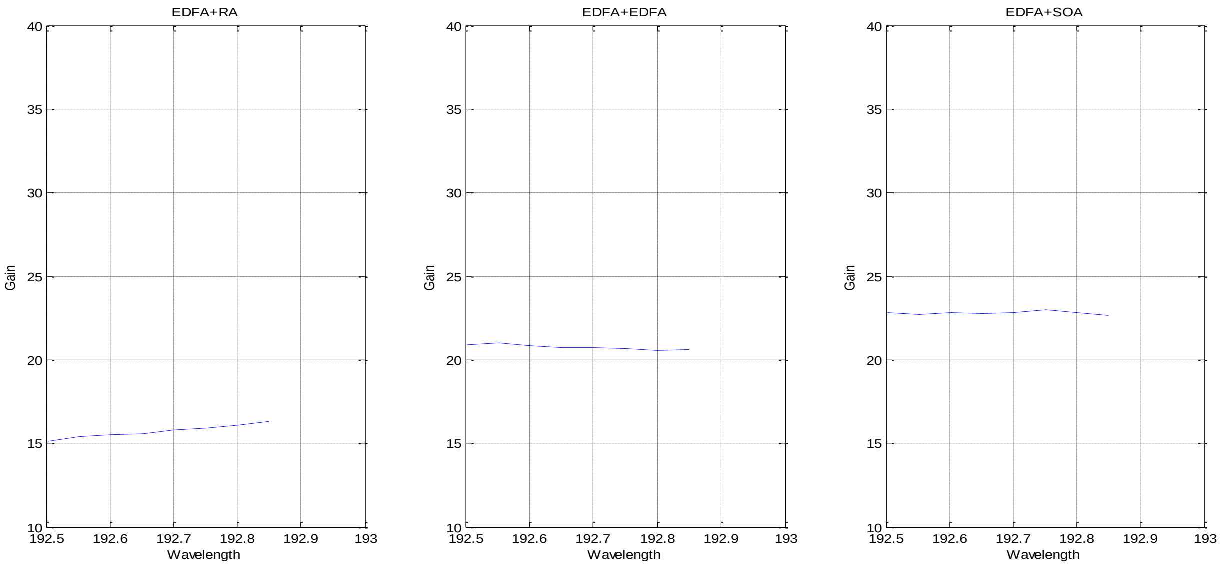

Fig No: 19 Flat gains for different hybrid optical amplifiers

Here in the EDFA-RA we can see the Flat gain at the range of 15-16 dBm which gives the flat results for the wavelength varies from 192.85 THz-193.20 THz. For the EDFA-EDFA we can have the maximum length up to 200 km which gives us the results of 20-21 dBm whereas the last hybrid optical amplifier EDFA-SOA provides us the maximum gain at 22-24 dBm

The Comparison gains for the different hybrid optical amplifiers at the wavelength spacing at 0.4 nm are shown in the figure: 20 here by comparing all these gains we can say EDFA-SOA provides us the maximum Gain at the length of 200 km.

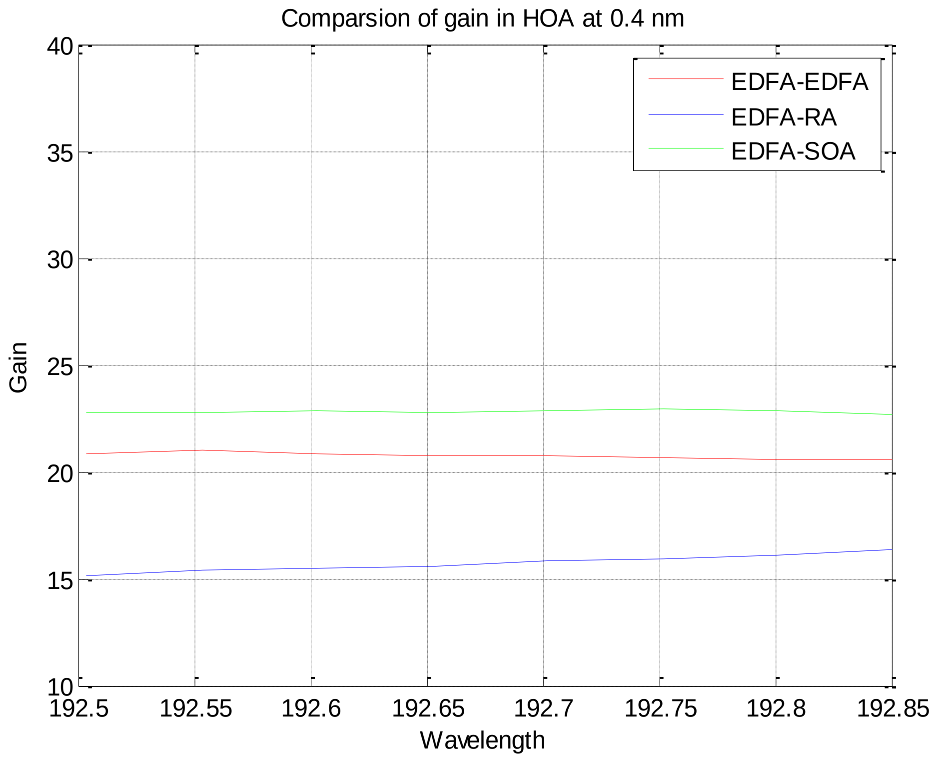

Fig No: 20 Comparison of gains for different hybrid optical amplifiers at 0.4 nm.

Compression of Gain for different HOA

HOA TYPE	100 Km	200 Km	300 Km
EDFA-SOA	31.890	22.807	10.433
RA-EDFA	23.451	15.129	8.081
EDFA-EDFA	34.324	20.872	13.677

Table No: 8 Comparison of gain for HOA at different length

Compression of Gain for different OA

OA TYPE	100 Km	200 Km	300 Km
EDFA	27.76	19.87	11.18
RA	23.69	16.78	8.79
SOA	34.78	23.26	15.45

Table No: 9 Comparison of gain for OA at different length

The Comparison gains for the different hybrid optical amplifiers (HOA) at the wavelength spacing at 0.2 nm are shown in the figure: 21 here by comparing all these gains we can say EDFA-SOA provides us the maximum Gain at the length of 200 km.

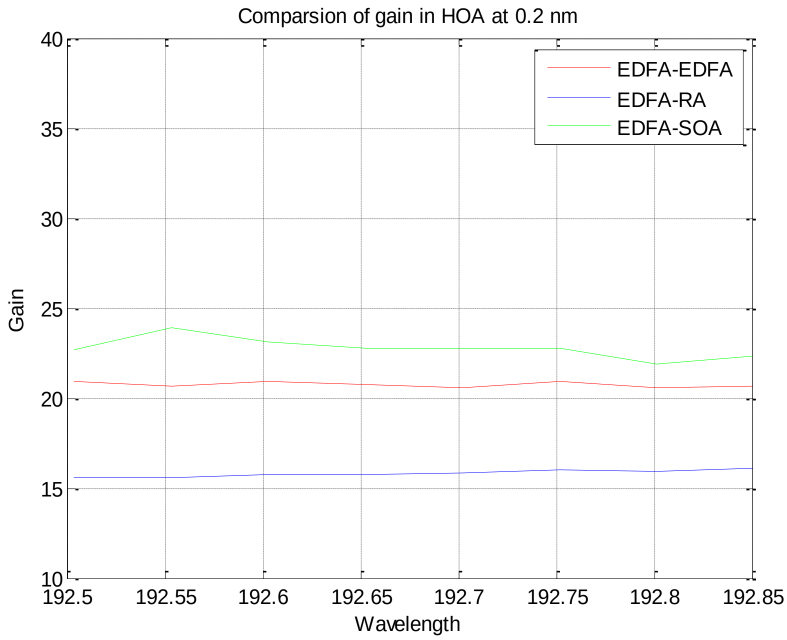

Fig No: 21 Comparison of gains for different hybrid optical amplifiers at 0.2 nm.

Noise figure:

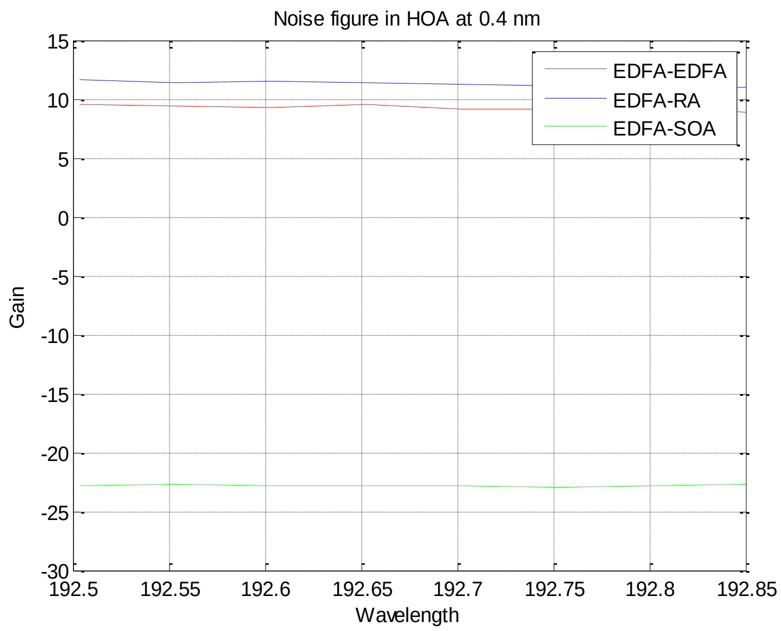

Fig No: 22 Noise figure for different hybrid optical amplifiers at 0.4 nm.

The Comparison gains for the different hybrid optical amplifiers (HOA) at the frequency spacing at 50 GHz are shown in the figure: 22 this shows the EDFA-EDFA, EDFA-RA has the high noise power where the EDFA-SOA has the very less noise figure and it varies in negatives.

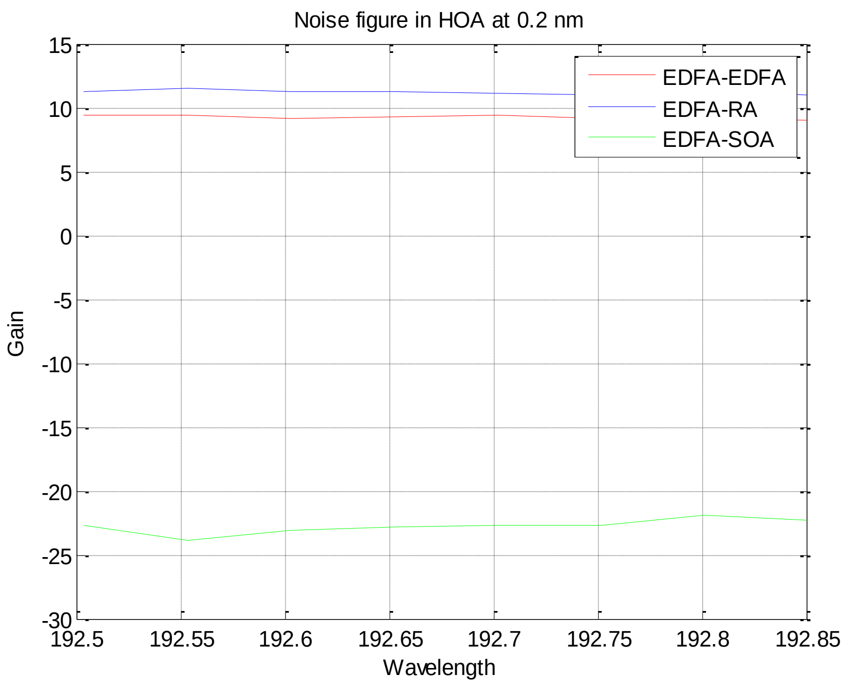

Fig No: 23 Noise figure for different hybrid optical amplifiers at 0.2 nm.

The Comparison gains for the different hybrid optical amplifiers (HOA) at the frequency spacing at 25 GHz are shown in the figure: 23 Here the spacing of 50 GHz and 25 GHz has slightly same. This graph shows the EDFA-EDFA, EDFA-RA has the high noise power at optical length of 200 km where the EDFA-SOA has the very less noise figure.

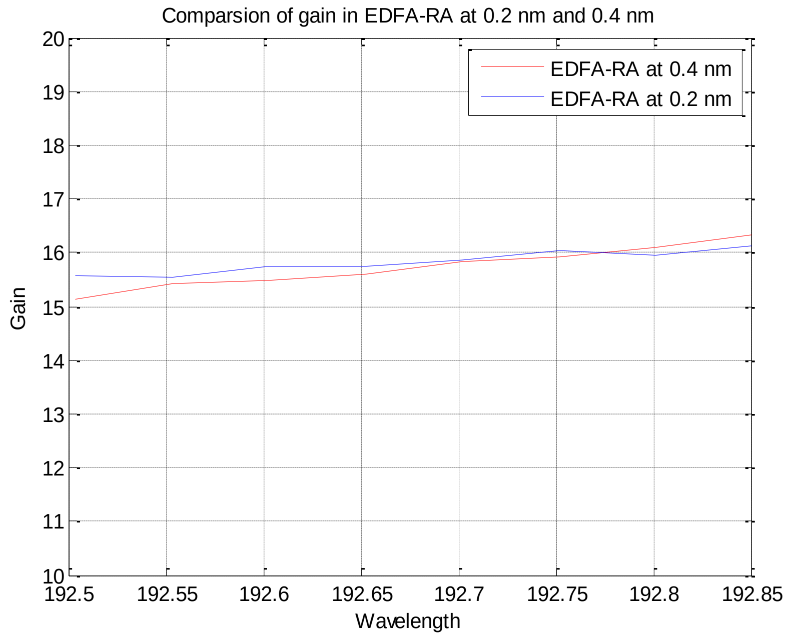

Fig No: 24 Comparison of gains for EDFA-RA HOA at 0.4 nm and 0.2 nm.

The Comparison shows the gains for the different hybrid optical amplifiers (HOA) at the wavelength spacing of 50 GHz and 25 GHz for the EDFA-RA are shown in the figure: 24. This graph shows both the channel spacing varies same up to 100 km and after that it starts increasing.

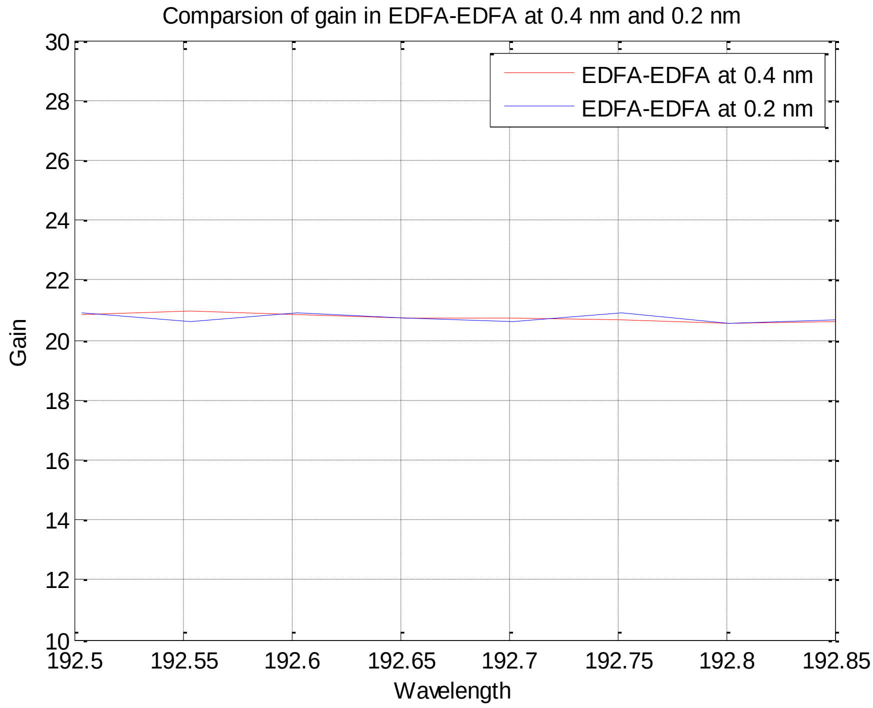

Fig No: 25 Comparison of gains in EDFA-EDFA HOA at 0.4 nm and 0.2 nm.

The Comparison shows the gains for the different hybrid optical amplifiers (HOA) at the frequency channel spacing of 50 GHz and 25 GHz for the EDFA-EDFA are shown in the figure: 25. This graph shows for both the channel spacing varies same up to 200 km and the difference between them in points.

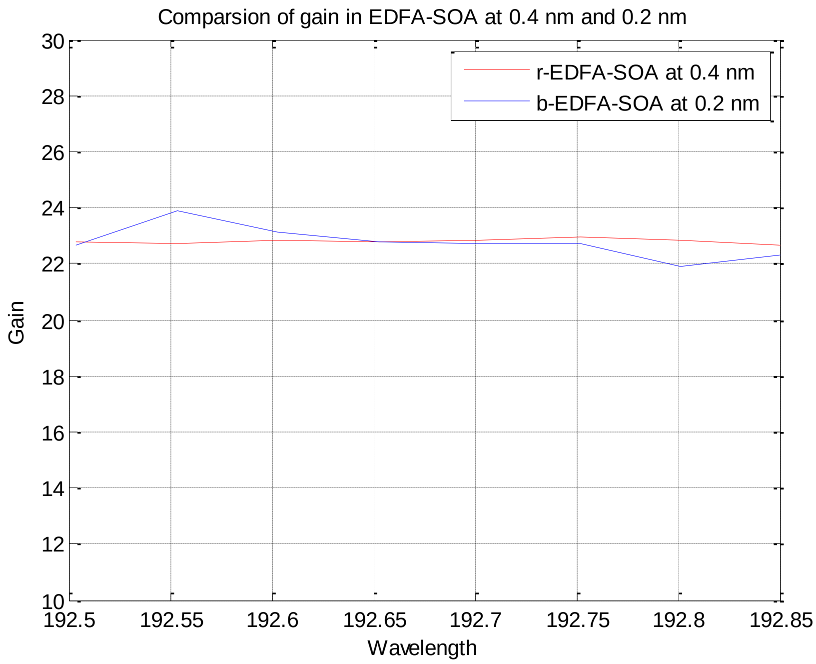

Fig No: 26 Comparison of gains for EDFA-SOA HOA at 0.4 nm and 0.2 nm.

The Comparison shows the gains for the different hybrid optical amplifiers (HOA) at the frequency channel spacing of 50 GHz and 25 GHz for the EDFA-SOA are shown in the figure: 26. Here at the wavelength of 50 GHz the signal is flat when compared to the channel spacing of 25 GHz. In the 0.2 nm the optical signal increases at 100 Km and then it starts degrading.

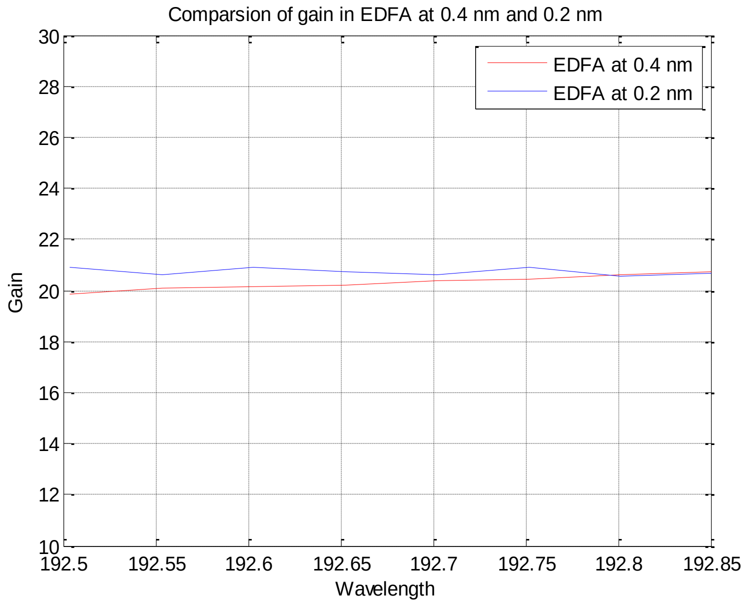

Fig No: 27 Comparison of gains for EDFA optical amplifier at 0.4 nm and 0.2 nm.

The Comparison shows the gains for the single optical amplifier EDFA at the different frequency channel spacing of 50 GHz and 25 GHz as shown in figure 27. Here the EDFA with 0.4 nm has the maximum gain when compared to the 0.2 nm after the long distance of 200 km both the wavelength has same gain. The wavelength of 0.2 nm has the less gain of 19 db.

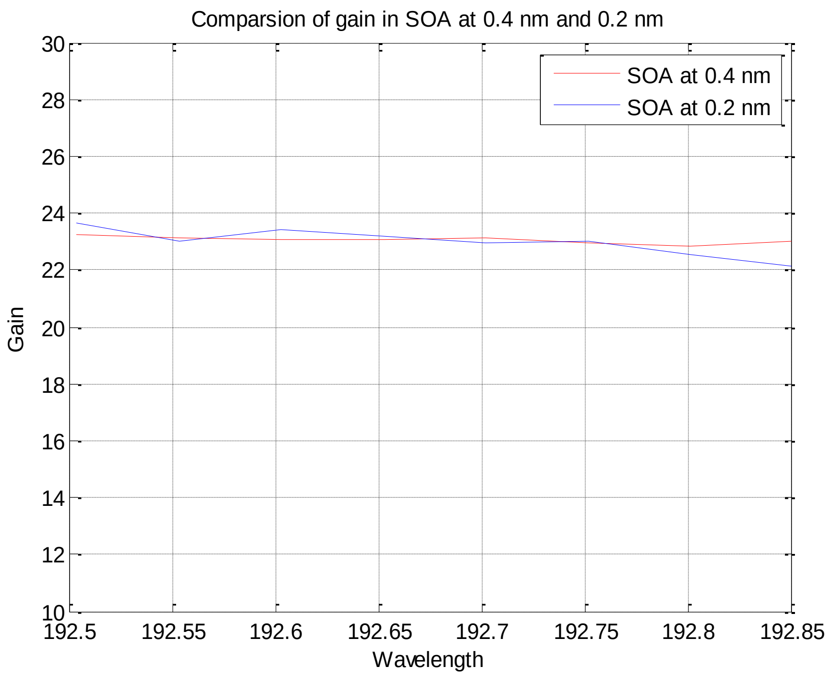

Fig No: 28 Comparison of gains for SOA optical amplifiers at 0.4 nm and 0.2 nm.

The Comparison shows the gains for the single optical amplifier SOA at the different frequency channel spacing of 50 GHz and 25 GHz as shown in figure 28. Here the SOA with 0.4 nm has the less gain when compared to the 0.2 nm after the long distance of 100 km after some distance of 150 km both the wavelength has same gain. At the distance of 200 km the frequency channel spacing of 50 GHz has high gain up to 23 db when compared to the channel spacing of 25 GHz.

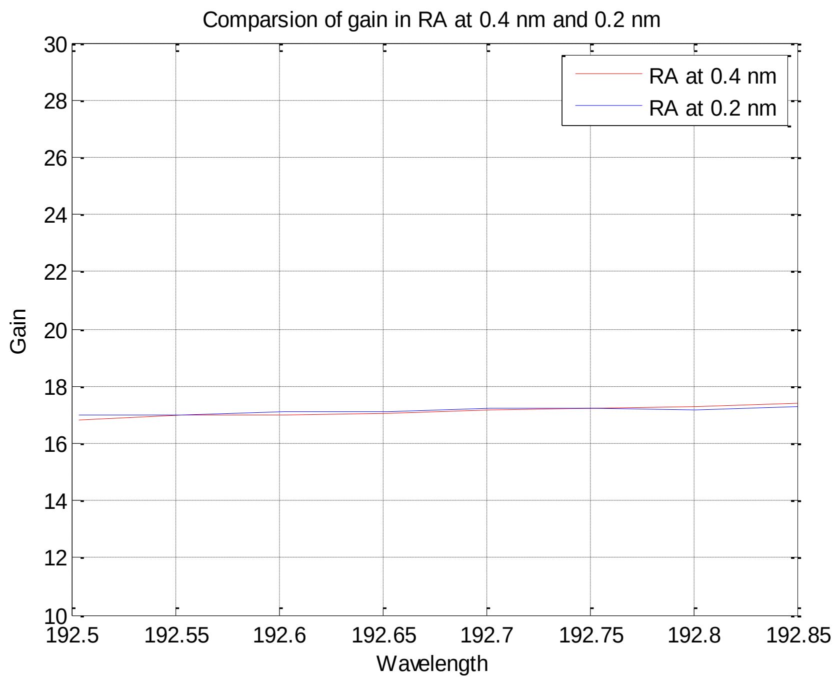

Fig No: 29 Comparison of gain for RA optical amplifiers at 0.4 nm and 0.2 nm.

The Comparison shows the gains for the single optical amplifier Raman Amplifier (RA) at the different frequency channel spacing of 50 GHz and 25 GHz as shown in figure 29. Here the RA with the channel spacing of 0.4 nm and the channel spacing of 0.2 nm has the equal gain when these are compared at the different optical fiber length up to 200 km.

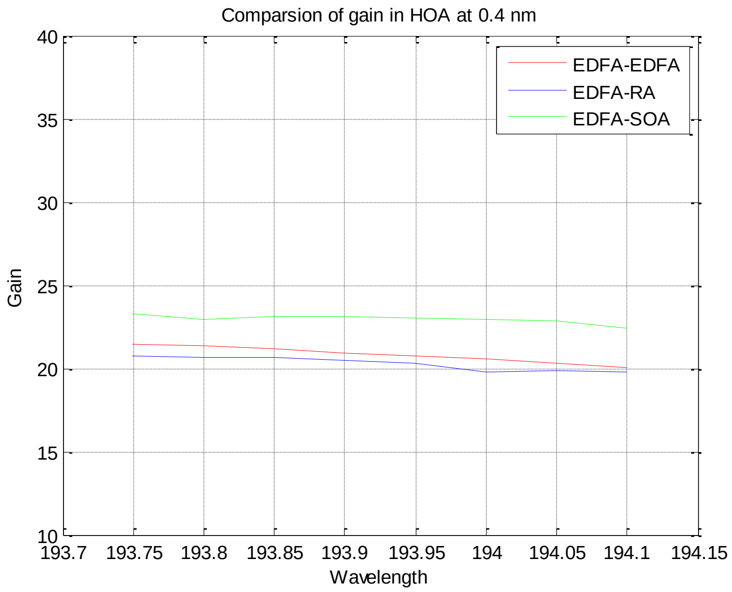

Fig No: 30 Comparison of gain for HOA amplifiers at 0.4 nm.

Here in the figure 30 we are proposing the new wavelength for the same parameters which is already taken in the methodology for the hybrid optical amplifiers like EDFA-EDFA, EDFA-SOA and EDFA-RA and here we getting the maximum gain for these wavelengths when compared to the wavelength taken in the methodology. Here we observe that EDFA-SOA provides the better gain in these wavelengths when compared to the other hybrid optical amplifiers (HOA).

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 Conclusion

Hybrid amplifiers have demonstrated effective in DWDM systems to increase the long-haul transmission distances with development of bandwidth along with the suppressed impairments and nonlinear effects. The largest problem with hybrid amplifier is to hold and provide high bandwidth in case for the higher number of channels. Hybrid Amplifiers can be definitive for DWDM systems the usage of Optical communication software in which various combinations of optical amplifiers could be combined in sequence to utilize their advantages in DWDM structures. Modeling of other parameters e.g. amplified spontaneous emission, gain, BER, length of fiber and variant of output energy can be done for proposed hybrid amplifier.

The optical amplifiers (OA) and hybrid optical amplifiers (HOA) design models had been correctly designed and implemented into OptSim. The 8 channel WDM systems at 10Gbps were investigated with the various hybrid optical amplifiers (HOA) and pumping systems and the overall performance are compared on the basis of the quality factor, transmission distance and the output power. It is found that optical hybrid amplifier RA-EDFA gives the better results when compared to the SOA-EDFA for the transmission distance and the SOA-EDFA provides the best output power. As the increase in the transmission distance increase the output power and the quality factor decreases.

The performance of hybrid optical amplifiers was investigated using the Eye diagram, BER, Eye opening and Q-factor. The schematic simulation results show that RAMAN-EDFA performed better than EDFA-EDFA and SOA-EDFA. The Eye opening for the SOA-EDFA has the best opening at 0.006 dB at 100 km. Raman amplifier shows the low power when compared to other amplifiers.

The flat gain for the different hybrid optical amplifiers gives us the maximum gain at 200 km and out of these all the hybrid amplifiers the EDFA-SOA provides the maximum output power and the maximum gain at 200 km.

6.2 Future Scope

In this thesis, the model is investigated by hybrid optical amplifier (HOA) that's aggregate of RAMAN, SOA and EDFA but this thesis work may be expand for different hybrid amplifiers like hybrid amplifiers combined with other advantage gain media, consisting of aggregate of RAMAN with the fibers doped with different rare elements like Nd and Yb. The simulation is proven that the transmission of 8-channel WDM channels at 10 GB/s channel data rate but this simulation can be implemented for DWDM channels at very high data rate. The channel spacing is also a main concern in the hybrid optical amplifiers (HOA). The version of RAMAN-EDFA-SOA also can be explored in broadcast topologies and optical communication the topologies.

The proposed system investigates the flat gain in the HOA like RAMAN-EDFA, EDFA-SOA and EDFA-EDFA by changing the fiber period. With more than two or more hybrid optical amplifiers there is also a greater increase in the performance.

CHAPTER 7

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