PERFORMANCE ANALYSIS OF OPTICAL AMPLIFIERS FOR INCORPORATION IN OPTICAL NETWORK

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ABSTRACT

This paper has mainly focussed on the use of optical amplifiers in multichannel wavelength division multiplexing (WDM) optical communication system and network. The aim of investigation is to increase the transmission distance and to amplify the signals in broad bandwidth optical networks by optimizing optical amplifiers. The performance of various optical amplifiers have been compared on the basis of transmission distance and frequency. Various types of configurations of optical amplifiers have been experimented and simulated to study the optical amplifier. It is observed that with less number of channels, SOA provide better results. With the increased no of channels SOA degraded the performance due of non-linearity induced. To overcome the problem, the RAMAN amplifier has been observed to be the best alternative.

We further optimized the optical amplifier (RAMAN) using different parameter of RAMAN and EDFA such as Raman fiber length, Raman pump wavelength, Raman pump power, EDFA noise figure and EDFA output power. Using this optimized optical amplifier we have achieved maximum single span distance for different dispersions.

Keywords: ***Optical communication, RAMAN, EDFA, SOA, wavelength division multiplexing (WDM).***

I. INTRODUCTION

The Information revolution implies that multimedia networks need high bandwidth for real- time communication services. At present, optical fiber is the only transmission medium offering such large bandwidth with low loss communication links. One of the requirement of the present era of the information society is high capacity optical fiber communications, which has been one of the fastest growing industries since the 1980s and is the key technology to fulfill the demands for bandwidth for broadband systems. The early optical fiber had a very high attenuation up to 1000 dB/km and could not be used for commercial fiber optical communication systems. In 1970, the scientists at Corning Glass Works were successful in producing a fiber with 20 dB/km loss which opened the doors for optical fiber communications and now, the optical fibers with losses up to 0.2 dB/km are commercially available. In fiber optic communication, there is degradation of transmission signal with increased distance. By the use of optoelectronic repeater, this loss limitation can be overcome. In optoelectronic repeater, optical signal is first converted into electric signal and then after amplification it is regenerated by transmitter. But such regeneration becomes quite complex and expensive for wavelength division multiplexing systems. So, to remove loss limitations, optical amplifiers are used which directly amplify the transmitter optical signal without converting it into electric forms. The optical amplifiers are used in linear mode as repeaters, optical gain blocks and optical pre-amplifiers. The optical amplifiers are also used in nonlinear mode as optical gates, pulse shaper and routing switches. The optical amplifiers are mainly used for amplification of all channels simultaneously in WDM light wave system called as optical in-line amplifiers. The optical amplifiers are also bit rate transparent and can amplify signals at different wavelengths simultaneously. The optical amplifier increases the transmitter power by placing an amplifier just after the transmitter called power booster. The transmission distance can also be increased by putting an amplifier just before the receiver to boost the received power. The optical amplifier magnifies a signal immediately before it reaches the receiver called as optical pre-amplifier. For the need of higher capacity and speed optical fiber communication systems are being extensively used all over the world for telecommunication, video and data transmission purposes. This is because the usable transmission bandwidth on an optical fiber is so enormous (as much as 50 THz) as a result of which, it is capable of allowing the transmission of many signals over long distances. However, attenuation is the major limitation imposed by the transmission medium for long-distance high-speed optical systems and networks. So with the growing transmission rates and demands in the field of optical communication, the electronic regeneration has become more and more expensive. The powerful optical amplifiers came into existence, which eliminated the costly conversions from optical to electrical signal and vice versa. The optical amplifie have attracted much attention as they amplify the broad bandwidth. The optical amplifie has wide gain spectrum ease of integration with other devices and low cost.

II. METHODOLOGY

Network management system is responsible for secure and continuous functioning of any network it keeps the network error free and manage all types of functioning of a network. There are many types of management in All-Optical Networks (AON) like security management, fault management and power management. While some available management mechanisms are applicable to different types of network architectures, many of these are not enough for all-optical networks (AONs).

2.1 Security Challenges in Management of Optical Network

Network management for optical networks faces additional security challenges that arise by using transparent optical components in communication systems. Key aspects include:

- Establishing a robust and flexible optical control plane for managing network resources, provisioning and maintaining network connections across multiple control domains.
- As domains of transparency become larger, physical constraints on connectivity and transmission become increasingly of concern to the optical control plane.
- Addressing security issues that arise, in particular, due to the peculiar behavior of fiber transmission medium and transparent optical components.
- Agreeing expertise techniques and monitoring methods for measurements of optical parameters.
- Specifying **a** comprehensive synthesis of optical parameters and attributes that could be implemented in an appropriate management information model for AONs.
- Designing suitable functions for managing all the specific features and requirements posed by AONs, taking into consideration network and system scalability **as** well as interoperability between equipment and components from different vendors.

One of the main promises of AONs is the establishment of **a** robust and flexible optical control plane for managing network resources, provisioning and maintaining network connections across multiple control domains. Such a control plane must have the ability to select lightpaths' for requested end-to-end connections, assign wavelengths to these lightpaths, and configure the appropriate optical resources in the network. Moreover, between a pair of core OXCs there may be multiple data links and it is therefore, more efficient to manage these as a bundle using a single separated out-of-band control channel. Efficient connection provisioning, however, requires more than simply advertising the availability of wavelengths and routes tn switches and routers in the network. Routing and wavelength assignment (RWA) requires additional information to be taken in account about the characteristics and performance measurements of all supported lightpaths in the network. Thus, the combination of both RWA and performance information, which should be disseminated and shared between network elements, will allow the adequate assessment of the status of all connections simultaneously. In particular, this necessitates enhancing the routing protocols to update and advertise the attributes and parameters that are necessary to compute routes for requested connections and pre-compute the corresponding restoration paths.

To satisfy this requirement, transmission impacts associated with the peculiar behavior of various transmission links and other transparent optical components must be not only taken in consideration at the network designing stage, but also continuously, during normal operation because:

- Transparency in AONs may introduce significant miscellaneous transmission impairments that aggregate and can impact the signal quality enough to reduce the QoS without precluding all network services.
- A nefarious user can take advantage of an AON's vulnerabilities to attacks and perform service disruption attacks despite careful network design.
- ***An*** attack, which is erroneously identified as failure, can spread rapidly through the network.
- Inappropriate action might be taken by the NMS**,** if both the locations and types of attacks are not identified

2.2 Principle of Optical Amplifier

Atom exists only in certain discrete energy state, absorption and emission of light cause them to make a transition from one discrete energy state to another state and related to difference of energy E between the higher energy state $E2$ and lower energy state $E1$ as shown in fig.1. When photon energy E is incident on atom, it may be excited into higher energy state $E2$ through absorption of photon called absorption as shown in figure. As atom in energy state $E2$ is not remain stable, atom returns to lower energy state in random manner by generating a photon as shown in figure. This is called spontaneous emission. Optical amplification uses the principle of stimulated emission, similar to the approach used in a laser. The stimulated emission occurs, when incident photon having energy $E = hv/ \lambda$ interact with electron in upper energy state causing it to return back into lower state with creation of second photon as shown in fig. 1, where h is plank constant, v is velocity of light and λ is the wavelength of light. The light amplification occurs, when incident photon and emitted photon are in phase and release two more photons.

To achieve optical amplification, the population of upper energy level has to be greater than that of lower energy level i.e. $N1 < N2$, where $N1$, $N2$ are population densities of lower and upper state. This condition is known as population inversion. This can be achieved by exciting electron into higher energy level by external source called pumping.

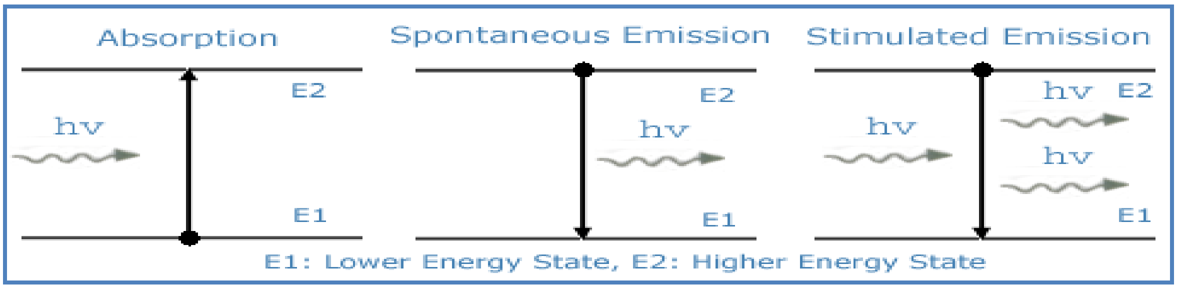


Fig. 1: Principle of Optical Amplifier

2.3 Erbium Doped Fiber Amplifier

The EDFA consists of three basic components: length of erbium doped fiber, pump laser and wavelength selective coupler to combine the signal and pump wavelengths as shown in figure. The optimum fiber length used depends upon the pump power, input signal power, amount of erbium doping and pumping wavelength. Erbium doped fiber amplifiers (EDFAs) can be extensively used in optical fiber communication systems due to their compatibility with optical fiber. An EDFA has a comparatively wide wavelength range of amplification making it useful as transmission amplifier in wavelength division multiplexing systems. Theoretically EDFA is capable of amplifying all the wavelengths ranging from 1500 to 1600 nm. However practically there are two windows of wavelength. These are C and L band. This allows the data signal to stimulate the excited atoms to release photons. Most erbium-doped fiber amplifiers (EDFAs) are pumped by lasers with a wavelength of either 980 nm or 1480 nm. The 980-nm pump wavelength has shown gain efficiencies of around 10dB/mW, while the 1480-nm pump wavelength provides efficiencies of around 5dB/mW. Typical gains are on the order of 25 dB. Typically noise figure lies between 4-5 dB with forward pumping and equivalent figures for backward pumping are 6-7 Db assuming 1480nm pumpinglight was used.

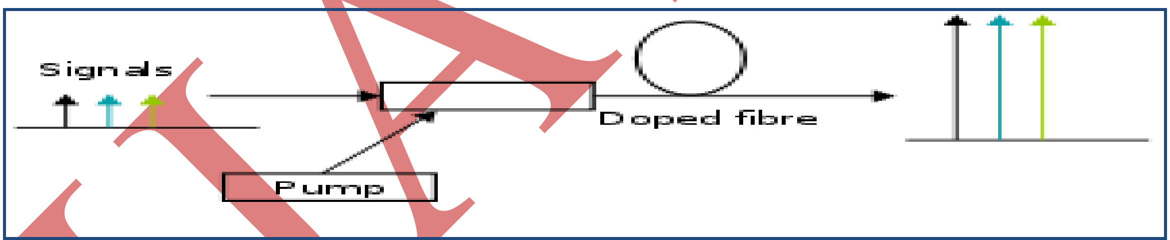


Fig.2: Erbium Doped Fiber Amplifier

2.4 Raman Amplifier

Raman gain in optical fibers occurs from the transfer of power from one optical beam to another through the transfer of energy of a phonon. A phonon arises when a beam of light couples with the vibration modes of the medium. In this instance the optical fiber is the amplifying medium making the gain provided by Raman amplifiers dependent on the optical fiber's composition. In silica fibers, the Raman gain bandwidth is over 260 nm, with the dominant peak occurring at 86 nm from the pump wavelength. This makes Raman gain available across the entire transmission spectrum of the fiber as long as a suitable pump source is available. The gain presented by the Raman Effect in fused silica glass is polarization dependent; therefore gain only occurs if both the signal and pump beams is of the same polarization.

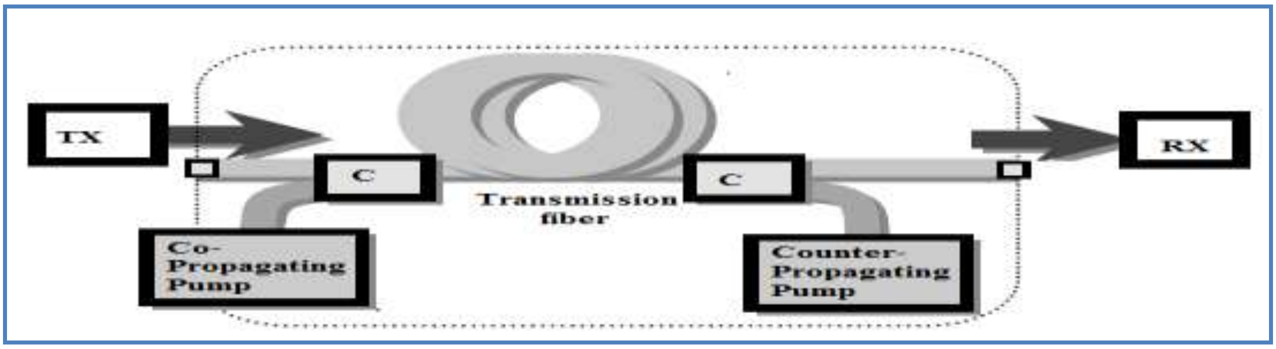


Fig. 3: RAMAN Optical Amplifiers

The fundamental advantages of Raman amplifier are three fold; first, Raman gain exists in every fiber, which provides a cost-effective means of upgrading from the terminal ends. Second, the gain is non-resonant, which is available over the entire transparency region of the fiber. The third advantage of Raman amplifiers is that the gain spectrum can be tailored by adjusting the pump wavelengths. For instance, multiple pump lines can be used to increase the optical bandwidth and the pump distribution determines the gain flatness. Another advantage of Raman amplification is that it is a relatively broad-band amplifier with a bandwidth > 5 THz and the gain is reasonably flat over a wide wavelength range.

2.5 Semiconductor Optical Amplifier

A semiconductor laser amplifier is a modified semiconductor laser, which typically has different facet reflectivity and different device length. Semiconductor optical amplifier is very similar to a laser except it has no reflecting facets. A weak signal is sent through the active region of the semiconductor, which, via stimulated emission, results in a stronger signal emitted from the semiconductor. SOA's are typically used in the following capacities:

- Power boosters following the source (optical Post-amplifier).
- Provide optical amplification for long-distance communications (in-line amplification, repeaters).
- Pre-amplifiers before the photo detector

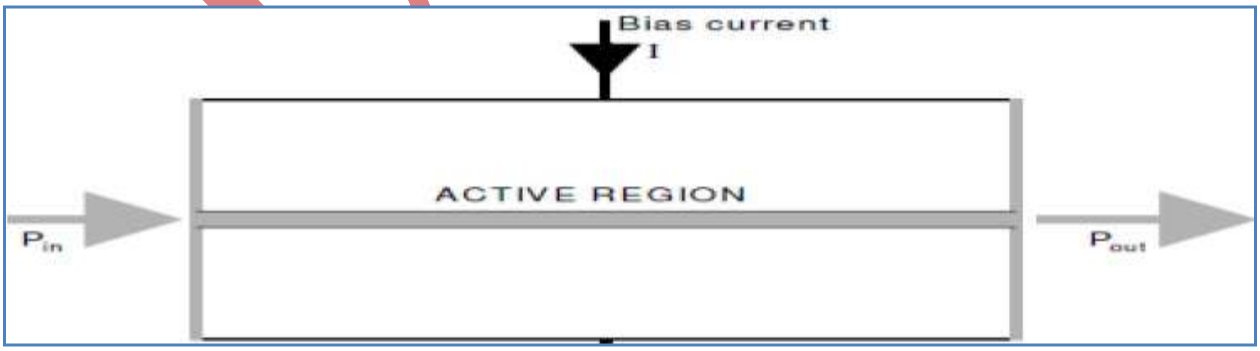


Fig. 4: Semiconductor Optical Amplifier

2.6 Simulation Tools

OPTISYSTEM 11.0 tool of OPTIWAVE SYSTEM INC is the only company which provides a full range of simulation and planning software and services across the entire component to network-level hierarchy. The new platform merges two powerful engines: block mode which excels at fast simulations and sample-mode which excels at longer simulation using unlimited sequence lengths.

2.7 Simulation Steps Used

Five steps to setting up a simulation of a communication system:

1. Creating Optisystem project and set simulation parameters
2. Drawing the schematic diagram
3. Setting parameter value of block models
4. Running simulation
5. Viewing results with data display tools

2.8 Simulation Results Analysis (Analyzers)

Optisystem 11.0 includes a wide range of tools for performing simulation results analysis, plotting, and post-processing of simulation results. Signal waveforms, eye diagram, frequency chirp, signal spectra, dispersion and power maps, Poincare spheres and plots of polarization, auto correlation plots, constellation and scattering diagram, and other results may be viewed at any point in the system topology using predefined plot or interactive analysis options. Interactive plot tool can be used to change the type and format of a plot produced at any point in the system without re-running the stimulation, as well as provide post-processing functionality that allows the user to stimulate the project and perform further analysis of result at a later time.

The analysis tools allow immediate analysis of simulation results as well as analysis of results using third part and custom tools. In addition, Optisystem 11.0 offers several other unique analysis capabilities. Signal summaries automatically provide the user with summary information on all the signals generated during the course of simulation. Double clicking on any input or output port of a component icon shows a summary of signal information (wavelength, power, noise, etc.) for that point in system topology. This feature can, however, be turned on and off in the user preferences settings. In addition, many component models provide a Test function that provides the capability to perform component-level analysis of the component parameters based on current parameters. Frequently, the test functions provide plots of component characteristics such as L-I curves for laser models, frequency response plots for filter, gain profiles for amplifiers, etc. Another unique feature is that many components produce component-level diagnostic and performance characteristics plots during the course of a simulation. For example, the physical EDFA and bidirectional fiber (Raman Amplifier) components models produce plots of characteristics such as the loss and gain spectra, doping profiles, forward and backward propagating spectral densities, etc.

III. RESULTS AND DISCUSSION

This research work carried out by simulation through Optisystem 11.0. Wrok progressed on the comparison analysis for the performance evaluation of power received by three optical amplifiers i.e. SOA, EDFA and Raman amplifiers by changing in input frequency and length of the fiber. In the following section the various simulated models have been analyzed. The first section deals with the different model setup for power received by changing in length for three amplifiers. The second section deals with comparative analysis of power received at the end by changing the input frequency for all optical amplifiers.

3.1 Setup for Received Power in All Optical Networks

The simulation setup of power received at the receiver by using optical amplifiers in all optical networks has shown in the Fig. 6. The scheme is achieved by placing the optical switches and optical amplifier before WDM de-multiplexer of the receiver. In this setup continuous wave lasers are used which have been modulated with the help of carrier generator and frequency modulator. Then this signal was multiplexed by WDM multiplexer before transmission. Simple single mode fiber has used in this setup as a media between transmitter and receiver.

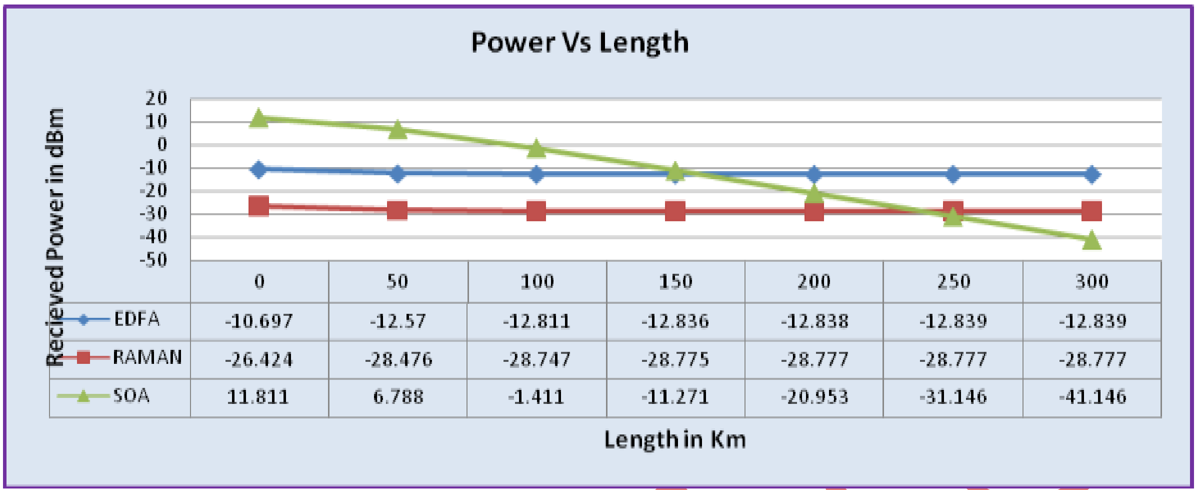


Fig. 5: Comparison Among Three Different Amplifier With Respect To Length And Received Power

Table 1: Data for Change in Length

length	Without Amplifier	EDFA	Raman	SOA
0	-23.665	-10.697	-26.424	11.811
50	-29.523	-12.570	-28.476	6.788
100	-42.765	-12.811	-28.747	-1.411
150	-51.233	-12.836	-28.775	-11.271
200	-67.654	-12.838	-28.777	-20.953
250	-76.243	-12.839	-28.777	-31.146
300	-81.342	-12.839	-28.777	-41.146

Table 2: Data for Change in Frequency

Input Frequency	EDFA	Raman	SOA
193.1	-12.811	-28.747	-1.411
193.2	-13.464	-28.700	-11.439
193.3	-12.805	-28.743	-0.920
193.4	11.106	-3.364	16.957

3.2 Comparative Analysis of Power with the Variation in Length

In the setup of the Optisystem, there are two types of system , first section do not have any optical amplifier and second section have three different types of optical amplifiers present for improving the received power. Transmitted signal is first received with optical amplifier and subsequently without amplifier. Now the length of the optical fiber is changed gradually upto 300 Km and the analysis was carried and for total received power for the different optical amplifiers. Total received power for different amplifier and different length are shown in Fig. 5. For without amplifier, total received power is only -23.411dBm that is very less. But powers with amplifiers are shown in Table 1. Amplifiers increased the received power.

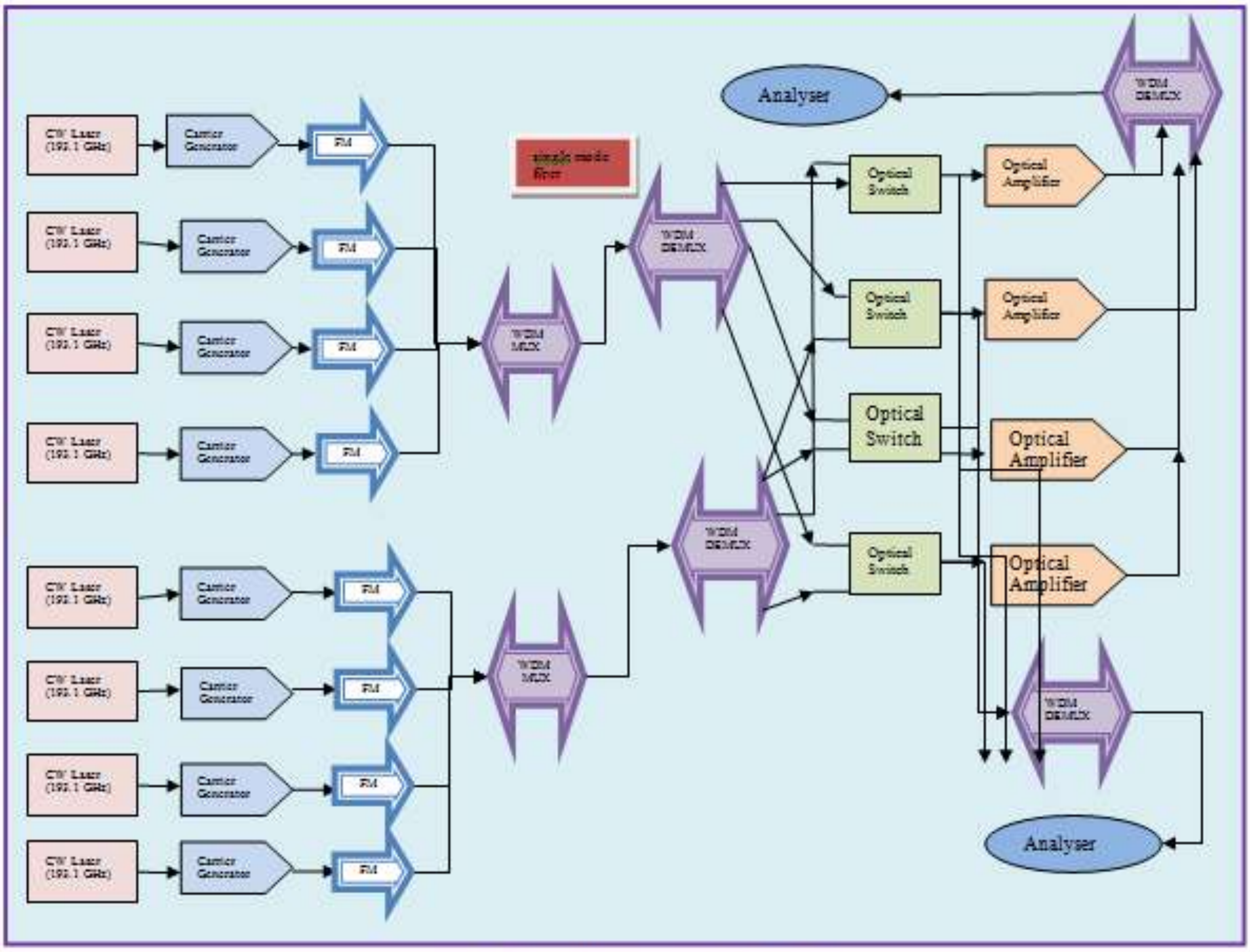
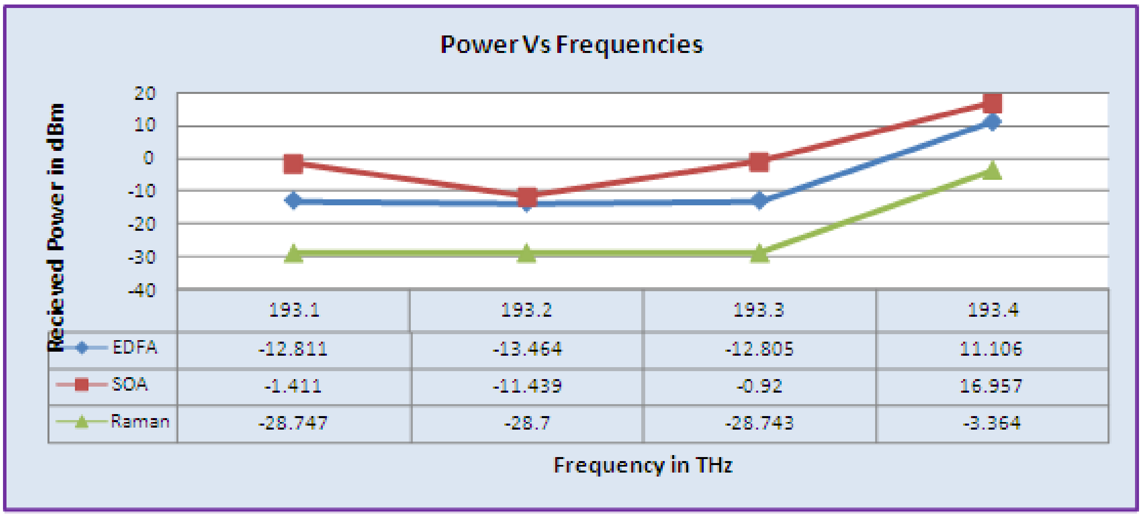


Fig. 6: Block Diagram of the SETUP

3.3 Comparative Analysis Of Power When Change In Frequency

For the analysis of the change in the frequencies we take a fixed length of the optical fiber i.e. 100 Km and change in the input frequency from 193.1 THz to 193.4 THz. The analysis is shown in the fig.7 and in Table 2.



	193.1	193.2	193.3	193.4
EDFA	-12.811	-13.464	-12.805	11.106
SOA	-1.411	-11.439	-0.92	16.957
Raman	-28.747	-28.7	-28.743	-3.364

Fig. 7: Comparison among Three Different Amplifiers With Respect To Input Frequency and Received Power

IV. CONCLUSIONS

Here the simulated system was analyzed with three different amplifiers (EDFA, Raman and SOA amplifier) for improving the received power in all optical networks. These amplifiers are used in optical communication system for amplifying the total power and it helps in error reduction also besides having capability of power equalization. On the basis of comparison and analysis the three system simulation results conclusions are as the followings. The received power of the all optical network with the simple optical amplifier is very good that is much greater than -29.324dBm (received power without amplifier).When EDFA, Raman and SOA applied and compared their output power, the power of EDFA and Raman amplifier was observed to be increased but after some length it becomes constant while SOA amplifier have very good output power as compared to EDFA and Raman Amplifier (SOA have11.811dBm while EDFA have -10.697dBm and Raman have - 26.424dBm) but when length increases the output power of SOA reduces continuously. When input frequencies changes from 193.1 to 193.4 THz SOA amplifier perform better than EDFA and Raman amplifier.

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