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ADVANCE TECHNIQUES OF DISPERSION REDUCTION IN WDM OPTICAL FIBER COMMUNICATION

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Abstract : Optical fiber is the medium through which data is travelled as light travel along a glass or fiber. Optical fiber system faces problems like dispersion, attenuation and non-linear effects. Among them dispersion affects the system most. Dispersion increases along the fiber length. There are different techniques are used for analyzing dispersion in optical fiber like Dispersion compensation by using EDFA and Dispersion compensation by using Pre DCF etc.

IndexTerms* – *WDM, Dispersion, Dispersion compensation by using EDFA, Dispersion compensation by using Pre DCF.

I. INTRODUCTION

Optical fiber is the medium through which data is travelled as light travel along a glass or fiber. In an optical communication system, information is transferred in the form of light signal through optical fiber. The information transferred is achieved by modulating the light signal with carrier signal which is electromagnetic signal in analog communication. Optical communication system has replaced RF techniques at the most demanding capacity application and uses low power consumption and low cost [13].

A significant advancement that high capacity optical communication was the invention of laser in 1960. In 1970 the first low loss fiber was developed and optical fiber became practical [25]. Transmission losses at optical frequencies are very low compared to RF technologies [13]. The losses in single mode fiber is less than 0.2dB at any bit rate which making which is possible to send over a much longer distance about 100 KM without the need for repeater or amplifier [13]. No electrical signal can flow through optical fiber by which owing to external radiation striking the fiber. Now we conclude that fiber is well protected from interference and coupling with other communication and coupling with other communication channels.
The optical fiber has unlimited bandwidth. As result, it has been the transmission media of choice in backbone network and is rapidly encroaching customer premises and enterprise networks [12]. In optical fiber, dispersion is a critical factor limiting the quality of signal transmission over optical links. Dispersion affects the optical transmission. Dispersion is a measure of the temporal spreading that occurs when a light pulse propagates through an optical fiber [29]. There are two types of dispersion in optical fiber:

1) Intramodal dispersion
2) Intermodal dispersion

The group velocity is use to define the dispersion in fibres. The velocity at which the energy in a particular mode travels along the fiber is called Group velocity. The combination of material dispersion and waveguide dispersion is called chromatic dispersion because both are depend on the wavelength [29].

Optical Fiber Communication System
Figure 1 below, shows communication in a general optical communication system. The key components of an optical fiber communication link are common to those of many digital communication links. These may be broken into their roles within the transmitter, channel, and receiver [12]. Electrical transmitter converts the digital information into electrical signal. Optical source is used to convert the electrical signal into the light signal means that optical source performs electrical-optical conversion such as

LED & LASER. Optical fiber is the medium or channel through which optical signal propagates. At the receiver side optical detector is used to convert optical signal into the electrical signal. Examples of optical detector are PIN photodiode and avalanche photodiode. Equalizer and the front end amplifier are used at the side of electrical receiver as they receive electrical signal and converts the signal into the original form of signal. Finally, at the destination original message is recovered.

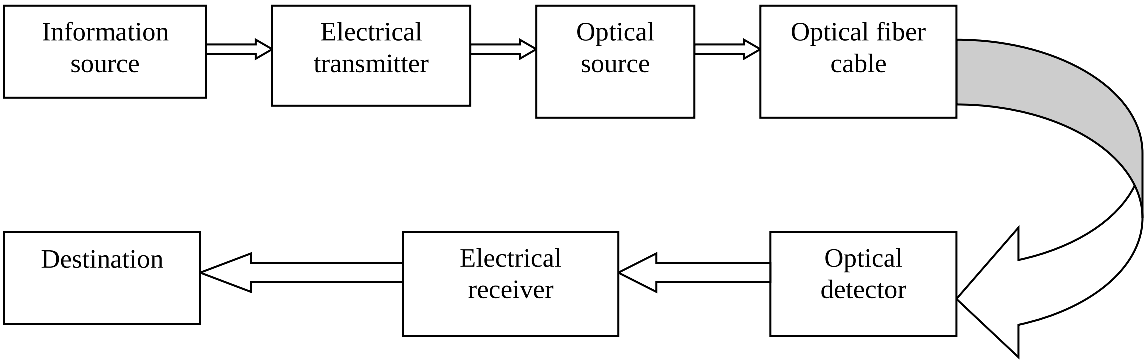

Fig 1: Communication in a general optical fiber Communication system

The most common are telecommunications, military, automotive, medicine and industrial. The advantages include:

- Long distance signal transmission
- Large bandwidth, Light weight, and Small diameter
- Long lengths
- Non-conductivity
- Security
- Designed for future applications needs.

As depicted in fig 2, information can be in either form such as voice, data, or video is encoded into electrical signals. At the input side light source is used to convert electrical signals into light signals. Once the electrical signals are converted to light, they travel along the fiber and they reach at detector, which is used to change the light signals back into electrical signals. The area between light sources to detector is the passive transmission subsystem. Finally, the obtained signals are decoded to give the original digital information in the form of voice, data, or video.

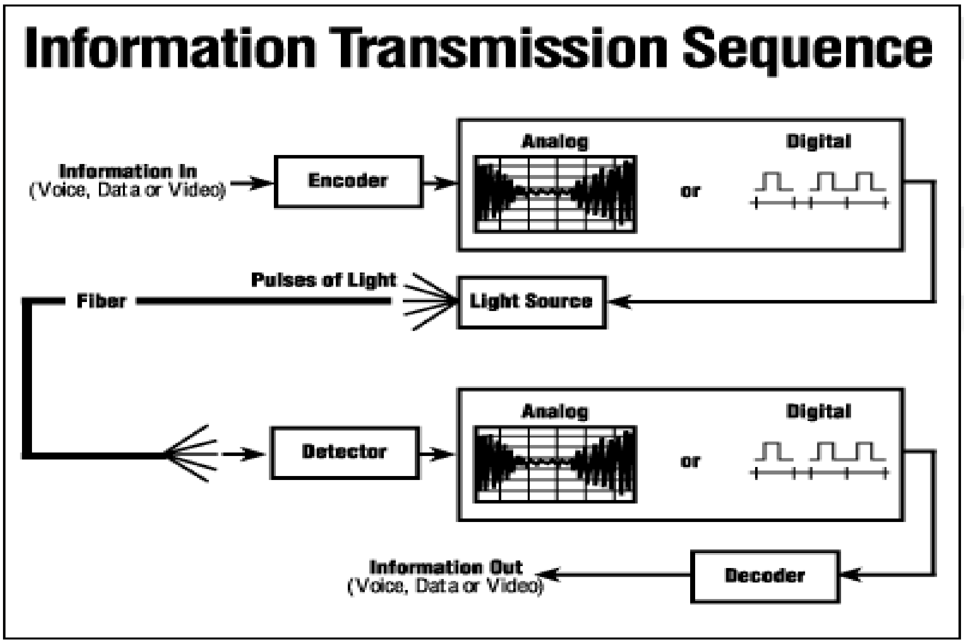

Fig 2: Information transmission sequence.

Dispersion in Optical Fiber

Dispersion in optical fiber is that the development within which the part rate of a wave depends on its frequency, or instead the cluster rate depends on the frequency. Dispersion is usually called chromatic once dispersion impact emphasizes on its wavelength-dependent nature and group-velocity dispersion (GVD) once dispersion impact emphasizes on the role of the group rate. When deliberating the major implementation of optical fiber transmission which involves digital modulation, then dispersion is the phenomenon within the fiber cause broadening of the transmitted light pulses as they travel along the medium. The phenomenon is illustrated in fig.3. It is clear from fig.3 that each transmitted pulse broadens and overlaps with its neighbours, finally at the receiver it becoming indistinguishable. This effect is called as inter symbol interference (ISI). The multimode step index fiber exhibits the best dispersion whereas multimode hierarchal index fiber offers improved performance. However, the amount of broadening of pulses depend upon the distance which is travelled by the pulse within the fiber, and hence there is restriction on usable bandwidth which is dictated by the distance between regenerative repeaters (i.e. the distance the light pulse travels before it is reconstituted) for a given optical fiber link. Thus the measurement of the dispersive properties of a particular fiber is usually stated as the pulse broadening in time over a unit length of the fiber (i.e. ns/km) [27].

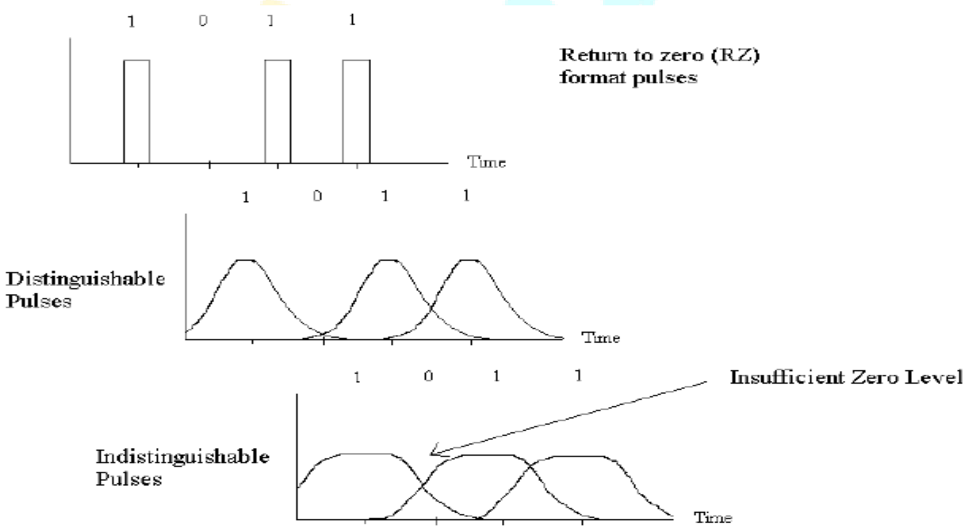

Fig 3: Pulse broadening of light pulses as they transmitted along a fiber

(a) Chromatic Dispersion (Intramodal Dispersion)

Chromatic or intramodal dispersion in all types of optical fiber occur due to the finite spectral line width of the optical source. When optical signals are transmitted over optical links, different wavelength components of the optical signals will generally experience different propagation times due to the fact that the transport medium has different effective refractive indices for different wavelengths. This phenomenon is referred to as dispersion, or chromatic dispersion [20]. Intramodal dispersion may also occurs due to the different dispersive properties of the optical fiber like as material (material dispersion) and the guidance effects of the optical fiber (waveguide dispersion).There are generally two sources of Chromatic dispersion (Intra modal Dispersion):

- Material dispersion
- Waveguide dispersion.

(b) INTERMODAL DISPERSION

Pulse broadening due to intermodal dispersion arises from the propagation delay differences between modes within a multimode fiber [27]. Due to intermodal dispersion different modes arrive at the exit end of the fiber at different times and hence there is pulse broadening of the signal. The amount of intermodal dispersion in a multimode step index fiber gives the greatest pulse broadening and it may be reduced by adoption of an optimum refractive index profile which is offered by the near parabolic profile of most graded index fiber.

Wavelength Division Multiplexing

To develop the robust and efficient networks, the basic foundation of this thesis on optical wavelength division multiplexing (WDM) networks that is used to satisfy the requirements of consumers, as more and more users start to use our networks, and as their usage pattern develop to include more and more bandwidth concentrated networking applications. The WDM technology allows to be multiplexed multiple optical circuits within a single fibre and every wavelength in the fibre may be considered as an essential fibre. Furthermore, the number of available wavelengths increases the capacity of the network, and new advances have shown that the highest number of wavelengths is distant from being reached. To increase the ability to carry much data with high speed of such networks, numerous techniques are utilized. One technique which is popular is wavelength division multiplexing. Figure 4 schematically shows a simplified WDM connection.

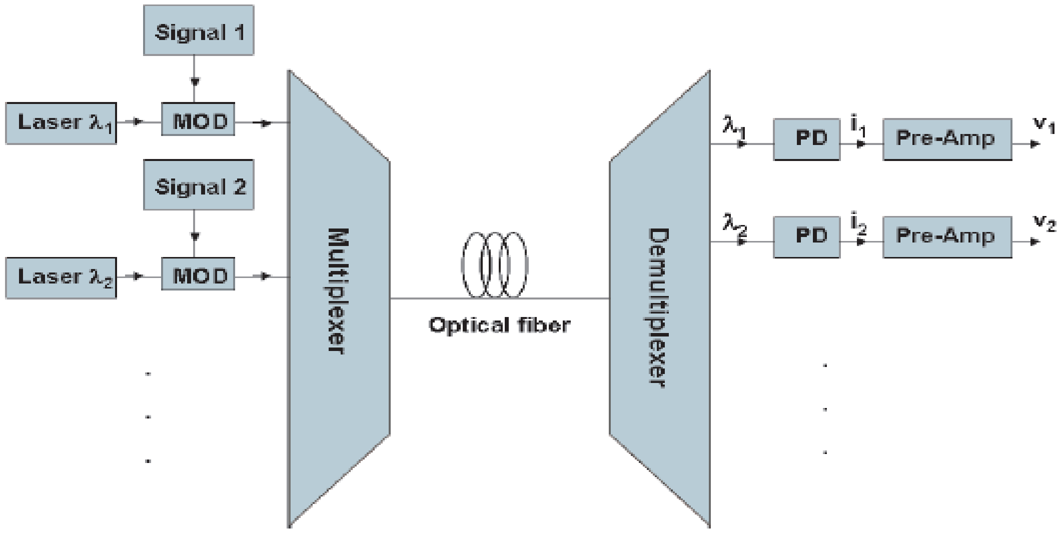

Fig. 4: Schematic diagram of a point-to-point WDM link
(MOD=modulator, PD=photo detector, pre-amp=front-end pre-amplifier)

A wavelength multiplexer is used at the transmitter to combine the different modulated signals of the transmitter lasers operating at a range of wavelengths. At the transmitter side the wavelengths combined in the multiplexer and then launched into the optical fiber and at the receiver the de-multiplexer separates them and couples the light to the photo detectors.

Problem Formulation

There square measure several analysis works that concentrate on analyzing fiber performance by exploiting whole wholly completely different aspects of fiber. We've already studied that the fiber communication is believed for high-speed transmission that gives monumental potential metric in regard to varied electrical cables and wire transmission. In general, most of the information transmission is greatly ill with these wires in little space network.) As network is set up in university campuses, office buildings, industrial plants, so, we have to increase the speed of transmission specially latency and throughput between a transmitter and receiver. (We have to attenuate the dispersion between supply and destination. we've thought of the performance management analysis of single mode glass fiber. owing to less dispersion, single mode fiber is employed.

Simulation Planning For WDM Optical Fiber System

The table.1 shows the simulation planning for 4x1 WDM optical networks. WDM optical network has mainly three sections named as Transmitter, Optical span and Receiver.

Table 1: Simulation planning for 4x1 WDM optical communication network

S. No.	Problem	Circuit Specification	Components Used
1	Designing and implementation of a 4x1 WDM Optical Network	WDM Transmitter Optical span with 80 km long OFC Receiver section	Pseudo Random Bit Sequence Generator NRZ Pulse Generator Mach Zehnder Modulator CW Laser 4x1wdm MUX Optical Fiber Cable 1x4 WDM DMUX PIN Photodiode Low Pass Bessel Filter BER Analyzer Optical Time Domain Visualizer Optical Spectrum Analyzer

Simulation Planning For Dispersion Compensation In Optical Fiber System Using Different Techniques

Table. 2 shows the simulation planning for compensation of dispersion for single-mode fiber by using different techniques.

Table. 2: Simulation planning for dispersion compensation in optical communication network

Simulation and Testing

S. No.	Technique used	Circuit specification	Components used
1	Dispersion compensation by using EDFA	WDM Transmitter, Optical span with 80 km long OFC & EDFA, Receiver section	All Above WDM Network Components with EDFA
2	Dispersion compensation by using Pre DCF	WDM Transmitter, Optical span with 80 km long OFC & 24 Km long DCF, Receiver section	All Above WDM Network Components with EDFA and DCF

Description of Simulation Planning For WDM Optical Fiber System

Fig 5 shows the circuit diagram for simulation of WDM optical fiber network. A laser is an electronic-optical device which is mainly used to emit coherent light radiation. The word "laser" is a short form of Light Amplification by Stimulated Emission of Radiation. Laser light have sharp contrast in comparison of other light sources such as the incandescent light bulb, which emits incoherent light (out of phase with itself) over a wide area and over a wide spectrum of wavelengths, and differs from LED light which is not coherent. If the continuous wave (CW) mode of operation is used then the output of a laser is relatively constant with respect to time. Wavelength division multiplexing (WDM) could be a technology that is employed to multiplex variety of optical carrier signals onto one glass fiber by exploitation totally different wavelengths (i.e. colors) of optical device light-weight. this system permits duplex communication over one strand of fiber, likewise as multiplication of capability. A WDM system uses a 4x1MUX at the transmitter to join the signals together and a 1x4 DMUX at the receiver to split them apart. With the right type of fiber it is possible to have a device that does both simultaneously, and can function as an optical add-drop multiplexer.

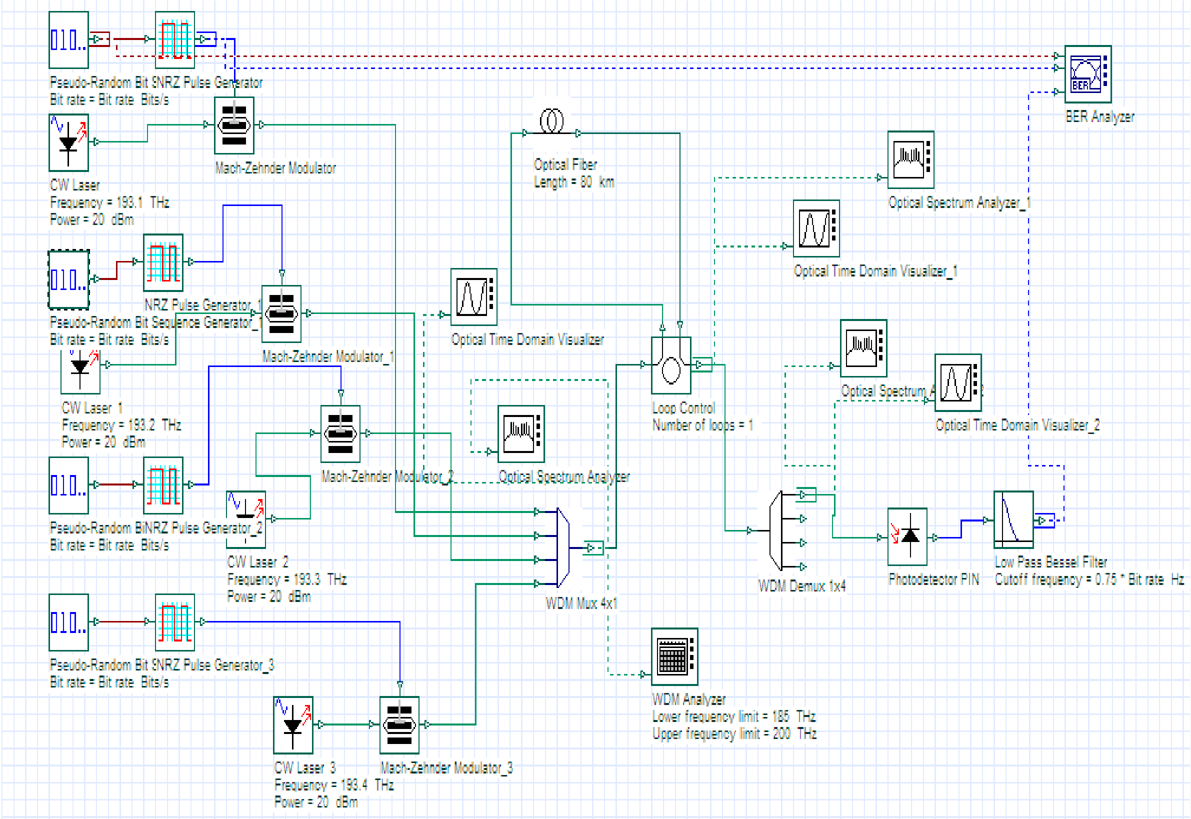

Fig. 5: Simulation of 4x1 WDM network

Simulation for Compensation of Dispersion by using EDFA

The circuit for simulation is shown in fig 6. By the mid-1990s, the erbium-doped fiber amplifier (EDFA) had made WDM highly attractive because it could simultaneously amplify many WDM channels [13]. The EDFA brought new exceptional possibilities in the design of high speed transmission and all-optical switching systems [29]. EDFA is used to compensate the power loss generating by SMF and the DCF signal [14]. At the heart of EDFA technology is the Erbium Doped Fiber (EDF), which is a conventional Silica fiber doped with Erbium [31].The scheme of signal influence affects the performance of an EDFA which is based on excited-state absorption (ESA). These types of effects are wavelength dependent because it depends on matching Photon energies to the transition energies between excited-states of the Er3+ ion. Some of the EDFA parameters are displayed in figure.

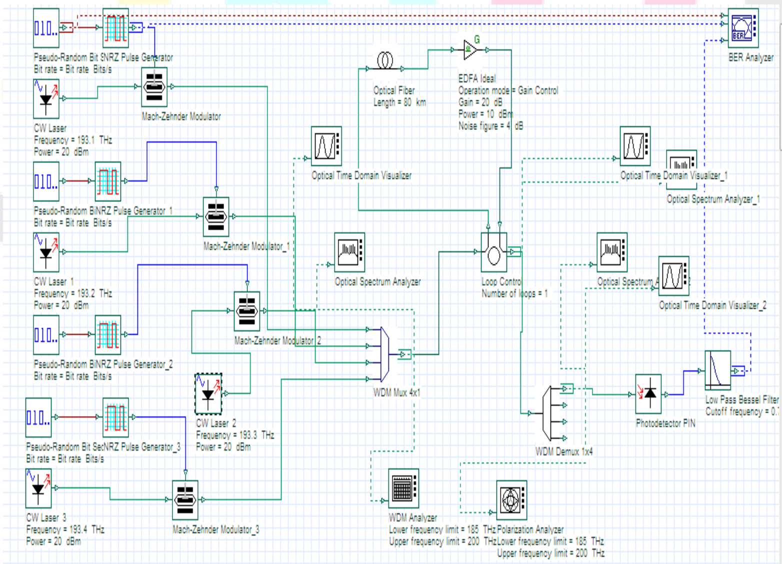

Fig. 6: Dispersion compensation using EDFA

Simulation for Compensation of Dispersion by using Pre DCF

The circuit for simulation is shown in figure 7. DCF has become a widely used method of dispersion compensation because products of DCF are more mature, stable, not easily affected by temperature and have wide bandwidth. It is basically an optical fiber which has a special feature in design such as it provides a large negative dispersion coefficient while the dispersion of the transport fiber is positive.

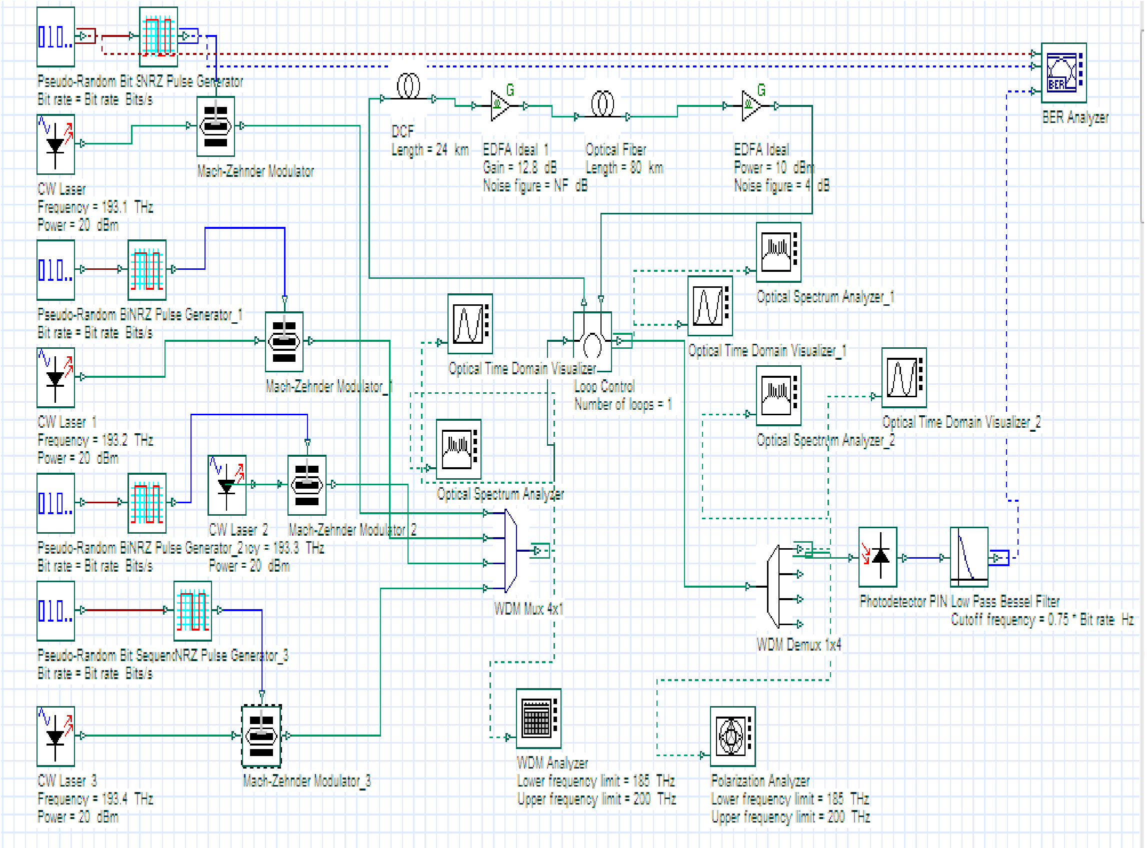

Fig. 7: Dispersion compensation using Pre DCF

The dispersion compensation in Pre DCF compensation scheme is achieve by place the DCF before a certain conventional single-mode fiber, or after the optical transmitter. The length of DCF is 24 km. In the transmission medium signal not only dispersed but also there are more transmission losses. So for minimizing these losses on optical hand we are using EDFA amplifier and on electrical hand we are using low pass Bessel filter [23,24]. It may be mentioned that a few hundred metres to a kilometre of DCF can be used to compensate for dispersion over tens of kilometres of the fiber length [29].

Result and Discussion

This chapter is having results and analysis including input spectrum, output spectrum, eye diagram, the value of signal power, noise power, bit error rate (BER), quality factor(Q factor), optical signal to noise ratio (OSNR) etc.

Simulation Results of 4x1 Wavelength Division Multiplexing Optical Fiber

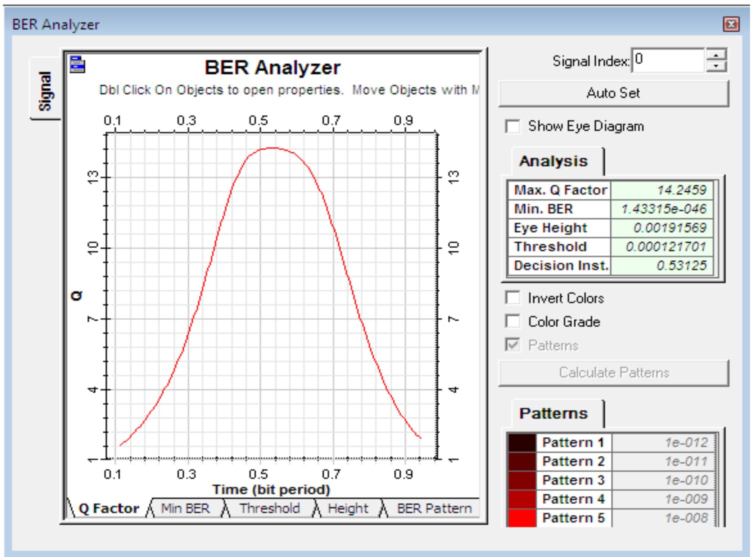

Fig 1: Graph showing Q factor of 4x1 wavelength division multiplexing

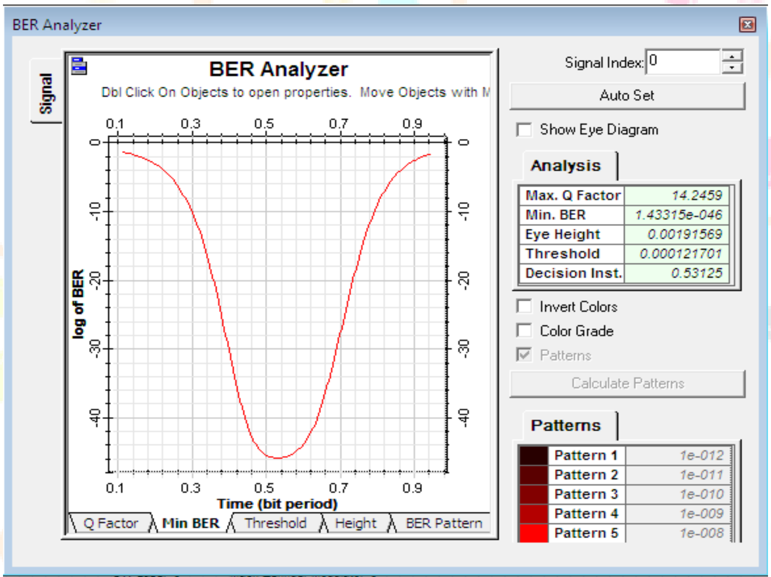

Fig 2: Graph showing Minimum Bit Error Rate of 4x1wavelength division multiplexing

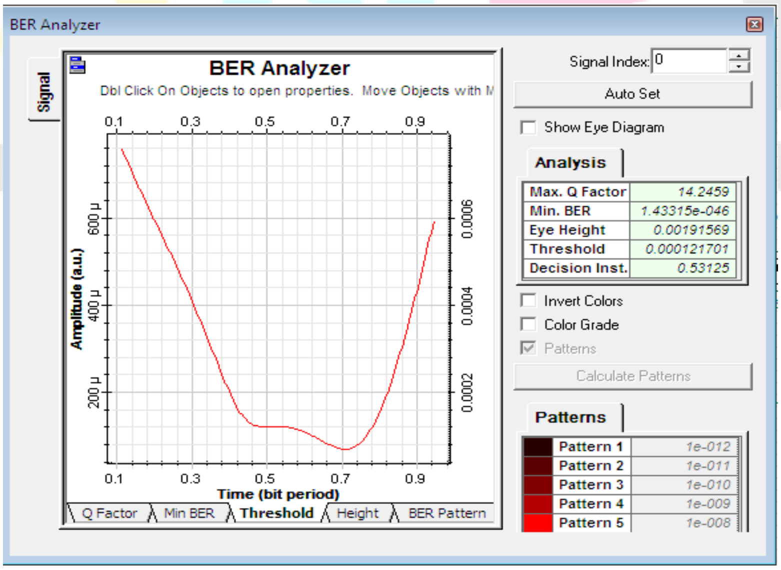

Fig 3: Graph showing threshold of 4x1wavelength division multiplexing optical fiber

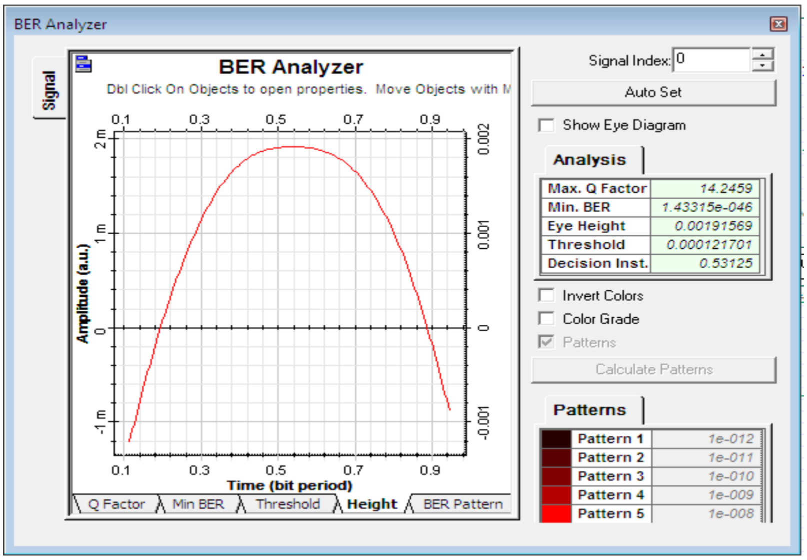

Fig 4: Graph Showing Signal height of 4x1 wavelength division multiplexing

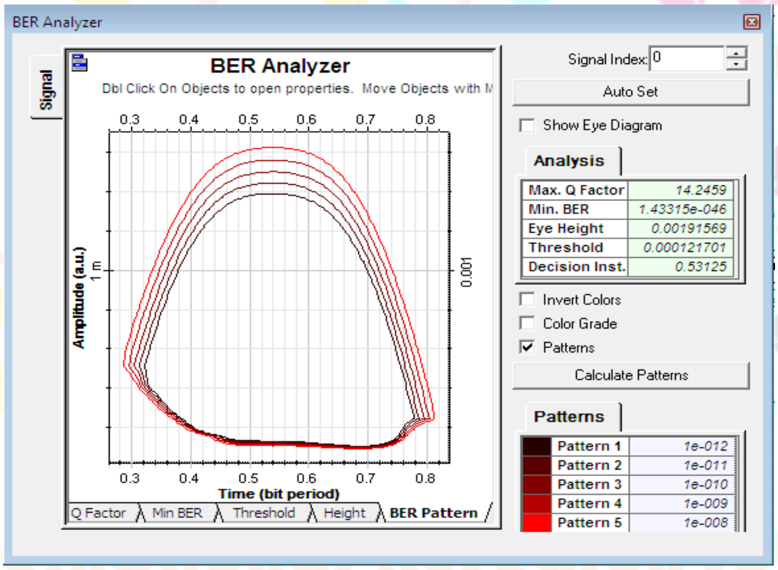

Fig 5: Graph Showing Bit error rate pattern of 4x1 wavelength division multiplexing optical fiber system

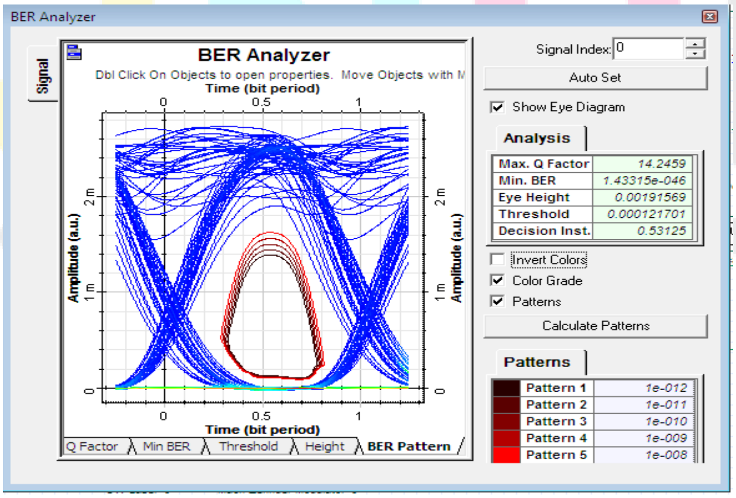

Fig 6: Graph Showing Eye diagram of 4x1 wavelength division multiplexing optical fiber system

Simulation Results For The Purpose Of Compensation of Dispersion in Optical Fibers Using Various Techniques

Simulation Output for Dispersion Compensation by Using Erbium Doped Fiber Amplifiers

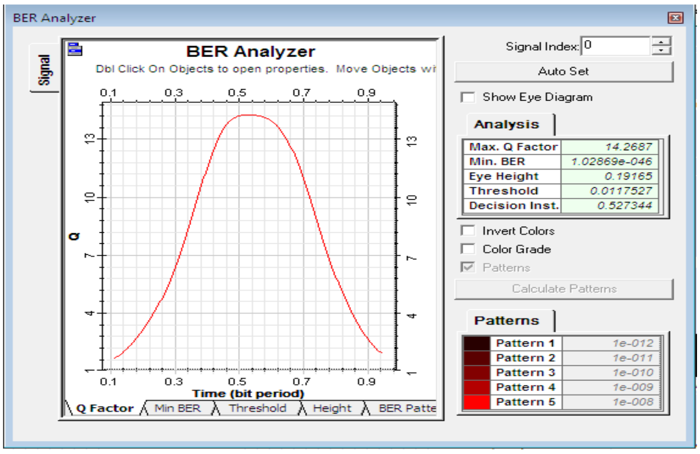

Fig 1: Graph Showing Q factor using Erbium Doped Fiber Amplifiers for dispersion compensation

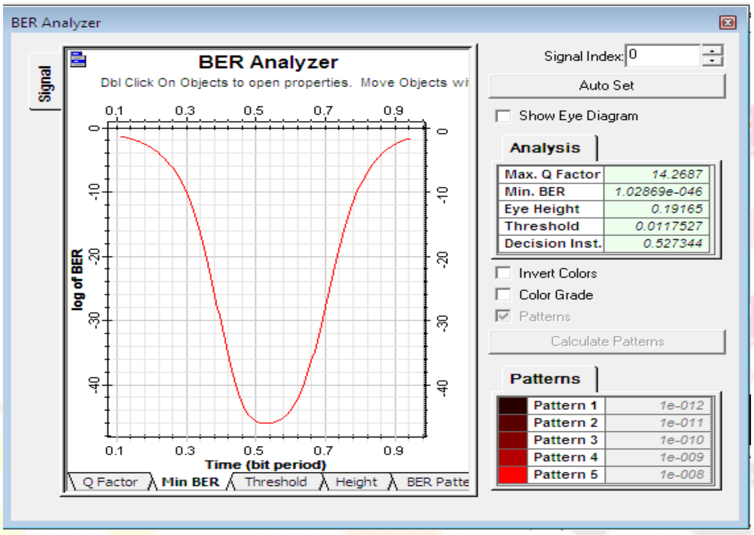

Fig 2: Graph Showing Minimum Bit Error rate using Erbium Doped Fiber Amplifiers for dispersion compensation

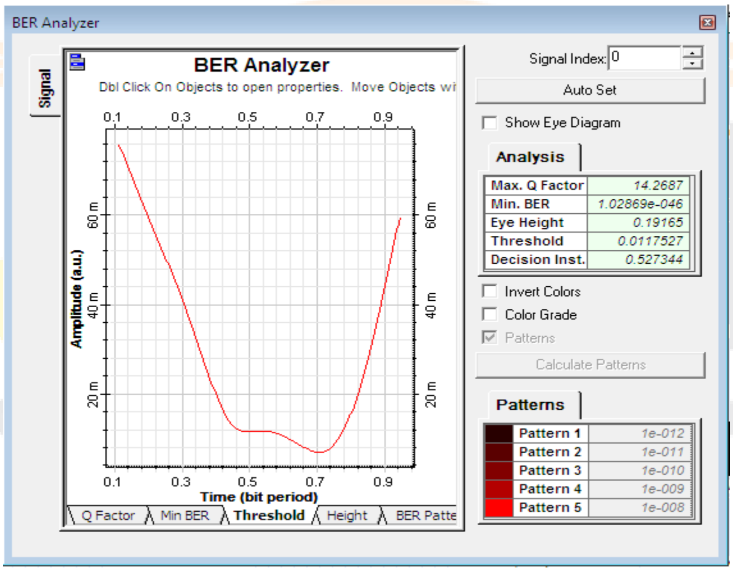

Fig 3: Graph Showing signal threshold using Erbium Doped Fiber Amplifiers for dispersion compensation

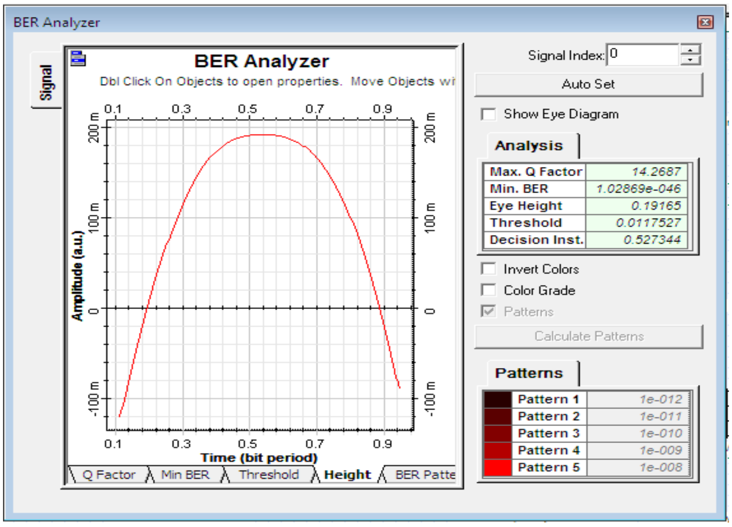

Fig 4: Graph Showing Signal height using Erbium Doped Fiber Amplifiers for dispersion compensation

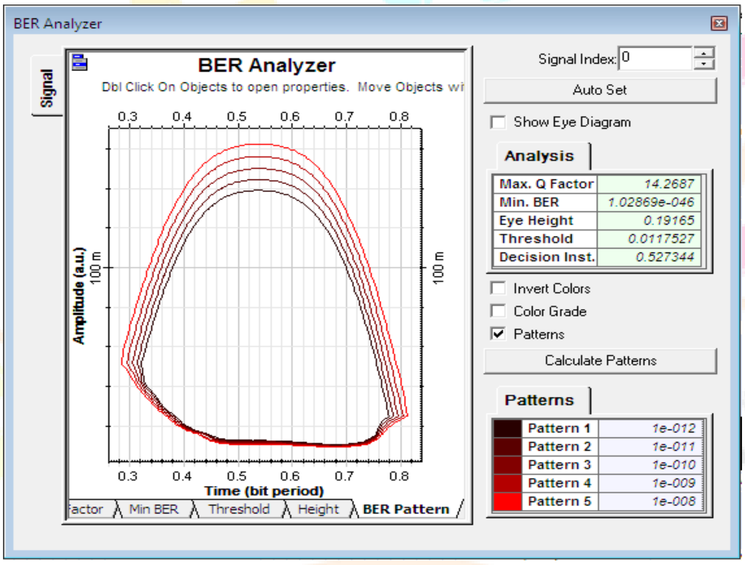

Fig 5: Graph Showing bit error rate using Erbium Doped Fiber Amplifiers for dispersion compensation

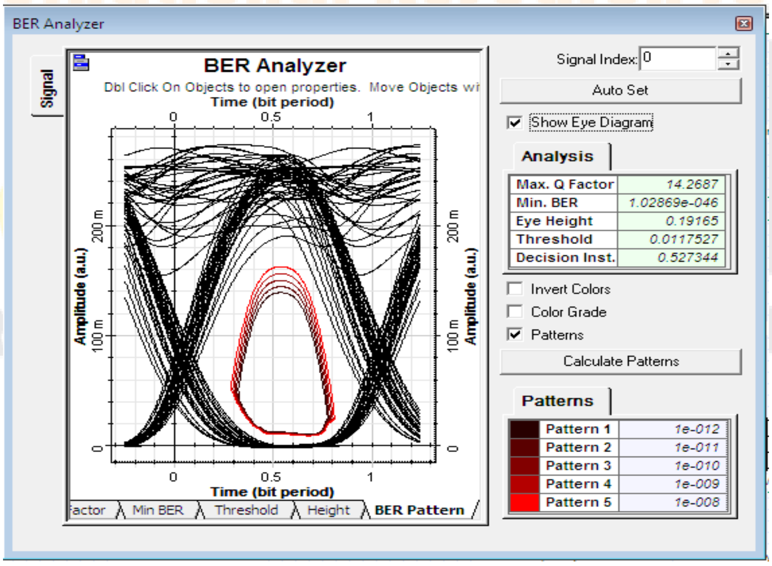

Fig 6: Graph Showing Signal eye diagram using Erbium Doped Fiber dispersion compensation

Table 1: Detailed outputs using Erbium Doped Fiber Amplifiers after wavelength division multiplexing and wavelength division demultiplexing for compensation of dispersion.

Parameters	outcome after wavelength division multiplexing MUX	Result after wavelength division multiplexing DMUX
	Output: Optical Signal	Output1: Optical Signal
Dispersion at 193.10 THz	2.16e+08 ps/nm	1.19e+08 ps/nm
Dispersion at 193.20 THz	-1.93e+08 ps/nm	4.65e+08 ps/nm
Dispersion at 193.30 THz	3.59e+07 ps/nm	1.84e+08 ps/nm
Dispersion at 193.40 THz	6.33e+07 ps/nm	1.09e+08 ps/nm
Noise at 193.10 THz	-1.00e+02 dBm	-3.58e+01 dBm
Noise at 193.20 THz	-1.00e+02 dBm	-8.24e+01 dBm
Noise at 193.30 THz	-1.00e+02 dBm	-9.27e+01 dBm
Noise at 193.40 THz	-1.00e+02 dBm	-9.98e+01 dBm
OSNR at 193.10 THz	1.16e+02 dB	5.59e+01 dB
OSNR at 193.20 THz	1.16e+02 dB	5.50e+01 dB
OSNR at 193.30 THz	1.16e+02 dB	5.33e+01 dB
OSNR at 193.40 THz	1.16e+02 dB	5.33e+01 dB
Power at 193.10 THz	1.67e+01 dBm	2.01e+01 dBm
Power at 193.20 THz	1.67e+01 dBm	-2.73e+01 dBm
Power at 193.30 THz	1.67e+01 dBm	-3.94e+01 dBm
Power at 193.40 THz	1.66e+01 dBm	-4.64e+01 dBm

QUALITY FACTOR	14.26	low then Pre, Post dispersion compensating fiber	
MINIMUM BIT ERROR RATE	01.02e-046		
THRESHOLD	00.01		
EYE HEIGHT	00.19	more than all other techniques	
DISPERSION	Change in dispersion		
193.10 THz	02.16e+08ps/nm	01.19e+08ps/nm	Noise reduces optical signal to noise ratio increases
193.20 THz	Dispersion Increases		Noise of decreases optical signal to noise ratio increases
193.30 THz	03.59e+07ps/nm	-01.84e+08ps/nm	Noise of decreases optical signal to noise ratio increases
193.40 THz	6.33e+07ps/nm	1.09e+06ps/nm	Noise of decreases optical signal to noise ratio increases

Simulation outcomes by pre dispersion compensating fiber For Compensation of Dispersion

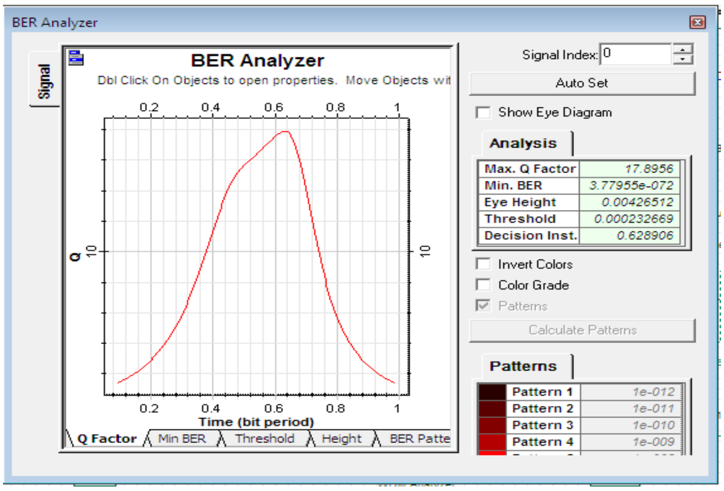

Fig 1: Graph Showing Q factor using pre dispersion compensating fiber for Compensation of Dispersion

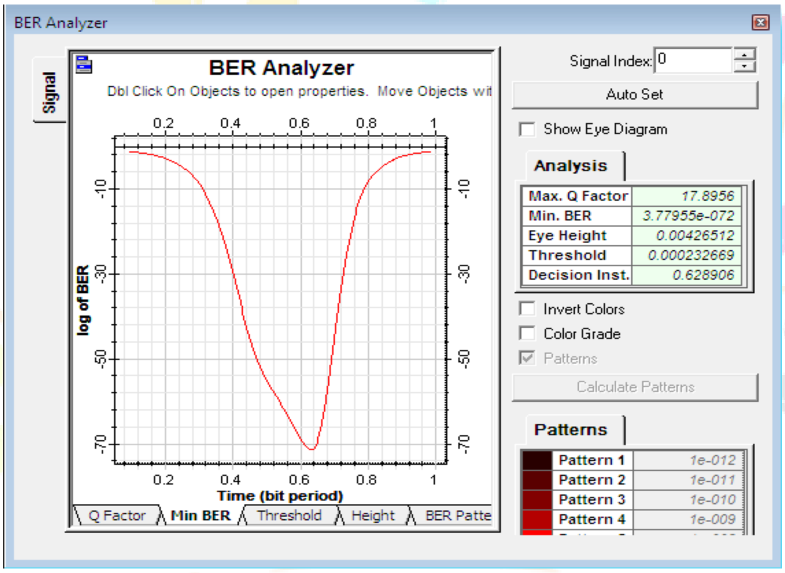

Fig 2: Graph Showing Minimum Bit error Rate using pre dispersion compensating fiber for Compensation of Dispersion

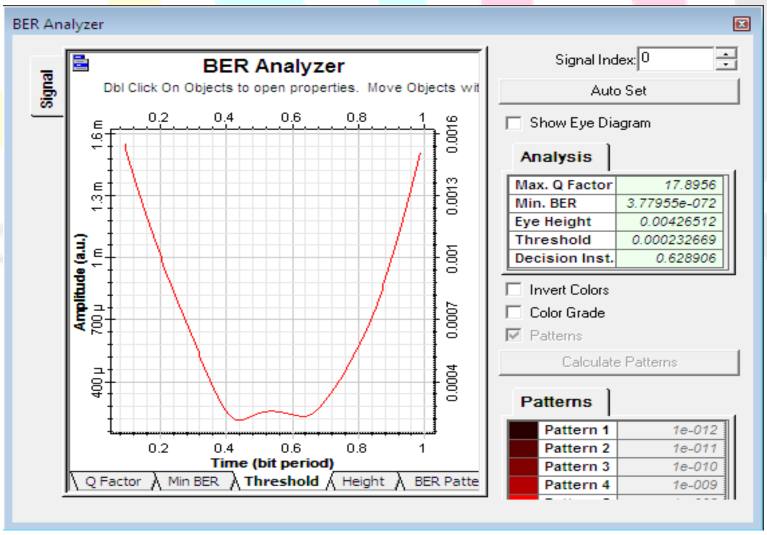

Fig 3: Graph Showing Threshold using pre dispersion compensating fiber for Compensation of Dispersion

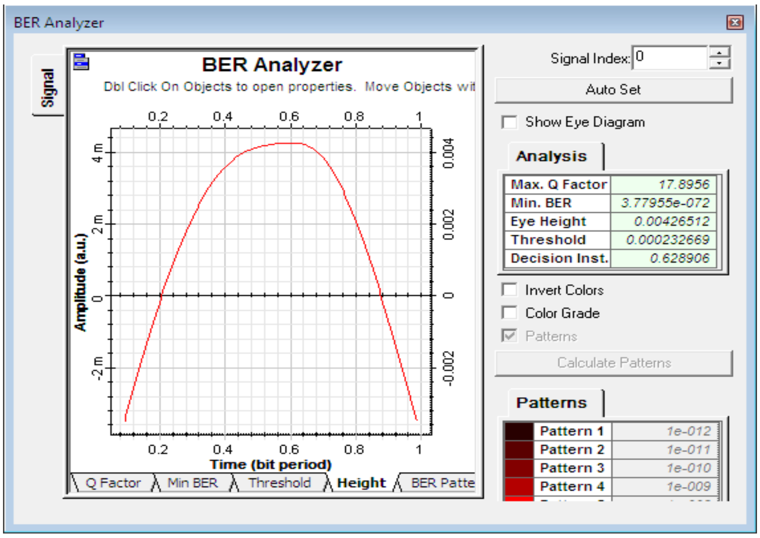

Fig 4: Graph Showing Height of signal for using pre dispersion compensating fiber for Compensation of Dispersion

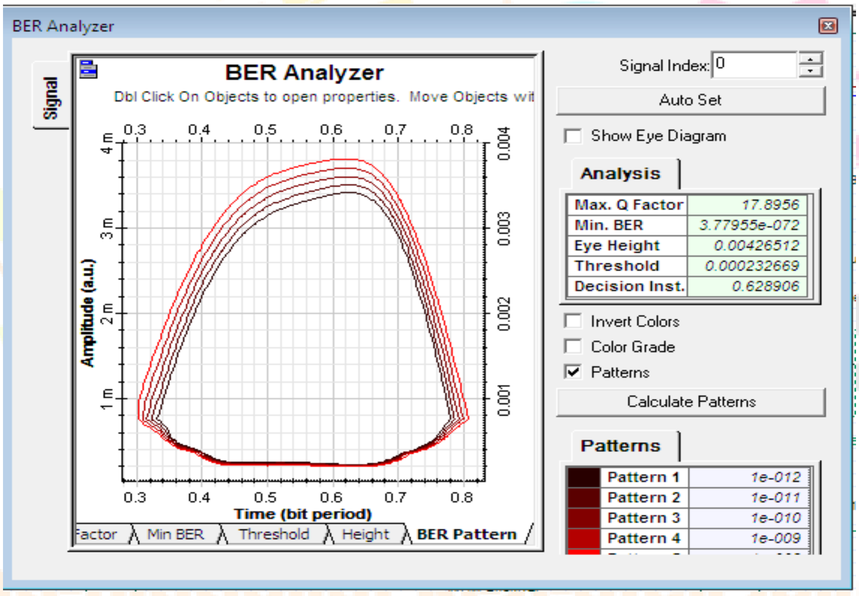

Fig 5: Graph Showing bit error rate outline using pre dispersion compensating fiber for Compensation of Dispersion

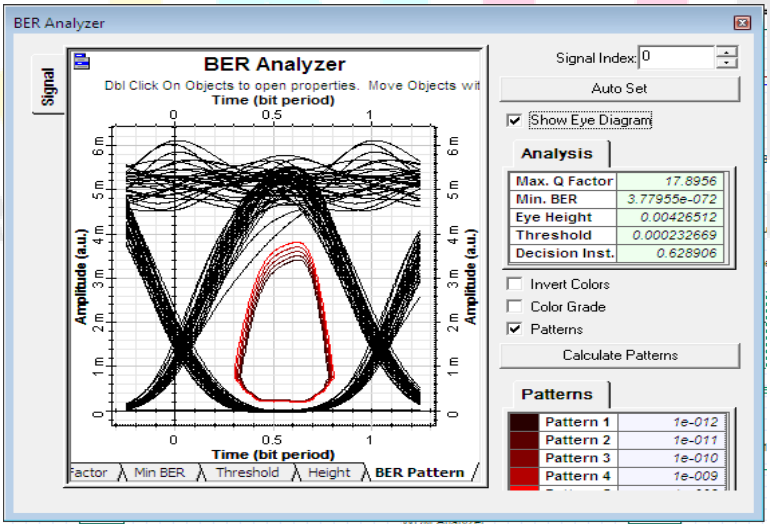

Fig 6: Graph Showing signal eye diagram using pre dispersion compensating fiber for Compensation of Dispersion

Table 1: detailed outputs using pre dispersion compensating fiber after wavelength division multiplexing and wavelength division demultiplexing for compensation of dispersion

Parameters	outcome after wavelength division multiplexing MUX	Result after wavelength division multiplexing DMUX
	Output: Optical Signal	Output1: Optical Signal
Dispersion at 193.10 THz	2.16e+08 ps/nm	-1.53e+08ps/nm
Dispersion at 193.20 THz	-1.93e+08 ps/nm	-6.07e+07 ps/nm
Dispersion at 193.30 THz	3.59e+07 ps/nm	-5.95e+07 ps/nm
Dispersion at 193.40 THz	6.33e+07 ps/nm	2.44e+07 ps/nm
Noise at 193.10 THz	-1.00e+02 dBm	-5.00e+01 dBm
Noise at 193.20 THz	-1.00e+02 dBm	-9.69e+01 dBm
Noise at 193.30 THz	-1.00e+02 dBm	-1.00e+02dBm
Noise at 193.40 THz	-1.00e+02 dBm	-1.00e+02dBm
OSNR at 193.10 THz	1.16e+02 dB	5.34e+01 dB
OSNR at 193.20 THz	1.16e+02 dB	5.29e+01 dB
OSNR at 193.30 THz	1.16e+02 dB	4.39e+01 dB
OSNR at 193.40 THz	1.16e+02 dB	3.68e+01 dB
Power at 193.10 THz	1.67e+01 dBm	3.43e+00dBm
Power at 193.20 THz	1.67e+01 dBm	-4.40e+01 dBm
Power at 193.30 THz	1.67e+01 dBm	-5.60e+01 dBm
Power at 193.40 THz	1.66e+01 dBm	-6.31e+01 dBm

QUALITY FACTOR	17.89	High then Post dispersion compensating fiber	
MINIMUM BIT ERROR RATE	3.77e-72		
THRESHOLD	00.000232		
EYE HEIGHT	00.0042	high then Post& Symmetrical dispersion compensating fiber, Opt grating	
DISPERSION	Change in dispersion		
193.10 THz	02.16e+08ps/ns	01.53e+08ps/ns	Noise reduces optical signal to noise ratio increases
193.20 THz	-01.93e+08	-6.07e+07	Noise of decreases optical signal to noise ratio increases
193.30 THz	3.59e+07ps/nm	3.59e+07ps/nm	Noise of decreases optical signal to noise ratio increases
193.40 THz	3.59e+07ps/nm	2.44017e+007ps/nm	Noise of decreases optical signal to noise ratio increases

CONCLUSION

In all the techniques we find that losses are reduced including dispersion but all performance parameters are changed with one technique to another technique. In each technique where eye opening is high and we get sharp eye diagram with a better value of noise and signal power. The eye-opening is larger when less attenuation occurs. Q-factor depends on the filter used. Higher value of BER, Q-factor and eye opening after using different compensation technique through fiber show the good communication through it. Q-factor is more with NRZ modulation format and different combinations of length and filters than RZ modulation format. So NRZ modulation format is better in WDM Technique.

II. ACKNOWLEDGEMENT

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