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# Compensation in Optical Fiber WDM System Using Different Compensation Techniques

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***Abstract: Optical fiber refers to as the medium and the technology associated with the transmission of information as light pulses along a glass or plastic wire or fiber There are several works focusing on analyzing fiber performance by exploiting different aspects of fiber. I have already studied that the optical fiber communication is known for high-speed transmission and provides greater bandwidth in respect to other electrical cables and wire transmission. In general, most of the data transmission is greatly affected by these wires in small area network. As a 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. I have to measure the dispersion between source and destination. I have considered the dispersion control analysis of single mode in optical network. Single mode fiber is used due to less dispersion. In this paper we are focuses on the multiplexing format used to measure the dispersion in optical fiber. I have used wave length division multiplexing technique. I have simulated for many important parameters i.e. Dispersion, Bit error rate (BER), eye opening and Q factor through optical simulator OPTISYSTEM .I mainly focus on the dispersion of optical spectrum of the signal that passes through the medium. I have used these filters at the output of the PIN photodiode and filter electrical spectrum obtained at electroscope and an optical spectrum shown on the optical spectrum analyzer.***

***Keywords:***

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## I. INTRODUCTION

Communication in an optical fiber communication system may be defined as the transfer of information from one point to another point in form of light signals. Within a communication system the information transfer is frequently achieved by superimposing or modulating the information with a carrier which is either an electromagnetic wave generally in analog communication system and satellite communication system. However, communication may also be achieved using an electromagnetic carrier which is selected from the optical range of frequencies. Optical fiber refers to the medium and the technology associated with the transmission of information as light pulses along a glass or plastic wire or fiber. Optical fiber carries much more information than conventional copper wire with high security of information. Optical fiber is compact, low-loss, immune to electromagnetic interference, secure, non-corrosive, and has almost unlimited bandwidth. Most telephone company long-distance lines are now of optical fiber. Over the past three decades fiber has become the transporting medium of choice for voice, video, and data, particularly for high-speed communications. Optical fiber has been proven to have the widest bandwidth compared to any other media known, including wireless, copper wire, sonar, and even free-space-optics. Tera Hertz (10 to the 12th power) bit rate has been demonstrated in the lab by using the standard single mode telecom fiber. As a comparison, the entire useful radio bandwidth worldwide is only 25Gbps, a mere 0.1 percent of the bandwidth supported by a single strand of fiber. As a result, a single strand of optical fiber can easily replace a large bundle of copper wires while significantly boosting system bandwidth. Optical fiber poses far lower loss to signal than any other transmission media. The typical loss per kilometer in a single mode fiber is around 0.4dB at any bit rate, making it possible to send signal over a much longer distance (more than 100km) without the need for repeaters or amplifiers. On the contrary, the typical loss figure for a coaxial copper cable is around 40dB/km at 10-100Mbps and grows linearly with bit rate. Unlike its copper counterparts, an optical fiber does not emit electromagnetic waves and therefore is extremely difficult to tap into. Even if the fiber were tapped into, it would create enough disturbances in the system to be detected.

## II. SIMULATION

An all-optical network simulator is used for the performance control and analysis of optical fiber Communication system in optical network. The simulator is OPTISYSTEM from OPTIWAVE SOFTWARE. This software is an intuitive modeling and simulation environment supporting the design and the performance evaluation of the transmission level of optical communication systems. It provides suitable platform for automated design of all optical networks. OPTISYSTEM features many attributes and the simulation in based on its performance analysis monitors. It also provides a wide and complete choice of its proprietary time- and frequency-domain algorithms allow simulation of complex systems with efficiency and accuracy. This thesis applies one scenarios for single-mode fiber. Simulation is done using WDM Mux , lengths of optical fiber i.e., the distance of data transmission and filters used at the receiving end.

## 2.1 Simulation Block Diagram

The block diagram of the work is shown in the Figure.1and 2. It describes the basic components used for the analysis of the effect of PMD compensation.

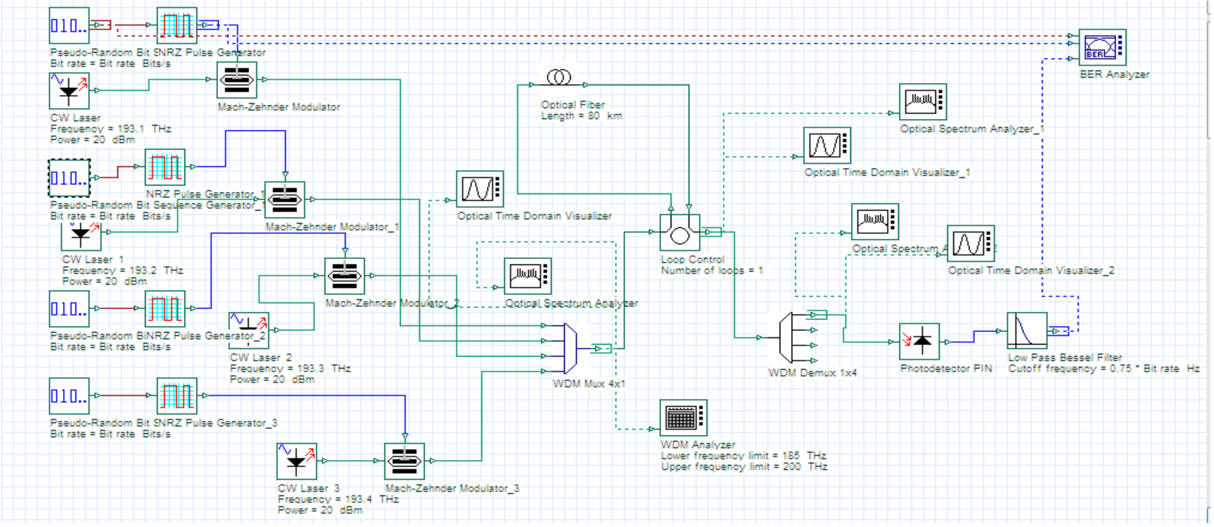


**Figure 7.1: Simulation of 4x1 WDM network.**

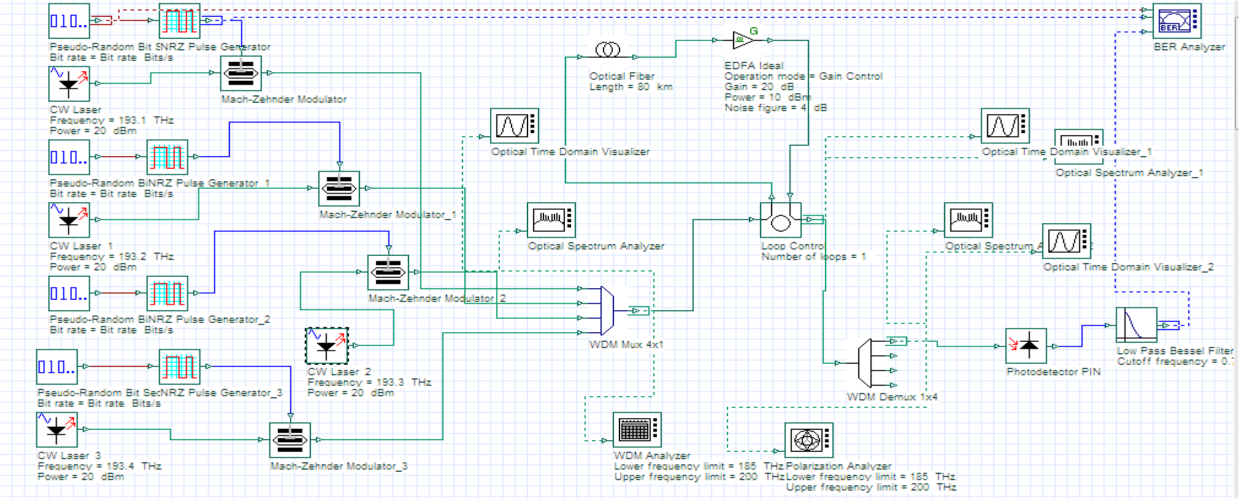


**Figure7.2 Dispersion compensation using EDFA**

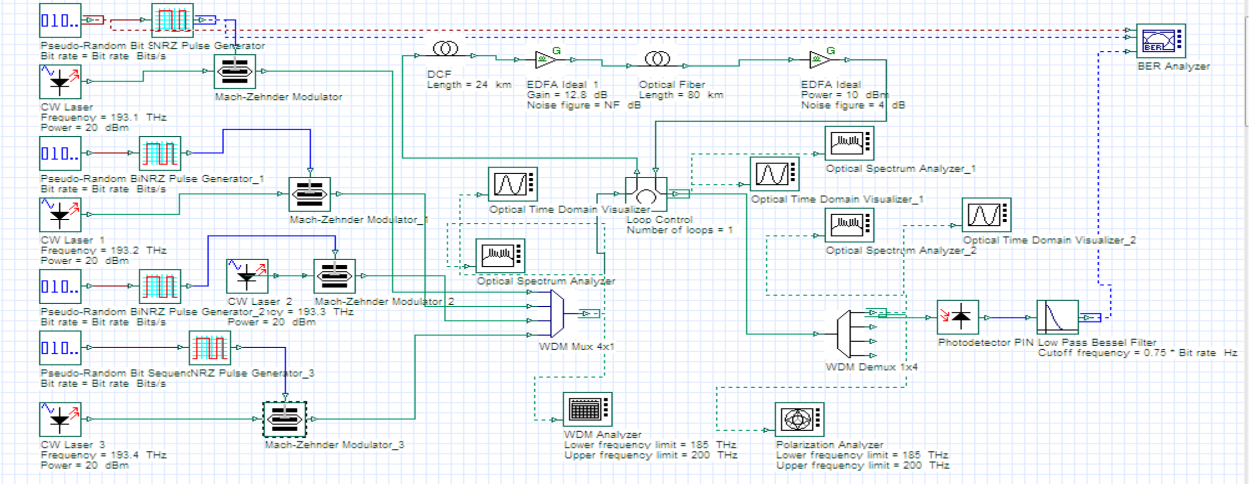


**Figure7.3 Dispersion compensation using PRE DCF**

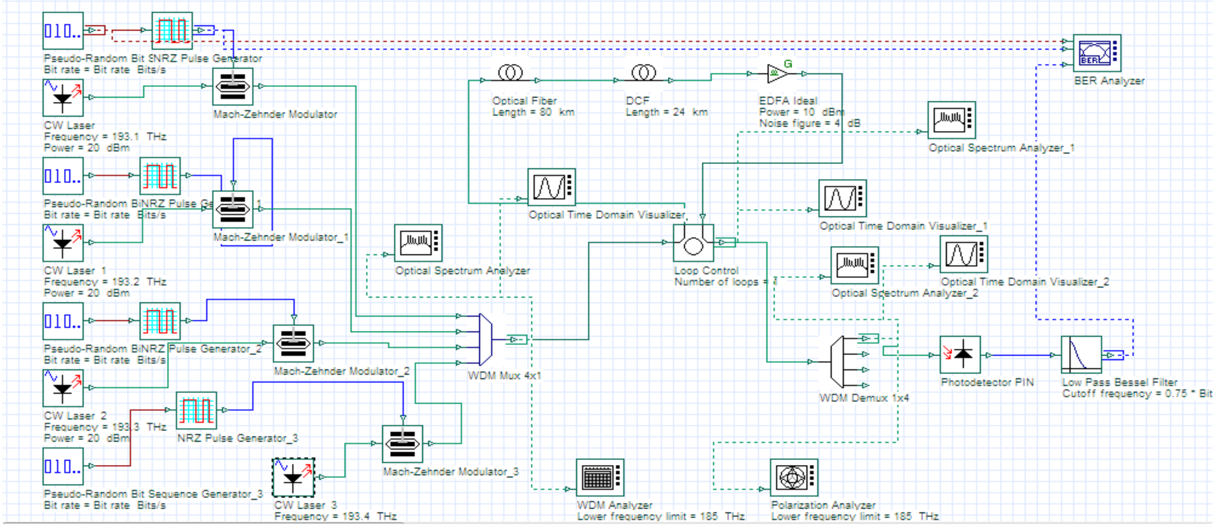


Figure7.4 Dispersion compensation using POST DCF

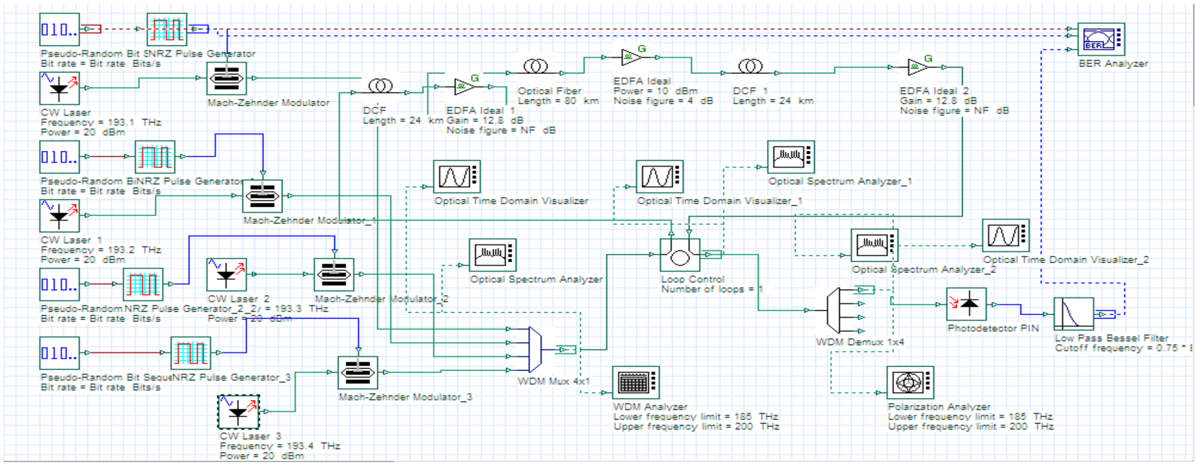


Figure 7.5 Symmetrical- dispersion compensation

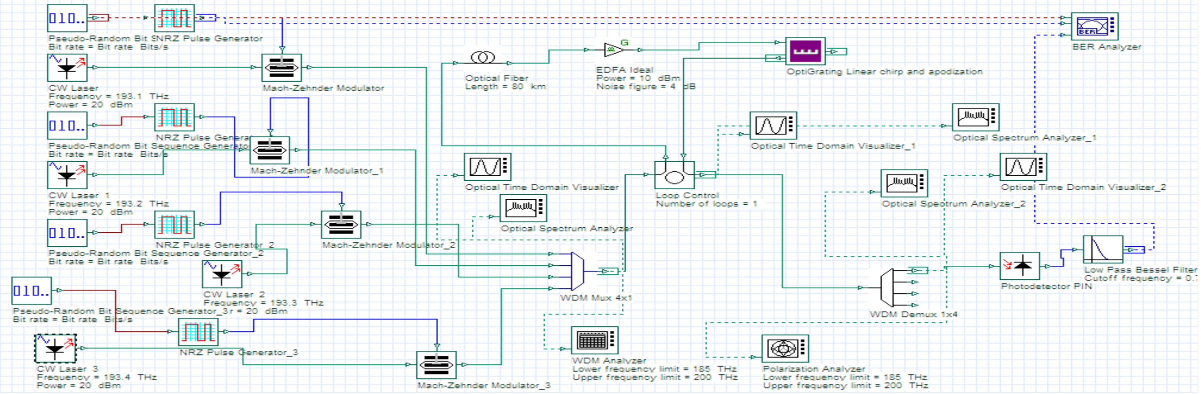


Figure 7.6 Dispersion compensation by using optigrating

Figure 1: Block diagram for **Simulation of 4x1 WDM network**
Figure 2: Block diagram for **Dispersion compensation using EDFA**
Figure 3: Block diagram for **Dispersion compensation using PRE DCF**
Figure 4: Block diagram for **Dispersion compensation using POST DCF**
Figure 5: Block diagram for **Symmetrical- dispersion compensation**
Figure 6: Block diagram for **Dispersion compensation by using optigrating**

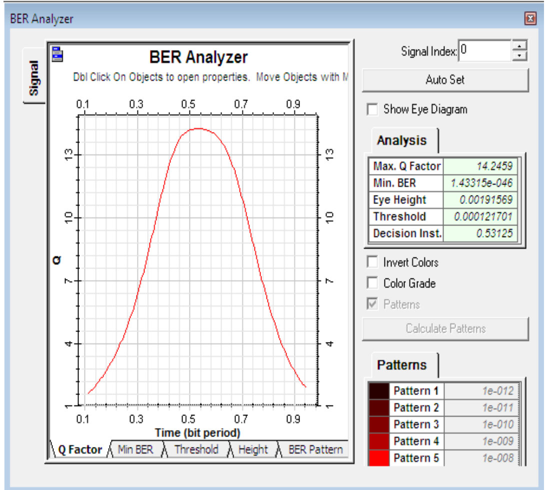
In figure 2 to 5 we will show three different schemes, pre-, post-, and symmetrical compensation, to compensate the fiber dispersion.

In Figure 6 In our simulations, we have used EDFA optical amplifiers Before and after of optical fiber to compensate for the span loss.

### 2.2 Simulation Block Diagram

All the results and analysis including input spectrum, output spectrum ,eye diagram ,the value of signal power, noise power, bit error rate (BER),Quality factor, Optical signal to noise ratio (OSNR) etc.

### 8.1 Result of simulation for 4x1 WDM optical fiber systems-



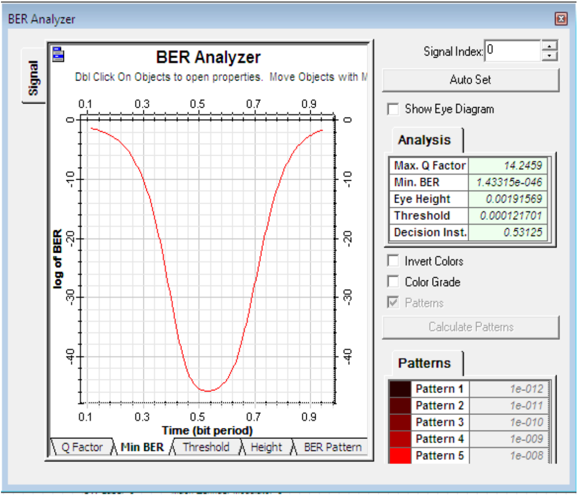
Signal Index: 0

☐ Show Eye Diagram

| Max. Q Factor | 14.2459 |
|---|---|
| Min. BER | 1.43315e-046 |
| Eye Height | 0.00191569 |
| Threshold | 0.000121701 |
| Decision Inst. | 0.53125 |

☐ Invert Colors
☐ Color Grade
☑ Patterns

| Pattern 1 | 1e-012 |
|---|---|
| Pattern 2 | 1e-011 |
| Pattern 3 | 1e-010 |
| Pattern 4 | 1e-009 |
| Pattern 5 | 1e-008 |



Signal Index: 0

☐ Show Eye Diagram

| Max. Q Factor | 14.2459 |
|---|---|
| Min. BER | 1.43315e-046 |
| Eye Height | 0.00191569 |
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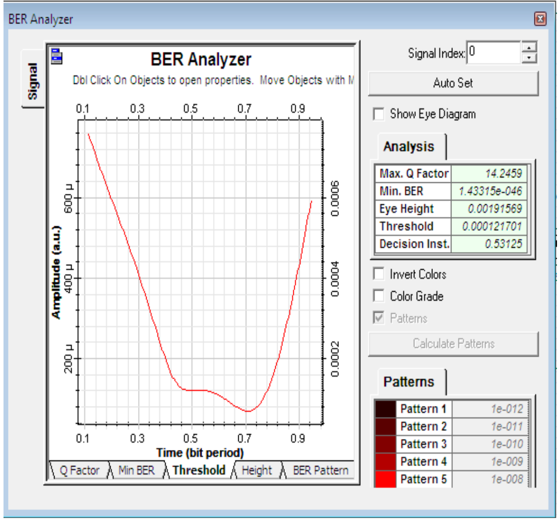
| Decision Inst. | 0.53125 |

☐ Invert Colors
☐ Color Grade
☑ Patterns

| Pattern 1 | 1e-012 |
|---|---|
| Pattern 2 | 1e-011 |
| Pattern 3 | 1e-010 |
| Pattern 4 | 1e-009 |
| Pattern 5 | 1e-008 |

**Figure 8.1: Minimum Q factor of 4x1 WDM system Figure 8.2 Minimum bit error rate of 4x1 WDM system**



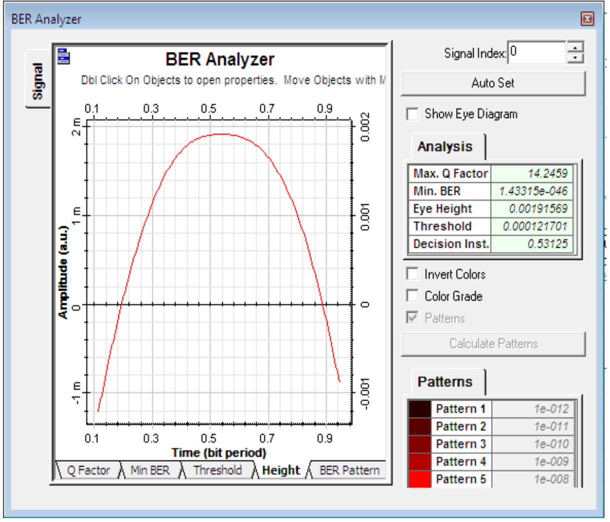
Signal Index: 0

☐ Show Eye Diagram

| Max. Q Factor | 14.2459 |
|---|---|
| Min. BER | 1.43315e-046 |
| Eye Height | 0.00191569 |
| Threshold | 0.000121701 |
| Decision Inst. | 0.53125 |

☐ Invert Colors
☐ Color Grade
☑ Patterns

| Pattern 1 | 1e-012 |
|---|---|
| Pattern 2 | 1e-011 |
| Pattern 3 | 1e-010 |
| Pattern 4 | 1e-009 |
| Pattern 5 | 1e-008 |



Signal Index: 0

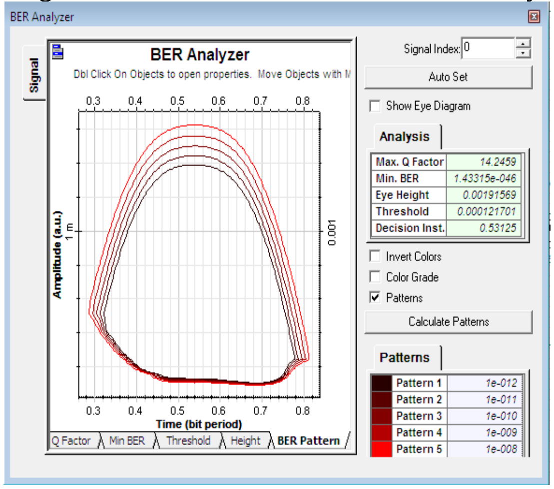
☐ Show Eye Diagram

| Max. Q Factor | 14.2459 |
|---|---|
| Min. BER | 1.43315e-046 |
| Eye Height | 0.00191569 |
| Threshold | 0.000121701 |
| Decision Inst. | 0.53125 |

☐ Invert Colors
☐ Color Grade
☑ Patterns

| Pattern 1 | 1e-012 |
|---|---|
| Pattern 2 | 1e-011 |
| Pattern 3 | 1e-010 |
| Pattern 4 | 1e-009 |
| Pattern 5 | 1e-008 |

**Figure 8.3 Threshold of channel 4x1 WDM system Figure 8.4 Height of signal in 4x1 WDM system**



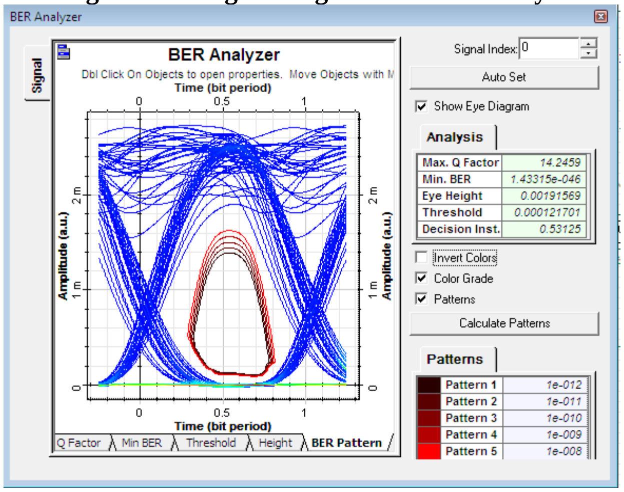
Signal Index: 0

☐ Show Eye Diagram

| Max. Q Factor | 14.2459 |
|---|---|
| Min. BER | 1.43315e-046 |
| Eye Height | 0.00191569 |
| Threshold | 0.000121701 |
| Decision Inst. | 0.53125 |

☐ Invert Colors
☐ Color Grade
☑ Patterns

| Pattern 1 | 1e-012 |
|---|---|
| Pattern 2 | 1e-011 |
| Pattern 3 | 1e-010 |
| Pattern 4 | 1e-009 |
| Pattern 5 | 1e-008 |



Signal Index: 0

☑ Show Eye Diagram

| Max. Q Factor | 14.2459 |
|---|---|
| Min. BER | 1.43315e-046 |
| Eye Height | 0.00191569 |
| Threshold | 0.000121701 |
| Decision Inst. | 0.53125 |

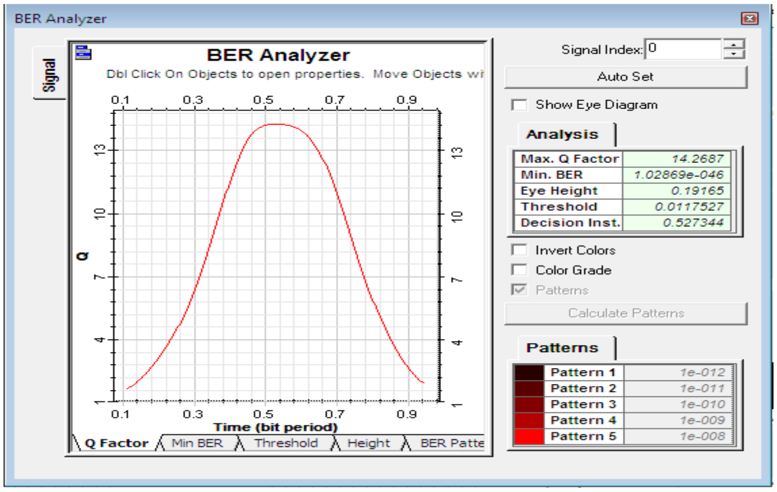
☐ Invert Colors
☑ Color Grade
☑ Patterns

| Pattern 1 | 1e-012 |
|---|---|
| Pattern 2 | 1e-011 |
| Pattern 3 | 1e-010 |
| Pattern 4 | 1e-009 |
| Pattern 5 | 1e-008 |

**Figure 8.5 BER Pattern of 4x1 WDM system Figure 8.6 EYE Diagram Pattern of 4x1 WDM system**

### 8.2 Result of simulation for dispersion compensation using different compensation techniques:

### 8.2.1Result of simulation for compensation of dispersion by EDFA–



Signal Index: 0

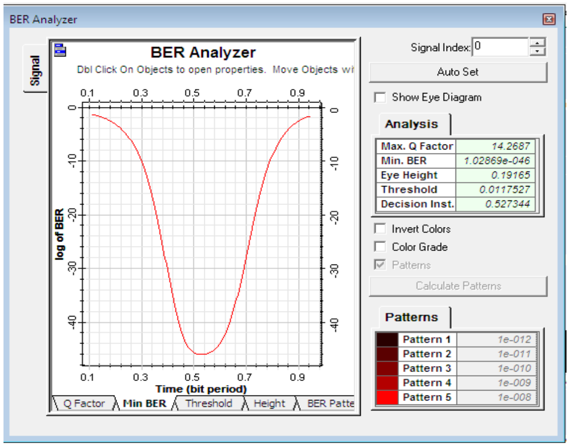
☐ Show Eye Diagram

| Max. Q Factor | 14.2687 |
|---|---|
| Min. BER | 1.02869e-046 |
| Eye Height | 0.19165 |
| Threshold | 0.0117527 |
| Decision Inst. | 0.527344 |

☐ Invert Colors
☐ Color Grade
☑ Patterns

| Pattern 1 | 1e-012 |
|---|---|
| Pattern 2 | 1e-011 |
| Pattern 3 | 1e-010 |
| Pattern 4 | 1e-009 |
| Pattern 5 | 1e-008 |

**Figure8.7 Quality Factor of signal for dispersion compensation using EDFA**



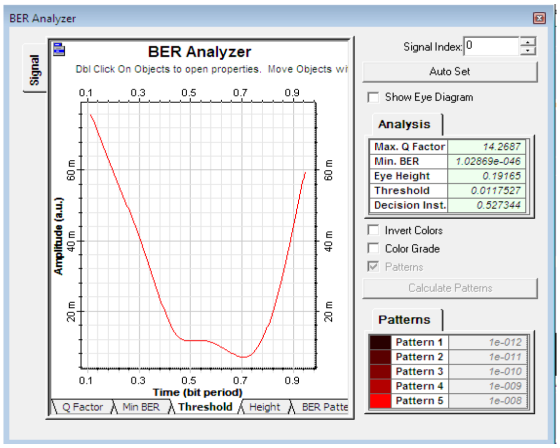
Signal Index: 0

☐ Show Eye Diagram

| Max. Q Factor | 14.2687 |
|---|---|
| Min. BER | 1.02869e-046 |
| Eye Height | 0.19165 |
| Threshold | 0.0117527 |
| Decision Inst. | 0.527344 |

☐ Invert Colors
☐ Color Grade
☑ Patterns

| Pattern 1 | 1e-012 |
|---|---|
| Pattern 2 | 1e-011 |
| Pattern 3 | 1e-010 |
| Pattern 4 | 1e-009 |
| Pattern 5 | 1e-008 |



Signal Index: 0

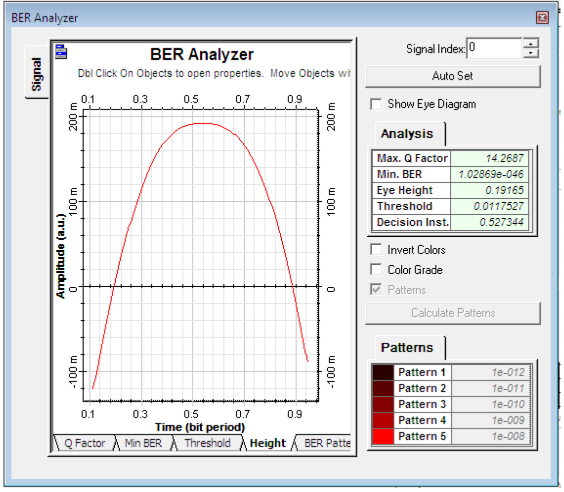
☐ Show Eye Diagram

| Max. Q Factor | 14.2687 |
|---|---|
| Min. BER | 1.02869e-046 |
| Eye Height | 0.19165 |
| Threshold | 0.0117527 |
| Decision Inst. | 0.527344 |

☐ Invert Colors
☐ Color Grade
☑ Patterns

| Pattern 1 | 1e-012 |
|---|---|
| Pattern 2 | 1e-011 |
| Pattern 3 | 1e-010 |
| Pattern 4 | 1e-009 |
| Pattern 5 | 1e-008 |

**Figure8.8 Min BER of signal for dispersion compensation using EDFA**
**Figure8.9 Threshold of signal for dispersion compensation using EDFA**



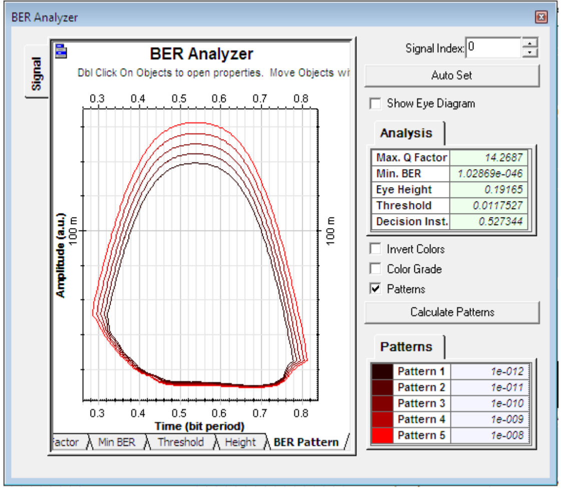
Signal Index: 0

☐ Show Eye Diagram

| Max. Q Factor | 14.2687 |
|---|---|
| Min. BER | 1.02869e-046 |
| Eye Height | 0.19165 |
| Threshold | 0.0117527 |
| Decision Inst. | 0.527344 |

☐ Invert Colors
☐ Color Grade
☑ Patterns

| Pattern 1 | 1e-012 |
|---|---|
| Pattern 2 | 1e-011 |
| Pattern 3 | 1e-010 |
| Pattern 4 | 1e-009 |
| Pattern 5 | 1e-008 |



Signal Index: 0

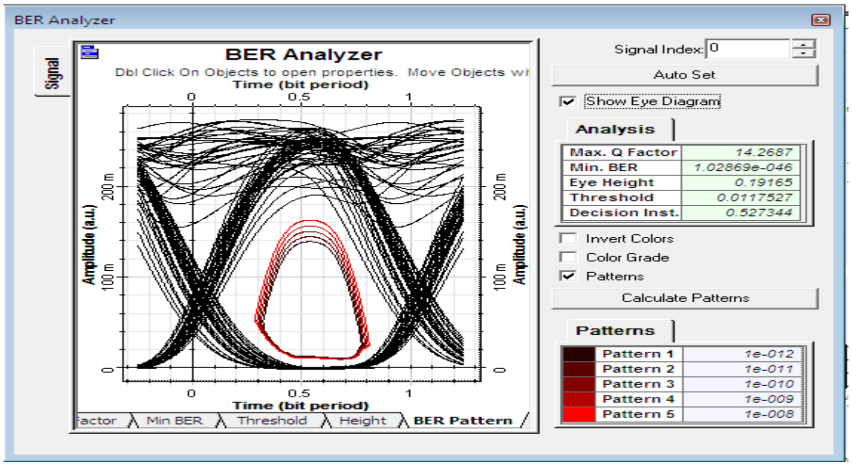
☐ Show Eye Diagram

| Max. Q Factor | 14.2687 |
|---|---|
| Min. BER | 1.02869e-046 |
| Eye Height | 0.19165 |
| Threshold | 0.0117527 |
| Decision Inst. | 0.527344 |

☐ Invert Colors
☐ Color Grade
☑ Patterns

| Pattern 1 | 1e-012 |
|---|---|
| Pattern 2 | 1e-011 |
| Pattern 3 | 1e-010 |
| Pattern 4 | 1e-009 |
| Pattern 5 | 1e-008 |

**Figure8.10 Height of signal for dispersion compensation using EDFA**
**Figure8.11 BER Pattern for dispersion compensation using ED**



Signal Index: 0

☑ Show Eye Diagram

**Analysis**

| | |
|---|---|
| Max. Q Factor | 14.2687 |
| Min. BER | 1.02869e-046 |
| Eye Height | 0.19165 |
| Threshold | 0.0117527 |
| Decision Inst. | 0.527344 |

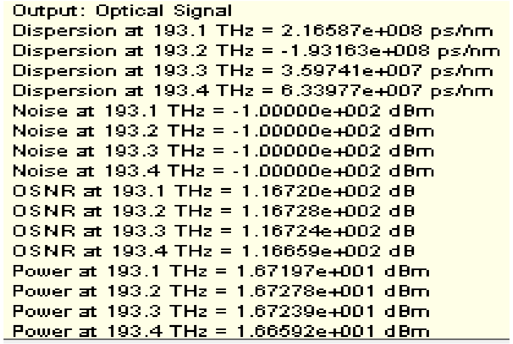
☐ Invert Colors
☐ Color Grade
☑ Patterns

**Patterns**

| | | |
|---|---|---|
| ■ | Pattern 1 | 1e-012 |
| ■ | Pattern 2 | 1e-011 |
| ■ | Pattern 3 | 1e-010 |
| ■ | Pattern 4 | 1e-009 |
| ■ | Pattern 5 | 1e-008 |

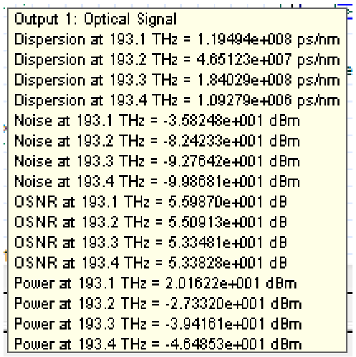
**Figure8.12 EYE Diagram for dispersion compensation using EDFA**

**Result After WDM MUX**



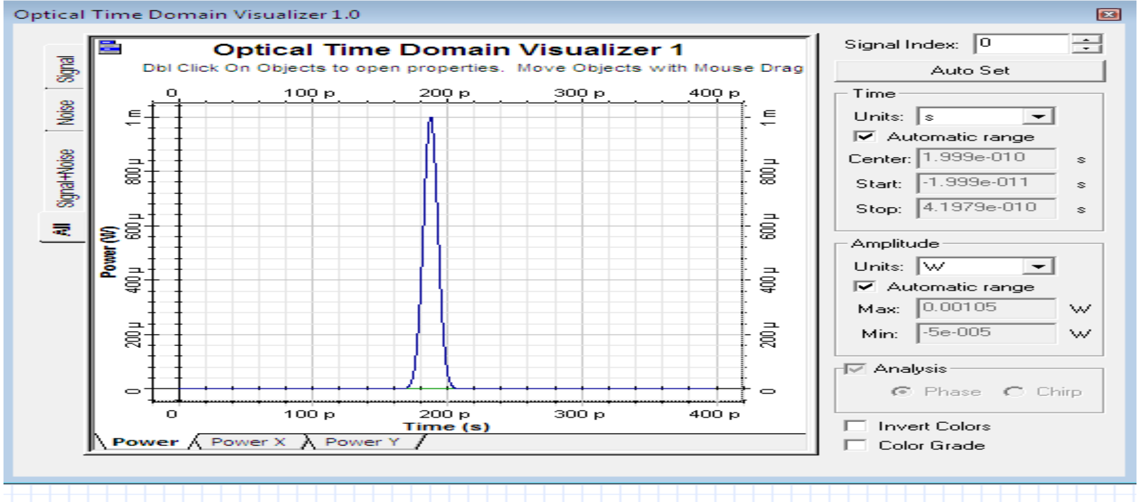
```
Output: Optical Signal
Dispersion at 193.1 THz = 2.16587e+008 ps/nm
Dispersion at 193.2 THz = -1.93163e+008 ps/nm
Dispersion at 193.3 THz = 3.59741e+007 ps/nm
Dispersion at 193.4 THz = 6.33977e+007 ps/nm
Noise at 193.1 THz = -1.00000e+002 dBm
Noise at 193.2 THz = -1.00000e+002 dBm
Noise at 193.3 THz = -1.00000e+002 dBm
Noise at 193.4 THz = -1.00000e+002 dBm
OSNR at 193.1 THz = 1.16720e+002 dB
OSNR at 193.2 THz = 1.16728e+002 dB
OSNR at 193.3 THz = 1.16724e+002 dB
OSNR at 193.4 THz = 1.16659e+002 dB
Power at 193.1 THz = 1.67197e+001 dBm
Power at 193.2 THz = 1.67278e+001 dBm
Power at 193.3 THz = 1.67239e+001 dBm
Power at 193.4 THz = 1.66592e+001 dBm
```

**Result After WDM DMUX**



```
Output 1: Optical Signal
Dispersion at 193.1 THz = 1.19494e+008 ps/nm
Dispersion at 193.2 THz = 4.65123e+007 ps/nm
Dispersion at 193.3 THz = 1.84029e+008 ps/nm
Dispersion at 193.4 THz = 1.09279e+006 ps/nm
Noise at 193.1 THz = -3.58248e+001 dBm
Noise at 193.2 THz = -8.24233e+001 dBm
Noise at 193.3 THz = -9.27642e+001 dBm
Noise at 193.4 THz = -9.98681e+001 dBm
OSNR at 193.1 THz = 5.59870e+001 dB
OSNR at 193.2 THz = 5.50913e+001 dB
OSNR at 193.3 THz = 5.33481e+001 dB
OSNR at 193.4 THz = 5.33828e+001 dB
Power at 193.1 THz = 2.01622e+001 dBm
Power at 193.2 THz = -2.73320e+001 dBm
Power at 193.3 THz = -3.94161e+001 dBm
Power at 193.4 THz = -4.64853e+001 dBm
```

In this simulation we are observing that the Q factor is 14.2887, Min BER is 1.02869e-046, Threshold is 0.0117527, Eye Height is 0.19165. The Q Factor is comparatively low then Pre, Post DCF and Ideal FBG. Eye Height is comparatively high then Pre, Post DCF and Ideal FBG. In this technique we can see the dispersion in 193.1 THz is reduced from 2.16587e+008ps/ns to 1.19494e+008ps/ns.noise is also reduce. OSNR ratio is improved. The power of these signals is decreased this is only one drawback and it can be overcome by using optical amplifier at output side. For 193.2 THz OSNR Improves while dispersion increases, power of signal is decrease. We can see this, the result are not in our favor for this signal while other signals are received with fine parameters. For 193.3 THz, dispersion is reduced from 3.59741e+007 ps/nm to -1.84029e+008 ps/nm while noise reduces and OSNR improves. For 193.4, dispersion is reduced from 6.33977e+007 ps/nm to 1.09279e+006ps/nm, noise is reduced and OSNR improves.



Signal Index: 0

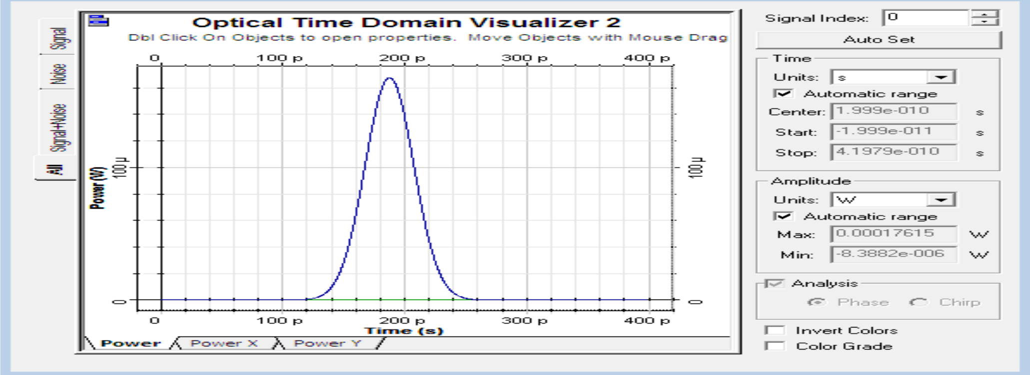
Time
Units: s
☑ Automatic range
Center: 1.999e-010 s
Start: -1.999e-011 s
Stop: 4.1979e-010 s

Amplitude
Units: W
☑ Automatic range
Max: 0.00105 W
Min: -5e-005 W

☑ Analysis
● Phase ○ Chirp

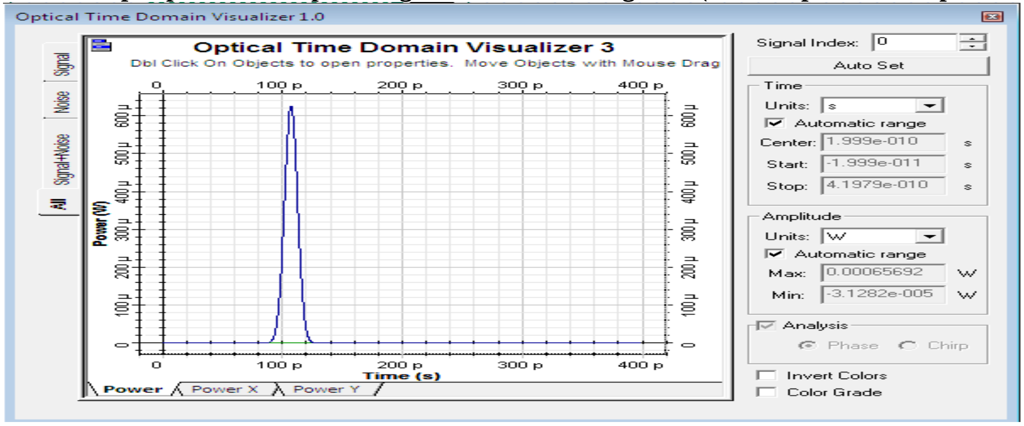
☐ Invert Colors
☐ Color Grade

**Figure8.54 output pattern of optical signal at optical Gaussian pulse generator (ideal dispersion compensation)**



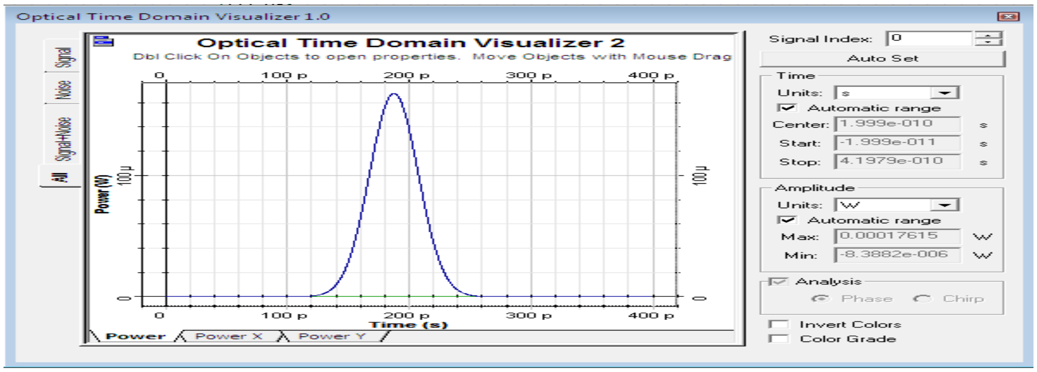
Signal Index: 0
Time
Units: s
☑ Automatic range
Center: 1.999e-010 s
Start: -1.999e-011 s
Stop: 4.1979e-010 s
Amplitude
Units: W
☑ Automatic range
Max: 0.00017615 W
Min: -8.3882e-006 W

**Figure8.55 output pattern for optical signal after 10km long OFC(ideal dispersion compensation)**



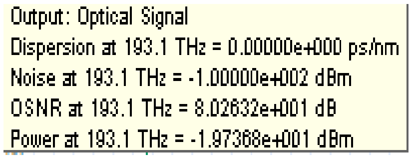
Signal Index: 0
Time
Units: s
☑ Automatic range
Center: 1.999e-010 s
Start: -1.999e-011 s
Stop: 4.1979e-010 s
Amplitude
Units: W
☑ Automatic range
Max: 0.00065692 W
Min: -3.1282e-005 W

**Figure8.56 output pattern for optical signal after 10km long OFC(ideal dispersion compensation)**



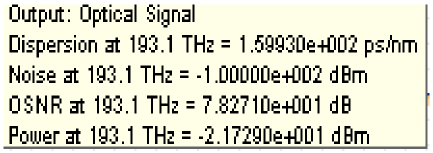
Signal Index: 0
Time
Units: s
☑ Automatic range
Center: 1.999e-010 s
Start: -1.999e-011 s
Stop: 4.1979e-010 s
Amplitude
Units: W
☑ Automatic range
Max: 0.00017615 W
Min: -8.3882e-006 W

**Parameters after Pulse Generator**



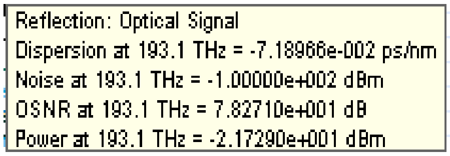
Output: Optical Signal
Dispersion at 193.1 THz = 0.00000e+000 ps/nm
Noise at 193.1 THz = -1.00000e+002 dBm
OSNR at 193.1 THz = 8.02632e+001 dB
Power at 193.1 THz = -1.97368e+001 dBm

**Parameters after optical Fiber**



Output: Optical Signal
Dispersion at 193.1 THz = 1.59930e+002 ps/nm
Noise at 193.1 THz = -1.00000e+002 dBm
OSNR at 193.1 THz = 7.82710e+001 dB
Power at 193.1 THz = -2.17290e+001 dBm

**Parameters after FBG**



Reflection: Optical Signal
Dispersion at 193.1 THz = -7.18966e-002 ps/nm
Noise at 193.1 THz = -1.00000e+002 dBm
OSNR at 193.1 THz = 7.82710e+001 dB
Power at 193.1 THz = -2.17290e+001 dBm

In this simulation result we can see dispersion at initial point is zero. When the signal passes through 10 km long optical channel then signal wave dispersed, the value of dispersion is 1.59930e+002ps/nm. For minimizing the dispersion, we insert the received optical signal into FBG component. This component minimizes the dispersion it is shown in above waveforms. The value of dispersion after FBG is -7.18966e-002ps/nm. Noise decreases and OSNR improved. Hence optigrating is an useful component for minimizing the dispersion.

## IV. CONCLUSION

This thesis work presents a study and analysis of dispersion in optical fiber WDM system using different dispersion compensation techniques, for NRZ modulation format, fiber lengths , filters using eye diagrams , EDFA amplifier and optical spectrums. Simulation is done using OPTISYSTEM. It is an intuitive modeling and simulation environment supporting the design and the performance evaluation of the transmission level of optical communication systems. For Traveling wave WDM system, graphs of optical spectrum (before and after transmission) show that performance parameter such as signal power, noise power , Bit error rate (BER), Quality factor and optical signal to noise ratio (OSNR) are poor with NRZ modulation format and it is almost constant or increasing with NRZ modulation format.

| S. No. | Technique used | Q factor | Min BER | Eye Height | Threshold | OSNR |
|---|---|---|---|---|---|---|
| 1 | EDFA | 14.28870 | 1.02869*e-046 | 0.191650000 | 0.011752700 | 54.70 |
| 2 | Pre DCF | 17.89560 | 3.77955*e-072 | 0.000426512 | 0.000232669 | 52.50 |
| 3 | Post DCF | 17.50000 | 4.19689*e-069 | 0.004215460 | 0.000220915 | 39.49 |
| 4 | Symmetrical DCF | 12.05910 | 6.28605*e-034 | 0.002422800 | 0.0004678420 | 42.67 |
| 5 | OPTIGRATING | 08.36609 | 2.23257*e-017 | 0.000060105 | 0.0000138807 | 47.50 |
| 6 | Ideal Fiber Bragg Grating | 17.18240 | 1.08833*e-066 | 0.004203590 | 0.000261783 | 56.85 |
| 7 | Post Fiber Bragg Grating with chrip | 13.86810 | 3.06393*e-044 | 0.000579026 | 0.000044048 | 58.02 |

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 and Jitter is lesser when less dispersion occurs. Q-factor depends on the filter used. Higher value of Jitter and BER and lesser value of Q-factor and eye opening after transmission through fiber show the good communication through it.To obtain the better signal at the receiving end we check for different combinations of dispersion compensation components and different length of DCF and EDFA. In first technique we used EDFA for minimizing core and cladding losses. EDFA are used in all circuits for removing these losses for improvement in signal strength and to minimize dispersion we use DCF .This DCF can be placed before and after the fiber. Dispersion can be compensate by using DCF for a particular length. In all the simulations we find that the maximum Q factor is in Pre DCF compensation technique and in minimum Q factor optigrating technique. Q factor is also not very fine in Symmetrical DCF technique. It is comparatively low than Pre, Post and FBG techniques.

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