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Experiment Calculation of Optical Fiber Dispersion Compensation

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Abstract

The intended application of our Dispersions in an optical fiber. Dispersion is the spreading of light pulse as its travels down the length of an optical fiber. Dispersion limits the bandwidth or information carrying capacity of a fiber. in this paper we try to use a new system built by software optics version 7.to understand the effect of dispersion compensation FBG in fiber optics using CW laser as a power source with frequency 193.1 THz, 0 dBm, NRZ pulse generator by the help of ideal desperation compensation at 193.1 THz frequency, Bandwidth 1 THz and dispersion equal to -2000 ps/nm, with one loop amplification system. At the receiver a PIN photodiode at dark current 10 nA is used. Finally we can get the results that will be measured by Eye diagram device corresponding to the fiber lengths.

Index Terms: CW Laser; Dispersions; NRZ; Ideal dispersion compensation; PIN photo detector; Low pass bassel filter; EDFA.

1. introduction

1.1. Dispersion

Dispersion is the spreading of light pulse as its travels down the length of an optical fiber. Dispersion limits the bandwidth or information carrying capacity of a fiber. The bit-rates must be low enough to ensure that pulses are farther apart and therefore the greater dispersion can be tolerated.

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There are three main types of dispersion in a fiber:

 Modal Dispersion.

 Material dispersion.

 Waveguide dispersion.

Any phenomenon in which the velocity of propagation of an electromagnetic wave is wavelength dependent. Note 2: In an optical fiber, there are several significant dispersion effects, such as material dispersion, profile dispersion, and waveguide dispersion, that degrade the signal.

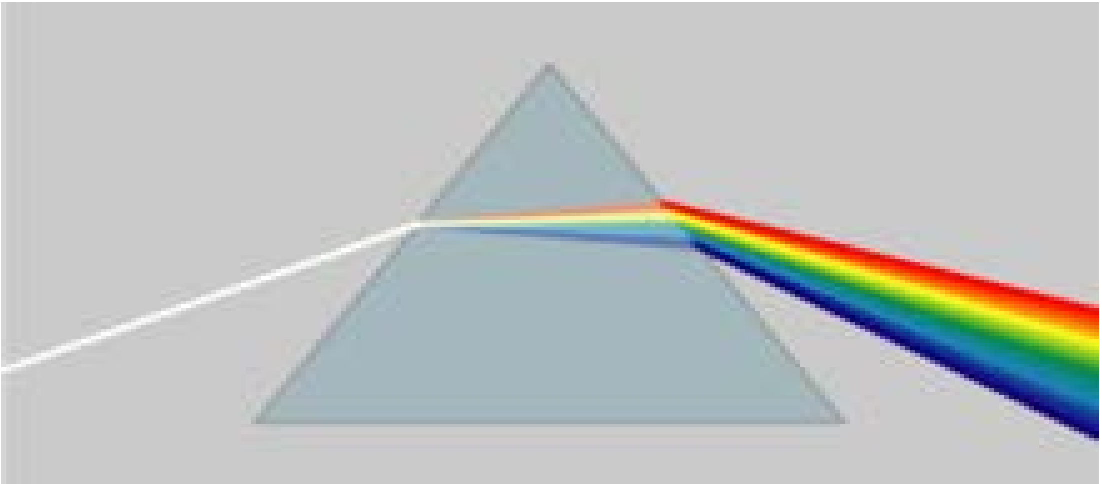

Figure 1: The dispersion of waves in optics.

In optics, dispersion is the phenomenon in which the phase velocity of a wave depends on its frequency [1]. Media having this common property may be termed dispersive media. Sometimes the term chromatic dispersion is used for specificity.

Although the term is used in the field of optics to describe light and other electromagnetic waves, dispersion in the same sense can apply to any sort of wave motion such as acoustic dispersion in the case of sound and seismic waves, in gravity waves (ocean waves), and for telecommunication signals along transmission lines (such as coaxial cable) or optical fiber.

1.2. Chromatic Dispersion

Chromatic dispersion represents the fact that different colors or wavelengths travel at different speeds, even within the same mode. Chromatic dispersion is the result of material dispersion, waveguide dispersion, or profile dispersion. Figure 1 below shows chromatic dispersion along with key component waveguide dispersion and material dispersion.

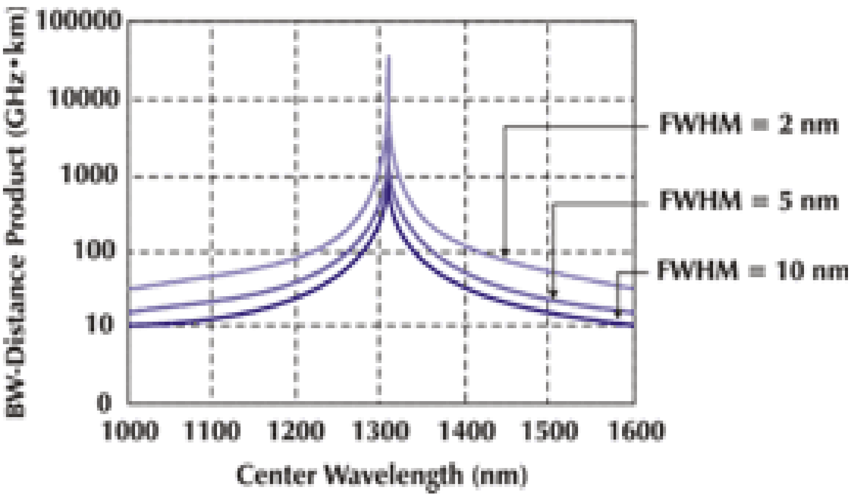

Figure 2: Chromatic Dispersion

The example shows chromatic dispersion going to zero at the wavelength near 1550 nm. This is characteristic of bandwidth dispersion-shifted fiber. Standard fiber, single-mode, and multimode have zero dispersion at a wavelength of 1310 nm.

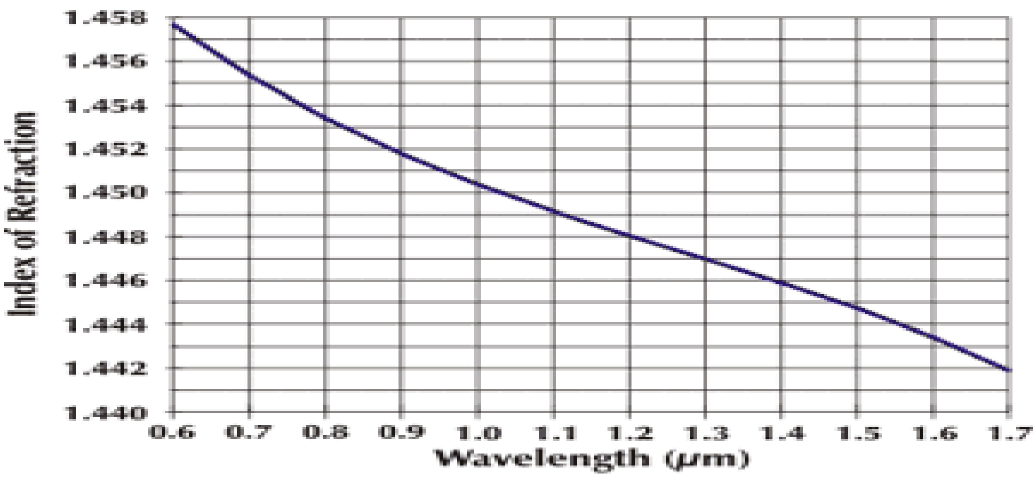

Figure 3: Refractive Index of Fused Silica

Every laser has a range of optical wavelengths, and the speed of light in fused silica (fiber) varies with the wavelength of the light. Figure 3 illustrates the refractive index of fused silica as it changes with wavelength. Since a pulse of light from the laser usually contains several wavelengths, these wavelengths tend to get spread out in time after traveling some distance in the fiber. The refractive index of fiber decreases as wavelength increases, so longer wavelengths travel faster. The net result is that the received pulse is wider than the transmitted one, or more precisely, is a superposition of the variously delayed pulses at the different wavelength.

1.3. Polarization Mode Dispersion (PMD)

Polarization mode dispersion (PMD) is another complex optical effect that can occur in single-mode optical fibers. Single-mode fibers support two perpendicular polarizations of the original transmitted signal. If be completely round and free from all stresses, both polarization modes would propagate at exactly the same speed, resulting in zero PMD. However, practical fibers are not perfect; thus, the two perpendicular polarizations may travel at different speeds and, consequently, arrive at the end of the fiber at different times.

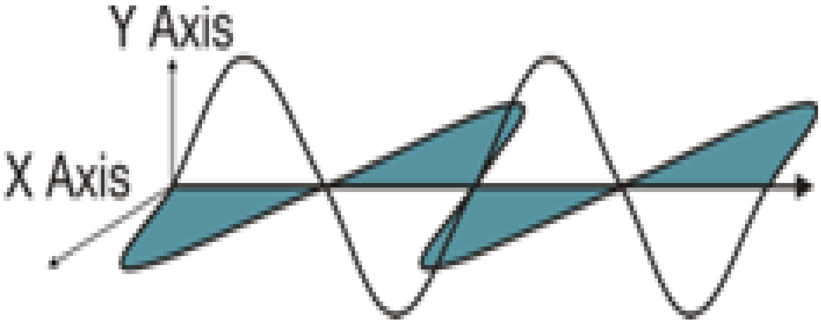

Figure 4: Polarization Mode Dispersion

Figure 4 illustrates this condition. The fiber is said to have a fast axis, and a slow axis. The difference in arrival times, normalized with length, is known as PMD ($ps/km^{0.5}$). Excessive levels of PMD, combined with laser chirp and chromatic dispersion, can produce time-varying composite second order (CSO) distortion in amplitude modulated (AM) video systems. This results in a picture that may show a rolling or intermittent diagonal line across the television screen. Like chromatic dispersion, PMD causes digital transmitted pulses to spread out as the polarization modes arrive at their destination at different times. For digital high bit rate transmission, this can lead to bit errors at the receiver or limit receiver sensitivity.

1.4. Dispersion in Waveguides

Waveguides are highly dispersive due to their geometry (rather than just to their Material composition). Optical fibers are a sort of waveguide for optical frequencies (light) widely used in modern telecommunications systems. The rate at which data can be transported on a single fiber is limited by pulse broadening due to chromatic dispersion among other phenomena.

In general, for a waveguide mode with an angular frequency $\omega(\beta)$ at a propagation constant β (so that the electromagnetic fields in the propagation direction z oscillate proportional to $e^{i(\beta z-\omega t)}$), the group-velocity dispersion parameter D is defined as

$$D = - 2\pi c/ \lambda^2 \times d^2\beta/ d\omega 2 \;\; = 2\pi c / V_g^2 \lambda^2 \times dV_g / d\omega \qquad (1)$$

Here $\lambda = 2\pi c/\omega$ is the vacuum wavelength and $v_g = d\omega/d\beta$ is the group velocity. This formula generalizes the one in the previous section for homogeneous media, and includes both waveguide dispersion and material dispersion. The reason for defining the dispersion in this way is that |*D*| is the (asymptotic) temporal pulse spreading Δt per unit bandwidth $\Delta\lambda$ per unit distance travelled, commonly reported in ps/nm/km for optical fibers [6].

1.5. Non-Return to Zero (NRZ)

In the NRZ format the pulse remains on throughout the bit slot and its amplitude does not drop to zero between two or more successive bits. As a result, pulse width varies depending on the bit pattern. In the early days or in commercial system NRZ are used in fiber-optical communication, due to a) it is not sensitive to laser phase noise b) it requires a relatively low electrical bandwidth for transmitters and receivers compared with RZ; c) it has the simplest configuration of transmitter and receiver; d)less cost. Unfortunately, NRZ modulation format is not appropriate for high bit rate and long distances optical communication system [5].NRZ modulation may be better in case of large number of channels.

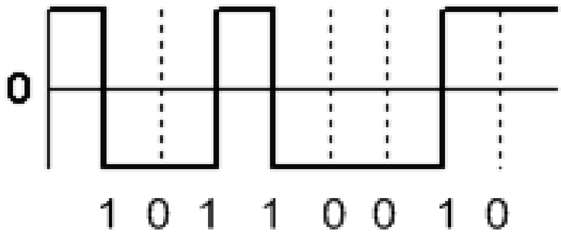

Figure5: NRZ data format

1.6. Erbium Doped Fiber Amplifier (EDFA)

Erbium Doped fiber amplifiers are the by far most important fiber amplifier in the context of long-range optical fiber communications; they can efficiently amplify light in the 1.5-m wavelength region, where telecom fiber have their loss minimum.

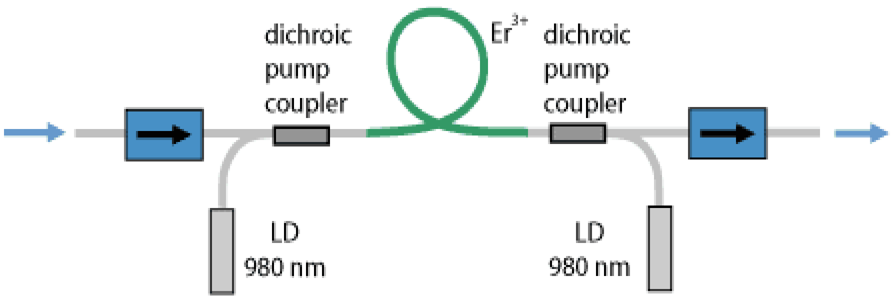

Figure 6: Schematic setup of a simple erbium-doped fiber amplifier.

Two laser diodes (LDs) provide the pump power for the erbium-doped fiber. The pump light is injected via diachronic fiber couplers. Pig-tailed optical isolators reduce the sensitivity of the device to back-reflections

[4].

2. Experiment calculating dispersion

Computing PMD is quite difficult unless specific measurements are made on the particular fiber span of interest. Because of this difficulty, and because PMD is generally a much smaller effect at any given data rate, we will not go into details of PMD computation. We will focus on computing the effects of chromatic dispersion. Let's first consider non dispersion-shifted single-mode fiber, such as Corning SMF-28 CPC3 single-mode fiber. This fiber type makes up the largest percentage of the installed fiber base. Its zero-dispersion wavelength lies between 1301 nm and 1321 nm. At the zero-dispersion wavelength, the fiber bandwidth is very high. However, the fiber attenuation in this range is about 0.5 dB/km. This attenuation limits transmission distances to perhaps 60 km. It would be more desirable to operate in the 1550 nm band where attenuation is about 0.2 dB/km. This attenuation would allow transmission to about 150 km as long as dispersion does not limit performance. Equation 1 can be used to compute the dispersion of Corning SMF-28 single-mode fiber.

$$D_\lambda = S_0 /4 \left(\lambda - \lambda_0^4 /\lambda^3 \right) \quad (2)$$

where

$S_0 = 0.092$ ps/(nm^2 . km)

$\lambda_0 = 1311$ nm (corning specifies a range of 1302-1322nm.this number is the average.)

D_λ = Dispersion (ps/nm/km)

For example: if we want to calculate the dispersion of 1552.52 nm wave length the result is as follows:

$D_\lambda = 0.092/4 \left(1552.52 - 1311^4 / 1552.52^3 \right)$

then

$D_\lambda =$ 17.55ps/nm.

For 150 Km transmision distance as in this system .the dispersion is as folowes:

D = (17.55ps/nm) /150Km = 0.11dBm

From this result we can find that the whole dispersion is not exceed the standard value of 2.5 dBm

3. Simulation setup

The simulation has been carried out by using opt system software version 7. In this occupation we used CW laser 193.1 THz as a lighting emission source to transmit data over 180 km length through one loop control and

EDFA gain 20 dB. The systems build as figure 7. This figure shows the system design of dispersion compensation FBG by simulation software version 7.we can use this system to find the effect and calculation of dispersion compensation in fiber optics.

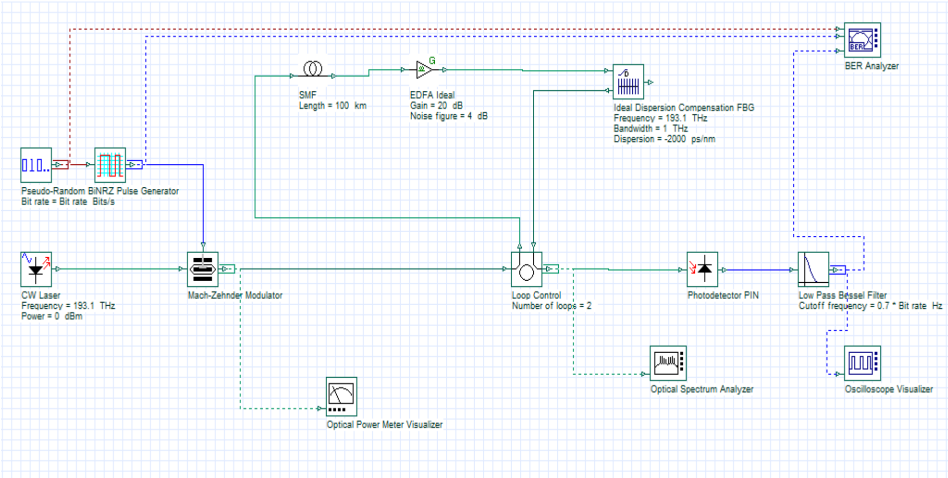

Figure 7: Simulation system of the calculation of dispersion in fiber optics

Figure 8 below shows the relation between fiber length and Bit Error rate measured by Eye diagram device. While at maximum length we reached the BER is measured at the value of 1.70 E-06.more than 180 km the signal disappeared, and a bandwidth equal to 8nm, insertion loss equal to 0dBm. This means that this system is designed to reach 180 km fiber length. This is the practical calculation.

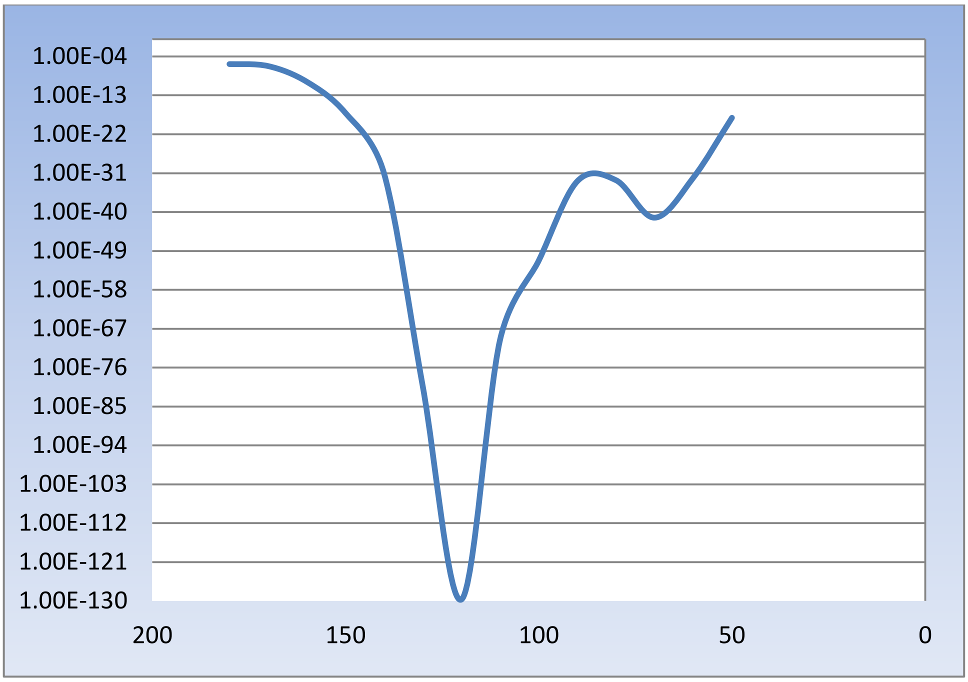

Figure 8: Relation between fiber length and minimum BER

Table 1: ideal dispersion with FBG

	Ideal Dispersion Compensation FBG
Sweeps	Dispersion [ps/nm]
1	0
2	-500
3	-1000
4	-1500
5	-2000

Figure 9 is the simulation setup calculation for the five iteration sweep and its dispersion values. Sweep 1 corresponds to zero dispersion, while the fifth sweep corresponding to -2000 ps/nm. This is the theoretical results.

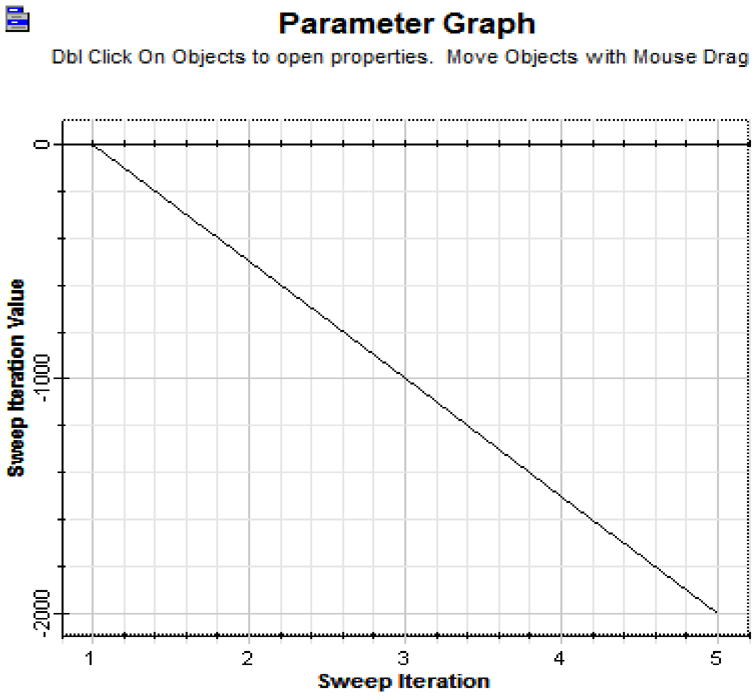

Figure 9: Sweep iteration and its dispersion

As in figure 10 we can illustrate eye diagram output at distance approach almost 180km, which is equal to $0.17x10^{-5}$,

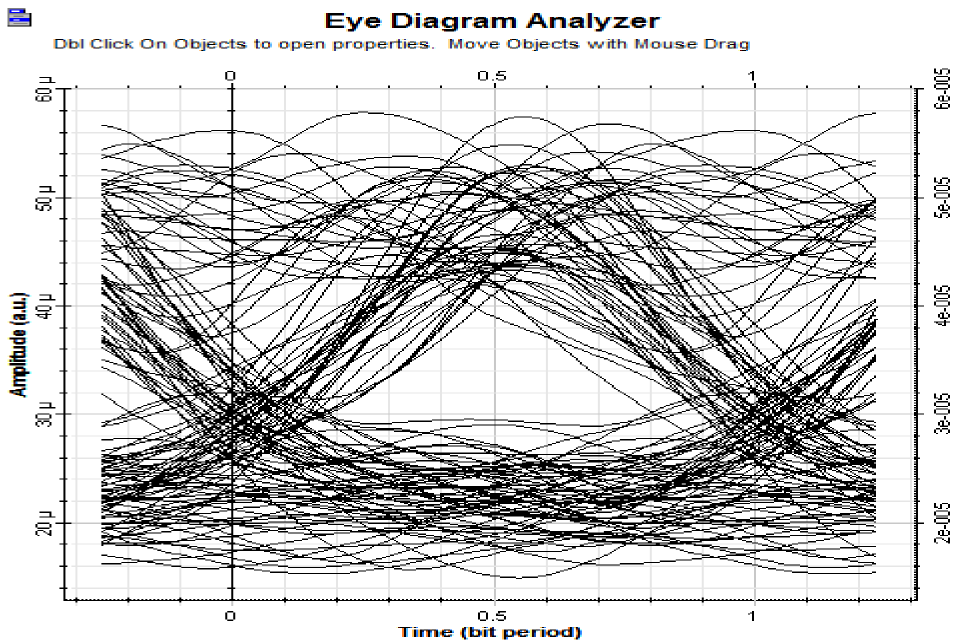

Figure 10: Eye diagram at 180km fiber length equal to $0.17x10^{-5}$

While figure 11 can illustrate eye diagram output at distance approach almost 50 km, this is equal to 5.29x10-52.

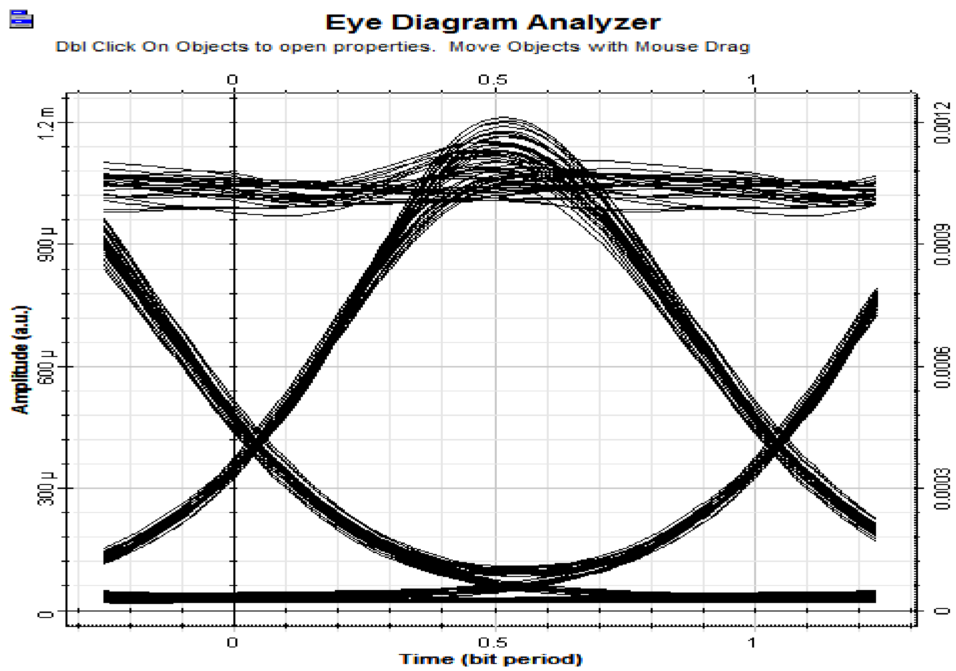

Figure 11: Eye diagram at 50 km fiber length equal to $5.29x10^{-52}$

So from this figure we can clearly mention the big eye achieved at 50 km, and almost closed eye at 180km, this is the best practical approach of the system design. For good results we must used the EYE Diagram device to measure the bit error rate (BER).

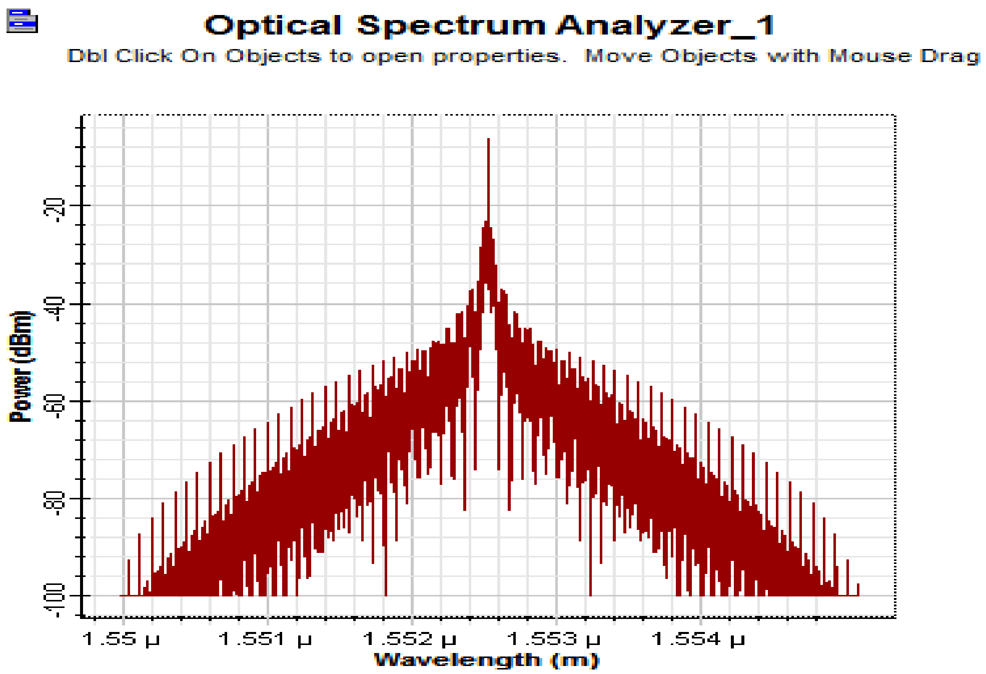

Figure 12: Optical spectrum at the transmitter channel

A transmitted spectrum signal from the transmitter channel .this spectrum is relation of wavelength of the signal and their power .its power is recording to the -3.3dBm value, at stop frequency equal to 1.93x10^{14}. This signal is the original signal.

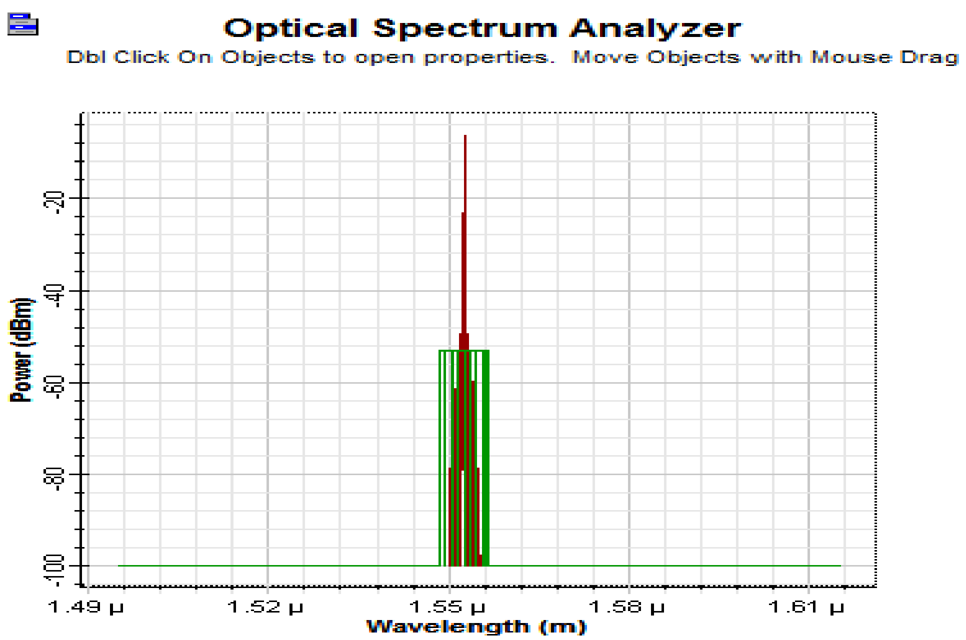

Figure 13: Optical spectrum analyzer at the receiver channel

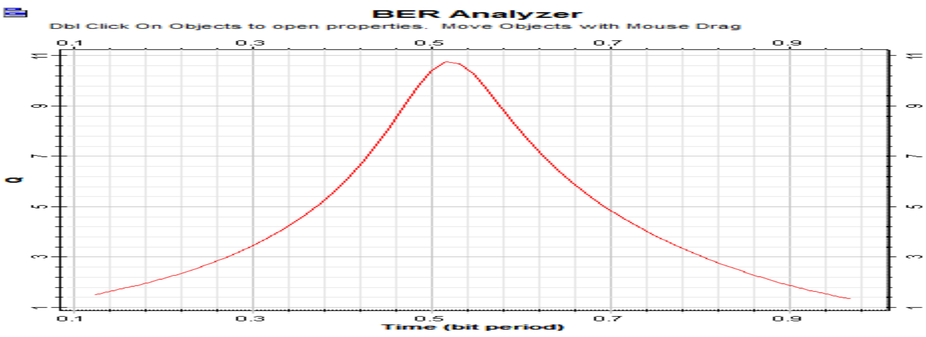

Figure 14: BER analyzer with Q-factor output

While this figure 13 gives a quick examination of the quality of the optical signal, the spectrum signal analysis referring to the shape of the signal at the receiver channel. Which is totally equal to (- 3.3dBm) as a power transmit with the center frequency equal to (1.9×10^{14} Hz) and at the receiver channel the power is almost equal to (-2.75 dBm) at the same frequency (2.013×10^{14} Hz) at 140Km max distance. From this figure we can see clearly the red colure which referring to the center frequency equal to 1.93×10^{14} and the green colure is the spectrum analysis of the center one. The same talk about this figure 14. The BER analyzer to illustrate the Q-factor .This practically works is done by simulation software optisys version 7. The BER is equal to 2.74×10^{-27} .Eye diagram is a good represent solution in this calculation.

4. Conclusion

This paper illustrated the practical calculation of dispersion in optical fibers depending on theoretical dispersion equation parameters which is especially wavelength (λ) and fiber transmitter length (L), the relation of them is reveres relation. The practical results taking directly from system designed by the help of software optisys.version 7.

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