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LIST OF ACRONYMS AND ABBREVIATIONS

NRZ	Non-Return-to-Zero
RZ	Return-to-Zero
MMF	Multi-Mode Fiber
GRIN-MMF	Graded-index Multimode Fiber
GVD	Group-Velocity Dispersion
SMF	Single Mode Fiber
DGD	Differential Group Delay
MCVD	Modified Chemical Vapor Deposition
OVD	Outside Vapor Deposition
VAD	Vapor-phase Axial Deposition
LED	Light Emitting Diode
OTDR	Optical Time-Domain Reflectometer
LASER	Light Amplification by the Stimulated Emission of Radiation
IM	Intensity Modulation
ASK	Amplitude-Shift Keying
FSK	Frequency-Shift Keying
PSK	Phase-Shift Keying
OOK	On-Off Keying
SOA	Semiconductor Optical Amplifiers
FPA	Fabry–Perot Amplifier

List of acronyms and abbreviations

TWA	Travelling Wave Amplifier
EDFA	Erbium Doped Fiber Amplifier
SRS	Stimulated Raman Scattering
APD	Avalanche Photo-Diodes
BER	Bit Error Rate
OSNR	Optical Signal to Noise Ratio

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LIST OF SYMBOLS

θ_i	The angle of incidence
θ_r	The angle of reflection
c	Speed of light in the vacuum
V	Speed of light in the medium with index of refraction n
NA	Numerical aperture
Θ	Acceptance angle
L	Length of the optical fiber
P_i	Input power
P_0	Output power
ΔT	The difference in arrival time
D	The dispersion parameter
τ	The group delay
Λ	Wavelength
E_R	The electric field associated to the optical wave
I_D	The output diode current
P	Optical power
H	Plank constant
$\Delta\lambda$	The propagation time difference between the slowest and fastest wavelength.
ΔT	The input voltage associated with a 180° phase shift
V_{in}	The voltage applied to the modulator
V_π	The input voltage associated with a 180° phase shift.

General Introduction

Since the information revolution, the needs for bits transmission with enormous numbers in short time became the first requirement; the solution was in the optical fiber. The optical fiber had made a big jump in the telecommunication world because of its outstanding advantages; the most significant one is its huge bandwidth. An optical fiber communication system uses a very high carrier frequency, around 200 THz, this carrier frequency is usually expressed as a wavelength, 1.55 μm . This enormous bandwidth provides the potential to transmit signals at a very high speed.

Some problems don't make the optical transmission system work perfectly which are the dispersion and the attenuation of the optical fiber. So how we can build an optical communication system with less attenuation and dispersion, and what are the conditions and the materials which we have to use to profit the huge bandwidth of the optical fiber as possible.

In this project, the optical telecommunication system will be studied, the first chapter will take a general idea about the optical fiber: its structure, types and its working principle, also the influence of the attenuation and the dispersion on its work.

Later, in the second chapter, the talking will be about the optical system and its main components and how the transmission operation happens from the transmitter stage (optical modulation) passing with the channel (optical fiber) to the receiver stage where the signal is demodulated and come back to its original format.

As a practical part, the simulation will take place by studying the performance of the transmission system (10Gbps NRZ). We will see the direct influence of the attenuation and the dispersion on the transmitted signal and what is its status at the output.

Chapter I The Optical Fiber

1.1 Introduction:

Optical fiber is a thin glass strand designed for light transmission. A single hair-thin fiber is capable of transmitting trillions of bits per second. In addition to their huge transmission capacity, optical fibers offer many advantages over electricity and copper wire. Light pulses are not affected by random radiation in the environment, and their error rate is significantly lower. Fibers allow longer distances to be spanned before the signal has to be regenerated by expensive "repeaters." Fibers are more secure, because taps in the line can be detected, and lastly, fiber installation is streamlined due to their dramatically lower weight and smaller size compared to copper cables.

1.2 Optical fiber structure [2]:

The typical fibers today are made out of glass or plastic since it is possible to make them thin and long. Also both glass and plastic are transparent at particular wavelengths, which allow the fiber to guide light efficiently. Basically, the optical fiber is composed of:

1.2.1 Core:

Thin glass center of the fiber where the light travels.

1.2.2 Cladding:

Outer optical material surrounding the core that reflects the light back into the core.

1.2.3 Jacket:

Usually consists of one or more layers of polymer. Its role is to protect the core and cladding from shocks that might affect their optical or physical properties. It acts as a shock absorber. It also provides protection from abrasions, solvents and other contaminants. The jacket does not have any optical properties that might affect the propagation of light within the fiber optic cable.

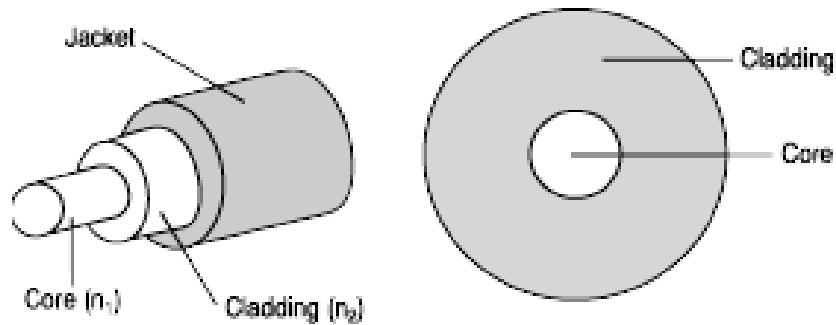


Figure 1.1: optical fiber cable, 3D view and basic cross section.

1.3 How the optical fiber works [4]?

A light ray that enters the fiber does not merely travel straight down through the center of the core. Instead light rays within the core are continually reflected at the core/cladding boundary so that the rays remain within the core. This process is called total internal reflection and it is the means by which an optical signal is confined to the core of a fiber.

1.3.1 Reflection:

When light strikes the surface of a material, some of the light is reflected. The reflection of light rays from a plane surface described by the law of reflection: The angle of reflection θ_r is equal to the angle of incidence θ_i or

$$\theta_i = \theta_r \quad \text{Eq1.1}$$

These angles are measured from a line perpendicular or normal to the reflecting surface at the point of incidence (Figure 1.2)

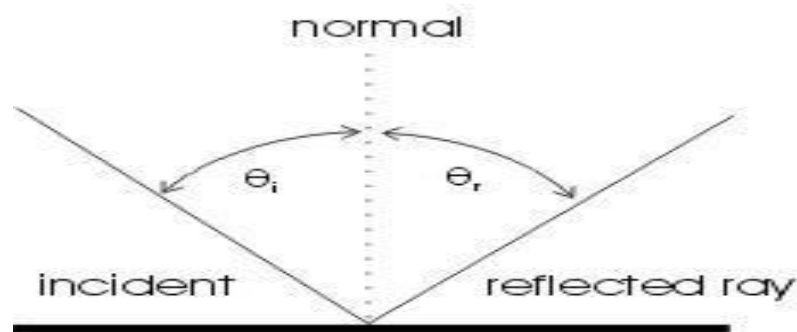


Figure 1.2: the reflection.

1.3.2 Refraction:

When light travels from a material with reflective index n_1 (core) into a material with reflective index n_2 (cladding), the reflected ray, the incident ray and the normal all lie in the same plane .the angle of refraction θ_2 is related to the angle of incidence θ_1 by:

$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2) \quad \text{Eq1.2}$$

Where
$$n = c/v \quad \text{Eq1.3}$$

c : Speed of light in the vacuum = 3×10^8 m/s

v : Speed of light in the medium with index of refraction n

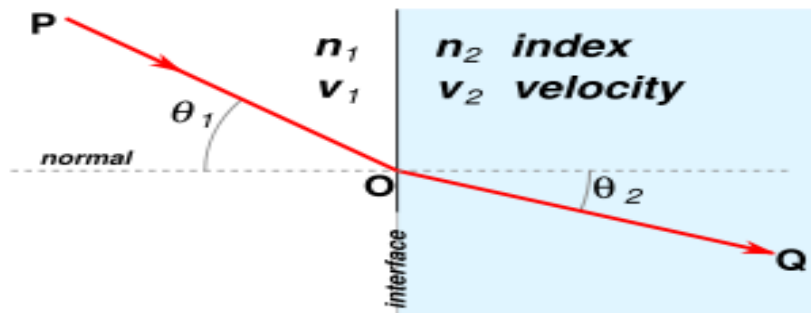


Figure 1.3: the refraction.

1.3.3 Numerical aperture [5]:

A light ray (i) entering the core at point A and then travelling through the core until it reaches the core cladding boundary at point B. As long as the light ray intersects the core/cladding boundary at a small enough angle the ray will be reflected back into the core to travel on to point C where the process of reflection is repeated. If a ray enters the fiber at a steep angle (ii), then when this ray intersects the core/cladding boundary the angle of intersection is too large and reflection back in to the core does not take place and the light ray is lost in the cladding. This means that to be guided through a fiber a light ray must enter the core with an angle that is less than the so called numerical aperture (acceptance angle for the fiber).

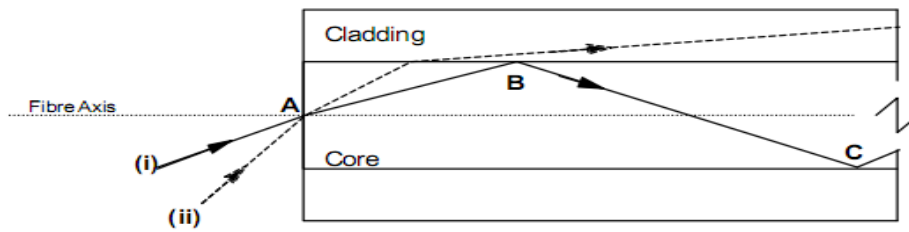


Figure 1.4: Propagation of a light ray down a fiber optic cable.

The fiber acceptance angle can be calculated from the refractive indices of the core and cladding using the formula:

$$\theta = \sin^{-1}[\sqrt{n_1^2 - n_2^2}] \quad \text{Eq1.4}$$

The numerical aperture of a fiber is simply equal to the mathematical sine of the fiber acceptance angle; hence the numerical aperture (NA) is given by:

$$NA = \sqrt{n_1^2 - n_2^2} \quad \text{Eq1.5}$$

1.4 Optical fiber types [10]:

There are two categories of optical fiber, as distinguished by their modal and physical properties:

1.4.1 Single mode fiber:

Has a very small core causing light to travel in a straight line and typically has a core size of 8 or 10 microns. It has unlimited bandwidth that can go unrepeated for over 80 km, depending on the type of transmitting equipment. Single mode fiber has enormous information capacity, more than multimode fiber.

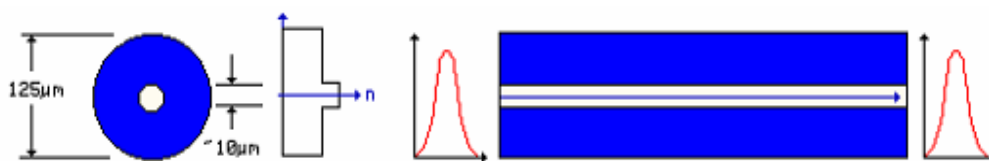


Figure 1.5: single mode fiber.

1.4.2 Multimode fiber:

Supports multiple paths of light and has a much larger core. The light travels down a much larger path in multimode fiber, allowing the light to go down several paths or modes.

Multimode fiber can be manufactured in two ways:

1.4.2.1 Step-index fiber:

Step-index fiber has an abrupt change or step between the index of refraction of the core and the index of refraction of the cladding.

Multimode step-index fibers have lower bandwidth than other fiber designs.

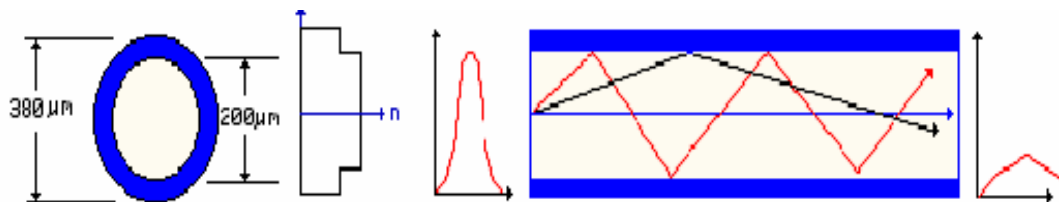


Figure 1.6: step-index multimode fiber.

1.4.2.2 Graded index fiber:

Graded index fiber was designed to reduce modal dispersion inherent in step index fiber. Modal dispersion occurs as light pulses travel through the core along higher and lower order modes. Graded index fiber is made up of multiple layers with the highest index of refraction at the core. Each succeeding layer has a gradually decreasing index of refraction as the layers move away from the center. High order modes enter the outer layers of the cladding and are reflected back towards the core. Multimode graded index fibers have less attenuation (loss) of the output pulse and have higher bandwidth than multimode step-index fibers.

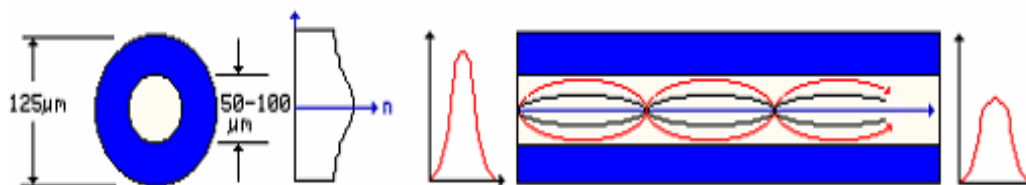


Figure 1.7: graded-index multimode fiber.

1.5 Optical fiber Characteristics:

The principal characteristics of the optical fiber are the attenuation, the chromatic dispersion, the modal dispersion and the polarization mode dispersion:

1.5.1 The attenuation [12]:

Is the loss of optical power as light travels along the fiber? Signal attenuation is defined as the ratio of optical input power (P_i) to the optical output power (P_o) with the formula:

$$Attenuation = \left(\frac{10}{L}\right) \log_{10}(P_o / P_i) \quad \text{Eq1.6}$$

Where:

L: length of the optical fiber

P_i : input power

P_o : Output power

There are many mechanisms which caused the attenuation in the optical fiber:

1.5.1.1 Absorption:

It is a major cause of signal loss in an optical fiber. It defined as the portion of attenuation resulting from the conversion of optical power into another energy form, such as heat. We can classify the absorption in two types:

1.5.1.1.1 Intrinsic absorption:

Caused by basic fiber material properties. In silica glass, the wavelengths of operation range from 700 nm to 1600 nm. This wavelength of operation is between two intrinsic absorption regions. The first region is the ultraviolet region (below 400-nm wavelength). The second region is the infrared region (above 2000-nm wavelength).

Intrinsic absorption in the ultraviolet region is caused by electronic absorption bands. Basically, absorption occurs when a photon interacts with an electron and excites it to a higher energy level.

Intrinsic absorption in the infrared region is caused by the characteristic vibration frequency of atomic bonds. In silica glass, absorption is caused by the vibration of silicon-oxygen (Si-O) bonds. The interaction between the vibrating bond and the electromagnetic field of the optical signal causes intrinsic absorption. Light energy is transferred from the electromagnetic field to the bond.

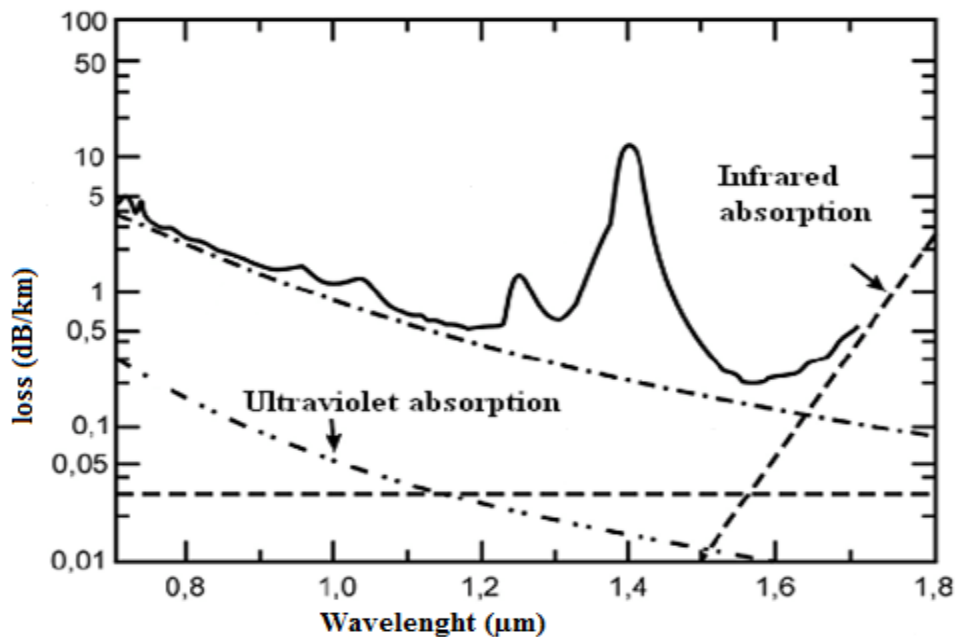


Figure 1.8: the intrinsic absorption.

1.5.1.1.2 Extrinsic absorption:

Caused by molecular vibrations of water molecules (OH impurities) embedded in the glass. The harmonics of the fundamental absorption occur in the region of operation, these harmonics increase extrinsic absorption at 1383 nm, 1250 nm, and 950 nm. Besides water, numerous other impurities can contribute to loss. Among these are the transition metals Fe, Cu, Co, Cr, Ni, and Mn.

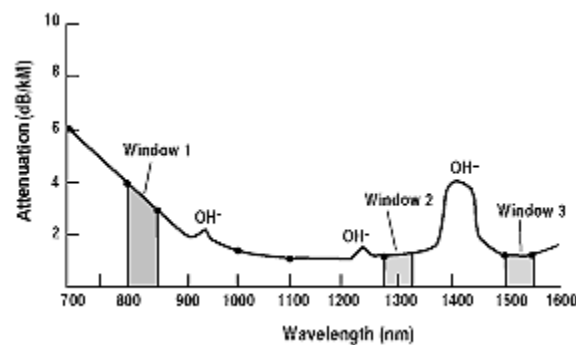


Figure 1.9: the extrinsic absorption.

1.5.1.1.3 Scattering:

Atoms and other particles scatter some of the light that hits them. The light isn't absorbed, just sent in another direction in a process called Rayleigh scattering.

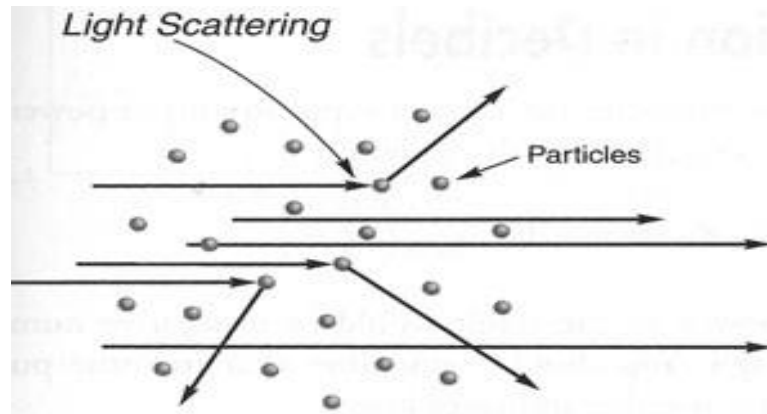


Figure 1.10: the Rayleigh scattering.

1.5.2 Dispersion:

There are three mechanisms of the dispersion in the optical transmission which are modal dispersion, chromatic dispersion and the polarization mode dispersion.

1.5.2.1 Modal Dispersion [12]:

An optical fiber consists of a core surrounded by a cladding that has a slightly lower refractive index than the core such that the light beam is guided by total internal reflection, as shown in Fig. 1.11. In principle, air, which has a lower refractive index than glass, could act as the cladding. However, the fiber surface then would be extremely sensitive to dirt and scratches, and two fibers touching each other would leak light. The invention of the clad fiber was a major breakthrough on the way to a practical optical fiber.

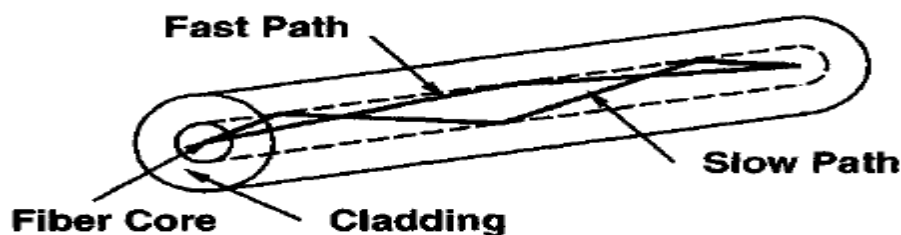


Figure 1.11: Modal dispersion in a multimode fiber.

Depending on the size of the fiber core, there is only a single or several pathways (so-called modes) for the light beam to propagate through the fiber. The core of a Multimode fiber (MMF) is large enough (50-100µm) for the light to take multiple pathways from the transmitter to the receiver, as shown in Fig. 1.11 (typically, several hundred modes exist). Each path has a slightly different propagation delay, thus producing a distorted (spread out) pulse at the receiver end. This effect is known as modal dispersion. The time difference between the longest and shortest path ΔT for a so-called graded-index multimode fiber (GRIN-MMF) can be approximated by:

$$\Delta T = \left(\frac{n_{\text{cor}} - n_{\text{clad}}}{8C \cdot n_{\text{cor}}} \right)^2 L \quad \text{Eq1.7}$$

Where L is the fiber length, C is the speed of light in vacuum, and n_{cor} and n_{clad} are the refractive indices of the core and cladding, respectively.

1.5.2.2 Chromatic Dispersion:

Chromatic dispersion, also called group-velocity dispersion (GVD), is another source of signal distortions and it is caused by different wavelengths (colors) traveling at different speeds through the fiber. Figure 1.12 illustrates how the group delay varies with wavelength for 1 km of standard SMF. It is recognized that the change in group delay is large around 1.55 µm, whereas it is nearly zero at 1.3 µm. In practice, chromatic dispersion is specified by the change in group delay per nm wavelength and Km length:

$$D = \frac{1}{L} \cdot \frac{\partial \tau}{\partial \lambda} \quad \text{Eq1.8}$$

Where D is known as the dispersion parameter, L is the fiber length; τ is the group delay, and λ is the wavelength. A standard SMF operated at 1.55 µm has $D = 17$ ps/nm/km, which means that a change in wavelength of 1 nm will change the group delay by 17 ps in a 1-km piece of fiber (Fig1.11).

How much pulse distortion is caused by chromatic dispersion depends on the spectral line width of the transmitter? If the transmitter operates at precisely a single wavelength, which implies an ideal, zero-line width laser without modulation, chromatic dispersion doesn't matter. However, if the transmitter operates over a range of wavelengths, as it does when transmitting information using a real laser, chromatic dispersion causes pulse distortions. The propagation time difference between the slowest and fastest wavelength for a transmitter that emits light over the range $\Delta\lambda$ [11] can be derived from Eq. (1.8) as:

$$\Delta T = |D| * L * \Delta\lambda \quad \text{Eq1.9}$$

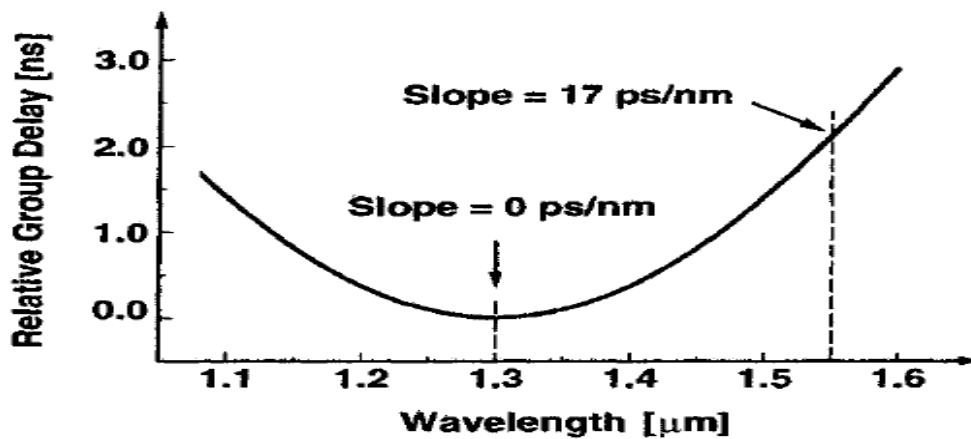


Figure 1.12 Relative group delay as a function of wavelength for 1km of standard SMF

The effects of chromatic dispersion on pulse spreading are rather important when designing a transmission system.

1.5.2.3 Polarization-Mode Dispersion (PMD):

Another source of distortions is polarization-mode dispersion (PMD), which is caused by different polarization modes traveling at different speeds. This effect occurs in fibers with a slightly elliptic core or asymmetrical mechanical stress. Figure 1.13 illustrates how, in such a fiber, horizontally and vertically polarized light propagates at slightly different speeds.

The difference in arrival time, ΔT , is known as differential group delay (DGD). Because, in general, the transmitter is exciting both polarization modes (horizontal and vertical), the receiver sees two time-shifted copies of the transmitted sequence superimposed on top of each other. The strength of each sequence depends on the alignment of the transmitter's linearly polarized light with the axes of the elliptic core [12].

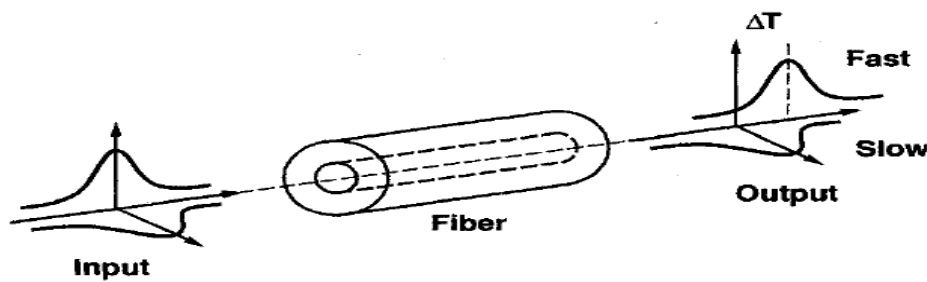


Figure 1.13: Polarization-mode dispersion in a short fiber segment.

1.6 Fabrication of Optical Fiber [13]:

The material of choice for low-loss optical fibers is pure silica glass synthesized by fusing SiO_2 molecules. The refractive-index difference between the core and the cladding is realized by the selective use of dopants during the fabrication process. Dopants such as GeO_2 and P_2O_5 increase the refractive index of pure silica and are suitable for the core, while materials such as boron and fluorine are used for the cladding because they decrease the refractive index of silica. Additional dopants can be used depending on specific applications. For example, to make fiber amplifiers and lasers, the core of silica fibers is co-doped with rare-earth ions using dopants such as ErCl_3 and Nd_2O_3 . Similarly, Al_2O_3 is sometimes added to control the gain spectrum of fiber amplifiers.

The fabrication of optical fibers involves two stages. In the first stage, a vapor-deposition method is used to make a cylindrical preform with the desired refractive-index profile and the relative core-cladding dimensions. A typical preform is 1-m long with 2-cm diameter. In the second stage, the preform is drawn into a fiber using a precision-feed mechanism that feeds it into a furnace at a proper speed.

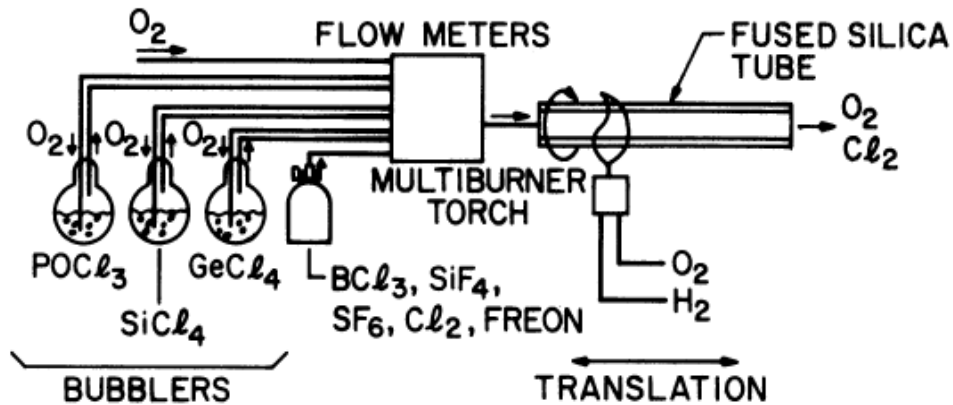


Figure 1.14: Schematic diagram of the MCVD process commonly used for fiber fabrication.

During this process, the relative core-cladding dimensions are preserved. Both stages preform fabrication and fiber drawing involve sophisticated technology to ensure the uniformity of the core size. Several methods can be used for making a preform, the three commonly used methods are modified chemical vapor deposition (MCVD), outside vapor deposition (OVD), and vapor-phase axial deposition (VAD). Figure 1.14 shows a schematic diagram of the MCVD process. In this process, successive layers of SiO_2 are deposited on the inside of a fused silica tube by mixing the vapors of SiCl_4 and O_2 at a temperature of $\approx 1800^\circ\text{C}$. To ensure uniformity, the Multi burner torch is moved back and forth across the tube length. The refractive index of the cladding layers is controlled by adding fluorine to the tube. When a sufficient cladding thickness has been deposited with multiple passes of the torch, the vapors of GeCl_4 or POCl_3 are added to the vapor mixture to form the core. When all layers have been deposited, the torch temperature is raised to collapse the tube into a solid rod known as the preform. This description is extremely brief and is intended to provide a general idea. The fabrication of optical fibers requires attention to a large number of technological details. The interested reader is referred to the extensive literature.

Conclusion

Optical fibers are the actual media that guides the light. They can be made of glass or plastic. The plastic fibers exhibit much loss and tend to have low bandwidths so glass fibers are usually preferred. A typical fiber is made up of a core, cladding and a jacket. The core is the center or the actual fiber where the light propagates. It has dimensions on the order of 5 to 600 μm . The cladding surrounds the core and has an index of refraction lower than that of the core, in this way the light will propagate through the core by means of internal reflection. Surrounding the cladding is the jacket, the outer most part of the fiber. The jacket serves to protect the entire optical fiber.

There are basically two types of fibers: stepped index and graded index. The stepped index fibers can be broken down into two types: single-mode and multi-mode. The stepped index fibers are fibers that have an abrupt change in refractive index from the core to the cladding while graded index fibers have a gradual change in index. The multi-mode stepped index fiber has, as one might guess, multiple paths for the light to travel while the single-mode fiber only allows a single light ray to propagate. Because the core diameter is so small, ILDs are usually used to couple light to the fiber. Multimode stepped index fibers exhibit what is referred to as modal dispersion.

This is because not all the rays travel through the center of the core. Some deviate from the core and are reflected back to the center. This reflected light takes a longer path and will therefore arrive at its destination at a later time. The graded index fibers will exhibit less of this dispersion because they gradually bend light back to the center allowing the light to travel faster when further from the core, making up for the longer distance. The single-mode stepped index fibers do not exhibit modal dispersion because of their small diameter core. Because of this they tend to have much wider bandwidths and lower losses. In general, if the modal dispersion of a fiber is low, then the output signal will be more likely to resemble the input signal. On the other hand, if the fiber has a high modal dispersion, the output signal will actually be spread out due to the different path lengths and therefore will be less likely to resemble the input signal. When such a case is present, repeaters are needed to re-construct the signal and then send it on its way again.

It is important to consider the characteristics involved when coupling a source to a fiber. Fibers have a certain ability to collect light. This light gathering ability of the fiber is called the numerical aperture (NA). A large NA means a larger signal, or ray loss, and larger distortion “of the intelligence being thus conveyed”. Also with an increase in NA comes a decrease in bandwidth. The NA is always less than 1 since it is a function of the refractive indexes of the fiber. There are four parameters that affect the efficiency of source-fiber coupling, the NAs of both the source and the fiber and the dimensions of the source and the fiber core. We have presented NA in the section 1.3.3

Another important fiber parameter is transmission or power loss. Signals that travel through fibers are sometimes attenuated. This is due to a variety of things such as impurities in the fiber, scattering within the fiber (variation in the uniformity of the fiber) and micro bending [4], in which radiation escapes because of small sharp bends that may occur in the fiber.

Typical fiber loss is measured in units of decibels per kilometer (dB/km) using the relation number 1.6

Where α_{dB} is the loss in decibels. Fiber loss is a function of frequency so this means that fibers will have greater losses at some frequencies than others. These losses are usually specified at certain wavelengths rather than at certain frequencies.

Another source of signal loss is at various locations where the light needs to re-enter or exit a fiber. These locations would include coupling to the fiber (the source end), splicing two fibers together and at the detector end of the fiber link. In order to minimize losses at these junctions, great care must be taken with the fiber. Two of the most common forms of splicing are mechanical and fusion splicing, where the fibers are actually fused together. The mechanical splice would consist of a connector matting the two ends of the fiber. Typical real world connectors cause 1 dB of loss each. These losses and other characteristics of the fiber can be measured with instruments such as an Optical Power Meter or an Optical Time-Domain Reflectometer (OTDR).

Chapter II Description of optical transmission system

2.1 Introduction:

Like all other communication system, the primary objective of optical fiber communication system is to transfer the signal containing information (voice, data, and video) from the source to the destination.

The source provides information in the form of electrical signal to the transmitter. The electrical stage of the transmitter drives an optical source to produce modulated light wave carrier. Semiconductor LASERs or LEDs are usually used as optical source here. The information carrying light wave then passes through the optical fiber cables. Now it reaches to the receiver stage where the optical detector demodulates the optical carrier and gives an electrical output signal to the electrical stage. The common types of optical detectors used are photodiodes (p-i-n, avalanche), phototransistors, photoconductors...etc. Finally the electrical stage gets the real information back and gives it to the concerned destination.

An optical communications system comprises a transmitter of optical signals, a length of transmission optical fiber coupled to the source, and a receiver coupled to the fiber. Next figure shows the basic scheme of an optical communication system:

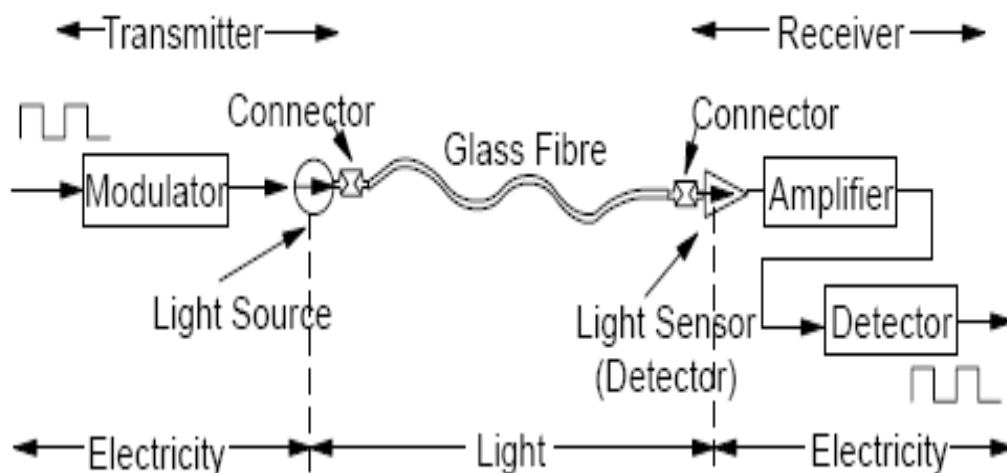


Figure 2.1: Optical communication sketch

The basic components of an optical communication system are shown in Figure 2.1, above.

* A serial bit stream in electrical form is presented to a modulator, which encodes the data appropriately for fiber transmission.

* A light source (laser or Light Emitting Diode - LED) is driven by the modulator and the light focused into the fiber.

* The light travels down the fiber (during which time it may experience dispersion and loss of strength) we tackled that in the first Chapter.

* At the receiver end the light is fed to a detector and converted to electrical form.

*The signal is then amplified and fed to another detector, which isolates the individual state changes and their timing. It then decodes

2.2 The Transmitter:

Optical transmitter is the core equipment of fiber optic transmission system; it consists of Source of information, optical source, electrical pulse generator and optical modulator.

2. 2.1 Source of information:

In most cases, the transmission is digital, making the system very versatile and relatively insensitive. There are various different modulation formats, i.e., different methods for encoding the information. For example, a simple non-return-to-zero (NRZ) format transmits subsequent bits by sending a high or low optical power value, with no gaps between the bits, and extra means for synchronization. In contrast, a return-to-zero (RZ) format is easily self-synchronizing by returning to a rest state after each bit.

2.2.2 Light source [12]:

There are two kinds of devices that are used as light sources: Lasers and LEDs (Light Emitting Diodes). The physical principle involved in semiconductor lasers and LEDs is as follows. Electrons and holes recombine at the junction and this recombination results in electrons going from the high energy “conduction” band to the lower more stable “valence” band. This can result in either spontaneous (LED) or stimulated (LASER) emission depending on how the device is constructed.

Laser is an acronym for “Light Amplification by the Stimulated Emission of Radiation” and produces far and away the best kind of light for optical communication. The key principle in laser operation is the principle of stimulated emission. For that phenomenon to be of relevance a condition known as population inversion is required in the material. The conduction band electron occupation should be higher to that in the valence band. That occurs above a certain feeding current known as threshold current.

Next figure shows a typical simplified configuration for direct signal modulation of the optical diode carrier. We see that above the threshold current there is a linear relation between the input current and the power emitted. We can obtain a linear power modulation (intensity modulation, IM) by biasing the diode above the threshold and injecting the signal as shown.

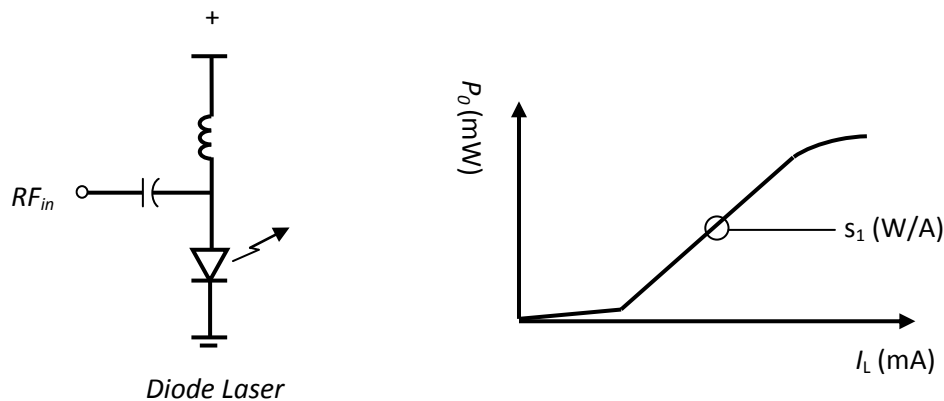


Figure 2.2: Direct modulation with diode laser transmitter

2.2.3 Direct and external modulation [1]:

Lasers and LEDs used in telecommunication applications are modulated using one of two methods: direct modulation or external modulation.

- In direct modulation (Figure 2.3), the output power of the device varies directly with the input drive current. Both LEDs and lasers can be directly modulated using analog and digital signals. The benefit of direct modulation is that it is simple and cheap. The disadvantage is that it is slower than indirect modulation with limits of less than approximately 3 GHz.

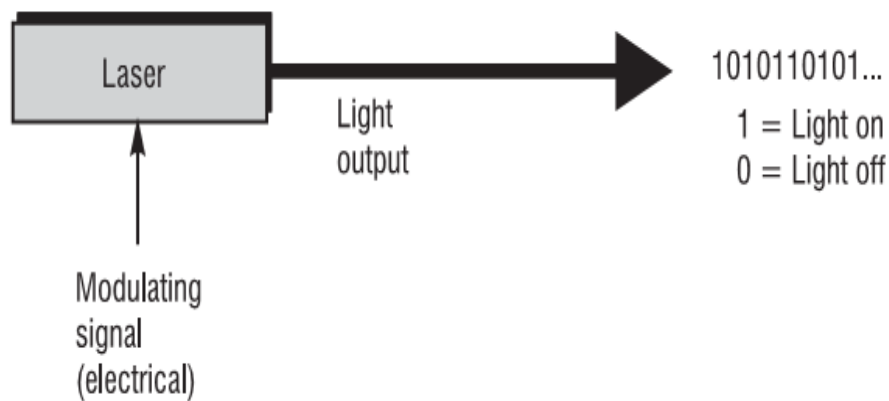


Figure 2.3: Direct modulation

- In external modulation (Figure 2.4), an external device is used to modulate the intensity or phase of the light source. The light source remains on while the external modulator acts like a “shutter” controlled by the information being transmitted. External modulation is typically used in high-speed applications such as long-haul telecommunication or cable TV head ends. The benefits of external modulation are that it is much faster and can be used with higher-power laser sources.

The disadvantage is that it is more expensive and requires complex circuitry to handle the high frequency RF modulation signal.

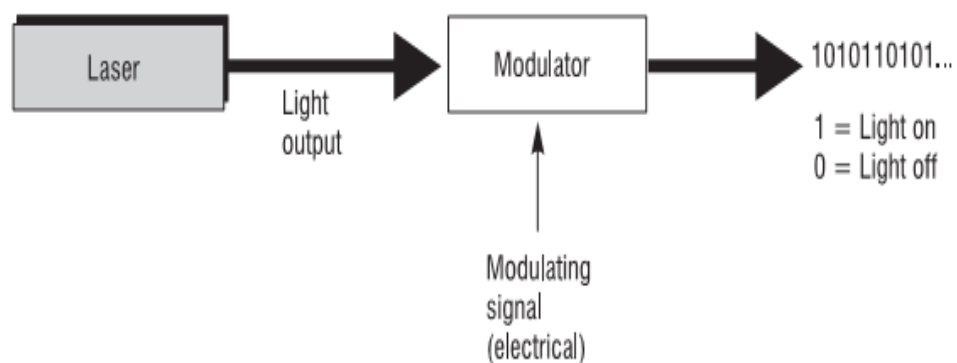


Figure 2.4: External modulation

External modulation is typically accomplished using an integrated optical modulator that incorporates a waveguide Mach-Zehnder interferometer fabricated on a slab of Lithium Niobate (LiNbO₃). The waveguide is created using a lithographic process

similar to that used in the manufacturing of semiconductors. The waveguide region is slightly doped with impurities to increase the index of refraction so that the light is guided through the device (Figure 2.5).

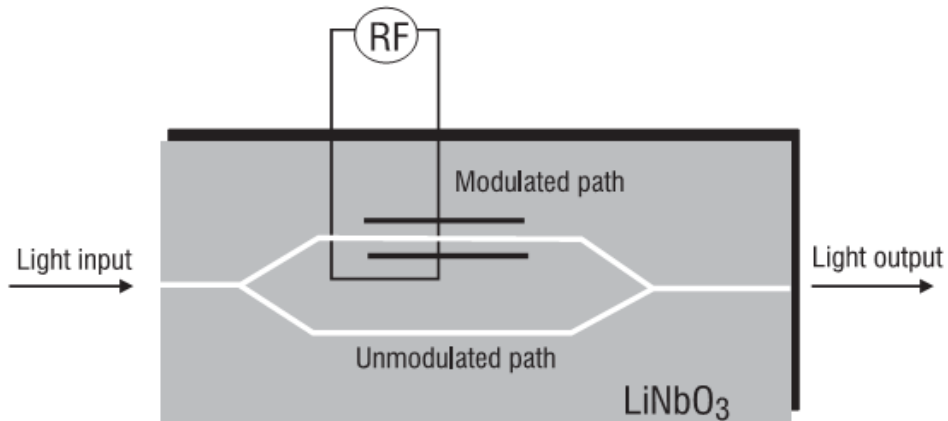


Figure 2.5: External modulation using Mach-Zehnder waveguide interferometer

Light entering the modulator (via fiber pigtail) is split into two paths. One path is unchanged or unmodulated. The other path has electrodes placed across it. Because LiNbO₃ is an electro-optic material, when a voltage is placed across the waveguide its index of refraction is changed, causing a phase delay proportional to the amplitude of the applied voltage. When the light is then recombined, the two waves interfere with one another. If the two waves are in phase, the interference is constructive and the output is on. If the two waves are out of phase, the interference is destructive and the waves cancel each other. The input voltage associated with a 180° phase shift is known as V_{π} . The induced phase shift can be calculated using:

$$\text{Phase shift} = \Delta\theta = 180^{\circ} * V_{in} / V_{\pi}$$

Where V_{in} is the voltage applied to the modulator. Lithium Niobate modulators are well developed and used extensively in both CATV and telecommunication applications. Devices are available at both the 1310-nm and 1550-nm wavelengths.

2.2.4 The modulations [6]:

Modulation is the process of facilitating the transfer of information over a medium. Sound transmission in air has limited range for the amount of power your lungs can generate. To extend the range your voice can reach, we need to transmit it through a medium other than air, such as phone line or radio.

The process of converting information (voice in this case) so that it can be successfully sent through a medium (wire or radio waves) is called modulation

We begin our discussion of digital modulation with the three basic techniques of digital modulation:

- Amplitude-Shift Keying (ASK)
- Frequency-Shift Keying (FSK)
- Phase-Shift Keying (PSK)

All of these techniques vary a parameter of a sinusoid to represent the information which we wish to send .A sinusoid has three different parameters than can be varied .These are its amplitude, phase and frequency, Modulation is a process of mapping such that it takes your voice (as an example of a signal) converts it into some aspect of a sine wave, leaving the actual voice behind. The sine wave on the other side is remapped back to a near copy of your sound.

The medium is the thing through which the sine wave travels. So wire is a medium and so are air, water and space. The sine wave is called the carrier .The information to be sent, which can be voice or data is called the information signal once the carrier is mapped with the information to be sent, it is no longer a sine wave and we call it the signal .The signal has the unfortunate luck getting corrupted by noise as it travels, in this example the information coding by system RZ.

Amplitude shift keying:

In ASK, the amplitude of the carrier is changed in response to information and all else is kept fixed. Bit 1 is transmitted by a carrier of one particular amplitude. To transmit 0, we change the amplitude keeping the frequency constant. On-Off Keying (OOK) is a special of ASK, where one of the amplitudes is zero as shown below.

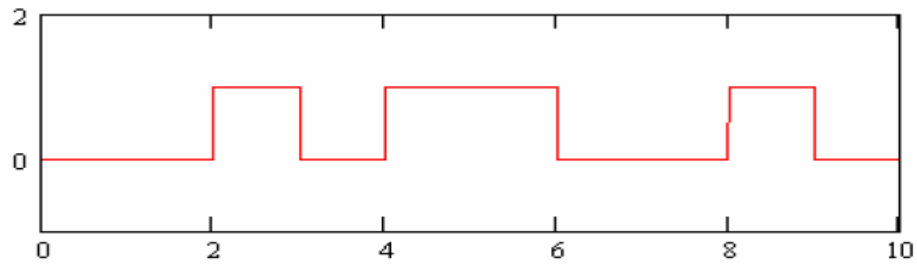


Figure 2.6: baseband information sequence 0010110010

$$ASK(t) = s(t) \sin(2\pi ft) \quad \text{Eq2.1}$$

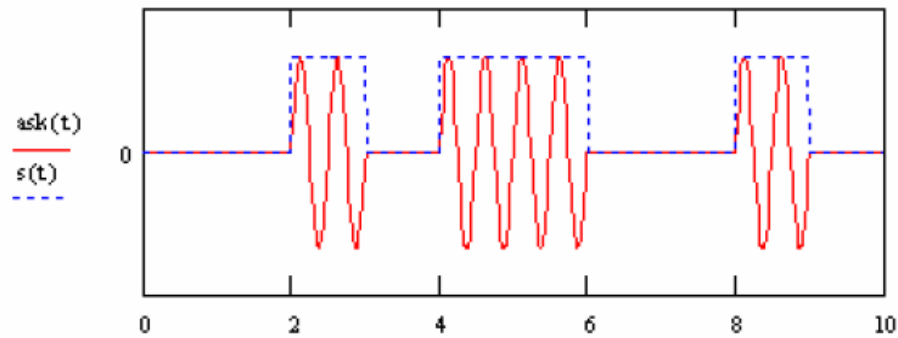


Figure 2.7: Binary ASK (OOK) signal

Frequency shift keying:

In FSK we change the frequency in response to information one particular frequency for a 1 and another frequency for a 0. In the example below, frequency F_1 for bit 1 is higher than frequency F_2 used for the 0 bit

$$FSK(T) = \begin{cases} \sin(2\pi f_1 t) & \text{for bit 1} \\ \sin(2\pi f_2 t) & \text{for bit 0} \end{cases} \quad \text{Eq2.2}$$

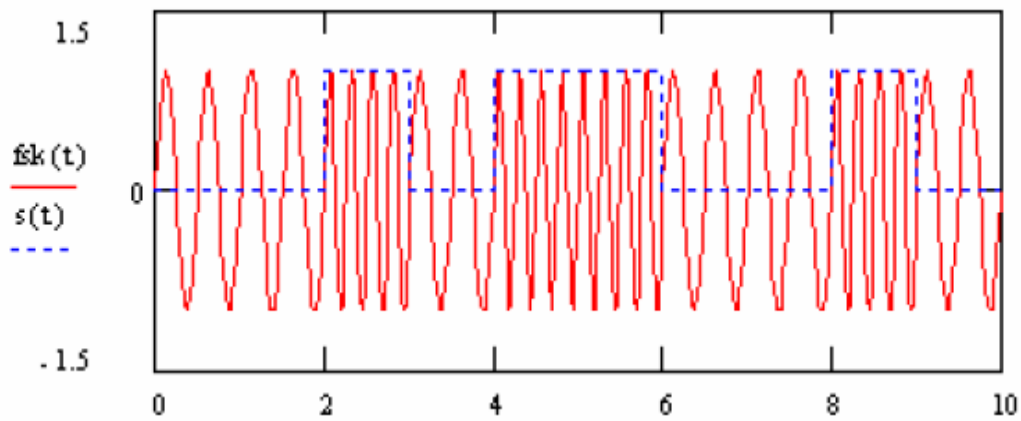


Figure 2.8: Binary FSK signal

Phase shift keying:

In PSK, we change the phase of the sinusoidal carrier to indicate information. Phase in this context is the starting angle at which the sinusoid starts. To transmit 0, we shift the phase of the sinusoid by 180 deg. Phase shift represent the change in the state of the information in this case.

$$FSK(T) = \begin{cases} \sin(2\pi ft) & \text{for bit 1} \\ \sin(2\pi ft + \pi) & \text{for bit 0} \end{cases} \quad \text{Eq2.3}$$

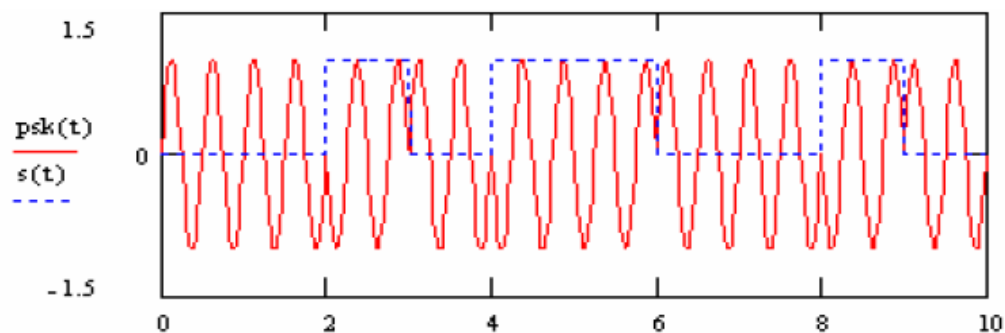


Figure2.9: Binary PSK Carrier

2.3 The optical Amplifiers:

To achieve optical amplification, the population of upper energy level has to be greater than that of lower energy level. $N_2 > N_1$, where N_1 , N_2 is population density 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. Stimulated emission occur, when incident photon having energy $E = (h \cdot c) / \lambda$ interact with electron in upper energy state causing it return to lower state with creation of second photon, where h is Plank constant, c is velocity of light and λ is the wavelength of light . So light amplification occurs, when incident photon & emitted photon are in phase and release two more photon, continuation of this process effectively creates avalanche multiplication. Therefore amplified coherent emission is obtained.

2.3.1 Types of Optical Amplifiers:

Optical amplifiers were classified on the basis of device characteristics, whether it is based on linear characteristic (Semiconductor optical amplifier and Rare-earth doped fiber amplifiers) or nonlinear characteristic (Raman amplifiers and Brillouin amplifiers). Optical amplifiers were also classified on the basis of structure, whether semiconductor based (SOAs) or fiber based (Rare-earth doped fiber amplifiers), Raman and Brillouin scattering amplifiers [9].

2.3.1.1 Semiconductor Optical Amplifiers:

Semiconductor Optical Amplifiers (SOAs) uses the principle of stimulated emission to amplify an optical information signal. Optical input signal carrying original data enters to semiconductor's active region through coupling. The coupling is required because the mode field diameter of single mode beam is 9.3 Mm, while size of active region is less. Injection current delivers the external energy to pump elements at conduction band. The input signal stimulates the transition of electrons down to valence band & emission of photon with same energy & same wavelength as the input signal, so amplified optical signal is obtained. SOA is of two types Fabry -Perot Amplifier (FPA) & Travelling Wave Amplifier (TWA). Fabry-Perot Amplifier (FPA) is same as SOA. In this, light entering the active region is reflected several times from cleaved face & amplified as it leaves the cavity. Travelling Wave Amplifier (TWA) is the SOA form. Here, TWA is an

active medium without reflective facets, so that input signal is amplified by a single passage through active region. Practical active region without reflective facets was made by covering the facets of semiconductor material by antireflection coating, tilting the active region with respect to facet and using buffer material between active region & facet to also reduce reflectance R as small as 10^{-4} . SOA's are typically used in the following ways as shown in the fig 2.10[8],

- Used as power boosters following the source (optical PA).
- Provide optical amplification for long-distance communications (in-line amplification, repeaters).
- Pre-amplifiers before the photo detector.
-

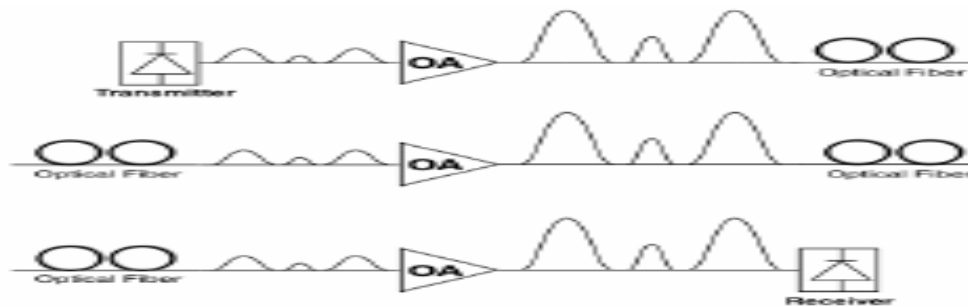


Figure 2.10: Optical Amplifiers (SOAs) applications

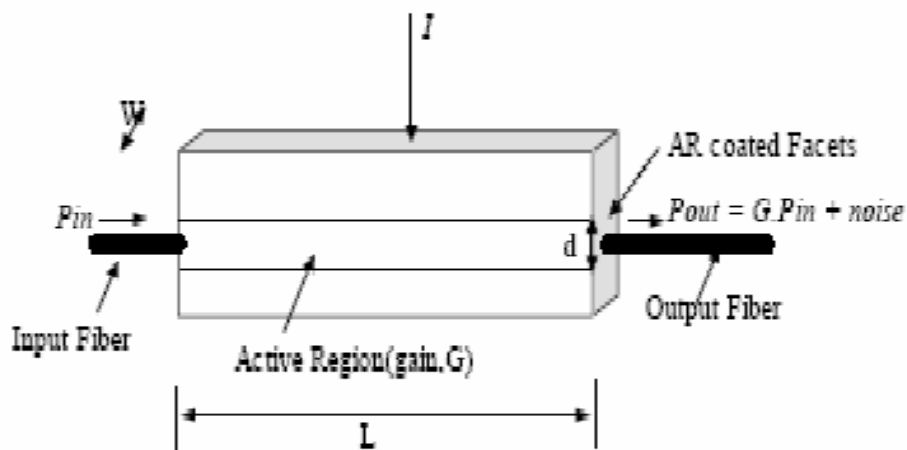


Figure 2.11: Semiconductor Optical Amplifiers

2.3.1.2 Fiber Amplifiers [1]:

Fiber amplifiers act as power amplifier, repeater, and a preamplifier. The gain medium comprises a length of single-mode fiber connected to WDM coupler, which provides low insertion loss at both, signal & pump wavelength. Excitation occurs through optical pumping laser combined with optical input signal within the coupler. Stimulated emission process occurred inside the fiber gain medium. The amplified optical signal is emitted from other end of fiber made from heavily doped ions depending upon type:

- Rare-earth doped fiber amplifier,
- Raman fiber amplifier.

2.3.1.2.1 Rare Earth Doped Fiber Amplifier:

Different rare-earth ions, such as erbium, holmium, neodymium, praseodymium, thulium and ytterbium can be used to realize fiber amplifiers operating at different wavelength covering visible to infrared region. In rare earth doped fiber amplifier, erbium's dopants in silica based single mode fiber used, so called erbium doped fiber amplifier (EDFA). A piece of fiber gain medium as an active medium is heavily doped with ions of Erbium. In this, population inversion is stronger due to large number of erbium ions that fall to level 2 from various upper levels. When optical information pass through such populated erbium doped fiber, it would stimulate transition of erbium ions from level 2 to level 1 & generating photons of same wavelength with direction & phase as input photon .EDFA consists of three basic components: length of erbium doped fiber, pump laser and wavelength selective coupler to combine the signal and pump wavelengths. Optimum fiber length used depends upon pump power, input signal power, amount of erbium doping and pumping wavelength. The 980 nm wavelength with semiconductor laser pumping source has proved to be best in terms of efficiency (more than 10 dB gain per mw pump power) and better noise performance .Typically noise figure lies between 4-5 dB and η between 40-50% with forward pumping and equivalent figures for backward pumping are 6-7 dB and 60-70% assuming 1480 nm pumping light.

In praseodymium-doped fluoride fiber amplifier similar to EDFA, But operated at 1300 nm with noise figure 3-5dB for best performance. Thulium-doped fiber amplifiers had extended transmission bandwidth of optical fibers beyond the range available from EDFA [3].

2.3.1.2.2 Raman Amplifiers:

A fiber based Raman amplifier uses stimulated Raman scattering (SRS) occurring in silica fibers when an intense pump beam propagates through it. In SRS, incident pump photon gives up its energy to create another photon & remaining energy is absorbed by the medium in the form of molecular vibrations (optical phonon). In Raman amplifier, standard single -mode optical fiber can be used generally. The main features of the Raman amplification were that it realized as continuous amplification along the fiber, bidirectional in nature and offers more stability, insensitivity to reflections. The saturation optical power level was very high as it depends on the pump power. The main disadvantage of this amplifiers that pump power requirement is relatively high in comparison with SOAs and EDFAs [4].

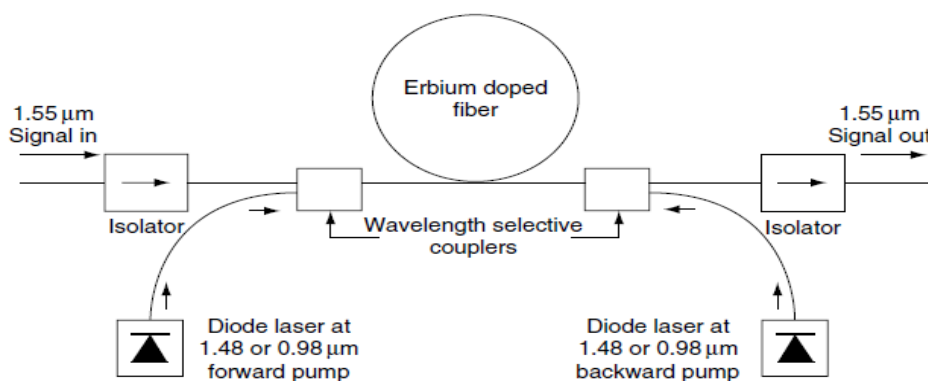


Figure 2.13: General Erbium-Doped Fiber Configuration

2.3.2 Device Structure

In order to be amplified efficiently, the signal must propagate through the amplifier in a well-confined manner. Therefore, amplifiers are usually waveguides with gain. The EDFA is the most well-known example: a waveguide (the optical fiber) is heavily doped with erbium ions, which provide gain when optically excited by injection of pump light (Fig. 2.14). Erbium can also be implanted into a planar waveguide structure, forming an EDWA. Similarly, a SOA is formed by enclosing an amplifying active layer, usually indium gallium arsenide phosphide (InGaAsP) of an appropriate band gap, between cladding layers of lower refractive index, creating a waveguide structure. Light is usually coupled into and out of it by means of lenses (see Fig. 2.15).

The cladding layers of the SOA waveguide are p-and n-doped, respectively, allowing electrical pumping by current injection.

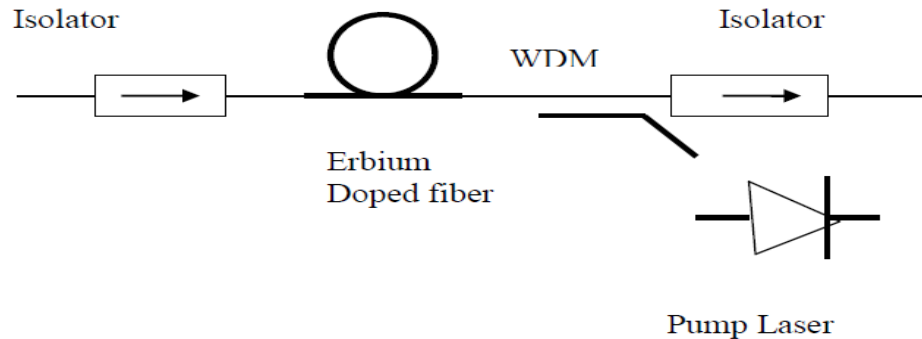


Figure 2.14: Basic EDFA configuration. A design with counter-propagating pump.

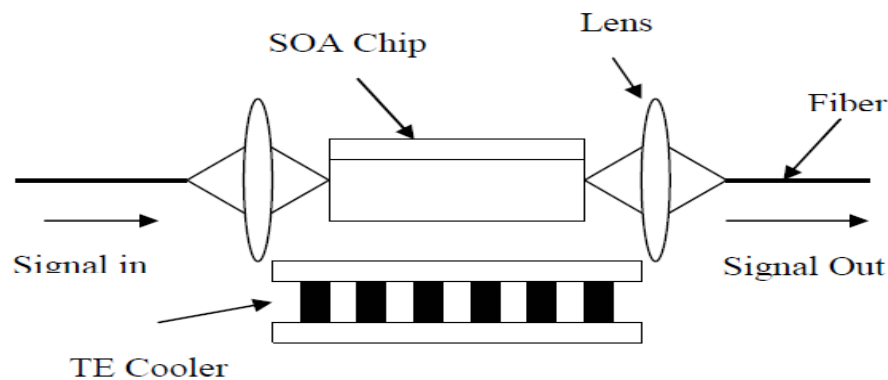


Figure 2.15: Typical packaged SOA chip

2.4 The transmission channels 'Optical Fibers':

An optical fiber (also called an optical waveguide) is the central part of a fiber optic cable. It consists of three main parts: the core, its cladding, and often, a protective coating. These three parts are usually manufactured together because of their close relationship. A fiber optic cables core, which is usually anywhere from two to several hundred microns thick (a micron is a millionth of a meter, usually designated by the symbol μ), is the central part of the fiber optic cable that actually carries the light signal. To put that size in perspective, a human hair is around 75 microns.

The fiber core is usually made of some type of plastic or glass. As a matter of fact, there are several types of materials that make up the core of a typical optical fiber. Each

material differs in its chemical makeup and cost as well as its index of refraction. The index of refraction is a number for a particular material that indicates how much light will bend when passing through that material. It also indicates how fast light will travel through a particular material. The cladding for the core has a lower index of refraction than the core itself. Therefore, light from the core that hits the “wall” between the core and cladding will be reflected back into the core.

A fiber optic cables cladding is the coating around the central core that performs two functions. First, it is the first, albeit the smallest, layer of protection around the glass or plastic core. Second, as mentioned earlier, it provides a surrounding surface for the light inside the core to reflect off of. This is because the cladding has a lower index of refraction than the core. Cladding is usually fairly thin (around 25 microns), except in the case of single-mode glass core fibers.

The protective coating around the optical fiber at the center of a fiber optic cable protects the fiber core and cladding from damage. It does not participate in the transmission of light at all. It is simply a protective measure. It protects the cladding from abrasion damage and adds additional strength to the core.

2.5 The Receiver [1]:

The main component of an optical receiver is a photo-detector, which converts light into electricity using the photoelectric effect. The photo-detector is typically a semiconductor-based photodiode. Several types of photodiodes include P-N photodiodes, P-I-N photodiodes, and avalanche photodiodes (APD). They need to be inversely polarized. Next figure shows the physical photo-detection process using semiconductor material:

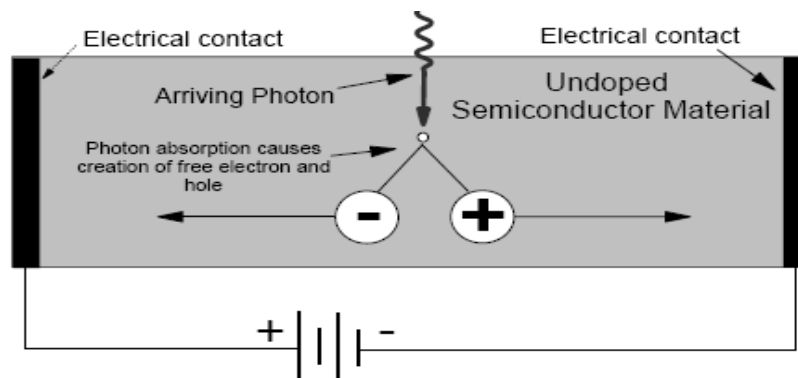


Figure 2.16: Semiconductor photo-detector principle

The detection process is based on the square-law rule which means that the output diode current I is proportional to the squared modulus of the electric field associated to the optical wave E , or mean optical power P . Next equation shows this relation:

$$I_D = |E_R|^2 \quad \text{Eq2.4}$$

Next figure shows a typical detection stage configuration and its transfer characteristic:

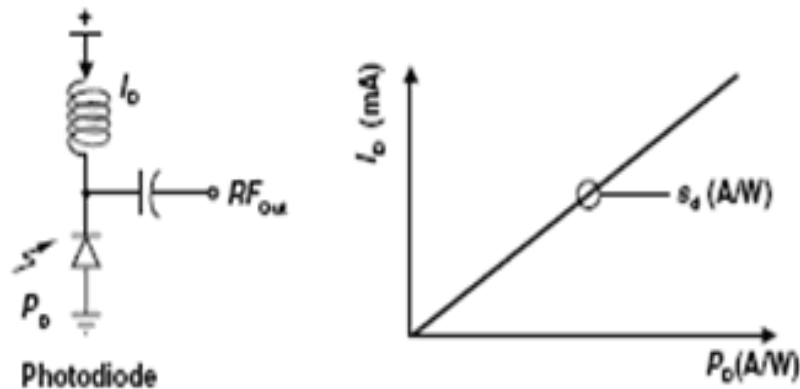


Figure 2.17: Photodiode detector

As seen, the characteristic input power - output current is linear. The slope of this characteristic is known as responsivity or conversion efficiency and depends on the reverse voltage applied to the photodiode

Conclusion

In this chapter we have studied the optical communication system. This is like any communication system consists of: The Transmitter. Optical Amplifiers. The transmission channels 'Optical Fibers' and Receiver

The Transmitter: The most commonly-used optical transmitters are semiconductor devices such as light-emitting diodes (LEDs) and laser diodes. The difference between LEDs and laser diodes is that LEDs produce incoherent light, while laser diodes produce coherent light. For use in optical communications, semiconductor optical transmitters must be designed to be compact, efficient, and reliable, while operating in an optimal wavelength range, and directly modulated at high frequencies.

The transmission channels 'Optical Fibers': An optical fiber consists of a core, cladding, and a buffer (a protective outer coating), in which the cladding guides the light along the core by using the method of total internal reflection. The core and the cladding (which has a lower-refractive-index) are usually made of high-quality silica glass

Optical amplifiers: The transmission distance of a fiber-optic communication system has traditionally been limited by fiber attenuation and by fiber distortion. By using opt-electronic repeaters, these problems have been eliminated. These repeaters convert the signal into an electrical signal, and then use a transmitter to send the signal again at a higher intensity than it was before. Because of the high complexity with modern wavelength-division multiplexed signals (including the fact that they had to be installed about once every 20 km), the cost of these repeaters is very high.

An alternative approach is to use an optical amplifier, which amplifies the optical signal directly without having to convert the signal into the electrical domain. It is made by doping a length of fiber with the rare-earth mineral erbium, and pumping it with light from a laser with a shorter wavelength than the communications signal (typically 980 nm). Amplifiers have largely replaced repeaters in new installations.

The receiver: The optical receiver is essential to optical communication because it converts the light energy from the transmitter to a form of electrical energy, then he decoding the signal received by channels the transmission. So it usually consists of demodulator and decoder and amplifier and filter.

Chapter III Simulation of optical transmission system

3.1 Introduction:

The simulation permits to evaluate the performance of the optical transmission system and it constitutes a powerful tool that helps to study the effects of the attenuation and the dispersion.

Here are some reasons showing the importance of this tool:

- 1- Some analysis stages are not possible to do with the traditional mathematical tools, especially if we are faced with the complex system and channel model.
- 2- It is very simple to pass from a simulation model of a system to its hardware implementation. Thus, the distinction between the simulation model and a prototype of a system will be minimum, hence the economical interest of simulation is evident since the time and cost of realization of a system is considerably reduced, and lead to a simpler correction and enhancement than a prototype.

In this project, the simulation will be applied using the OptiSystem v7.0 program, and it will study the effects of the attenuation and the chromatic dispersion to an optical transmission system which displayed in the figure 3.1

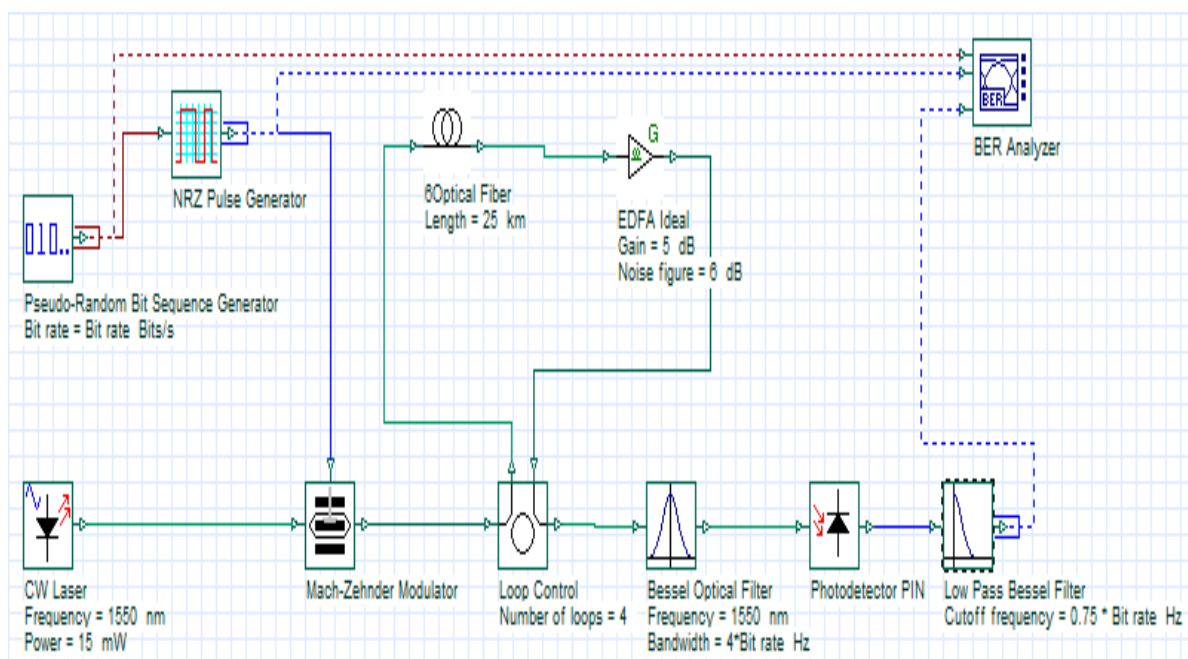


Figure 3.1: the structure of optical transmission system NRZ

3.2 Optical transmission system NRZ with 10 GB/s:

This system is combined of many components, each one has a specific characteristics. Those components are:

- An optical fiber SSMF (Standard Single Monomode Fiber) with a length of 100km.
- An optical amplifier EDFA (Erbium Doped Fiber Amplifier) with gain of 5dB

The transmitter is composed of:

- Pseudo-random bit sequence generator
- NRZ pulse generator
- CW laser with wavelength 1550 nm and power 15 mW
- An external modulator of Mach-Zehnder

At the receiver level:

- An optical filter of Bessel
- A photo detector PIN
- Low pass filter of Bessel

In this simulation, the modulation which will be use is the OOK (On Off Keying) because of its simplicity of implementation.

To properly study the impact of the attenuation and the chromatic dispersion, we consider two situations: the first is a default attenuation of optical fiber with varying in the dispersion value; the second is default dispersion with varying in the attenuation.

3.2.1First case:

The simulation is done by keeping the default optical fiber attenuation value (0.2 dB/km) and taking different values of the chromatic dispersion .The Q factor, the bite error rate and the opening eyes are shown in the table below:

The dispersion	Q	BER	Opening eye
1	147.862	0	0.0147227
2	70.3919	0	0.0143813
4	27.5654	$1.41907 \cdot 10^{-167}$	0.0134906
6	15.1844	$1.99782 \cdot 10^{-52}$	0.0125206
12	9.50573	$9.61446 \cdot 10^{-19}$	0.0108145
14	9.12554	$3.45035 \cdot 10^{-20}$	0.0100339
16	7.6019	$1.40754 \cdot 10^{-14}$	0.0083536
20	5.13815	$1.34682 \cdot 10^{-7}$	0.0046709

Table 1: The Q factor, the bite error rate and the opening eye for different chromatic dispersion values

From the table 1, the Q factor and the opening eye are decreased when the chromatic dispersion is increased. Their developments are showing in the figures below:

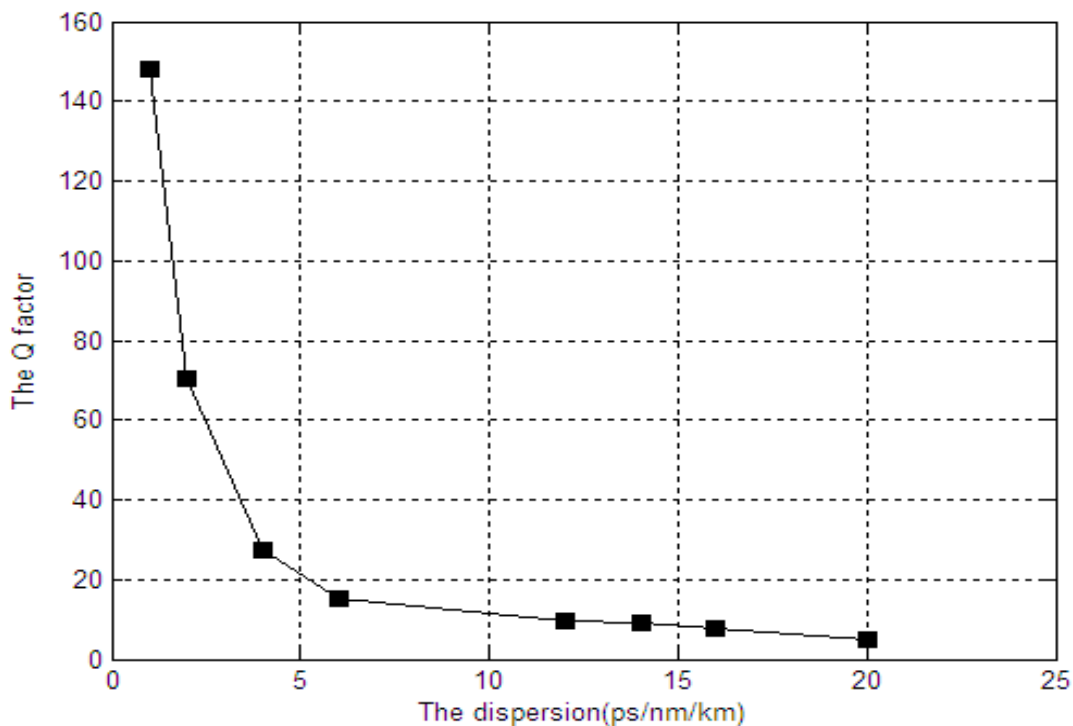


Figure 3.2: the development of the Q factor as the chromatic dispersion function for NRZ transmission system with 10Gbps

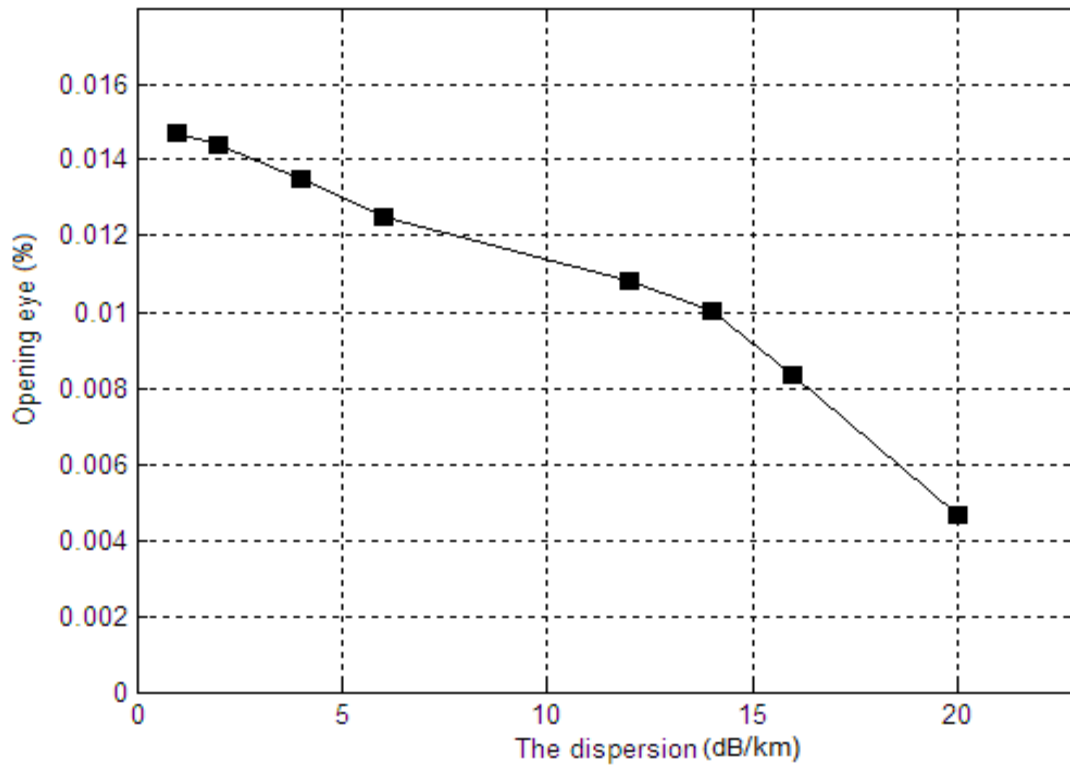


Figure 3.3: the development of the opening eye as the chromatic dispersion function for NRZ transmission system with 10Gbps

3.3.2- Second case:

Here, the dispersion will be fixed in the value 16 ps/nm/km (default), with varying in the attenuation values .the results are shown in the table:

The attenuation	Q	BER	Opening eye
0.2	7.6019	$1.40754 \cdot 10^{-14}$	0.0083536
0.3	7.23909	$2.2559 \cdot 10^{-13}$	0.000716514
0.35	6.48563	$4.41306 \cdot 10^{-11}$	0.000202659
0.4	5.96143	$1.24936 \cdot 10^{-9}$	$5.82616 \cdot 10^{-5}$
0.45	5.52099	$1.68541 \cdot 10^{-8}$	$1.67439 \cdot 10^{-5}$
0.5	4.97764	$3.21448 \cdot 10^{-7}$	$4.56782 \cdot 10^{-6}$
0.55	4.08319	$2.1921 \cdot 10^{-5}$	$9.56694 \cdot 10^{-7}$

Table 2: The Q factor, the bite error rate and the opening eye for different attenuation values

The results are showing that the Q factor and the opening eye are decreased when the attenuation is increased. Their developments are displaying in the figures below:

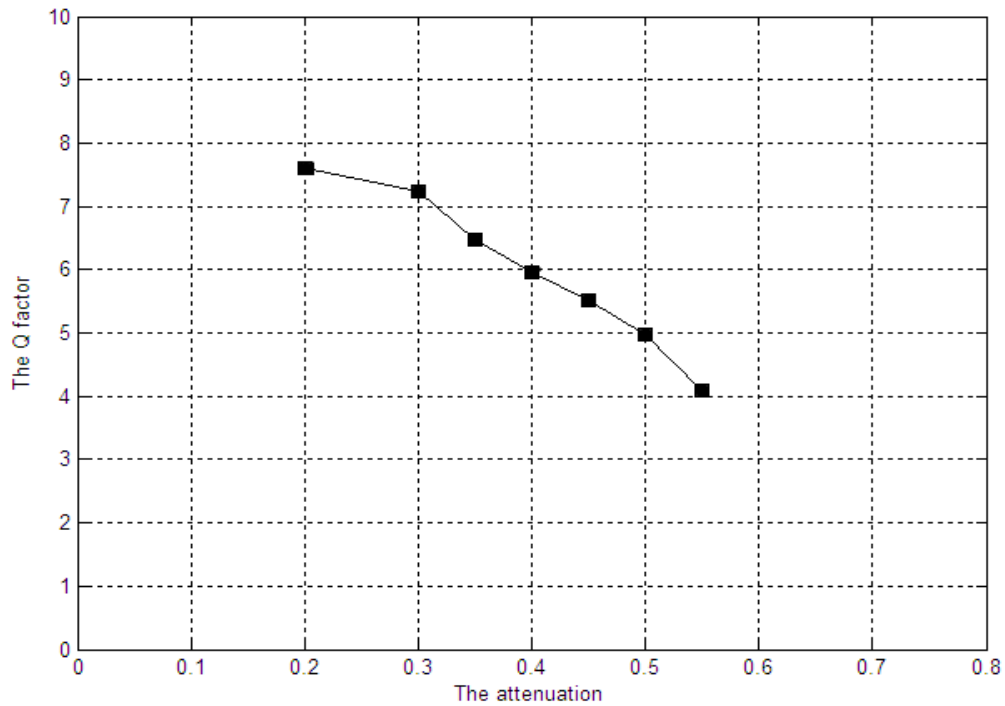


Figure 3.4: the development of the Q factor as the attenuation function for NRZ transmission system with 10Gbps

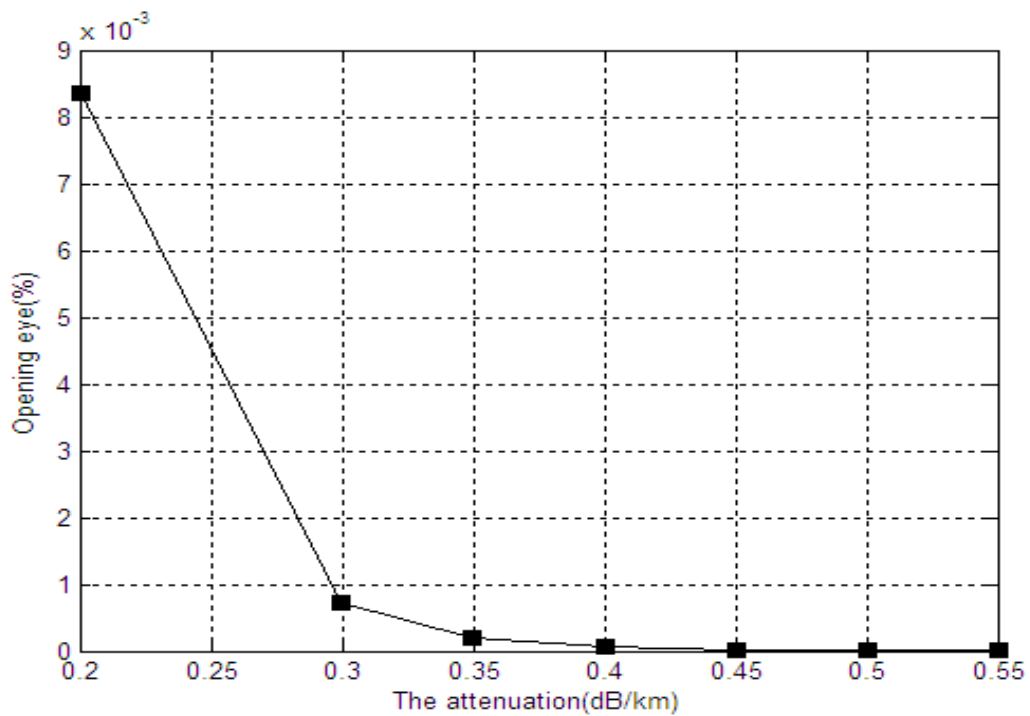


Figure 3.5: the development of the opening eye as the attenuation function for NRZ transmission system with 10Gbps

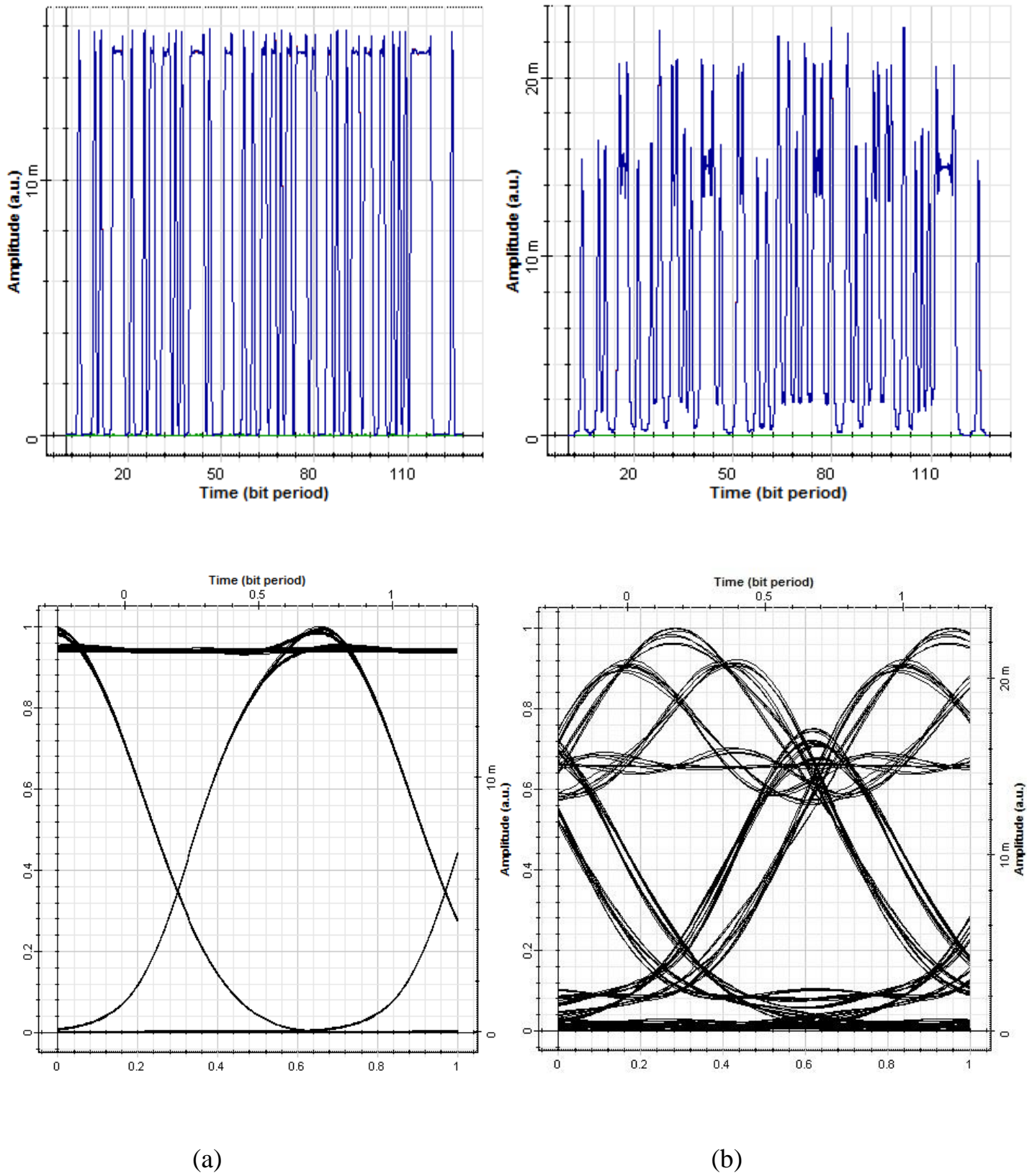


Figure 3.6: the output signal and the correspondent opening eye for a chromatic dispersion values of: 2 ps/nm/km (a), 16 ps/nm/km (b) of 10Gbps system

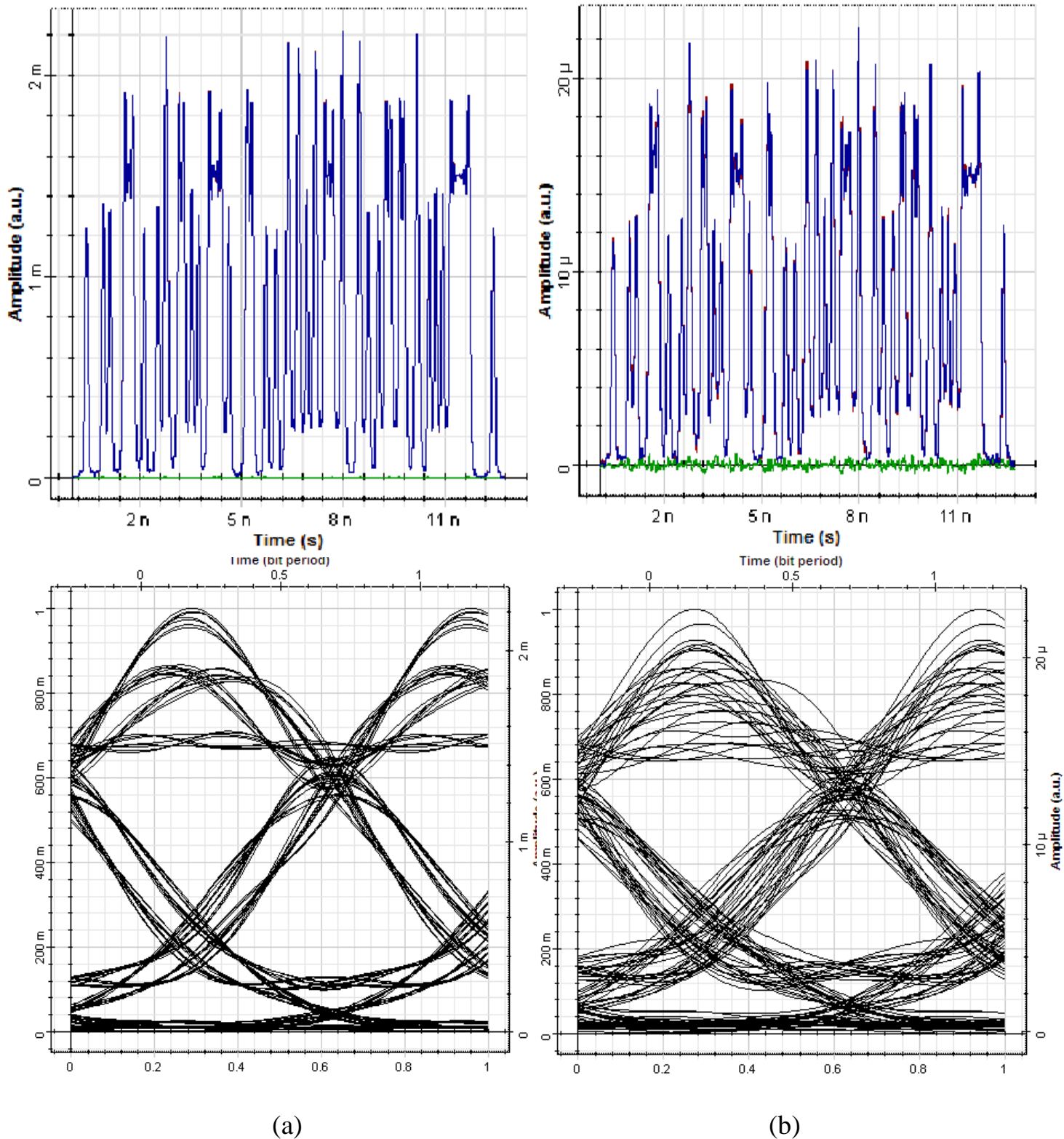


Figure 3.7: the output signal and the correspondent opening eye for an attenuation factor of: 0.3dB/km (a), 0.5dB/km (b) of 10Gbps system

Conclusion

The simulation results show that the attenuation and the chromatic dispersion caused a serious damage on the transmitted signal. For decrease this negative influence, the single mode optical fiber can be used, the length of the optical fiber cable must be taken under consideration so when the signal became weak, the amplifiers can help, also the using of the laser as light source and 1550nm as wavelength. At this moment, those are the possible solutions and they are not perfectly solve the problem, for that the science is still trying to find out a finally solutions for this information loss.

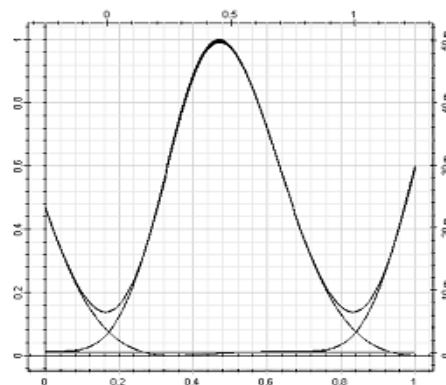
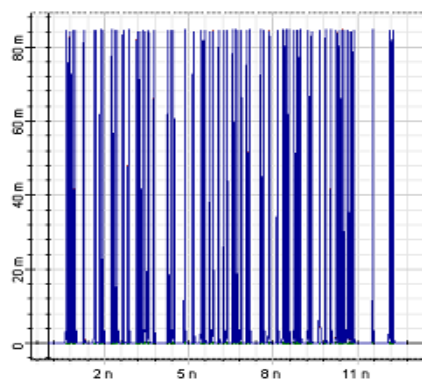
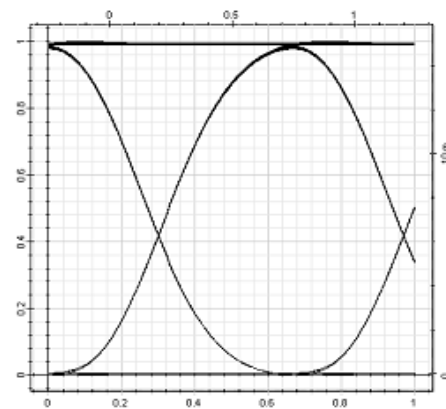
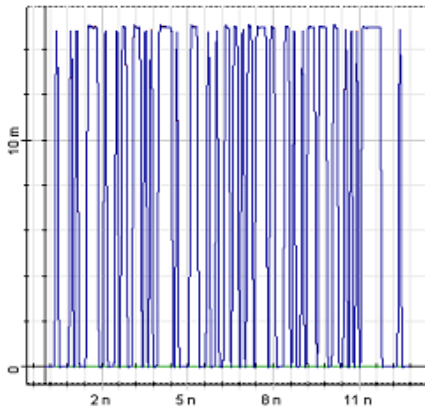
APPENDIX A**Criterion of the optical transmission:**

In order to determine the optical transmission performance, some parameters are used like the eye diagram, bit error rate (BER) and quality factor

1- Eye diagram[14]:

An eye diagram shows a relative performance of the signal. The horizontal and vertical openings of the eye provide valuable information about the ability of the receiving to detect a 1 bit and a 0 bit correctly. The vertical eye opening shows the ability to distinguish between a 1 and 0 bit, and the horizontal opening gives the time period over which the signal can be sampled without any errors

For good transmission systems, the eye opening should be as wide and open as possible. The eye diagram also displays information such as maximum signal voltage, rise and decay time of pulse, and so on.



2- Quality factor[14]:

The Q-factor is the electrical signal-to-noise ratio at the input of the decision circuit in the receiver's terminal. For the purpose of calculation, the signal level is interpreted as the difference in the mean values, and the noise level is the sum of the standard deviations. The Q-factor is formed by the following ratio:

It can calculate by:

$$Q = \frac{V_1 - V_0}{\sigma_1 + \sigma_0}$$

Where V_1, V_0 denotes the separation between the intensity levels of "1" and "0", and σ_1, σ_0 is the sum of the standard deviations of the intensities around the levels of "1" and "0".

3- Bit error rate (BER)[14]:

One of the best ways to measure the data-transmission quality of any digital transmission system is to determine the bit error rate characteristics.

The BER is defined as the probability of incorrect identification of a bit by the decision circuit of the receiver.

Based on the Gaussian approximation for the noise distribution in the received signal, one can derive the relation between BER and Q:

$$BER_{min} = \frac{1}{2} \left[\operatorname{erfc} \left(\frac{Q}{\sqrt{2}} \right) \right]$$

Where erfc is the complementary error function

$$\operatorname{erfc}(x) = \frac{2}{\sqrt{\pi}} \int_x^{+\infty} \exp(-y^2) dy$$

For a satisfactory performance the BER has to be less than 10^{-9}

4- Optical Signal to Noise Ratio (OSNR)

The Optical Signal-to-Noise Ratio (OSNR) represents a widely used evaluation criterion for the characterization of system performance in already deployed transmission lines. The OSNR can be understood as a measure of the ratio of the signal (PS) to noise (PN) power in an optical channel:

$$OSNR = \frac{P_s}{P_n}$$

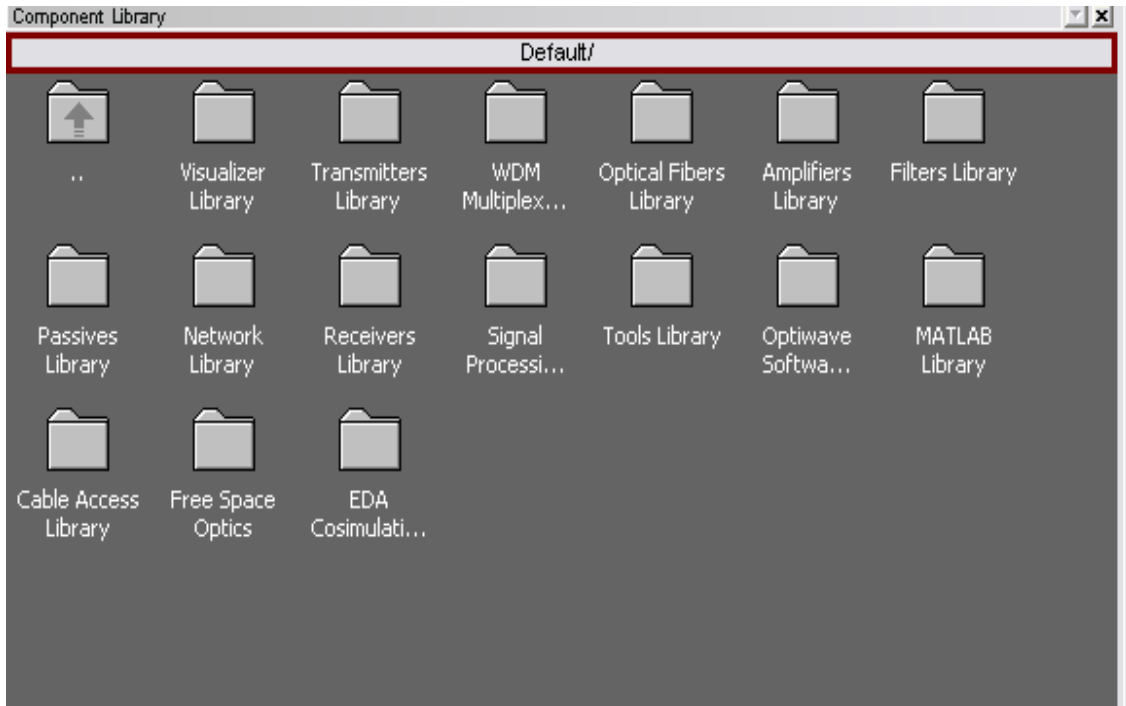
Depending on the amplifier infrastructure used in a transmission system, the OSNR value is proportional to the number of optical amplifiers as well as to the gain flatness of a single amplifier. The resulting OSNR varies from channel to channel and is limited by the OSNR value of the worst case channel. Also, the OSNR measurement can be realized by measuring the signal power as the difference between the total power of the signal peak and the amount of the background noise. The background noise is measured by determining the noise contributions on either side of the signal peak. However, the separation and measurement of the signal and noise power is difficult to realize in practice, because the noise power in an optical channel is included in the signal power. Below are the data obtained from the WDM analyzer after the signal propagating through the fiber. For your information, after the signal propagating through the multiplexer, the ideal amplifier's gain and noise figure will set in order to obtain the desired optical signal power which follows the formula:

$$P_{composite} = P_{channel} + 10 \log(N) - \text{Insertion loss}$$

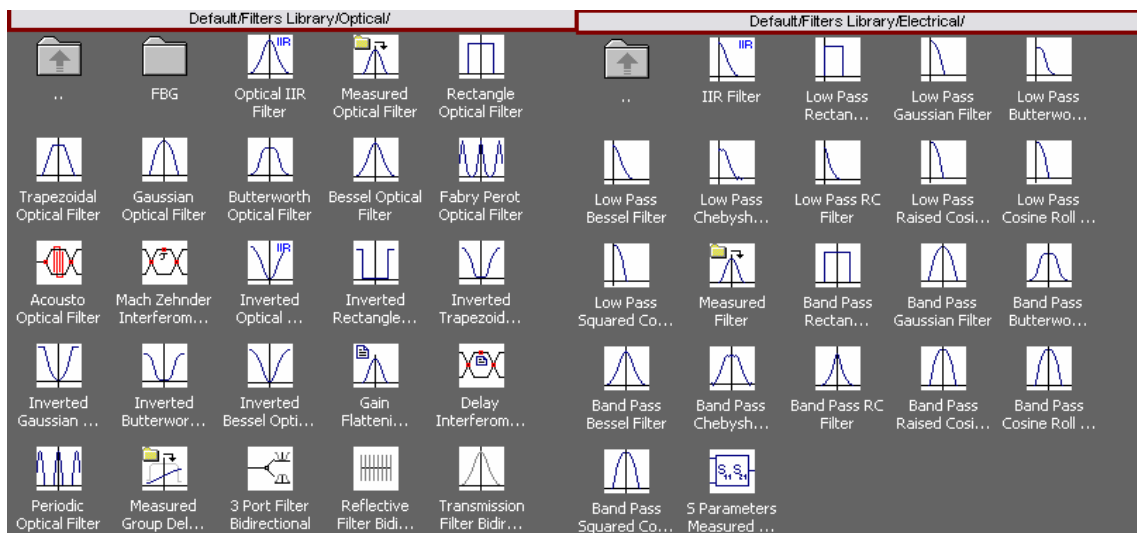
Where N is the number of channels.

APPENDIX B

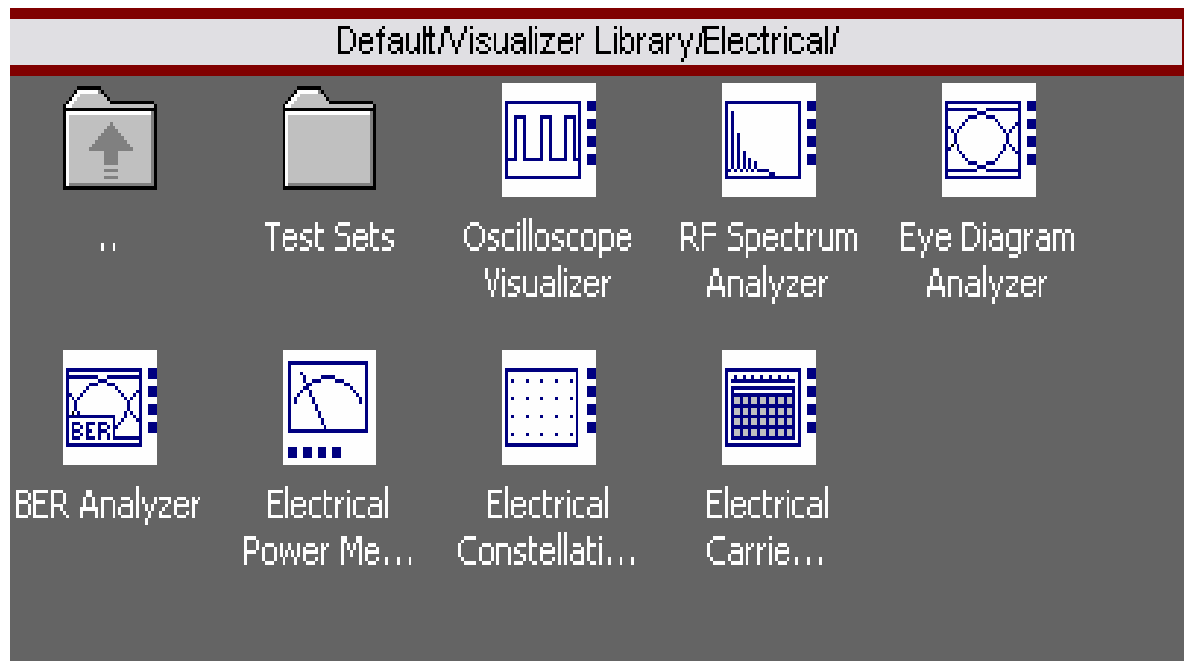
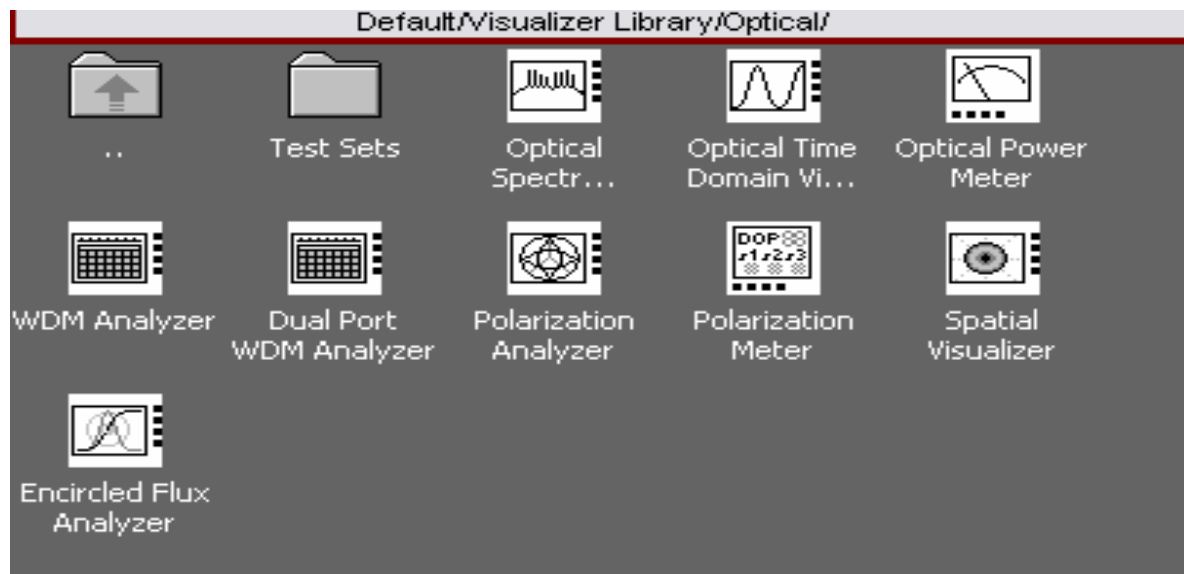
COMPONENT LIBRARY IN OPTIWAVE SOFTWARE



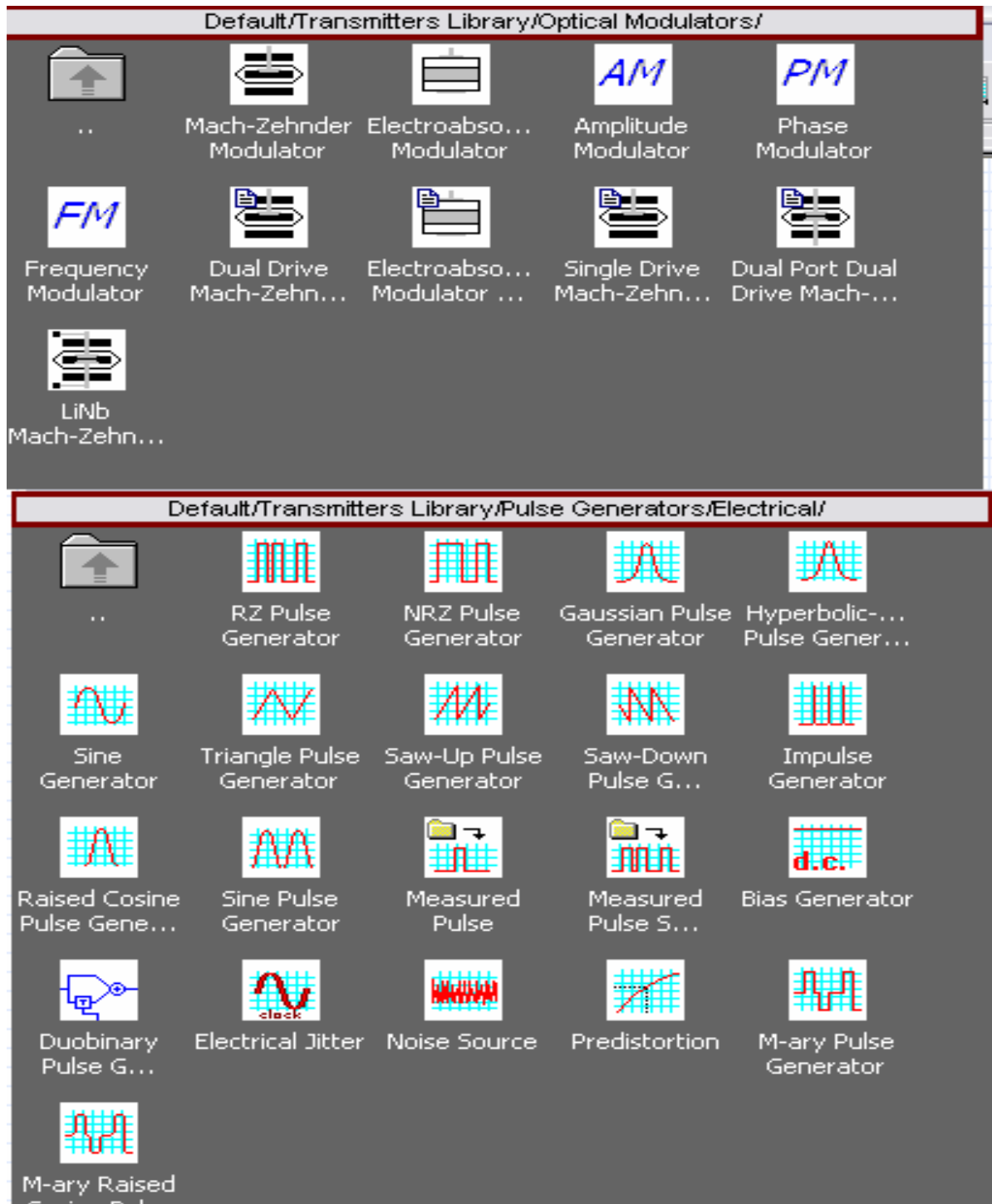
OPTICAL AND ELECTRICAL FILTER LIBRARY IN OPTIWAVE SOFTWARE

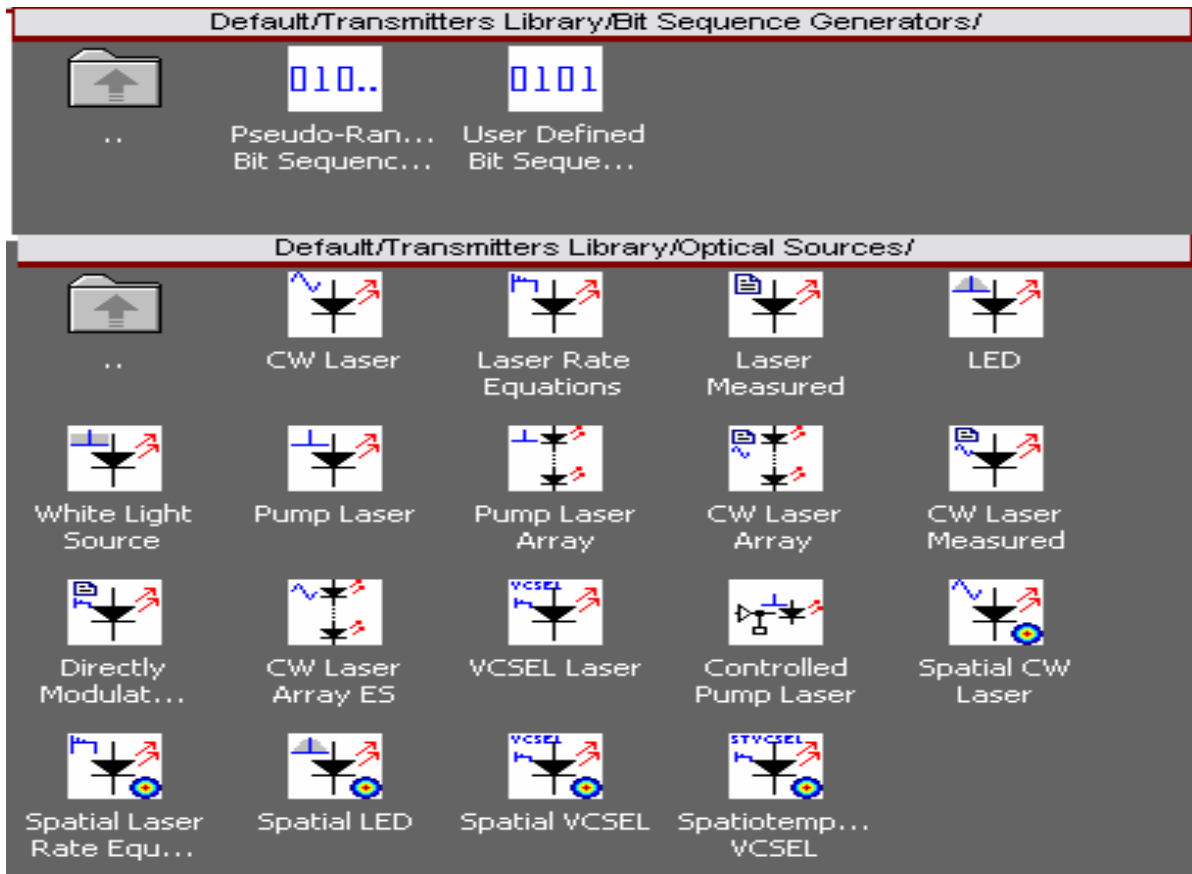


VISUALIZER LIBRARY IN OPTIWAVE SOFTWARE

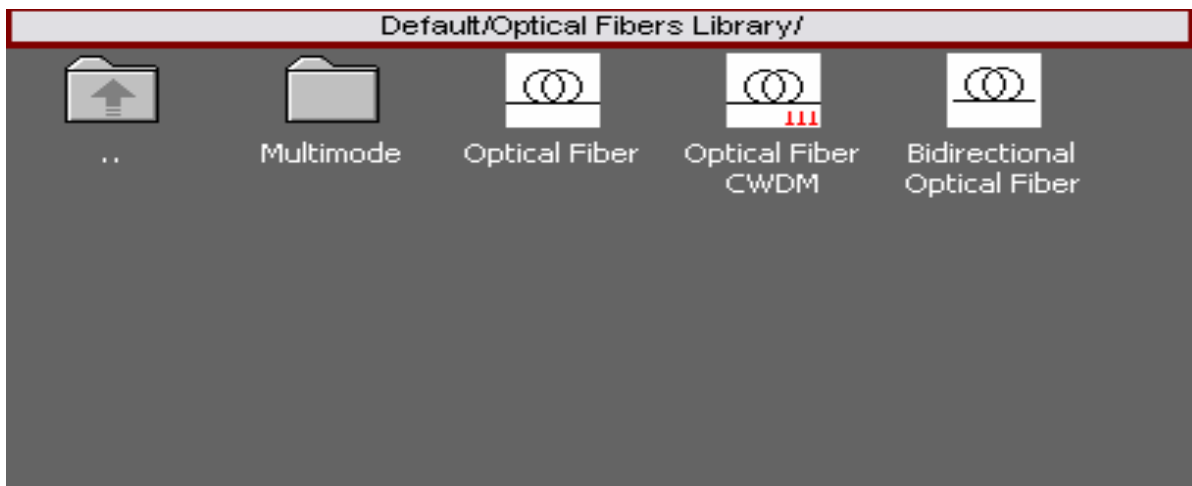


TRANSMITTER LIBRARY IN OPTIWAVE SOFTWARE

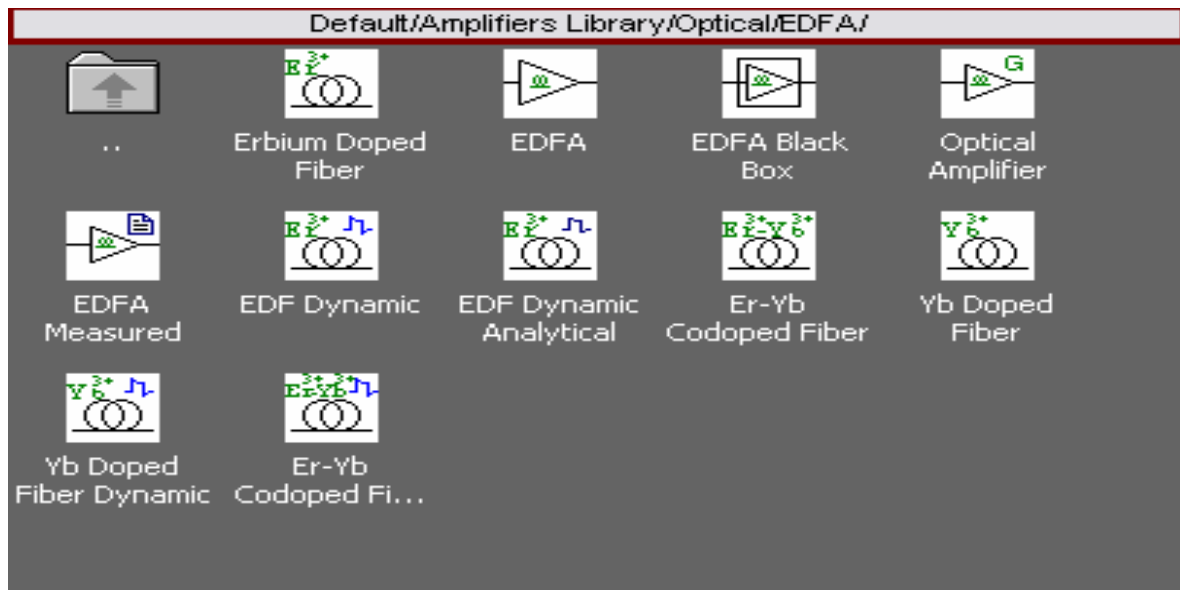




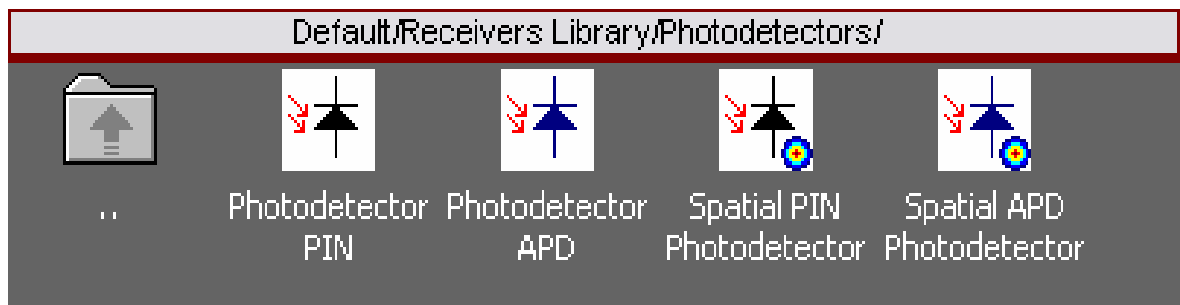
OPTICAL FIBERS LIBRARY IN OPTIWAVE SOFTWARE



AMPLIFIERS LIBRARY IN OPTIWAVE SOFTWARE



RECEIVERS LIBRARY IN OPTIWAVE SOFTWARE



General Conclusion

This thesis has been devoted to the study of the performance of an Optical Telecommunication system. We took that in two parts. The first is the theoretical part and second is the simulation one.

The purpose of the first part is to provide a theoretical background of optical telecommunication system. We have studied this in two parts:

We have studied in the first parts: Fiber optic components and functionality of the optical-fiber types (Single mode fiber, Multimode fiber) and characteristics of the most important element (Attenuation, Chromatic Dispersion) which will be the focus of our study in the last part. In the second part of the theoretical part, we studied the optical telecommunication system which consists of a transmitter, receiver, amplifier and the transmission Channel.

In this part, we also provided a review of the different types of modulation (ASK, FSK, PSK) and (direct modulation, external modulation) and some sources of light, we have taken the laser and LED. As for the amplifiers, we have stated two categories; the first category is Semiconductor Optical Amplifiers (SOAs) and the second category is the Fiber amplifier consists of two types: Rare-earth doped fiber amplifier and Raman Amplifiers. And the last point in this part we have studied is the receiver, one of the necessary parts in the optical telecommunication system; we have focused on photo-detector (P-N photodiodes and P-I-N photodiodes)

The second part is the realization of simulation allowing the evaluation of optical communication system performances, and this is by studying the most important factors are: the attenuation and the dispersion in terms of The Q factor and Opening eye. In the Optical transmission system NRZ with 10 GB/s

Though there are some negatives of optical fiber communication system in terms of fragility, splicing, coupling, set up expense etc. but it is an unavoidable fact that optical fiber has revolutionized the field of communication. As soon as computers will be capable of processing optical signals, the total area of communication will be opticalized immediately.

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ABSTRACT

The optical fiber technology has become one of the most reliable and fastest transmission media in the communication world. It's potential in supporting high speed transmission in particular is very attractive. The focus of this work was set at 10 GB/s data rate optical transmission system with varied attenuation and dispersion values, in order to investigate the performance of the optical transmission system in terms of signal quality. The modulation format that we investigate is non return-to-zero (NRZ). Standard Single Mode Fiber (SSMF) is used as the transmission link due to its optimization in the 1550 nm window and low dispersion, and an optical amplifier EDFA (Erbium Doped Fiber Amplifier) with gain of 5dB/km. OptiSystem v7.0 software will be used to simulate this whole project and it will show the performance of the optical transmission system over the Bit Error Rate (BER) and Q factor.

Key words:

Optical fiber, attenuation, dispersion, modulation

Résumé

La technologie de la fibre optique est devenue l'un des supports de transmission la plus fiable et la plus rapide dans le monde de la communication. C'est susceptible de favoriser la transmission à grande vitesse en particulier, est très attrayant. L'objectif de ce travail a été fixé à 10 Gb/s de données du système de taux de transmission optique avec des valeurs variés d'atténuation et dispersion afin d'étudier la performance du système de transmission optique en termes de qualité du signal. Le format de modulation que nous étudions est non retour à zéro (NRZ). Standard Single Mode Fiber (SSMF) est utilisé comme la liaison de transmission en raison de son optimisation dans la fenêtre de 1550 nm et une faible dispersion, et un amplificateur optique EDFA (Erbium Amplificateur à fibre dopée) avec un gain de 5 dB/km. OptiSystem v7.0 sera utilisé pour simuler l'ensemble du projet et il montrera les performances du système de transmission optique avec le Bit Error Rate (BER) et facteur Q.

Mots clé :

Fibre optique, atténuation, dispersion, modulation

ملخص

لقد أصبحت تكنولوجيا الألياف البصرية من أكثر وسائل الاتصال السريعة و الموثوقة في عالم الاتصالات. قدرتها على استيعاب سرعات نقل هائلة على وجه الخصوص مطلوبة جدا. التركيز في هذا العمل سيكون على نظام الاتصال الضوئي ذو التدفق 10 جيقابت/ ثا مع التغيير في قيم التوهين والتشتت. من أجل دراسة أداء نظام الاتصال الضوئي من حيث جودة الإشارة نقوم باستخدام نوع التضمين عدم العودة إلى الصفر NRZ، أما الليف البصري المستخدم في هذه المحاكاة فهو من نوع أحادي النمط وذلك لأدائه الجيد في النافذة 1550 nm ولقيمة التشتت الصغيرة؛ إضافة إلى مضخمات ضوئية من نوع EDFA ذات كسب يقدر ب 5 dB/km وسوف نستخدم برنامج v7.0 OptiSystem لمحاكاة هذا المشروع والذي سوف يظهر أداء نظام الاتصال البصري من خلال: BER و عامل Q

كلمات مفتاحية:

الليف البصري، التوهين، التشتت، التضمين