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The Power Loss in a Fiber Optical Cable

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ABSTRACT
Optical fibers are a developed technology for transmitting various data in the form of light signals or pulses. Fine filaments or filaments made of high-purity glass and special types of plastic are used. Optical fiber cables are distinguished by their ability to transmit huge amounts of data at high speeds without a high loss of power. Light signals are what carry the data.Also, Fiber optic cables are distinguished by being unaffected from various other external sources, which makes them safer to use and helps maintain the confidentiality of the data transmitted through them. A single optical fiber cable, which is less than one inch thick, can carry hundreds of thousands of voice or telephone conversations and information for a distance of 90 km and at speeds ranging from 2.5 GB/s to 10 GB/s without the need to amplify the optical signal, while copper cables need to be re-amplified approximately every 0.25 km.Light is the one that carries the information through an optical fiber, and the laser light is used as a type of light that passes through the optical fiber, as laser rays are a single-wavelength electromagnetic rays, and they have photons of equal frequency that are united in the same wavelength, and due to its characteristics that distinguish it, Laser light is used to travel through optical fibers and transmit data through them.

***Keywords*–**Fiber Optic, Fiber Mode, Fiber Components, Fiber Optic Properties, Attenuation, Dispersion, Noise, power loss.

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I. INTRODUCTION

Humans have used several means to communicate and transfer information, and in the late nineteenth century, humans have used many means of communication, through certain wires above the ground to communicate and transfer various information and then they used wired cables, which were considered a great development in the field of communication, but in our time Fiber Optics have been used, which are mediums that use light to transmit information and data through glass and sometimes a type of plastic is used, unlike copper cables that use copper to transmit electrical signals and in the past period optical fibers have become more widespread, especially in cases that need high speeds andcontinuity in transmitting data over very long distances without disruption or interruption, such as medical or military fields, and many other fields.The use of optical fibers began as an application in communication lines which paved the way for a great revolution in the world of communications in terms of the huge amount of information that could be transmitted over the lines over long distances and with high quality. The idea of using light as a means of communication got very old,so, attempts to send light through the space surrounding us had begun since the invention and manufacture of lasers in 1968, which required the absence of obstacles and a straight vision range. In the year 1970, actual attempts to send light through glass fibers with an attenuation rate of less than 20 dB / km began.

In the scope of experimental laboratories, researchers continued to develop the production of optical fibers of pure glass with lower attenuation rates. In the mid-seventies of the last century, Corning Inc. managed to manufacture optical cables and put them on the commercial market.

The development and manufacture of optical fibers came in stages, in the first stage it was operating at a wavelength of 850 nm, which was called the first window, at an attenuation rate that was

3dB/Km, which was a great achievement in its time. The manufacturers moved to the second window, where optical fibers operating at a wavelength of 1300 nm were manufactured, with an attenuation rate of about 0.5dB/km. At the end of 1977, The company, NTT, moved to the third window using a wavelength of 1550 nm, where it was possible to obtain fiber optic with an attenuation rate of about 0.2 dB/km, which is theoretically the lowest possible limit for the value of loss in fiberglass.

In the current years, all of the aforementioned wavelengths are manufactured and operated in most, if not all, countries of the world. The actual application of optical communication systems began at the beginning of the seventies of the last century, when an optical cable was installed and the countries of the world were connected to it to transmit phone calls.

Optical fibers are fibers made of pure glass that are long and thin, and their thickness does not exceed to the thickness of a single strand of hair. Many of these fibers are bundled into optical cables and are used to transmit optical signals over very long distances

In this research, we will get to know about optical fibers by passing through the mechanism of its work, its components, the various types of its components and the uses of each of them, in addition, we will get to know the most important advantages of this modern technology and what are its most important disadvantages.

II. OPTICAL FIBER BASICS

2.1The main components of the optical fiber network and its mechanism of action:

As shown in figure 1, any system that needs to transmit data and information through optical fibers needs three main components:

• Transmitter: It is used to convert electrical impulses into light pulses, as it lights up when an electric current passes, and turns off when it does not pass.

• Optical fiber cable: It is the medium that transmits light from the transmitter to the receiver.

• Receiver: It is the one that receives light pulses and converts them into electrical pulses.

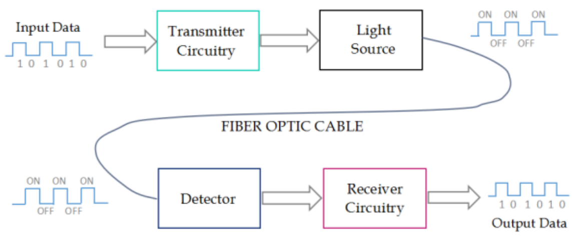


Figure 1: Main components of the optical fiber network.

2.2 Basic components of an optical fiber:

An optical fiber consists of six main components:

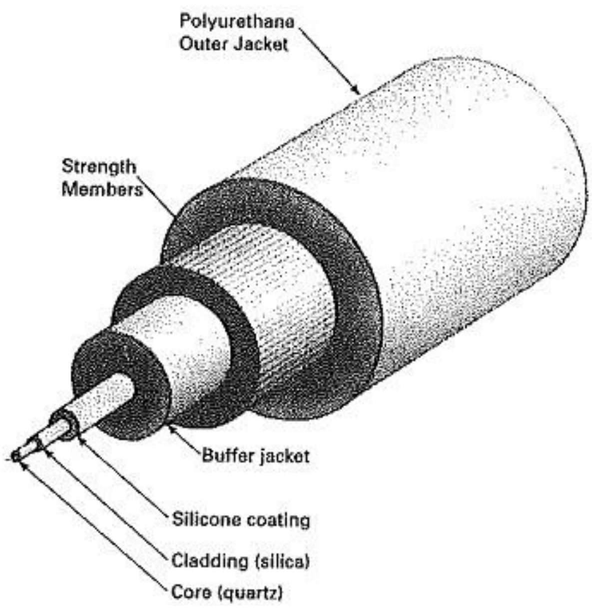


Figure 2: The six main components.

1. Core: It is made of glass or plastic through which light is spreaded and transmitted, and the types of optical fiber cables differ according to the diameter of the core, where there are types called single-mode, the thickness of the core is very narrow from 4 to 10 micrometers, and another type, which is multi-mode and has the thickness of the core that's in 4 specific sizes 50, 62.5, 80 or 100 micrometers.

2. Cladding: It is a cover that surrounds the core and is also made of glass or plastic, but it has a different refractive index that helps prevent dispersion and exit

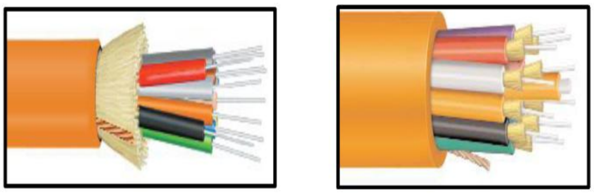
of light that is transmitted in the core so that the transmitted signal is not lost.

3. Coating: It is a protective layer surrounding the glass casing, it protects the core and casing from damage and breakage and it prevents corrosion to the casing material.

4. Buffer Jacket: It surrounds the basic parts of the optical fiber (the core, the glass cover, and the layer), it gives protection to those parts. Optical fibers are classified according to this insulating element into two basic types:

A. Narrow tube casing:

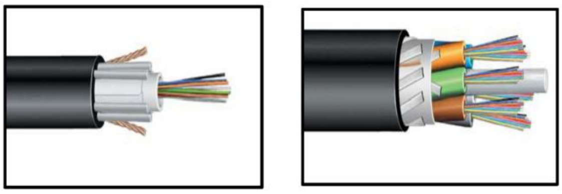
- It is a tight nylon sheath that directly surrounds the core parts of the optical fiber.
- Each sheath contains one optical fiber, but a fiber optic cable can contain more than one narrow sheath, and each narrow sheath contains one fiber.
- The narrow sheath makes the fiber optic cable easy to handle and flexible, which facilitates installation in connectors and patch panels.
- It is often used for extensions inside buildings through walls and ceilings and inside equipment and communications rooms.
- It has two basic types: Distributed Fiber Optic Cable and aSplit Optical Fiber Cable.



Picture 1: Narrow tube casing.

B. Wide tube casing:

- It is a rigid plastic tube.
- Each tube or casing contains multiple optical fibers, and each optical fiber inside the tube has a color code for easy identification.
- It gives more protection to the optical fiber cable from damage when wiring in difficult outdoor environment.
- The tube containing the optical fibers is filled with gel material to protect the cable from water.
- It is often used in wiring outside buildings.
- It is a strong and inflexible cable and it is difficult to connect it to connectors and connection boards, so we need a welding process with another fiber optic cable that is easy to handle inside buildings.
- It has two basic types: The cable that contains more than one wide tube and the support material in the middle, and the other type that contains one tube in the middle of the cable and around it the support material.



Picture2: Wide tube casing.

5: Strength Member: It is aramid filaments, and it is one of the heat-resistant synthetic fibers similar to nylon in strength, and surrounds the barrier to protect it when stretched.

6. Outer Jacket: It's job is to protect all internal parts of the optical fiber.

These are considered the basic components of an optical fiber cable, but there are other additional components depending on the use of the optical fiber.For example, it is possible to add a metal sheath inside to protect the cable during external installations, and the cable may contain more than one optical fiber.

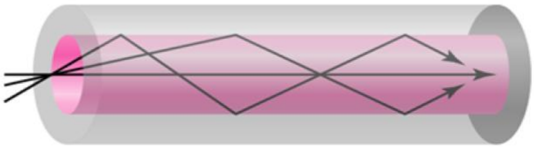
2.3Optical Fiber Patterns:

There are two types of optical fibers:

Single Mode: It uses one optical path to send a single signal. This type is used when we need a higher speed and a greater distance that may reach 100 km for data transmission. Also, in telephone companies, special devices are used that enable transmissions up to 100 km using single-mode fiber, after which a signal repeater is needed, always. It is used between cities and countries in telephone networks.

Picture3: Single mode optical fiber.

Multi Mode: It uses several optical paths to transmit different signals with one optical cable, up to a distance of 2000 meters without the need to amplify the signal. It is also used in local LAN networks.



Picture4: Multi mode optical fiber.

Table 1 shows the difference between a single-mode fiber and a multi-mode fiber:

Multimode Fiber	Single mode Fiber
Low-cost sources	High-cost sources
Low precision packaging	High precision packaging
Low-cost connectors	High-cost connectors
Low installation cost	High installation cost
High fiber cost	Low fiber cost
Low system cost	High system cost
Higher loss, lower bandwidth	Lower loss, higher bandwidth
Distance up to 2 km	Distance to 100 km
LAN, SAN, Data Center, CO	WAN, MAN, Access, Campus

Table 1. Comparative between Single and Multi mode fiber.

2.4The properties of an Optical Fiber Transmission:

Fiber optic is a very thin and long cylinder of silicon, consisting of two main parts: The Core and The Shell.

The core is a cylinder of glass surrounded by a cladding shell. The core has a higher refractive index than the shell, therefore, the surface separating them plays the role of a perfect mirror that keeps the light within the fiber and the signa so that it's not lost as it exits the core. When an optical pulse is sent through the fiber, it reaches its end at an energy level lower than the transmission energy level and has a time delay. It also suffers from distortion. This phenomena is caused by:

2.4.1 Attenuation

Attenuation is considered an essential element in the design of the communication system in the world in general and in the design of the optical fiber network in particular, as the attenuation in networks takes place for several reasons, including the incoming and outgoing links of the signals.

Likewise, light ray is subjected to attenuation when passing through the fiber due to the material from which the carrier is made and its molecular structure. As for leakage and rebound, they result from the granular and geometric structure of the optical carrier. The presence of both metallic and OH impurities leads to scattering of light. It should be noted that the ratio of absorption and scattering within the fiber is related to the wavelength, in addition to the chemical composition of the glass used within the fiber.

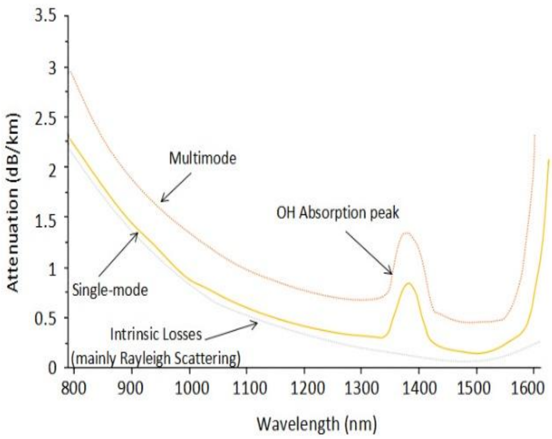


Figure 3: Optical fiber absorption.

Figure 3 shows a graph of light absorption according to the wavelength in nanometers and attenuation in decibels. In addition, Rayleigh is the attenuation that's being scattered by the minute.

The reason for the presence of Rayleigh scattering within the fiber is that the crystal structure of silicon dioxide SiO_2 changes depending on the temperature, especially near the melting state, because the applied heat increases the movement of these molecules and when the liquid cools the molecules stop moving, and therefore when a light beam passes through such a structurepart of it scatters it's energy and it's the problem of Rayleigh loss and attenuation and it's inversely proportional to λ^4, there is another type of scattering called Mie scattering of the order of wavelength and it is a result of manufacturing defects as incomplete mixing and dissolution of chemicals leads to inhomogeneity in the nucleus and the imperfect treatment causes a rough surface between the nuclei and cover.

2.4.2Dispersion

Dispersion occurs when the optical pulse increases in width and is affected by the previous pulse, which leads to the appearance of interference and that makes the bit retrieval process difficult.

There are several types of dispersion:

- Material dispersion: Optical diodes and lasers emit a bundle of wavelengths, not just a single wavelength. The refractive index of the fiber is related to the wavelength that's used according to the Sellmeier relation, so the propagation speed will change according to the frequency, which leads to the arrival of the pulse to the end of the fiber at different times, which increases the width of the optical pulse.

- Intermodal dispersion: When using a multi-mode fiber, the light can follow several paths and each path has a different length than the other, so when sending light pulses throughfiber, it will cut it at different times, which leads tooverlapping of the pulses. This type of dispersion is called mode dispersion.

- Waveguide dispersion: It is a complex effect related to the structure and shape of the fiber.

2.4.3 Noise

One of the important advantages of fiber is that it is not affected by external noise sources, because it is made of an insulating material and therefore no electric currents flow through it, even if the cause comes from a transmitted signal or from external radiation, so, just as the waves coming from the external medium cannot spread within the fiber, it does not get affected. In addition to this, because the light wave inside the fiber is reserved and does not leak out, therefore, it does not interfere with the signals of other fibers within the same cable. However, there are other sources of noise that may come from the manufacturing technology and technological limitations of the fiber itself.

2.5 Capacity and Loss Measurement:

To measure the loss in optical fibers, two devices are used together:

- The first device: A light source placed at one end of the fiber, and the light source is either a laser or an LED.
- The second device is: A power meter placed at the second end, and receives light from a light source device. The difference between the light power at the light source device and the light power at the power meter device is the amount of light loss in an optical fiber.

The loss in light in an optical fiber varies according to the wavelength of light that passes through it; Therefore, when measuring losses, the power measuring device must be set at the same wavelength as the light source device. For example, if the light source device operates at a wavelength of 1310 nm, the power measuring device must be set at 1310 nm.

2.5.1 Decibel

The decibel unit is used to measure the loss and gain in the field of electrons, that includes, measuring the loss in the power of light passing through the optical fiber from the light source to the power meter and denoted by the symbol dB, and the value of loss in decibels is expressed in negative terms as shown in table 2, while the value of the gain in decibels is expressed in positive.

light power loss in dB	The percentage of light power loss	The remaining light power percentage
-0.1	2.3%	97.7%
-0.2	4.5%	95.5%
-0.5	10.9%	89.1%
-1	21%	79%
-3	50%	50%
-6	75%	5%
-10	90%	10%
-20	99%	1%

Table 2. Comparative between single and multi mode fiber.

To measure power and loss in light, we need:

1. Light source device: It emits light of different wavelengths, such as a power meterfor any type of fiber optic, whether it is single-mode or multi-mode. It contains different connectors to be a light source for

all types of different fiber optic connections. The light can be laser or LED.

2. Power meter: It can measure the power of light in different wavelengths and it also contains different connectors to measure the power of light for all kinds of optical fiber connections, measuring single-mode or multi-mode connections.

3. Measuring connections that are ready: At least two connections of 1m to 5m single-mode and multi-mode, with known loss value.

The generally allowed loss values are shown, as followed in table 3:

Loss value in dB	Examination type
Min =0.5 ، Max=0.7	Connector
0.2 dB	Splicing
3dB/Km ،source 850 nm	Multi-mode
1dB/Km ،source 1300 nm	
0.5/Km dB ،source 1300 nm	Single-mode
0.4/Km dB ،source 1550 nm	

Table 3. Allowed loss values in fiber optic cable.

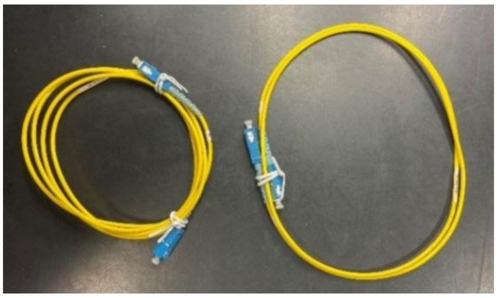
III. THE PRACTICAL SIDE

3.1 Introduction:

In this chapter, we will show in a practical way the study of the attenuation of light when it passes through two types of optical fibers (Single mode, Multi mode) with different lengths (0.5 meter, 1.0 meter and 1.5 meter).

3.2 Equipment tools:

1. Single mode fiber (0.5 meter, 1.0 meter and 1.5 meter).



Picture5: Single mode optical fiber.

2. Multi mode fiber (0.5 meter, 1.0 meter and 1.5 meter).

Picture6: Multi mode optical fiber.

3. Optical laser source.

Picture7: Optical laser source.

4. Optical power meter.

Picture8: Optical power meter.

3.3Experiment steps:

1. Using an optical laser source. The laser light is generated on a **<u>0.5-meter single mode fiber</u>**and it's placed in a straight line and it receives the light coming from the optical fiber on the optical power meter, and the voltage is read in each of the following cases:
   - ✓ The wavelength is 1310 nm
   - ✓ The wavelength is 1550 nm

The results are recorded in the table below:

	1310 nm	1550 nm
0.5 meter	-0.8	-0.5

2. Using an optical laser source. The laser light is generated on a **<u>1.0-meter single mode fiber</u>**and it's placed in a straight line and it receives the light coming from the optical fiber on the optical power meter, and the voltage is read in each of the following cases:
   - ✓ The wavelength is 1310 nm
   - ✓ The wavelength is 1550 nm

The results are recorded in the table below:

	1310 nm	1550 nm
1 meter	-0.9	-0.56

3. Using an optical laser source. The laser light is generated on a **<u>1.5-meter single mode fiber</u>**and it's placed in a straight line and it receives the light coming from the optical fiber on the optical power meter, and the voltage is read in each of the following cases:
   - ✓ The wavelength is 1310 nm
   - ✓ The wavelength is 1550 nm

The results are recorded in the table below:

	1310 nm	1550 nm
1.5 meter	-1	-0.61

4. Using an optical laser source. The laser light is generated on a **<u>0.5-metermulti mode fiber</u>**and it's placed in a straight line and it receives the light coming from the optical fiber on the optical power meter, and the voltage is read in each of the following cases:
   - ✓ The wavelength is 850 nm
   - ✓ The wavelength is 1300 nm

The results are recorded in the table below:

	850 nm	1300 nm
0.5 meter	18.75	18.15

5. Using an optical laser source. The laser light is generated on a **<u>1.0-meter multi mode fiber</u>**and it's placed in a straight line and it receives the light coming from the optical fiber on the optical power meter, and the voltage is read in each of the following cases:
   - ✓ The wavelength is 850 nm
   - ✓ The wavelength is 1300 nm

The results are recorded in the table below:

	850 nm	1300 nm
1 meter	18.82	18.2

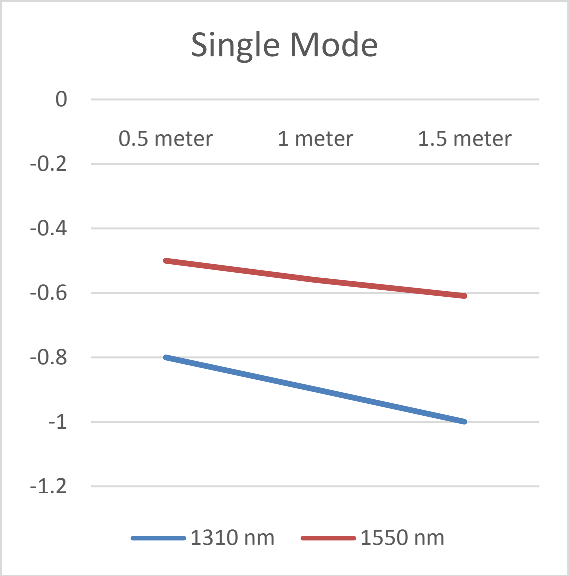
6. Using an optical laser source. The laser light is generated on a **<u>1.5-meter multi mode fiber</u>**and it's placed in a straight line and it receives the light coming from the optical fiber on the optical power meter, and the voltage is read in each of the following cases:
   - ✓ The wavelength is 850 nm
   - ✓ The wavelength is 1300 nm

The results are recorded in the table below:

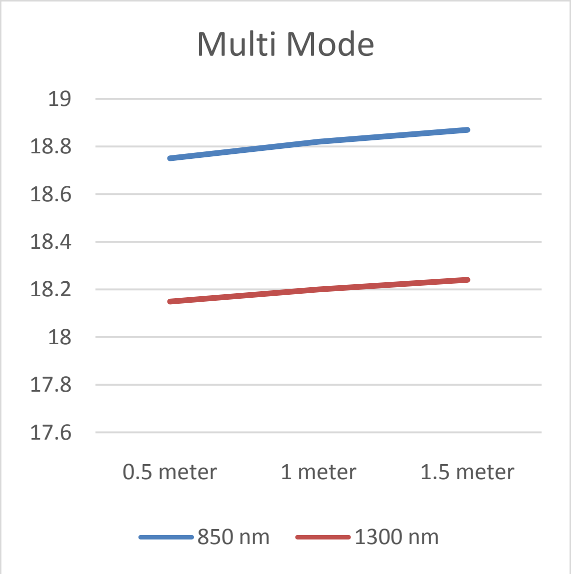
	850 nm	1300 nm
1.5 meter	18.87	18.24

3.4Results:

After conducting the experiment and studying the effect of the change in wavelength and the length of the fiber, the following results were included:



Graph1: The relationship between wavelength and luminous intensity Single mode optical fiber.



Graph2: The relationship between wavelength and luminous intensityMulti mode optical fiber.

3.5Discussion:

Graph 1 presents the result of the relationship between the wavelength and the luminous intensity at different lengths of the three single mode fibers, which shows the following:

- The relationship is directed and that is, the greater the length, the greater the attenuation.
- The attenuation at 1550nm is lower than the attenuation at 1300nm.

Graph 2 presents the results of the relationship between wavelength and luminous intensity at different lengths of the multi mode fiber, which shows the following:

- The relationship is directedand that is, the greater the length, the greater the attenuation.
- The attenuation at a wavelength of 1300nm is lower than the attenuation at a wavelength of 850nm.

3.6Conclusion*:*

The light attenuation was studied on two different types of optical fibers (Single and Multimode) at different optical fiber lengths and wavelengths it was found that there is a loss in energy, meaning that the longer optical fibers and the shorter the wavelengths are, the greater the attenuation.

REFERENCES

[1]. GHATAK, J. and THYAGARAJAN, K. Introduction to Fiber Optics. Cambridge University Press, New Delhi, 1997,565.

[2]. BARRY ELLIOTT, MIKE GILMORE, “Fiber Optic Cabling” in Newnes , Oxford, Auckland, Boston, Johannesburg, Melbourne, New Delhi,2002,318.December 5, 2001, ISBN : 97800805-0628-9.

[3]. GHATAK, J. and THYAGARAJAN, K. Introduction to Fiber Optics. Cambridge University Press, New Delhi, 1997,565.

[4]. HUI, R; O’SULLIVAN, M. Fiber Optic Measurement Techniques. Elsevier Academic Press, USA, 2009,636.

[5]. JAY, J, A. An Over View of Macrobending and Microbending of Optical Fibers, Corning, 2010, 21

[6]. BILL WOODWARD and EMILE B.HUSSON, “Fiber Optics Installer and Technician Guide” inSYBEX Inc., 1151 Marina Village Parkway, Alameda, CA 94501, ISBN : 0-78210-4390-3.

[7]. BORN, M. and WOLF, E. Principles of Optics . 7th ed., Cambridge University Press, New York, 1999 , 986.