STUDY OF CHARACTERISTIC AND VARIOUS LOSSES MECHANISMS OF PLASTIC OPTICAL FIBER (POF) IN AN OPTICAL COMMUNICATION SYSTEM

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Tesis Dikemukakan Kepada
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Dedicated to my beloved family.

Because of them, I work harder...

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ABSTRAK

Masalah Utama yang menghadkan pengoperasian Gentian Optik Plastik (POF) adalah kadar data dan jarak penghantaran. Oleh kerana POF dibuat daripada polymer, ia adalah kurang daya pemancaran, mengalami attenuasi yang lebih tinggi, serakan cahaya yang lebih banyak dan muatan lebar jalur yang kurang jika dibanding dengan Gentian Optik Kaca (GOF). Walaubagaimanapun, untuk aplikasi yang tertentu, POF adalah lebih cost-effrktor daripada GOF dari segi sistem saluran optik keseluruhan yang termasuk media, tenaga buruh, alat pemancar dan alat penerima. Oleh itu, tesis ini mengkaji mekanisma kehilangan gentian optik secara am dalam bab satu. Ciri-ciri POF merupakan isu utama untuk ditinjau dalam bab kedua. Beberapa eksperimen telah dilaksanakan untuk memahami jenic-jenis mekanisma kehilangan dalam POF dan seterusnya mengesan ciri-ciri positif POF jika dibandingkan dengan GOF dalam bab ketiga. Bab keempat akan membincangkan faktor-faktor yang menyebabkan serakan denyut dan peranjakkan masa dalam sistem komunikasi optik dengan merujuk kepada beberapa keputusan eksperimen yang telah dilakukan. Akhirnya, bab kelima mengulungkan kebaikan dan keburukan bagi POF berdasarkan eksperiment yang telah dijalankan. Kesemua perbincangan dalam tesis ini lebih cenderung kepada perbandingan ciri-ciri POF dengan GOP dari segi sistem komunikasi optik.

ABSTRACT

The major constrains placed on the operation of Plastic Optical Fiber (POF) are data rate and transmission distance. Since the plastic fiber is actually a polymer, it is less transmissive than glass, higher attenuation, greater dispersion and less bandwidth capacity. However, for some specific applications, plastic optical fiber is significantly more cost effective than glass optical fiber in terms of total link, which includes media, labor, transmitters and receivers. Therefore, this thesis paper studies the general optical fiber losses mechanism in chapter one. The characteristics of POF are the major issue to be concerned in chapter two. Several experiments are conducted to understand the various losses mechanisms and further discover the possible positive characteristics of POF over glass fiber are present in chapter three. And, chapter four will discuss the factors that cause pulse broadening and time jittering in an optical communication system, which are complemented with some experiment results. Finally, chapter five will summarise the advantages and drawbacks of POF based on the paper experiment reviews. All the discussions in this thesis paper are more towards to discover the differences in characteristics of POF over Glass Optical Fiber (GOF) from an optical communication system stand point.

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INTRODUCTION

"The communications revolution is happening now and it is changing the way people interact, work, and live. Voice, data and video continue to merge, and as the world of high speed communications moves to the desk top, affordable high bandwidth Plastic Optical Fiber (POF) will be the key to this Future" (Edward Berman, chairman of BOF)

Application such as multimedia and computer-base training requiring increased bandwidth become more commonplace in the market. The need for instant information has driven the growth for faster, more robust data communication bandwidth technologies. As a result, Plastic Optical Fiber has emerged as a technology that enables industry to increase speed up to gigabits per second. Unlike the existing networks of copper wire and glass fiber, POF offers more bandwidth than copper and is more rugged and affordable than glass.

Due to the existence of increasing potential of POF in the future market, this thesis paper presented a study of the characteristic and various losses mechanisms of POF in an optical communication system. Several essential experiment works have been conducted to find out the characteristic of POF that may contributed to the losses in an optical communication system. The basic advantages and characteristics of POF have been reviewed and presented as it has the potential of being utilized in inexpensive optoelectronic components and connectors in an optical communication design stand point.

Nevertheless, it should be noted that all the experiment conducted for this thesis paper is based on a special training kit, namely Optical Fiber and Digital Communication Trainer (OFT). The photograph of OFT and other vital equipment which used by the author in carry out the experiments also shown in Appendix A.

CHAPTER ONE

VARIOUS LOSSES MECHANISMS IN OPTICAL COMMUNICATION SYSTEM

1.0. INTRODUCTION

Fiber loss or signal attenuation is one of the essential consideration in the design of any optical fiber communication system. The losses of fiber limits the performance of an optical fiber communication system as it reduced the average power reaching the receiver. Since optical receivers need a certain minimum amount of power for recovering the signal accurately, the transmission distance is inherently limited by fiber loss. Thus, the use of fiber for optical communications became practical only when the loss was reduced to an acceptable level to achieve a certain transmission distance which can be detect accurately by the receiver. This chapter will discuss the various loss mechanisms in optical fiber communication system.

1.1. BASIC FIBER OPTIC COMMUNICATION SYSTEM

A fiber optic communication system converts the electrical signal into light, transmits the light through the fiber, and converts the light back into an electrical signal. The input electrical signal can be either an analog such as sound, voice, video camera or in digital format. A typical system, as illustrated in Figure 1.1 has five major parts that send communication from one point to another point: encoder, light source or transmitter, the optical fiber, a light detector or receiver, and the decoder. The driver converts the signal, whether analog or digital, to a format that is useful to the light source or transmitter. The light source takes the electrical signal from the driver and converts it to light pulses. Since the light source is directly coupled to the optical fiber, the light pulses will be guided down the length of the fiber optic cable to the coupled light detector. The light pulse strikes the surface of the light detector and is converted to an electrical current corresponding to the intensity of the light that was transmitted. The signal then is decoded and is a replica of the original pulse.

Figure 1.1. Block diagram of basic optical fiber communication system

1.2. SIGNAL ATTENUATION

Attenuation is defined as the ratio of light power couple into the fiber cable to the light power coupled out the cable's far end. Under quite general conditions power attenuation inside an optical fiber is governed by

$$dP/dz = -\alpha P \tag{1.1}$$

where α is the attenuation coefficient and P is the optical power. α in equation 1.1 includes the material absorption and other sources of power attenuation. If P is the power launched at the imput of a fiber of length L, the output power Pout from equation 1.1 is given by:

$$P_{out} = P_{in} \exp(-\alpha L). \qquad (1.2)$$

It is customary to express α in units of dB/km by using the relation

$$\alpha(dB/km) = -(10/L) \log 10 (P_{out}/P_{in}) = 4.343\ \alpha \qquad (1.3)$$

and refer to it as the fiber loss.

Most of the fiber loss depends on the wavelength of transmitted light. Figure 1.2 shows the spectral loss profile of a single mode fiber. Wavelength dependence of fiber attenuation for several fundamental loss mechanisms is also shown. Figure 1.2 show that the fiber exhibits a minimum loss nears the wavelength region at 1550nm. This value is close to the limit of about 0.15dB/km for a silica fiber. The loss spectrum also exhibits a strong peak near 1390nm and several other smaller peaks. A secondary minimum found to occur near 1300mm, where the fiber loss is below 0.5 dB/km. Since fiber dispersion is also minimum near 1300nm, this low loss window is often used for optical communication system. The loss is considerably higher for shorter wavelengths and exceeds 5dB/km in the visible region of the optical spectrum.

Several factors also contribute to the loss; their relative contributions are shown in Figure 1.2. The two important among them are material absorption and Rayleigh scattering losses, these will discuss in other subsections.

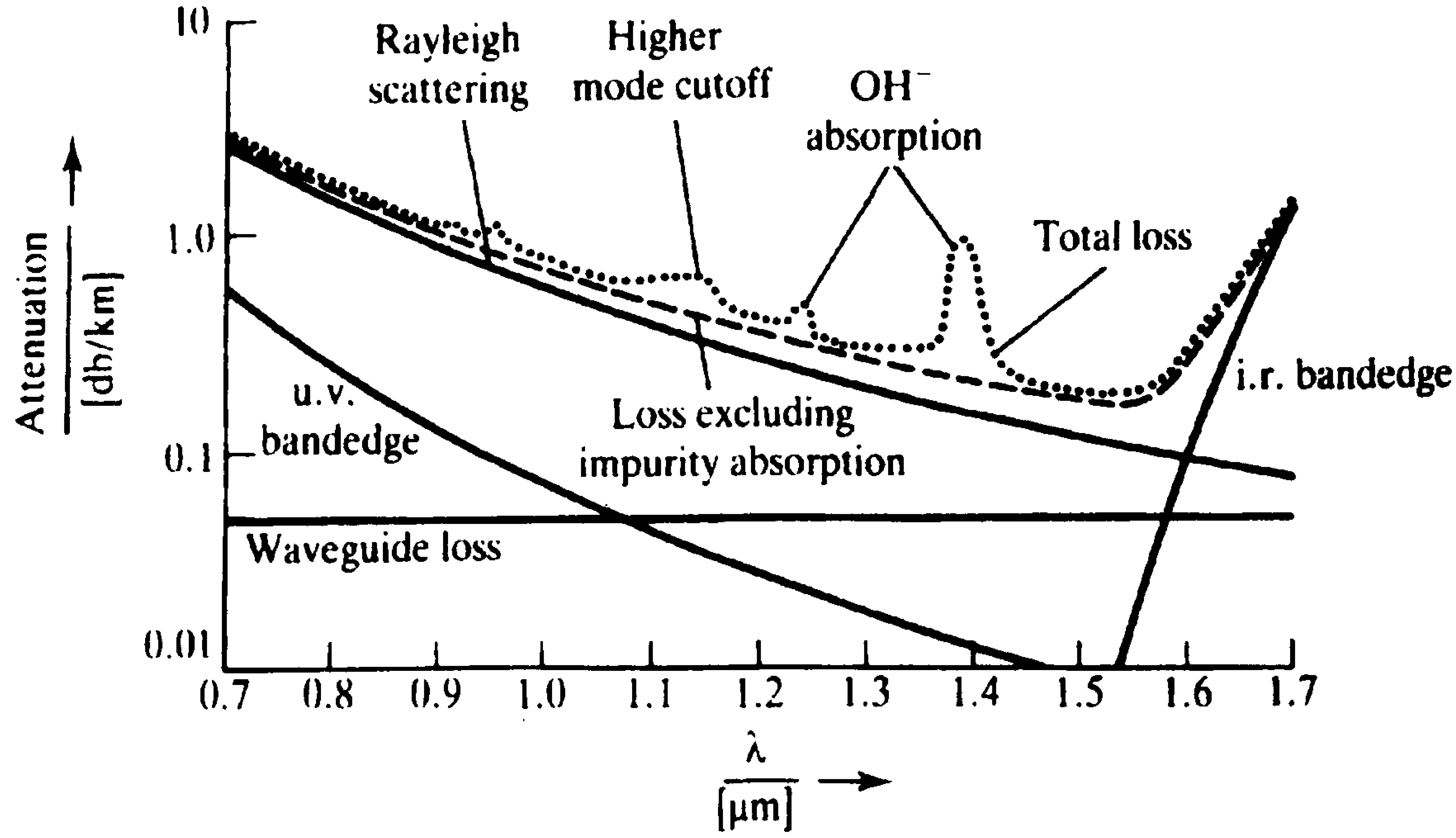

Figure 1.2. Spectral loss profile of a single mode fiber

1.3. FIBER ATTENUATION MECHANISMS

Various mechanisms are predominant contributed to the transmission losses in optical fiber. Losses in the fiber result in a reduction in the light power and thus reduce the system bandwidth, information transmission rate, efficiency, and overall system capacity. This section will discuss most of the predominant losses in an optical fiber communication system.

1.3.1. Material Absorption Losses

Material absorption can be divided into two categories. Intrinsic material absorption corresponding to the loss caused by the pure material itself, whereas extrinsic absorption is related to the loss caused by impurities. Any material absorbs at certain wavelength corresponding to the electronic and vibrational resonances associated with specific molecules.

Extrinsic material absorption results from the presence of impurities. To reduce extrinsic material absorption, a high-purity material can be obtained by using modern techniques. The main source of extrinsic absorption in state-of-the art fibers is the presence of water vapors. A vibration resonance of the OH ion occurs at 2.73um. its harmonic and combination tones produce strong absorption at 1.39, 1.24, and 0.95um wavelengths. The three spectral peaks see in Figure 1.2. occur near these wavelengths and are due to the presence of water vapor in the relative fiber material.

1.3.2. Rayleigh Scattering Losses.

Rayleigh scattering loss mechanism is related by the manufacturing process and the material of fiber. Light rays will diffract when it propagated down a fiber strike on the impurities of material. Diffraction causes the light to spread out in many directions and escapes through the cladding. Eventually, this represents a loss in light power.

For all-plastic fiber, Rayleigh scattering loss is mainly cause by the long-chain molecules that make up the polymer, together with the effect of dust particle. These