EXPERIMENTAL INVESTIGATION OF THE OPTICAL FIBERS BENDING LOSS UNDER DIFFERENT BENDING RADII

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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DEDICATION

I would like to dedicate this thesis to my beloved parents Ong Chee Mun and Chung Oi Lane for giving countless supports in numberless ways. Besides, I would like to dedicate this thesis to my dearest sister, Ong Zi Qi for her prayers and mental support throughout my four years of studies in degree.

ABSTRACT

Optical fiber is a type of cabling technology that is used to transmit data via propagation and reflection of light inside a transparent core made by very thin plastic strands or silica glass. It has higher efficiency and higher bandwidth than electrical cable. It is also immune to electromagnetic interference which is the cause of power loss in the electrical cable. However, during the transmission, bending of fiber can cause attenuation which in the end reduce the signal quality due to bending loss. In this project, the effect of bending loss was investigated to see the effect on transmission link. The experiment was conducted based on the radius of bending curvature in optical fiber for SMF and MMF. Bending radius range from 3 mm to 15 mm was set. Power loss with respect to each radius of bending curvature was evaluate, and then the experimental result is compared to the theoretical result. The percentage difference between theory and practical is about 75%. In theoretical result, the critical bending radius of SMF is around 4 mm and approximate 5 μm for MMF. In conclusion, MMF is highly immune to the bend loss due to it has higher number of modes than SMF which provides more light rays propagate at the same time.

ABSTRAK

Gentian optik merupakan medium bagi teknologi penghantaran yang digunakan untuk menghantar isyarat atau data melalui penyebaran dan pantulan cahaya di dalam gentian plastik atau kaca silika yang sangat halus dan tipis. Ia mempunyai kecekapan yang tinggi dan jalur lebar yang lebih baik daripada kabel elektrik. Ia juga kebal terhadap gangguan elektromagnetik yang merupakan punca kehilangan kuasa dalam kabel elektrik. Walau bagaimanapun, masih terdapat beberapa faktor yang akan menyebabkan pengurangan dalam gentian optik seperti kehilangan lenturan. Dalam projek ini, kehilangan lenturan akan dikaji untuk melihat kesannya terhadap sistem penghantaran. Eksperimen yang dijalankan adalah berdasarkan jejari kelengkungan lenturan dalan gentian optik untuk pelbagai jenis gentian seperti SMF dan MMF. Kehilangan kuasa bagi setiap jejari kelengkuangan lentur telah dinilaikan seterusnya hasil daripada eksperimen dibandingkan dengan nilai pengiraan teori. Didapati peratus perbezaan adalah sebanyak 75%. Berdasarkan pengiraan, nilai teori jejari kelengkuran kritikal adalah 4 mm bagi SMF dan 5 μm bagi MMF. Kesimpulannya, MMF adalah sangat kebal terhadap kehilangan lentur disebabkan ia memiliki bilangan mod yang tinggi berbanding SMF maka, lebih banyak sinaran cahaya tersebar pada masa yang sama.

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LIST OF SYMBOLS AND ABBREVIATIONS

TV	:	Television
IPTV	:	Internet Protocol Television
HD	:	High Definition
BC	:	Before Christ
AD	:	Anno Domini
UK	:	United Kingdom
POF	:	Plastic Optical Fiber
SMF	:	Single-mode Fiber
MMF	:	Multi-mode Fiber
CVD	:	Chemical Vapour Deposition
OVD	:	Outside Vapour Deposition
MCVD	:	Modified Chemical Vapour Deposition
VAD	:	Vapour Axial Deposition
LAN	:	Local Area Network
PVC	:	Polyvinyl Chloride
DIY	:	Do-it-yourself
FC	:	Ferrule Connector
PC	:	Physical Contact

CHAPTER 1

INTRODUCTION

This chapter consists of five section which is briefly describe the overview of the project. It starts with the overview of study and followed by problem statements and objectives of the research. Next is the scope of research which is the project coverage area as well as the limitation and lastly is the significance of research.

1.1 Overview of Study

Optical fiber is a type of cabling technology that is used to transmit data via propagation and reflection of light inside a transparent fiber made by incredibly thin plastic strands or drawing glass which is made of silica [1]. A form of light energy which called photons is used to transmit data in fiber cable. The light energy or light signals are reflecting off the core and cladding in a series of zig-zag bounces along the internal wall of the optical fiber and causing a process of total internal reflection.

However, the light signals travelling about 30% slower than speed of light due to density of glass layer causing the refraction which slow down the travelling speed. To overcome this problem, repeater is used to regenerate or replicate optical signal that are weakened or distorted in a long range fiber optic communication system to maintain the speed of travel of signal inside the fiber optic [2].

The concept of reflection of light was first introduced in 1840s by Daniel Colladon. He used shine light along a water pipe to witness how water carry the light along the pipe by using internal reflection. Later, John Tyndall who improved Colladon's idea by introducing "bending light" which exactly explained what happens in optical fiber during transmission of data. His idea is investigated by shone light into a jug of water. A light curved round following the water's path can be observed when poured some waters out of the jug. In 1930, two German students, Heinrich Lamm and Walter Gerlach were tried to invent a gastroscope by using light pipe for looking inside someone's internal structure of body to improve the scientific technology in medical field. A successful investigation of sending a simple picture using light pipe made from thousands of glass fibers is done by Indian physicist and British Physicist in 1950.

In 1957, the world first gastroscope fiber optic technology was invented successfully by three American scientists at University of Michigan. Later, a Chinese-born US physicist Charles Kao discovered that impure glass has higher attenuation and causing power loss in data transmission during long range fiber optics. He used a fiber cable that made from pure glass and able to carry telephone signal over a much longer distances. In 1960s, Corning Glass was established and made the first fiber optic cable which capable of carrying signal of telephone where the global

communication system has greatly improved. The first fiber-optic telephone cable was landed between Long Beach and Artesia, California in 1977. Due to vigorous development in optical fiber communication system in 1980s, fiber optic telephone cable was able to transatlantic between United States, France, and UK to enhance the entire communication system. Until now, the fiber optic already became a main structure in communication system around the world to provide fastest internet and transmission of data. According to report from TeleGeography, there are currently around 450 fiber-optic submarine cables which are carrying communications under the ocean around the earth, stretching a total of 1.2million km fiber cable under the sea to connect every country.

Basically, there are 3 types of fiber optic cables which are single-mode fiber (SMF), multimode fiber (MMF), and plastic optical fiber (POF). SMF has smaller diameter of the fiber core which enable to decrease the possibility for attenuation to reduce the signal strength. Moreover, smaller diameter also isolates the light into a single beam, laser to offer direct route and provide higher bandwidth compare to MMF. Therefore, SMF usually used for long range communication and transmission system. However, SMF is more expensive compare to MMF and POF as it needs accurate and precise calculation to produce laser at small opening to transfer data. MMF has larger diameter which enables it to permit multiple light signal sent through the cable at once. MMF can achieves higher speed compare to SMF but the possibility for energy loss is higher due to reduction of energy is fast and light interference each other during transmission. POF is an optical fiber that is made out of pure plastic. Plastic materials is cheap components and it has greater flexibility as well as not easy to break when bending. Nowadays many applications in digital home appliances, home network, and

industrial networks are using the POF for low speed and short distance of signal transmission.

Nowadays, fiber optic is a most common communication linking structure around the world. Fiber optic greatly contribute in the industry of broadcasting, medical and military. Fiber optic already replace coaxial cable in most of places around the world. After the fiber optic is introduced, the TV broadcasting slowly changed from analog to digital broadcast. A single optical fiber cable can carry a lot of data in one time for several hundred TV channels at the same time. Instead of offering higher capacity, fiber optic also suffers less from interference and offer better signal in picture and sound quality and provide full HD video clip in smart TV.

Although optical fiber has higher efficiency and higher bandwidth than electrical cable, there are some factors that cause attenuation and power loss in optical fiber such as bending and light dispersion. Thus, some solutions must be investigating and discover to overcome the problem in fiber optic in order to achieve maximum power efficiency during transmission of data and reduce the percentage of data loss.

1.2 Problem Statement

There are number of physical characteristics that are inherent in optical fibers. These characteristics affect the bandwidth, attenuation and signal quality of the transmission. Among the factors that affect the transmission characteristics are chromatic dispersion absorption loss, scatter loss, bending loss, radiation loss and etc. Bending loss in optical fiber has become one of the major issue of the power loss in fiber optic transmission system and sensing application [4]. The reason why bending loss became the major issue in power loss is because user always ignore the bending while setup a communication and transmission system. More and over, these loss rise

quickly once a certain critical bend radius happen too frequently in line of fiber optic. Thus, power loss caused the slowing down of data transmission speed. As a result, the internet service speed is not in the range of their demands. Therefore, an investigation based on the issue is needed to improve the data transmission system and sensing application.

1.3 Objectives of Research

The objectives of this research are:

I. To investigate the effect of bending loss for SMF and MMF.

II. To evaluate the effective bending radius through experiment.

III. To verify the effective bending radius between theoretical and experimental.

1.4 Scope of Research

The scope of the research is to identify the critical bending radius of various optical fiber namely SMF, MMF and POF using theoretical formula and design the experiment using the set of range of parameter obtained from the theoretical formula using 1550nm laser source. Later, the result from experiment was verified and compare with the result from the theoretical formula. Investigation of power loss against number of fiber wrapping turns under different radii also was done through the experiment and analyze. Figure 1.1 shows the block diagram to explain the scope of research.

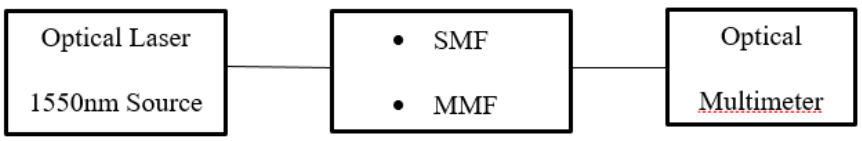

Figure 1.1: Block Diagram to Explain Scope of Research

1.5 Significance of Research

This research aims to investigate how bend loss effect the power transmission in optical fiber. Different bending radius can be used as guideline to indicate the critical radius that lead to the significant power losses in optical fiber. Besides, this research initially identifies the critical bending radius of both SMF and MMF by using theoretical and analytical method through mathematical calculation. After that, the experiment was conduct based on the value obtain from theoretical result and the range of bending radius that is going to be measure is set. Later, the experimental result was observed, tabulated and recorded. Since the results from both theoretical and experimental are obtained, the results were compared and analyzed. According to the research, it should be able to find out the solution to overcome the bend loss problem in optical fiber.

CHAPTER 2

BACKGROUND STUDY

This chapter is about background of optical fiber which describe the structure and uses of optical fiber. Next is the history of optical fiber and followed by types of optical fiber which are SMF, MMF, and POF. Furthermore, bending effect in optical fiber as well as how bending occur and the introduction of microbending and macrobending were also discussed here. Then, theory of propagation of light in optical fiber was explained. Lastly, the article review section is to compare previous related research that have been done by others.

2.1 Background of Optical Fiber

Optical fiber is a long, hair-fine filament, and can be made up of thin strands of very pure silica glass or plastic which can transmit light signal from 1 point to another with a speed of light. Because of that, optical fibers have been enhanced and greatly

use in the industry of communication and replacing the older method of metal wire which used electrical signal as the transmission medium for high speed and capacity at past.

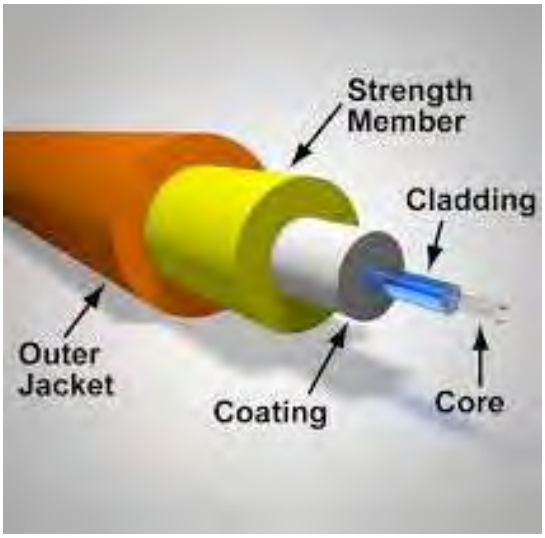

Figure 2.1: Fiber Optic

Figure 2.1 shows a basic construction of a fiber optic. It consists of outer jacket, coating, core and cladding. Core is a center filled with thin glass of fiber which allow the light signal to travel through it. Cladding is outer optical material surrounding the core use to reflect the light back to the core to complete the propagation of light in the fiber. After that, coating is made up from plastic use to protect the fiber from damage and moisture. Furthermore, strength member is the added component to preserve the integrity and separation in the mated ferrules. The outer jacket is use to identify the type of fiber and final protective layer for individual strand.

In the past, internet speed largely limited by metal cable which use moving electrical signals to transmit data. Among the drawback are it has lot of data loss and easy to be manipulated by electromagnetic interference. By development of technology year by year, the fiber optic cable slowly dominate the communication