ANALYSIS OF THE BENDING EFFECT OF SINGLE MODE FIBER (SMF) STRUCTURE TOWARDS THE PERFORMANCE OF MULTIMODE-SINGLE MODE-MULTIMODE (MSM) FIBRE OPTIC SENSOR FOR LIQUID CONCENTRATION MEASUREMENT

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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

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DEDICATION

I would like to dedicate the appreciation to my beloved family especially to my parents as their support. I would like also to thank my supervisor, Dr. Hanim Binti Abdul Razak for her advice.

ABSTRACT

The fiber optic sensors also called an optical fiber sensor using an optical fiber or sensing element. These sensors are used to sense some quantities like temperature, pressure, vibrations, displacements, rotations or concentration of chemical species. Fibers have so many uses in the field of remote sensing because they require no electrical power at the remote location. The Fiber Optic Sensor (FOS) has an optical fiber connected to a light source to allow for detection in tight spaces or where a small profile is beneficial. In this project, FOS has been employed for liquid concentration measurement by using a Mach-Zehnder Interferometer (MZI) structure by using Multimode-Single Mode-Multimode (MSM) configuration as a FOS to analyze the sensitivity of the MSM configuration. The MSM is designed and fabricated. The MSM is developed by using a fusion arc splicing technique and etching technique. The fibers are used for the lead-in and lead-out sections are multimode fiber (MMF) while the single mode fiber (SMF) represents the sensing-region and it will analyze with different size of the diameter of bending and a different number of loops. The diameter that involves is 2.4 cm, 2.8 cm, and 3.3 cm while the number of loops is 1 loop, 2 loops, and 3 loops respectively. The etched sensors were tested in water, 1.0 mol sucrose solution and palm oil with the refractive index (RI) respectively. The best

sensitivity of the sensor achieved at an operating wavelength of 1310 nm, the diameter of 3.3 cm and loop 3 which is -17.22 nm/RIU. It can be seen that the sensitivity of the sensor increase with the increase of refractive index, diameter and number of the loop.

ABSTRAK

Sensor serat optik juga dikenali sebagai sensor serat optik menggunakan serat optik atau elemen penginderaan. Sensor ini digunakan untuk memahami beberapa kuantiti seperti suhu, tekanan, getaran, perpindahan, putaran atau kepekatan spesies kimia. Serat mempunyai begitu banyak kegunaan dalam bidang penginderaan jarak jauh kerana mereka tidak memerlukan kuasa elektrik di lokasi terpencil. Sensor Fiber Optic (FOS) mempunyai serat optik yang disambungkan kepada sumber cahaya untuk membolehkan pengesanan di ruang yang ketat atau di mana profil kecil bermanfaat. Dalam projek ini, FOS telah digunakan untuk pengukuran tumpuan cecair dengan menggunakan struktur Mach-Zehnder Interferometer (MZI) dengan menggunakan konfigurasi Multimode-Single Mode-Multimode (MSM) sebagai FOS untuk menganalisis kepekaan konfigurasi MSM. MSM direka dan direka bentuk. MSM dibangunkan menggunakan teknik penyambungan arka dan teknik penampingan. Serat-serat yang digunakan untuk bahagian memimpin dan memimpin ialah serat multimode (MMF) manakala serat mod tunggal (SMF) mewakili kawasan sensing dan ia akan menganalisis dengan saiz yang berbeza dari diameter lenturan dan bilangan yang berbeza gelung. Diameternya ialah 2.4 cm, 2.8 cm dan 3.3 cm manakala bilangan gelung adalah 1 gelung, 2 gelung, dan 3 gelung masing-masing. Sensor terukir telah

diuji dalam air, larutan sukrosa 1.0 mol dan minyak kelapa sawit dengan indeks bias (RI). Sensitiviti terbaik sensor dicapai pada panjang gelombang operasi 1310 nm, diameter 3.3 cm dan gelung 3 iaitu -17.22 nm / RIU. Ia dapat dilihat bahawa sensitiviti sensor meningkat dengan peningkatan indeks biasan, diameter dan bilangan gelung.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

SMF	:	Single mode fiber
MMF	:	Multimode fiber
MSM	:	Multimode-Single mode-Multimode
FOS	:	Fiber Optic Sensor
MZI	:	Mach-Zehnder Interferometer
FPI	:	Fabry-Perot Interferometer
SI	:	Sagna Interferometer
HF	:	Hydrofluoric Acid
SiO_2	:	Silica
FOS	:	Fiber optic sensor
RI	:	Refractive Index
nm	:	Nanometer
FBG	:	Fiber Bragg Grating
POF	:	Plastic optical fiber
EMI	:	Electromagnetic interference
GaAs	:	Gallium arsenide
NaCl	:	Sodium Chloride
LED	:	Light emitting diode
nm/RIU	:	Nanometer/refractive index per unit

CHAPTER 1

INTRODUCTION

In this chapter, it will discuss the project background. It also consists the problem statement, the objective of this project and the scope of this project.

1.1 Introduction

Fiber optic cables are well known can transmit data fast and also carry more data than metal cable. An optical fiber or optical fiber is a flexible, transparent fiber made by drawing glass (silica) or plastic to a diameter slightly thicker than that of a human hair [1]. Optical fibers are used most often as a means to transmit light between the two ends of the fiber and find wide usage in fiber-optic communications, where they permit transmission over longer distances and at higher bandwidths (data rates) than wire cables. Fibers are used instead of metal wires because signals travel along them with less loss; in addition, fibers are immune to electromagnetic interference(EMI), a problem from which metal wires suffer excessively [2]. Fibers are also used for illumination and imaging and are often wrapped in bundles so that they may be used to carry light into, or images out of confined spaces, as in the case of a fiberscope [3]. Specially designed fibers are also used for a variety of other applications, some of them being fiber optic sensors and fiber lasers [4].

The fiber optic sensors also called an optical fiber sensor using an optical fiber or sensing element. These sensors are used to sense some quantities like temperature, pressure, vibrations, displacements, rotations or concentration of chemical species. Fibers have so many uses in the field of remote sensing because they require no electrical power at the remote location and they have tiny size.

In fiber optic sensor, there are two types of sensor material that has been used which are Plastic Optical Fiber (POF) and Glass Optical Fiber. For POF, it is an optical fiber which is made out of plastic. Since the late 1990s, significantly higher execution POF in light of perfluorinated polymers has started to show up in the market. In large diameter of fibers, 96% of the cross-section is the core that allows the transmission of light. Like customary glass fiber, POF transmits light through the core of the fiber. The core size of POF is 100 times bigger than glass fiber [5]. Meanwhile, for Glass Optical Fiber, they are constructed of tiny strands of glass that are bundled together inside an application-specific sheathing like stainless steel for durability and high temperatures. Glass optical fibers have an impressive temperature range, as low as -40 °F and up to +900 °F. That’s because the cables have no electrical components.

They merely act as a conduit or light guide between the target and the sensor. Other than that, glass cores are efficient at transmitting light, allowing for significantly higher transfer speeds, they can be used at long sensing distances. Even more, glass fiber optic cables are optimized for small spaces and small targets. They can be utilized with both visible red and infrared light and are compatible with a long list of fiber heads.

In this project, fiber optic sensor (FOS) has been employed for liquid concentration measurement by using a Mach-Zehnder Interferometer (MZI) structure. The multimode-single mode-multimode (MSM) will be fabricated by using the fusion splicing technique by using a splicer. Then, the sensing region which is single mode fiber is bending with the same length but varied bending diameter which is 2.4 cm, 2.8 cm, and 3.3 cm. The sensor device will be tested in 3 types of solution which is water, 1.0 mol sucrose, and oil. The bending effect of the sensor device will be experienced by a wavelength shift and it is also being observed the sensitivity of FOS.

This project is environmentally friendly because it does not release any chemical or any hazardous gas. This project also is using standard communication fiber optics which is single mode (SMF) and multimode (MMF) optical fiber. So, it is a low-cost project. Moreover, the FOS also uses less power compared to the conventional electronic sensor. The safety aspect of this project is safe because there is no large amount of power needed to operate. Thus, it does not have any harm potential to people.

1.2 Problem Statement

The fiber optic sensor (FOS) has an optical fiber connected to a light source to allow for detection in tight space or where a small profile is beneficial. When using fiber optic as the waveguide it is known as the fiber optic interferometer (FOI). FOI is a device that can be used to control and analyze the optical signal. The resultant wave can be analyzed in terms of phase modulation, intensity, power loss, extinction ratio and phase shifting. FOI induced the Michelson interferometer, Fabry-Perot interferometer (FPI), Mach-Zehnder interferometer (MZI) and Sagna interferometer (SI) for fiber optic sensor. MZI is used for high-temperature sensor and liquid level sensor.

The exact modeling of bending loss is very important for designing macro-bending systems and optical instruments. Bending of optical fibers cause the evanescence wave that can enhance the performance of the sensor device in terms of sensitivity. It is well-known that evanescence wave can increase with bending until specific radius. So, it will be varied the bending radius and increase the evanescent wave. In order to continuously monitor liquid concentration especially in chemical industries, a liquid concentration measurement based on fiber optic is a solution. Furthermore, the cost can be reduced by using the standard communication optical fibers. Thus, the optical fiber is a better choice to replace the electronic sensor. The cost can be reduced by using the standard communication optical fibers. Thus, the optical fiber is a better choice to replace the electronic sensor.

1.3 Objectives

Based on the problem above, the objectives of the project are:

i. To design fabricate the multimode-single mode-multimode fiber optic (MSM).
ii. To analyze the bending effect of the single mode fiber optic sensor.
iii. To determine the sensitivity of the sensor for liquid concentration measurement based on bending effect.

The objective of this project is to fabricate the multimode-single mode-multimode (MSM) fiber optic sensor (FOS). The device is fabricated using the fusion splicing technique. The fibers are used for lead-in and lead-out section are multimode fiber (MMF) while sensing area section is single mode fiber (SMF). The lead-in of the sensor connects to input which is optical light source while the lead-out of the sensor device connects to an ILX Lightwave Optical Multimeter Power Meter.

After that, analyze the bending effect on the sensor with the same length but the different diameter and maximum to three loops. By bending the fiber optic, the attenuation change. The new attenuation peaks appear while original peaks decrease. The new peaks grow and shift in wavelength as the refractive index increase.

Finally, after we test the bending of the fiber with a certain radius, we will insert the optical fiber into the liquid to determine the sensitivity of the sensor for liquid concentration measurement based on bending effect. The data will be taken through ILX Lightwave Optical Multimeter Power Meter.