ANALYSIS OF WAIST-ENLARGED TAPERS TOWARDS THE PERFORMANCE OF THE SINGLE MODE-MULTIMODE-SINGLE MODE (SMS) FIBER OPTIC SENSOR FOR LIQUID TEMPERATURE MEASUREMENT

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DEDICATION

This humble effort especially to my beloved parents, family, lecturers and friends, whose love can never be forgotten, whose support, guidance and encouragement upon completing this research and thesis.

ABSTRACT

During the last decades, there were a great achievement in the electronic communication sectors and one of them is optical fiber sensor. Optical fiber sensor has received a great attention in recent years due to their specialty on sensitivity, technology which capable to measure various conditions and immune to electromagnetic interference (EMI) or any short circuit. In addition, fiber optic sensor consumes less energy compared to the conventional sensors. In this project, fiber optic sensor (FOS) was developed and designed to measure the liquid temperature with the connection of Single mode-Multimode-Single mode (SMS) by using Waist-Enlarged Tapers. The sensitivity of the sensors was determined based on the overlap distance for waist enlargement. Five different overlap distances were been set in the conventional fiber splicer (Fujikuma FSM-60S) which are 30µm, 60µm, 90µm, 120µm and 150µm. Then, fiber optic sensors were tested in the oil. The oil was heated during experiment to vary its temperature from 30°C to 100°C. The highest sensitivity was produced by SMS sensor with overlap distance 150µm. The sensitivity produced by two different input, 1310nm and 1550nm for this sensor was 0.0984nm/°C and 0.0742nm/°C. From the observation, Waist-Enlarged Tapers was affected the sensitivity produced by the sensor.

ABSTRAK

Sedekad yang lalu, terdapat pencapaian yang hebat dalam sektor komunikasi elektronik dan salah satunya ialah sensor fiber optik. Sensor fiber optik telah mendapat perhatian yang sangat baik dalam beberapa tahun kebelakangan ini kerana kecanggihan mereka terhadap kepekaan, teknologi yang mampu mengukur pelbagai keadaan dan kebal terhadap gangguan elektromagnetik (EMI) atau sebarang litar pintas. Di samping itu, sensor fiber optik menggunakan kurang tenaga berbanding dengan sensor konvensional. Dalam projek ini, sensor fiber optik (FOS) dicipta dan direka bentuk untuk mengukur suhu cecair dengan sambungan mod, Single mode-Multimode-Single mode (SMS) dengan menggunakan Waist-Enlarged Tapers. Sensitiviti sensor ditentukan berdasarkan jarak tindih untuk pembesaran waist. Lima jarak bertindih yang berbeza akan ditetapkan dalam splicer (Fujikuma FSM-60S) iaitu 30µm, 60µm, 90µm, 120µm dan 150µm. Kemudian, sensor fiber optik telah diuji di dalam minyak. Minyak dipanaskan semasa eksperimen dijalankan untuk mengubah suhunya dari 30 °C hingga 100 °C. Kepekaan tertinggi dihasilkan sensor SMS dengan jarak 150µm. Kepekaan yang dihasilkan oleh dua input berbeza, 1310nm dan 1550nm untuk sensor ini ialah 0.0984nm/°C dan 0.0742nm/°C. Dari pemerhatian, Taper Waist-Enlarged Taper mempengaruhi sensitiviti yang dihasilkan oleh sensor.

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Firstly, I would like to express my gratitude to the Almighty for His blessing and grace in giving me strength to complete my Final Year Project, titled "Analysis of Waist-Enlarged Tapers towards the performance of the single mode-multimode-single mode (SMS) fiber optic sensor for liquid temperature measurement". With the strength given, I am able to complete this research and able to overcome all the problems and obstacles that occur during research periods.

Then, I would like to express my profound gratitude and deep regards to my supervisor for this project, Dr. Hanim Binti Abdul Razak for her exemplary guidance, providing the time and idea, monitoring and constant encouragement regarding my project.

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LIST OF SYMBOLS AND ABBREVIATIONS

For examples:

SMS	:	Single Mode-Multimode-Single Mode
MSM	:	Multimode-Single Mode-Multimode
FOS	:	Fiber Optic Sensor
SMF	:	Single Mode Fiber
MMF	:	Multimode Fiber
WET	:	Waist-Enlarged Tapers
POF	:	Plastic Optical Fiber
EMI	:	Electromagnetic Interference
TIR	:	Total Internal Reflection
FPI	:	Fabry-Perot Interferometer
FBG	:	Fiber Bragg Grating
RI	:	Refractive Index
SCF	:	Suspended-Core Microstructure Optical Fiber
LPFG	:	Laser-Induced Long Period Fiber Grating
MMM	:	Multimode-Multimode-Multimode
MZI	:	Mach-Zehnder Interferometer
OSA	:	Optical Spectrum Analyzer

CHAPTER 1

INTRODUCTION

1.1 Introduction

Massive increase in electronic communication during the last decades has spurred the development of ways to transport and process large quantities of data. Optical fiber has received great attention in recent years due to its application which are used as information transmission lines and also as sensors. It's specialty on sensitivity, size and immunity to electromagnetic interference in the biological, chemical and environment industries makes it as a very popular devices nowadays [5][1]. Fiber optic sensor is a technology that is capable to measure various parameters and conditions. This is a step forward for fiber optic sensor because other sensing device such as electronic sensors cannot reach and unsuitable to the certain condition. The advantage of fiber optic sensor includes that it carries more information at speed of light compared to conventional copper wire [6][2].

Optical fiber contains three parts which are core, cladding and coating (plastic buffer). The core functions as a central tube of the fiber optic and it is very thin. In Figure 1.1, the diameter of fiber optic is about 9µm up to 62.5µm while the cladding is 125µm [7][3]. The main function of the core is to propagate the optical signal. Meanwhile for cladding, it acts as outer optical material which is around the core. The main function of the cladding is enable the optical signal propagation through the core by the total internal reflection. Lastly, plastic buffer is made of silicon rubber to protect the fiber.

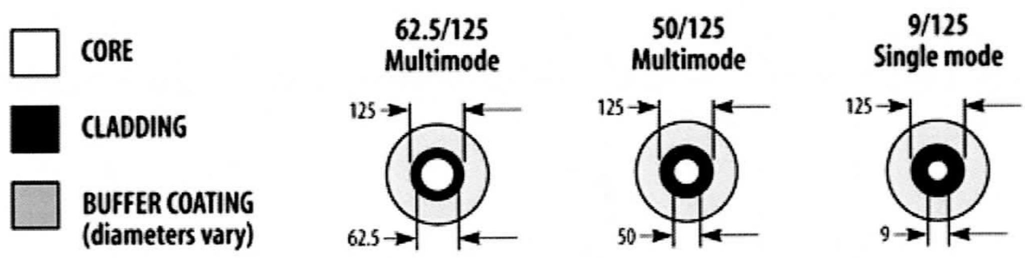

Figure 1.1: Measurement of the Fiber Optic

Fiber optic sensor or called it as FOS has been used to monitor a wide range of environmental parameters such as mechanical strain, humidity, temperature, pressure, vibration, concentration of chemical and other environmental factors [8][4]. Since FOS uses light source to be transmitted through the cable, the environmental around fiber optic will affect or change the direction of light propagation in the core.

In this project, a fiber optic sensor will be created to test the liquid temperature. The FOS consists of two types of fiber optic which are single mode fiber and multimode fiber. Single mode-Multimode-Single mode connection was been used in this project to detect the change of temperature for the oil. Based on Figure 1.2, The connection of the SMF and MMF was done by using the Waist-Enlarged Tapers structure. In order to analyze the sensitivity based on the Waist-Enlarged Tapers, the overlap distance between SMF and MMF were varied from 30μm to 150μm.

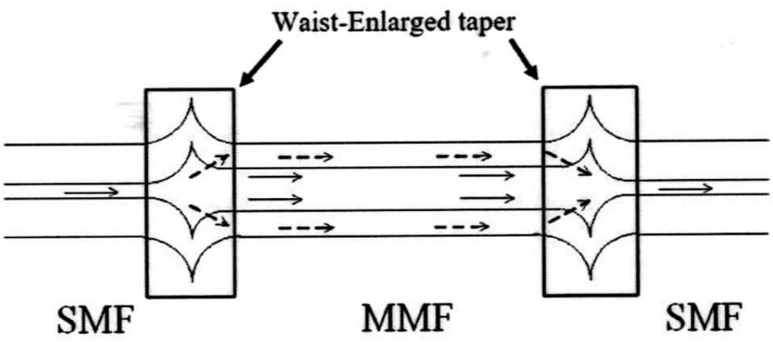

Figure 1.2: Waist-Enlarged connection between single mode and multimode

This FOS is environment friendly because it does not release any hazardous gas or react with the chemical. In addition, this sensor needed a very low power supply compared to the normal electronic sensor. Moreover, it is a low-cost project since it does not use a lot of electronic component and low power consumption.

1.2 Problem Statement

There are a lot of liquid temperature sensor measurement devices normally based on the electronic type devices. The electronic sensor works well in practice, but it is flammable due to the electromagnetic interference, EMI. However, the fiber optic cable is made from silica and immune to EMI. In addition, fiber optic cable uses light pulse to transmit the signal or information and that is why it is more suitable in determining liquid temperature compared to normal electronic devices.

Then, energy is also one of the problem. Electronic sensor needed more power supply for its operation compared to the fiber optic sensor. Normally for the chemical industries, the sensor needed to continuously turn on to monitor the liquid temperature. In addition, fiber optic sensor will be more effective because it is cost efficient.

Lastly, the overlap distance is affecting the sensitivity of the FOS. So, the sensor is very sensitive towards the change of the liquid temperature when the FOS is applied to the solution. Since the measurement of the liquid temperature is very important for the chemical industries, fiber optic sensor is the best sensor to be applied.

1.3 Objective

i. To fabricate and design the single mode-multimode-single mode fiber optic (SMS) by using Waist Enlarged-Tapers.

ii. To analyze the effect of different overlap distance on SMS fiber optic sensor.

iii. To determine the sensitivity of the SMS fiber optic sensor on temperature based on Waist-Enlarged Tapers.

1.4 Scope of Work

The scope of work of this project is to analyze the effect of Waist-Enlarged Tapers on fiber optic sensor for liquid temperature. The FOS is fabricated by using commercial splicer Fujikura FSM-18R and to obtain flat and clean end faces uncoated fiber, high quality cleaver Fujikura CT-30 is used.

Table 1.1: Apparatus and parameter use in this project

	Experiment Details
Fiber Optic	Single mode
	Multimode
Overlap Distance	30 µm
	60 µm
	90 µm
	120 µm
	150 µm
Solution	Cooking Oil (Refractive Index=1.47)
Temperature	30°C to 100°C
Hardware	OSA M9740A
	Optical Light Source
	Commercial Splicer

CHAPTER 2

BACKGROUND STUDY

2.1 Introduction

The literature review is where the knowledge and concepts that are already established is outlined. This chapter is about the discussion about the issue, analysis of objectives and methodology used needed to be supported by the established information that reviewed from books, articles, journals and web site. For this project, the study is conducting to learn more about fiber optic characteristic such as fiber optic's evolution, fundamental, type and its application. Figure 2.1 shows the content of the literature review.