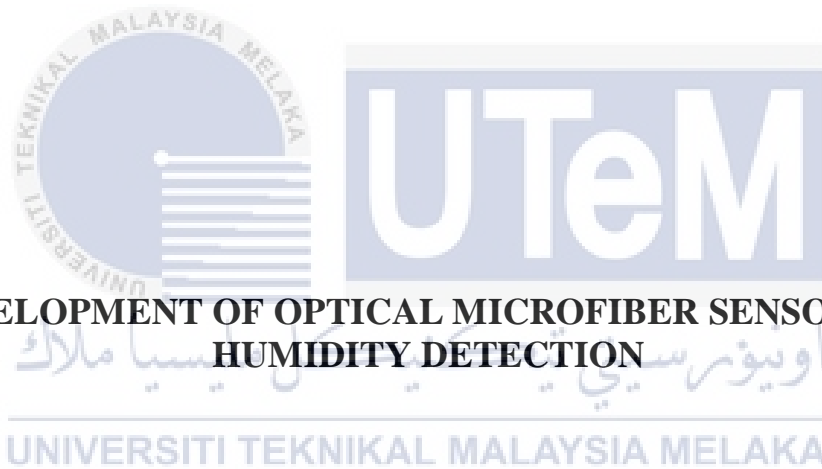




**Faculty of Electrical and Electronic Engineering Technology**



**DEVELOPMENT OF OPTICAL MICROFIBER SENSOR FOR  
HUMIDITY DETECTION**

**ABDUL HAFIZ BIN AHMAD ZAINI**

**Bachelor of Electronics Engineering Technology (Telecommunications) with Honours**

**2023**

**DEVELOPMENT OF OPTICAL MICROFIBER SENSOR FOR HUMIDITY  
DETECTION**

**ABDUL HAFIZ BIN AHMAD ZAINI**

**A project report submitted  
in partial fulfillment of the requirements for the degree of  
Bachelor of Electronics Engineering Technology (Telecommunications) with Honours**



**Faculty of Electrical and Electronic Engineering Technology**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2023**

BORANG PENGESAHAN STATUS LAPORAN  
PROJEK SARJANA MUDA II

Tajuk Projek : Development of Optical Microfiber Sensor For Humidity Detection

Sesi Pengajian : 1 – 2022/2023

Saya ABDUL HAFIZ BIN AHMAD ZAINI mengaku membenarkan laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (✓):

**SULIT\***

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

(Mengandungi maklumat yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

**TIDAK TERHAD**

Disahkan oleh:



(TANDATANGAN PENULIS)

Alamat Tetap: MT 1858 LORONG 29  
TAMAN SRI AMAN 78300 MASJID  
TANAH MELAKA



**DR. MD ASHADI BIN MD JOHARI**

(COP DAN TANDATANGAN PENYELIA)

Jabatan Teknologi Kejuruteraan Elektronik Dan Komputer  
Fakulti Teknologi Kejuruteraan Elektrik Dan Elektronik  
Universiti Teknikal Malaysia Melaka

Tarikh: 13 JANUARY 2023

Tarikh: 16 JANUARY 2023

## DECLARATION

I declare that this project report entitled “Development of Optical Microfiber Sensor for Humidity Detection” is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature

:



Student Name

:

ABDUL HAFIZ BIN AHMAD ZAINI

Date

:

25 JANUARY 2023



اونيورسيتي تيكنيكل مليسيا ملاك  
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology with Honours.

Signature :



Supervisor Name :

DR MD ASHADI BIN MD JOHARI

Date :

27/01/2023

اونيورسيتي تيكنيكل مليسيا ملاك

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## DEDICATION

*Alhamdulillah, all praise to Allah.*

*I dedicate this report to my beloved parents, AHMAD ZAINI BIN OTHMAN and*

*MAINMON BINTI ABU BAKAR, As well as my precious siblings,*

*And to all my families, friends, partner in crime,*

*And those who supported me along this long journey,*

*Cheers to their constant encouragement and endless, repetitive motivational rants.*



## ABSTRACT

This research describes the development of an effective optical microfiber sensor for humidity detection. As for the objective of this project is to study the operation and the performance of humidity sensor by using optical microfiber technology, to develop the humidity sensor using optical microfiber and testing its sensitivity and performance in several humidity level tests, and last but not least to analyze the performance of Humidity Sensor using optical microfiber in different environment and experiments. The technique of producing a new size of optical microfiber is through tapering or D-shape but in this it using tapering. Basically tapering is a firing the fiber until the size of fiber up to the smallest size before it going to broken. For this project, it managed to get to 7.8 um with different wavelength (1310nm and 1550nm) for testing. In this project, the sensitivity and linearity of the sensing are the findings due to the comparison value of gradient and  $R^2$  based on the graph from OTDR. From all the comparison results, we can know the best ideal of wavelength for sensing. Hence, it shows that we managed to fulfilled the objectives.

## ***ABSTRAK***

Penyelidikan ini menerangkan pembangunan penderia mikrofiber optik yang berkesan untuk pengesanan kelembapan. Bagi objektif projek ini adalah untuk mengkaji operasi dan prestasi sensor kelembapan dengan menggunakan teknologi microfiber optik, untuk membangunkan sensor kelembapan menggunakan microfiber optik dan menguji kepekaan dan prestasinya dalam beberapa ujian tahap kelembapan, dan akhir sekali untuk menganalisis prestasi Penderia Kelembapan menggunakan mikrofiber optik dalam persekitaran dan eksperimen yang berbeza. Teknik menghasilkan saiz baru microfiber optik adalah melalui tirus atau bentuk D tetapi dalam ini menggunakan tirus. Pada asasnya tirus ialah penembakan gentian sehingga saiz gentian sehingga saiz terkecil sebelum ia pecah. Untuk projek ini, ia berjaya mencapai 7.8  $\mu\text{m}$  dengan panjang gelombang yang berbeza (1310nm dan 1550nm) untuk ujian. Dalam projek ini, sensitiviti dan lineariti penderiaan adalah dapatan kerana nilai perbandingan kecerunan dan  $R^2$  berdasarkan graf daripada OTDR. Daripada semua hasil perbandingan, kita boleh mengetahui panjang gelombang ideal terbaik untuk penderiaan. Oleh itu, ia menunjukkan bahawa kami berjaya mencapai objektif.



## ACKNOWLEDGEMENTS

First and foremost, I would like to thank my supervisor, Dr Md Ashadi Bin Md Johari, for his excellent advice, suggestions, wise words, and patience during this project's development.

My deepest gratitude goes out to my parents, Ahmad Zaini and Maimon Abu Bakar, and other family members for their blessings, support and prayers during my studies. Furthermore, for all of the inspiration and understanding,

Not to mention my other classmates and colleagues, who were all eager to share their brilliant views and futuristic ideas on the project with me.

Finally, I would like to express my gratitude to all of the staff members at the FTKEE and lecturers, other colleagues and classmates, the Project Panels, and other persons not named here for their utmost cooperation and assistance.

## TABLE OF CONTENTS

	<b>PAGE</b>
<b>DECLARATION</b>	
<b>APPROVAL</b>	
<b>DEDICATIONS</b>	
<b>ABSTRACT</b>	<b>i</b>
<b>ABSTRAK</b>	<b>ii</b>
<b>ACKNOWLEDGEMENTS</b>	<b>iii</b>
<b>TABLE OF CONTENTS</b>	<b>i</b>
<b>LIST OF TABLES</b>	<b>iv</b>
<b>LIST OF FIGURES</b>	<b>v</b>
<b>LIST OF SYMBOLS</b>	<b>viii</b>
<b>LIST OF ABBREVIATIONS</b>	<b>ix</b>
<b>LIST OF APPENDICES</b>	<b>x</b>
<b>CHAPTER 1 INTRODUCTION</b>	<b>1</b>
1.1 Background	1
1.2 Problem Statement	3
1.3 Project Objective	3
1.4 Scope of Project	3
<b>CHAPTER 2 LITERATURE REVIEW</b>	<b>5</b>
2.1 Introduction	5
2.2 Microfiber Optic	5
2.2.1 Single Mode Fiber Optic	6
2.2.2 Multi-Mode Fiber Optic	8
2.2.3 The Propagation of Light through Optical Fiber	10
2.2.4 Reflection and Refraction of light in Fiber Optic	10
2.2.5 Total internal Reflection – Step Index Multimode Fiber	11
2.2.6 Various Type of Fiber Optic Sensor	12
2.2.7 Evanescent wave sensors	13
2.2.8 Fabry-Perot Interferometric sensors	17
2.3 Comparison of Research Papers	20
2.4 Summary	22
<b>CHAPTER 3 METHODOLOGY</b>	<b>23</b>
3.1 Introduction	23
3.2 Flow of Project	23

3.2.1	Stripping and cleaving of fiber optic cable	26
3.2.1.1	Fiber Optic Cable Splicing Procedure	28
3.2.1.2	Tapering Technique	32
3.2.1.3	Microfiber Under Microscope	33
3.2.1.4	The Characterization of Fiber Optic Cable	34
3.2.1.5	Limitation of proposed methodology	35
3.2.1.6	Insertion Loss	35
3.2.1.7	Optical Return Loss (ORL)	36
3.2.1.8	Polarization Mode Dispersion	37
3.2.1.9	Chromatic Dispersion Test	38
3.2.1.10	The Characterization of Fiber Optic Sensor	39
3.2.1.11	Equipment Used for the Experiment	40
3.3	Summary	43
<b>CHAPTER 4 RESULTS AND DISCUSSIONS</b>		<b>44</b>
4.1	Introduction	44
4.2	Results and Analysis	44
4.2.1	100% of Humidity (no Calcium Chloride) tested on wavelength of 1310nm & 1550nm wavelength	45
4.2.2	90% of humidity (1 piece calcium chloride) tested on wavelength of 1310nm & 1550nm wavelength	46
4.2.3	80% of humidity (2 pieces calcium chloride) tested on wavelength of 1310nm & 1550nm wavelength	47
4.2.4	70% of humidity (3 pieces calcium chloride) tested on wavelength of 1310nm & 1550nm wavelength	48
4.2.5	60% of humidity (4 pieces calcium chloride) tested on wavelength of 1310nm & 1550nm wavelength	49
4.2.6	50% of humidity (5 pieces calcium chloride) tested on wavelength of 1310nm & 1550nm wavelength	51
4.2.7	Comparison	52
4.3	Interaction for Humidity against Time	52
4.3.1	1310nm and 1550nm wavelength observed for 1 minute	53
4.3.2	1310nm and 1550nm wavelength observed for 2 minutes	54
4.3.3	1310nm and 1550nm wavelength observed for 3 minutes	55
4.3.4	1310nm and 1550nm wavelength observed for 4 minutes	56
4.3.5	1310nm and 1550nm wavelength observed for 5 minutes	57
4.3.6	1310nm and 1550nm wavelength observed for 6 minutes	59
4.3.7	1310nm and 1550nm wavelength observed for 7 minutes	60
4.3.8	Comparison	61
4.4	Average	62
4.5	Summary	63
<b>CHAPTER 5 CONCLUSION AND RECOMMENDATIONS</b>		<b>64</b>
5.1	Conclusion	64
5.2	Future Works	65
<b>REFERENCES</b>		<b>66</b>
<b>APPENDICES</b>		<b>68</b>



## LIST OF TABLES

<b>TABLE</b>	<b>TITLE</b>	<b>PAGE</b>
Table 2-1	Literature Review	20
Table 4-1	Shows the data collected at 100% humidity	45
Table 4-2	Shows the data collected at 90% humidity	46
Table 4-3	Shows the data collected at 80% humidity	47
Table 4-4	Shows the data collected at 70% humidity	48
Table 4-5	Shows the data collected at 60% humidity	49
Table 4-6	Shows the data collected at 50% humidity	51
Table 4-7	The data comparison between 1310nm and 1550nm with different Humidity	52
Table 4-8	Shows obtained data at 1 minute	53
Table 4-9	Shows obtained data at 2 minutes	54
Table 4-10	Shows obtained data at 3 minutes	55
Table 4-11	Shows obtained data at 4 minutes	56
Table 4-12	Shows obtained data at 5 minutes	57
Table 4-13	Shows obtained data at 6 minutes	59
Table 4-14	Shows obtained data at 7 minutes	60
Table 4-15	The data comparison between 1310nm &1550nm with different Time	61
Table 4-16	Results for average output power (dBm)	62
Table 5-1	GANTT CHART	70

## LIST OF FIGURES

FIGURE	TITLE	PAGE
Figure 2-1	Cross section of fiber optic cable	6
Figure 2-2	The diameter of single-mode fiber optic cable	7
Figure 2-3	The Single-Mode Light Propagation	7
Figure 2-4	The diameter of multi-mode fiber optic cable	9
Figure 2-5	The Multi-Mode Light Propagation	9
Figure 2-6	The Total Internal reflection in Fiber Optic Cable	11
Figure 2-7	The Total Internal reflection in Step Index Multimode Fiber	12
Figure 2-8	ESA overlay on a taper humidity sensor structure	13
Figure 2-9	Tapered fiber sensor relative humidity step response compared to commercial capacitive relative humidity sensor	15
Figure 2-10	The Humidity Response Experimental Setup	16
Figure 2-11	Continuous human breathing response of the sensor	16
Figure 2-12	The step-change in relative humidity.	17
Figure 2-13	Moisture ingress rate measurement using Fiber Bragg grating humidity sensors	18
Figure 2-14	Sensor measurements	18
Figure 2-15	Fiber optic Fabry–Perot interferometric humidity sensor	19
Figure 3-1	The Flow Chart of development of humidity sensor by optical microfiber for medical industry	25
Figure 3-2	Stripping process for fiber optic cable.	26
Figure 3-3	Cleaver tools for fiber optic cable.	27
Figure 3-4	The differences between a good and bad cleaving technique.	28
Figure 3-5	Fujikura Fusion Splicing Machine	28
Figure 3-6	The splicing technique using fusion splicing machine.	29

Figure 3-7 Fiber cable splicing technique.	30
Figure 3-8 Fiber cable spliced successfully with 0 loss.	30
Figure 3-9 Fiber cable spliced successfully with 0 loss.	31
Figure 3-10 The setup for Humidity Sensor by optical fiber	32
Figure 3-11 Burning the fiber with tapering technique	32
Figure 3-12 Result after tapering	33
Figure 3-13 Observing the size of fiber	33
Figure 3-14 Size of a Microfiber	34
Figure 3-15 The Comparison Between Contaminated And Clean Pigtail Connector	35
Figure 3-16 Power Meter and Light Source Test	36
Figure 3-17 The direction of light reflected back into the transmitter	37
Figure 3-18 The Differential of Arrival Time	38
Figure 3-19 Longer wavelength travelling faster induce chromatic dispersion in the fiber	38
Figure 3-20 Amplified Spontaneous Emission (ASE)	40
Figure 3-21 Optical Spectrum Analyzer	40
Figure 3-22 Fiber Pigtail (2 pieces)	41
Figure 3-23 Splicing Machine	41
Figure 3-24 Stripper / Cutter	41
Figure 3-25 Cleaver	42
Figure 3-26 Alcohol Cleaning Pad	42
Figure 3-27 Calcium Chloride (CaCl <sub>2</sub> )	42
Figure 4-1 Graphs shown above are outputs at 100% Humidity	45
Figure 4-2 Graphs shown above are outputs at 90% humidity	47
Figure 4-3 Graphs shown above are outputs at 80% humidity	48
Figure 4-4 Graphs shown above are ouputs at 70% humidity	49

Figure 4-5 Graphs shown above are outputs at 60% humidity	50
Figure 4-6 Graphs shown above are outputs at 50% humidity	51
Figure 4-7 Graph show results obtained at 1 minute	53
Figure 4-8 Graph show results obtained at 2 minutes	54
Figure 4-9 Graph show results obtained at 3 minutes	56
Figure 4-10 Graph show results obtained at 4 minutes	57
Figure 4-11 Graph show results obtained at 5 minutes	58
Figure 4-12 Graphs show results obtained at 6 minutes	59
Figure 4-13 Graphs show results obtained at 7 minutes	61
Figure 4-14 Shows the average for 1310nm & 1550nm	63





## LIST OF SYMBOLS

$\delta$	-	Voltage angle
$\lambda$	-	Wavelength
$c$	-	Speed of light
$n$	-	Cavity length
	-	
	-	
	-	
	-	



## LIST OF ABBREVIATIONS

<i>FBG</i>	-	Fiber Bragg Grating
<i>ORL</i>	-	Optical Return Loss
<i>ISAM</i>	-	Indexed Sequential Access Method
<i>LAN</i>	-	Local Area Network
<i>FSR</i>	-	Free Spectral Range
<i>IPA</i>	-	Isopropyl Alcohol
<i>OTDR</i>	-	Optical Time Domain Reflectometer
<i>PMD</i>	-	Polarization Mode Dispersion
<i>COD</i>	-	Coefficient of Determination
<i>FOS</i>	-	Fiber Optic Light Source



## LIST OF APPENDICES

APPENDIX	TITLE	PAGE
Appendix A	Laboratory where we finishing the project	68
Appendix A	Testing the after splice fiber to see if laser passing through along the fiber	68
Appendix B	Example of Appendix B	71



# CHAPTER 1

## INTRODUCTION

### 1.1 Background

Optical microfiber is a data transmission mechanism that uses light pulses to convey information through a microfiber, which is often constructed of plastic or glass. Electromagnetic interference has no effect on optical microfibers since they are made of glass. In order to transmit signals, total internal reflection of light (TIR) is used in microfiber cable transmission. The microfibers, in conjunction with the optical microfiber, are meant to aid in the transmission of light, depending on the optical power source and transmission distance requirements. Long-distance transmission is accomplished via the use of single-mode microfiber, while short-distance transmission is accomplished through the use of multimode microfiber. Compared to metal wires, microfiber optic claddings need greater protection because to the delicate and soft nature of the material used on the outside of the microfiber optic cable.

Microfiber optic sensors, which employ optical microfiber cables to detect objects correctly in a number of applications, are becoming more popular. An example of a sensing device that makes use of microfiber optic technology is a microfiber optic sensor, which monitors physical quantities such as temperature and humidity as well as pressure, strain, voltages, and acceleration. The term "intrinsic sensor" refers to a sensor that is built into the device itself. In the context of signal transmission between a distant sensor and an associated signal processing module, it is referred to as an optical microfiber transfer system (extrinsic sensor). Microfiber optic

sensors are becoming more popular as the sensor of choice in a variety of industries due to its resistance to electromagnetic interference and ability to sustain very high temperature.

They have increased environmental sensitivity, arguably the highest resistance to electromagnetic interference, compact size, low weight, robustness, flexibility, and the capacity to offer multiplexed or scattered sense. They also have the potential to provide multiplexed or dispersed sense. One of the most frequent sensors is a Fabry-Perot (FP) based optical sensor used as a sensing element, which is characterized by its high sensitivity, small size, and durability in harsh settings. When compared to the intensity demodulation method, the spectrum demodulation method is frequently more expensive or not fast enough to demodulate acoustic waves of high frequency or rapidly fluctuating pressure signals for high bandwidth applications requiring rapid response time. However, when compared to the intensity demodulation method, the spectrum demodulation method is frequently more expensive or not fast enough.

The goal of this project is to design and develop a humidity sensor for the medical market using optical microfiber technology. The optical microfibers have exceptional optical and mechanical qualities, including greater resistance to water and corrosion, resistance to electromagnetic interference and nuclear radiation, and the ability to work effectively in low-temperature environments, in addition to their high sensitivity. This project's major goal is to target the medical business in particular. In order to properly get the information of the patients without any environment interference, the medical industry standard mandates a better accuracy of measurement, as well as reduced interference in radio frequency (radiation).

## 1.2 Problem Statement

In the medical industry, product quality is held to a very high level. Because the technology and uses of optical microfibers in the medical sector have grown significantly in recent years, the need for an accurate and long-lasting sensors system has risen. To increase the quality of precise measurements, the typical electrical sensor equivalent must be replaced with a wireless and light weighted material with superior performance.

## 1.3 Project Objective

The goal of this project is to provide an efficient and acceptable method for evaluating humidity sensor use with high accuracy using an optical microfiber distribution network. There are several objectives that will be achieved in this study as shown below :-

- a) To study the operation and the performance of humidity sensor by using optical microfiber technology.
- b) To develop the humidity sensor using optical microfiber and testing its sensitivity and performance in several humidity level tests.
- c) To analyze the performance of Humidity Sensor using optical microfiber in different environment and experiments.

## 1.4 Scope of Project

The scope of the project is specified as follows to prevent any confusion about the project owing to various limits and constraints:

- a) Trying with variety level of humidity.

- b) Analyze the microfiber optic sensor with humidity sensor.
- c) Keep observing the same light source in the optical fiber.
- d) Differentiate the output of all level humidity in different medium.



## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Introduction

The fundamental concept of microfiber optics, as well as the microfiber optic sensor, are addressed in this chapter. The major sources for this project include previous efforts as well as supplementary resources such as journals, articles, and books related to the subject. Toward the end of this chapter, the theoretical underpinning and operation of microfiber optic sensors are described in depth. This chapter also summarizes all of the previous studies on the issue.

#### 2.2 Microfiber Optic

Glass microfiber optics, which have a diameter about equal to the diameter of a human hair, are tiny strands of highly clean glass. Sending the light will messages over long distances while the optical microfibers been bundled together.

The jacket, which is the cable's outer covering, protects the bundles and is made up of three layers: buffer coating, cladding, and core. A plastic buffer coating is put to the microfiber to protect it from moisture and damage. The outer optical material that surrounds the core and reflects light into the core is referred to as cladding. The thin glass center of the microfiber, through which light is transmitted and received, is the core of a microfiber optic cable.

Single-mode and multi-mode microfiber optics are the two forms of microfiber optics. The single-mode communication system has a smaller core and transmits infrared laser light across