

Faculty of Electrical and Electronic Engineering Technology



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Bachelor of Electronics Engineering Technology (Telecommunications) with Honours

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DEVELOPMENT OF OPTICAL MICROFIBER SENSOR FOR HUMIDITY DETECTION

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



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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.

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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.



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 sensoring are the findings due to the comparison value of gradient and R² based on the graph from OTDR. From all the comparison results, we can know the best ideal of wavelength for sensoring. 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 um dengan panjang gelombang yang berbeza (1310nm dan 1550nm) untuk ujian. Dalam projek ini, sensitiviti dan lineariti penderiaan adalah dapatan kerana nilai perbandingan kecerunan dan R2 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.

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LIST OF SYMBOLS

- Voltage angle Wavelength δ -
- λ _
 - -
 - Speed of light Cavity length _
 - -

с

n

- _
- -
- _



LIST OF ABBREVIATIONS

FBG	-	Fiber Bragg Grating
ORL	-	Optical Return Loss
ISAM	-	Indexed Sequential Access Method
LAN	-	Local Area Network
FSR	-	Free Spectral Range
IPA	-	Isopropyl Alchool
OTDR	-	Optical Time Domain Reflector
PMD	-	Polarization Mode Dipersion
COD	-	Coefficient of Determination
FOS	-	Fiber Optic Light Source



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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 lowtemperature 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 UNIVERSITI TEKNIKAL MALAYSIA MELAKA 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.

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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 cloaking. 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 vast distances. The multi-mode transmissions have bigger cores and are often used over short distances.



Figure 2-1 Cross section of fiber optic cable

Despite the fact that fiber optics and copper wires are identical, fiber optics are gradually replacing copper wires as a reliable means of signal transport in communication systems and other applications. Fiber optics provide a number of benefits way more than copper does, including reduced prices, thinner construction, and higher carrying capacity. Optical fibers are the most efficient way to carry digital data. The reason is the electricity did not exist in the transmission hence the chances of fire sparkling occurred is lower. Fiber optics cables are smaller, light weight and flexible.

2.2.1 Single Mode Fiber Optic

In order to convey the light signal, the core of the fiber has just one index of refraction. Light can only go in one direction using a single-mode optical cable. The single-mode fiber has a core diameter of 5 to 10 micrometers and a cladding diameter of 125 micrometers. Here, a schematic of single mode fiber optic diameter size is shown (Figure 2.2).



Figure 2-2 The diameter of single-mode fiber optic cable

Fast data speeds and low signal loss necessitate the use of single-mode fibers in applications such as lengthy distances between repeater and amplifier. In addition, single-mode fiber does not suffer from modal dispersion, as does multimode fiber, since it only enables the transmission of a single mode or ray (the lowest-order mode). Figure 2.3 shows how light travels over a single mode fiber optic cable.

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Figure 2-3 The Single-Mode Light Propagation

A larger data rate may be greatly impacted even when single-mode fiber is unaffected by modal dispersion. This issue may be solved in a variety of ways. Glass's index of refraction is very

constant at about 1310nm, hence one may transmit at this wavelength using an optical source with a very narrow output.

LAN and WAN (local area network and wide area network) backbones are among the many applications for single-mode fiber's high capacity and long distance capabilities.

Single-mode fiber is challenging to work with due to its tiny core size (for example, splicing and termination). Furthermore, single-mode fiber is normally only used with laser sources because of the high coupling losses associated with LEDs.

2.2.2 Multi-Mode Fiber Optic

The term "multimode optical fiber" refers to the fact that many light rays may be transported simultaneously via a waveguide. With a core size five to six times larger than singlemode, it is possible to use less costly electro-optic equipment and collect more light. Transmission distance and bandwidth have been restricted in the past due to the use of numerous modes or light channels in parallel along the fiber.



Figure 2-4 The diameter of multi-mode fiber optic cable

Multimode fiber has a higher attenuation than single-mode fiber because of its larger core diameter. There is extremely little attenuation in light flowing through single-mode fiber cables because of the tiny diameter of the fiber core. A typical multimode fiber for telecommunications has a core diameter of 50-62.5 nm and a cladding diameter of 125 nm. As a consequence, the fiber may be capable of propagating numerous modes.

For example, a local area network (LAN) requiring high capacity (up to 1GHz) across short distances might benefit from multi-mode fiber (under 3km). A few of the most notable benefits of multimode fiber are as follows: Second, it is a rather easy problem to solve. The light is immediately connected with it because to its larger core size. It may also be used with lasers and LEDs as a source. Single-mode fiber has lower coupling losses than multi-mode fiber.



Figure 2-5 The Multi-Mode Light Propagation

As a result of permitting a large number of modes to propagate, modal dispersion arises.

Furthermore, bandwidth is constrained due to modal dispersion, resulting in decreased data rates.

2.2.3 The Propagation of Light through Optical Fiber

Fiber optics is the scientific study of how light travels through transparent optical fibers to reach its destination. Fiber optic cables direct light based on the properties of the light and the structure of the optical fibers. An optical cable transmitting light energy is called a wave motion in fiber optics. The term "wave motion" refers to the movement of a recurring disturbance over space, whether or not it is accompanied by a physical medium.

2.2.4 Reflection and Refraction of light in Fiber Optic

There are several components that go into optical fiber. A fiber optic cable is made up of a core, an outer jacket, a cladding, a buffer coating, and a strength member. The optic core is the light-carrying element in the center.

Because of complete internal reflection, light can only enter an optical fiber if it travels through it. An optical fiber has a core that carries light and a cladding around it that traps light in the core. Glass fibers are shielded from the elements by a plastic buffer coating, which also makes splicing and terminating easier.



Figure 2-6 The Total Internal reflection in Fiber Optic Cable

It is possible to bend light by changing the glass refractive index, which is a measurement of the material's light speed (3x108 m/s). Beyond a certain angle, light is refracted and reflected back from the surface. By choosing core and cladding materials with an adequate index of refraction, optical fibers are able to transmit light in the core by using this reflection.

The angle at which a fiber's internal reflection is complete may be determined for each individual fiber. This means that a narrow beam of light will not be able to reflect into the core. Because of this, the fiber's coating will bury it. However, if it falls below that angle, it will be reflected into the fiber's core and transported to the fiber's end. The angle of total internal reflection, a typical fiber metric, is used to determine the numerical aperture of fibers.

2.2.5 Total internal Reflection – Step Index Multimode Fiber

One kind of optical material makes up the core and cladding of a step-index multimode fiber, whereas another type of optical material has varying optical characteristics. Many applications cannot benefit from this core's dispersion because it is too slow and attenuated due to its varying route lengths for the various modes. Step index multimode fiber has a high total internal reflection, as seen in figure 2.7.



Figure 2-7 The Total Internal reflection in Step Index Multimode Fiber

2.2.6 Various Type of Fiber Optic Sensor

The telecommunications industry has grown considerably as a result of recent advances in fiber-optic technology. The ability to transmit gigabit data at the speed of light improved optical fiber's research potential. Optoelectronic components have advanced rapidly and cost-effectively, resulting in new devices. Fiber optic sensors have been developed in the last revolution by linking optical fibers with optoelectronic components. External disturbances' phase, intensity, and wavelength might be detected fast due to the lack of material losses and the improved sensitivity to them. Fiber optic sensors were created as a consequence.

Optoelectronic and fiber optic sensor technology has been one of the most important in recent years. Fiber optic sensors were originally meant to be used in these places, and many of the components used were originally designed for that purpose. Fiber optic sensor technologies were often advanced via the development and subsequent mass manufacture of components for these firms. Fiber optic sensors have become more popular as the cost and quality of componentry has decreased.

2.2.7 Evanescent wave sensors

Many forms of intensity modulated Fiber Optic Sensors may be made using exponentially fading evanescent fields around the cladding region of a fiber optics (FOS). Physically changing the fiber, such as removing etching from the cladding, creating a taper, or bending the fiber to allow contact of the evanescent field with the target object, may be used to absorb evanescent waves in an external medium. The fiber structures are then coated with a species-specific overlay that reacts to an external measure, in this case humidity variations, after they have been physically deformed. This enables relative humidity to be measured. Corres et al. demonstrated a single-mode tapered fiber coated with a [PDDA/Poly R-478] nanostructured overlay, with the overlay thickness modified to improve the sensor's sensitivity by stopping the deposition process when the transmitted signal's maximum slope was attained. Figure 2.8 shows the inside structure of the relative humidity sensor.



Figure 2-8 ESA overlay on a taper humidity sensor structure

With a reaction time of 300ms and relative humidity fluctuations ranging from 75% to 100%, an optical power fluctuation of 16 dB was achieved for changes in relative humidity from 75% to 100%. The sensor was developed for applications such as human breathing monitoring,

the control of highly humidity-dependent chemical processes, and weather prediction because of its fast response (compared to many other relative humidity sensors), high dynamic performance, and low-temperature cross sensitivity. Figure 2.9 shows the specifications of the sensor system for variable relative humidity, as well as the results of a capacitive relative humidity sensor that is commercially available.





Figure 2-9 Tapered fiber sensor relative humidity step response compared to commercial capacitive relative humidity sensor

Mathew et al. recently proposed another evanescent wave-based sensor for human breathing monitoring, which utilized a buffer-stripped bent SMF with resonant peaks in the transmission response owing to cladding mode coupling. This response oscillates in terms of bend radius and wavelength, and it also changes with ambient RI. The coupling conditions will vary if the bent fiber's surrounding RI is modified, leading in a shift in the wavelength of the resonant peaks. To cover the bend that is sensitive to relative humidity, the hydroscopic polymer Polyethylene Oxide (PEO) was utilized. To improve humidity sensor sensitivity, a high bend loss fiber (1060XP) with a bend radius of 15 mm was used. The experimental apparatus, as well as the coated fiber bed, are shown in Figure 2.10.



Figure 2-10 The Humidity Response Experimental Setup

Although the sensor was tested against relative humidity levels ranging from 30% to 90%, there was no discernible wavelength attenuation band below 85% relative humidity. Because the RI of the coated PEO film was higher than that of the cladding, the PEO coating acted as an absorption layer. However, once the surrounding relative humidity rises over 85%, mode coupling causes relative humidity resonant dips in the transmission spectrum, which suffer a redshift as relative humidity rises.



Figure 2-11 Continuous human breathing response of the sensor

To demonstrate the sensor's use as a breath rate monitor, it was positioned 2 cm from the nose tip and the sensor's subsequent breath relative humidity response was recorded for 1 minute, as shown in Figure 2.11.

For the intended application, a reasonable sensor recovery time and accuracy were obtained. The same group proposed an intriguing evanescent field relative humidity sensor in a U-bend arrangement using humidity-sensitive Agarose coating on an SMF. Figure 2.12 shows the sensor response to a step-change in relative humidity.



Figure 2-12 The step-change in relative humidity.

2.2.8 Fabry-Perot Interferometric sensors

Optical interferometry is a powerful method for producing high-quality fiber optic sensors in optical fiber sensing. Fiber optic interferometric sensors frequently provide geometric variety in terms of sensor design and high measurement sensitivity, in addition to the advantages of fiber optics. The sensing mechanism is based on an external environment disrupting the phase properties of the light signal going through the optical cable. To detect phase shifts, the signal of interest must be combined with a reference signal, which turns the phase difference between the two signals into an optical intensity shift. The suggested sensor architecture comprises of a thin film Fabry Perot interferometer constructed at the optical fiber tip, as shown in Figures 2.13 and 2.14.



Figure 2-13 Moisture ingress rate measurement using Fiber Bragg grating humidity sensors



Figure 2-14 Sensor measurements
The interference of optical signals reflected by the mirror at both ends of the cavity induces a spectrum response that produces maximum intensity output at specified wavelengths (resonances). The free spectral range (FSR), which is defined by separates these multiple resonances;

$$\lambda FSR = \frac{c}{2nd}$$

c = speed of the light

n = cavity's refractive index

d = cavity length



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As shown in Figure 2.15, the Fabry–Perot cavity was made by sandwiching a layer of titanium dioxide between two partly reflecting mirrors, with the cavity thickness chosen for operation at the wavelength of the input diode laser source.

Because humidity affects the refractive index of the cavity material, the resonance shifted in response to variations in humidity, which may be readily determined by measuring intensity at a given wavelength. To correct the sensor's cross-sensitivity to temperature, an appropriate compensation approach may be applied. It did, however, respond quickly between 0 and 80 percent relative humidity, with a reaction time of under a minute. A standard multilayer thin film interferometric cavity was created by stacking bilayers of alternating cationic and anionic polymers at the fiber tip. The ISAM technique was used to do this, which allows for exact control of cavity length and material composition for each coating layer.

Sensors with a cavity length (or number of bilayers) tailored for a certain operating wavelength have been shown to function in a broad variety of humidity conditions. With a response time of less than a few seconds, the sensor has been suggested as a potential diagnostic tool for monitoring human breathing.

2.3 Comparison of Research Papers

	QQ			
No	Title	Author	Source	Remark
1	The Phenomenon of Total	[1]	Fiber Optic	Refraction and
	Internal Reflection and		Communication	Reflection
	Acceleration of Light in			
	Fiber Optics			
2	Advances in Fiber Optics	[2]	Fiber optic	
	ل سیسیا سرے		Communication	9
			1.0	
3	An Introduction to Fiber	[3]KAL MAL	Fiber Optic	Introduction to
	Optic		Communication	Fiber Optic
4	Fiber Optic Sensors And	[4]	Fiber optic	Application of
	Their Applications		sensor	Fiber Optic
				Sensor
5	Recent Developments in	[5]	Fiber optic	The new
	Fiber Optics Humidity		sensor	technology of
	Sensors			fiber optic
				sensor
6	Intrinsic Fiber-optic	[6]	Fiber optic	Intrisic and
	Sensors		Sensor	Extrisic Sensor.
7	Fiber-Optic Sensors for	[7]	Fiber optic	Fiber-Optic
	Biomedical Applications		sensor	Sensors in
				Medical
				Industry

 Table 2-1 Literature Review

8	Fibre-optic sensor	[8]	Fiber optic	Development of
	technologies for humidity		sensor	fiber optic
	and moisture			humidity sensor
	measurement.			
9	A Highly Stable Optical	[9]	Fiber optic	Development of
	Humidity Sensors Based		sensor	fiber optic
	On Nano-Composite Film			humidity sensor
10	Characterization of a fiber	[10]	Fiber optic	Characterization
	optic sensor based on		sensor	of Fiber Optic
	LSPR and specular			Sensor
	reflection			
11	High Sensitivity Humidity	[11]	Fiber optic	Humidity
	Fiber-Optic Sensor Based		sensor	sensors based
	on All-Agar Fabry–Perot			on Fabry–Perot
	Interferometer			Interferometer
12	A Study of Relative	[12]	Fiber optic	Development of
	Humidity Fiber Optic		sensor	fiber optic
	Sensors			humidity sensor



No	Title	Author	Source	Remark
13	Fiber-optic Fluorosensor	[13]	Fiber optic	Development of
	for Oxygen and Carbon		sensor	fiber optic
	Dioxide			Gasses sensor
14	Whispering gallery modes	[14]	Fiber optic	Development of
	on optical micro-bottle		sensor	fiber optic
	resonator			humidity sensor

2.4 Summary

Fiber optic sensing technology, in addition to having various advantages over conventional sensing technologies, is a potential alternative to traditional moisture/humidity monitoring. As a result, the review concludes with a thorough examination of the different optical fiber sensing technologies used in the research for humidity monitoring. Finally, it's a good idea to go at the different extrinsic and intrinsic techniques that have been published over the years, with many of them focusing on sensory qualities gained in a lab setting.

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CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will go through the techniques for completing the project's goal in great detail. The technique for stripping the fiber optic cable, splicing the fiber optic cable, and characterization of the fiber optic sensor will also be covered. This chapter will go through the general method for completing the project as well as how to overcome obstacles in order to meet the project's goal. The project's whole workflow is shown in Figure 3.1.

3.2 Flow of Project



goal:

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- i) Look for a title that's related to the subject matter you're researching.
- ii) Use diaries, webpages, and chats with the project supervisor to gather information.
- iii) Collecting the crucial information from variety of books.
- iv) Thinking this project may apply similar tactics to the one that was effective in the past.
- v) Selecting the original materials for my project.

- vi) This project's criteria and equipment, as well as the procedure of stripping and splicing the fiber optic cable, should be discussed with the supervisor.
- vii) Make a sensor out of the mentioned items.
- viii)Based on the results of humidity level tests in various kinds of environments, develop a humidity fiber optic sensor.
- ix) Analysis of sensor testing to determine the sensitivity and effectiveness of the humidity sensor in determining the degree of humidity in a variety of environments.
- x) Inspect the output obtained from the sensor.
- xi) Conduct an analysis of the data gathered from the humidity sensor in order to see if there is any potential for the sensor's credibility and reliability to be improved.xii) In this study, the results obtained were compared with those acquired from other types of sensors, including classic electric sensors and other types of humidity

sensors.

- xiii) Putting together a proper report.
- xiv) To document the full process of producing a humidity sensor for the medical market using optical microfiber. The data is recorded to guarantee that the optical fiber humidity sensor can accurately detect humidity levels in accordance with medical industry standards.



Figure 3-1 The Flow Chart of development of humidity sensor by optical

microfiber for medical industry

3.2.1 Stripping and cleaving of fiber optic cable

For fusion splicing, the protective polymer covering surrounding optical fiber is stripped away. The preparation of both fiber ends for fusion, which comprises removing or stripping all protective covering from the ends of each fiber, is the first step in the splicing method. Fiber optics may be stripped of their coating using a specific stripping tool. Stripping fiber using mechanical devices is similar to stripping copper wire with copper wire strippers. Figure 3.2 depicts the fiber optic cable stripping procedure.



Figure 3-2 Stripping process for fiber optic cable.

The most common technique for joining two optical fibers is a mechanical splice, also known as a fusion splice. For optical fiber splicing methods, the fiber tips must have a smooth end face perpendicular (90°) to the fiber axis, as illustrated below. Furthermore, an optical fiber cleaver is a tool used in the fiber optic industry to cut (or cleave) the fiber in a clean 90° cut. Figures 3.3 and 3.4 depict the mechanical cleaver of fiber optic cable, as well as the distinctions between a good and poor cleaving approach.



Figure 3-3 Cleaver tools for fiber optic cable.



Figure 3-4 The differences between a good and bad cleaving technique.

3.2.1.1 Fiber Optic Cable Splicing Procedure

Splicing two fiber optic cables together is known as fiber optic splicing. As a consequence, when properly installed, the new cable can transfer data at the same speed and efficiency as a regular fiber optic link. Although mechanical splicing is less costly than fusion splicing, fusion splicing is more durable. Using the fusion technique, the fiber cores are fused with minimal attenuation and insertion loss of less than 0.1dB. The fusion splicing machine is seen in Figure 3.5.



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Figure 3-5 Fujikura Fusion Splicing Machine

The two fiber ends are perfectly aligned using specialist fusion splicer equipment. In the fusion splicing procedure, the fiber ends are fused or welded together using an electric arc or another kind of heat. As a consequence, the fibers are connected in a clear, nonreflective, and continuous manner, allowing for reduced light loss. Figure 3.6 depicts a fusion splicing machine splicing approach.



To begin, properly line the two strands. Second, produce a small electric arc to melt the fibers and weld them together to splice single-mode and multimode fiber cables. Fusion splicing provides a number of benefits, including lower splicing loss (approximately 0.1dB) and reduced back reflection. The splicing method and loss in the splicing process are shown in Figures 3.7 and 3.8, respectively.







Figure 3-8 Fiber cable spliced successfully with 0 loss.



Figure 3-9 Fiber cable spliced successfully with 0 loss.

The spliced cable will next be carefully put within a container, as illustrated in Figure 3.9 above. The weather, the amount of light available, and neighboring heat sources all influence the amount of moisture in the container. As a consequence, the container walls may grow chilly, but the air within the container may stay the same or warm up. The humidity controller in this instance was a dehumidifier agent, such Calcium Chloride (CaCl2), and the data was collected throughout the observation. Figure 3.10 depicts the optical fiber Humidity Sensor setup.



Figure 3-10 The setup for Humidity Sensor by optical fiber



3.2.1.2 Tapering Technique

Figure 3-11 Burning the fiber with tapering technique

In the tapering technique, the Oxygen and Hydrocarbon (Propane and Butane) are being controlled to the best shape of flames in order to burn the fiber perfectly. The tapering devices also controlled the position of fire handler for going front or back. Figure 3.11 shows that the fiber almost completely burnt. In addition, the fiber will break up if it been fired for too long. The tapering technique need highest precaution in order to get the best thin microfiber. The result after the tapering technique is given in figure 3.12.



Figure 3-13 Observing the size of fiber

To get to know better the size of microfiber after the tapering process, it should be measured on microscope. The microfiber need to be under the light of microscope in order to get the measurement and then it need to center by adjusting the x-axis, y-axis and z-axis of position of the light. Right when the thinnest part found, the axes (X,Y and Z) will be reset to zero and it automatically captured the ideal sizing of the microfiber. Figure 3.14 shows that the result of the size of a microfiber. The size obtained is 7.8 μ m from its original size which is 125 μ m.



3.2.1.4 The Characterization of Fiber Optic Cable

It is necessary to verify the fiber line before checking the sensor. The insertion loss, optical return loss, polarization, and dispersion of a fiber cable may be measured to evaluate whether it can carry transmission and to provide a standard for debugging and troubleshooting.

3.2.1.5 Limitation of proposed methodology

In fiber optics, dirty connections are a major problem, causing high connection loss, high reflectivity, and transceiver contamination. Dirty connections are said to be the cause of 50% of all network failures, according to network operators.

The pigtail connection surface is cleaned with 99 percent isopropyl alcohol and a lint-free wipe to ensure there is no contamination. Isopropyl alcohol (IPA) is a solvent that may be used to remove most oily impurities and was shown to be harmless to the fiber termination epoxies. The contrast between a polluted and a clean pigtail connection is shown in Figure 3.11.



Figure 3-15 The Comparison Between Contaminated And Clean Pigtail Connector

3.2.1.6 Insertion Loss

Using a Power Meter and Light Source combination to provide end-to-end loss measurements on an optical span, including fiber attenuation and the starting and end connections of the fiber under examination, is the most precise method (Loss Test Set). The Insertion Loss Test is shown in Figure 3.12.



Figure 3-16 Power Meter and Light Source Test

A power meter and a light source are used to send continuous-wave light from the source to the power meter. The difference in power is what causes the total span decrease. By launching power into the fiber or cable under test and measuring the loss at the other end using a power meter, an insertion loss test simulates link operating conditions.

3.2.1.7 Optical Return Loss (ORL)

Optical return loss is the ratio of the light source's output power to the total amount of back-reflected power (reflections and scattering). According to the definition, it is a positive amount. ORL may be used to calculate the amount of total light reflected into the transmitter by a fiber and its components, such as connector pairs, mechanical fusion splices, and so on. It may also be used to determine a fiber plant's overall efficiency by reading light that does not reach the opposite end of the fiber. The direction of light reflected into the transmitter from the receiver is seen in Figure 3.13.



Figure 3-17 The direction of light reflected back into the transmitter

Reflective occurrences include all connection pairs and mechanical splices. The higher the ORL value, the better the reflections in the test fiber; the higher the ORL value, the better the reflections in the test fiber. The purpose of this test is to identify areas with reflectance issues.

3.2.1.8 Polarization Mode Dipersion UNIVERSITI TEKNIKAL MALAYSIA MELAKA

PMD (Polarization Mode Dispersion) refers to the difference in arrival time of several polarization components of an input light pulse sent across an optical connection. At any point, this light pulse may be divided into two orthogonal polarization modes. Because of the refractive index of the fiber, it creates a slow and fast axis, these polarization modes propagate at different speeds. The difference in arrival time is seen in Figure 3.14.



Figure 3-18 The Differential of Arrival Time

3.2.1.9 Chromatic Dipersion Test

Because of the non-zero spectral breadth of transmitters, chromatic dispersion occurs when different wavelengths travel at different speeds. Because transmitters are made up of several wavelengths moving at different speeds, the difference in arrival time of each wavelength causes pulse spreading or dispersion. This phenomena is measured using the ps/nm scale. Longer wavelengths going faster cause chromatic dispersion in the fiber, as seen in Figure 3.15.



Figure 3-19 Longer wavelength travelling faster induce chromatic dispersion in the fiber

Two variables induce chromatic dispersion: material dispersion and waveguide dispersion. Material dispersion is caused by differences in a material's index of refraction throughout wavelength. Waveguide dispersion is more difficult to understand. Light flowing through a single-mode fiber travels in an area that exceeds the diameter of the core because the wavelength of light is not bigger than the diameter of the core. As a result, longer wavelengths pass through a larger mode field diameter, whereas shorter wavelengths go through a smaller field diameter.

By capturing traces at multiple distinct wavelengths and computing Chromatic Dispersion from the data acquired from the traces, the OTDR test approach permits testing in the field from one end of the cable.

3.2.1.10 The Characterization of Fiber Optic Sensor

Fiber optic sensor characterization is a collection of tests carried out on a fiber optic sensor to ensure its integrity, installation processes, and performance in a given environment. This is important because, as data rates increase and systems get more complex, a variety of factors may decrease system performance.

To monitor humidity, a fiber-optic humidity sensor (FOHS) based on an optical time-domain reflectometer (OTDR) was created. The detecting probe of a fiber optic humidity sensor is made up of a single-mode optical fiber and a moisture-sensitive substance that alters its refractive index in response to relative humidity. The moisture-sensitive material was deposited onto the end of the fiber using the dip coating process.

Due to Fresnel reflection between the sensor material and the single-mode fiber, the optical power of the OTDR varies with relative humidity. To improve the fiber optic humidity sensor, it is recommended to examine the change in optical power according to the contents of the laser source's moisture-sensitive material and wavelengths. As a consequence, the moisture-sensitive material, as well as the sensor's sensitivity level, will decide the humidity reading.

3.2.1.11 Equipment Used for the Experiment

In most situations, these equipment are used to conduct an experiment or take measurements while collecting data.





Figure 3-21 Optical Spectrum Analyzer



Figure 3-22 Fiber Pigtail (2 pieces)



Figure 3-24 Stripper / Cutter



Figure 3-25 Cleaver



Figure 3-27 Calcium Chloride (CaCl2)

3.3 Summary

The methods employed to fulfill the project's goal is described in depth in this chapter. In addition, the general technique for completing the project and methods for overcoming obstacles to attain the project's goal are covered in depth.



CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter discussed the findings and data collected during the creation of an optical microfiber humidity sensor for use in the medical field. A variety of tests are used to show how well the project performs. The sensitivity and linearity of the sensor, as well as the results of the tests, the sensor's capabilities, and repeatability of operation, will all be evaluated. It's important to note that the goal of these tests is to help with the sensor's development.

UTeM

4.2 Results and Analysis

In the experiment, two single-mode fiber pigtails coupled at the splice with a length of an unclad section in the middle of the transmission are used to transmit a modulated light source to an optical time domain reflectometer (OTDR). Because some light particles would evaporated from the optical cable's core, the transmission from the light source would be unequal. This study used two different wavelengths, 1310nm and 1550nm. The duration of this investigation might range from one minute to seven minutes. The outcomes will change based on the humidity level employed.

4.2.1 100% of Humidity (no Calcium Chloride) tested on wavelength of 1310nm & 1550nm wavelength

	Output power of 100% Humidity (dBm)		
Time(min)	1310nm	1550nm	
1	-31.06	-36.02	
2	-37.00	-36.45	
3	-39.95	-36.52	
4	-40.47	-36.57	
5 MAL	-40.73	-36.57	
6 10 10	-40.88	-36.59	
17	-40.97	-36.61	
2			

Table 4-1 Shows the data collected at 100% humidity



Figure 4-1 Graphs shown above are outputs at 100% Humidity

The table 4.1 shows slightly decreases on both wavelength (1310nm and 1550nm). As for 1310nm, there is greater decrease than on 1550nm which is -31.06 dBm to -40.97 dBm while for 1550nm wavelength only slightly decreases from -36.02 dBm to -36.61 dBm.

From figure 4.1, the graph showed that 1310nm has the gradient of -1.3668 and for 1550nm is -0.075. Hence, the 1310nm wavelength has better sensitivity at 100% humidity.

4.2.2 90% of humidity (1 piece calcium chloride) tested on wavelength of 1310nm & 1550nm wavelength

	Output power of 90% Humidity (dBm)			
Time(min)	1310nm	1550nm		
1	-30.95	-34.82		
2 MAL	-45.19	-34.82		
33	-46.50	-36.54		
1 4 E	-46.95	-36.54		
5.34/40	-47.33	-36.82		
ا مالاك	Junio 147.54	اوىيۇم سىخ ز		
		-36.84		

Table 4-2 Shows the data collected at 90% humidity



Figure 4-2 Graphs shown above are outputs at 90% humidity

The table 4.2 shows slightly decreases on both wavelength (1310nm and 1550nm). As for 1310nm, there is greater decrease than on 1550nm which is -30.95 dBm to -47.54 dBm while for 1550nm wavelength only slightly decreases from -34.82 dBm to -36.84 dBm. From figure 4.2, the graph showed that 1310nm has the gradient of -1.975 and for 1550nm is - 0.3693. Hence, the 1310nm wavelength has better sensitivity at 90% humidity.

4.2.3 80% of humidity (2 pieces calcium chloride) tested on wavelength of 1310nm & 1550nm wavelength

UNIVER	Output power of 80% Humidity (dBm) SITI TEKNIKAL MALAYSIA MELAKA			
Time(min)	1310nm	1550nm		
1	-45.75	-30.92		
2	-48.01	-38.16		
3	-48.77	-38.98		
4	-49.11	-39.41		
5	-49.47	-39.49		
6	-49.58	-39.61		
7	-49.62	-39.67		

Table 4-3 Shows the data collected at 80% humidity



Figure 4-3 Graphs shown above are outputs at 80% humidity

The outputs that have been gained are then insert into the table and graphs for 1310nm and 1550nm wavelength. From the table 4.3, it shows that 1550nm wavelength has greater decreases which is from -30.92 dBm to -39.61 dBm than at 1310nm wavelength. On figure 4.3, the 80% humidy it is not simillar at 100% and 90% of humidity because this time light source of 1550nm is more sensitivity. The gradient of 1550nm is -1.0593 while for 1310nm is -0.5518. This section includes data that was gathered across a range of periods, from one minute to seven minutes.

4.2.4 70% of humidity (3 pieces calcium chloride) tested on wavelength of 1310nm & 1550nm wavelength

	Output power of 70% Humidity (dBm)		
Time(min)	1310nm	1550nm	
1	-44.59	-37.32	
2	-44.91	-37.76	

Table 4-4 Shows the data collected at 70% humidity

3	-45.08	-37.86
4	-45.15	-37.95
5	-45.15	-37.97
6	-45.20	-38.01
7	-45.26	-38.03



Figure 4-4 Graphs shown above are ouputs at 70% humidity

The outputs that have been gained are then insert into the table and graphs for 1310nm and 1550nm wavelength. From the table 4.4, it shows that 1550nm wavelength has slightly decreases which is from -37.32 dBm to -38.03 dBm than at 1310nm wavelength. On figure 4.4, the gradient of 1550nm is -0.0979 while for 1310nm is -0.095. This section includes data that was gathered across a range of periods, from one minute to seven minutes.

4.2.5 60% of humidity (4 pieces calcium chloride) tested on wavelength of 1310nm & 1550nm wavelength

	Output power of 60% Humidity (dBm)		
Time(min)	1310nm	1550nm	
1	-44.75	-33.80	

Table 4-5 Shows the data collected at 60% humidity
--

2	-45.02	-36.07
3	-45.21	-36.36
4	-45.27	-36.43
5	-45.27	-36.48
6	-45.33	-36.50
7	-45.40	-36.52



Table 4.5 shows data collected at 60% humidity and it showing slightly decreasing in power (dBm) for both wavelength (1310nm and 1550nm). The difference between 1st reading and 7th reading is 0.65 for 1310nm while for 1550nm is 2.72. Apart from that, Figure 4.5 shows the graph of both wavelength and the gradient for 1310nm is -0.0939 while -0.3264 for 1550nm. Hence, the 1550nm is more sensitive than 1310nm.

4.2.6 50% of humidity (5 pieces calcium chloride) tested on wavelength of 1310nm & 1550nm wavelength



Table 4-6 Shows the data collected at 50% humidity

Figure 4-6 Graphs shown above are ouputs at 50% humidity

Table 4.6 shows Output power (dBm) versus Time (min) respectively. For 1310nm the data obtained from -44.75 until -45.40. The difference for 1st and 7th data is 0.65 (dBm). While for 1550nm the data obtained from -33.80 until -36.52. The difference for 1st and 7th data is 2.72. From Figure 4.6, for 1310nm the gradient is -0.0771 while -0.2993 for

1550nm. Hence, the sensitivity for 1550nm wavelength is greater than 1310nm wavelength.

4.2.7 Comparison

Table 4-7 The data comparison between 1310nm and 1550nm with different Humidity

	1310nm		1550nm	
Humidity(%)	Sensitivity (dBm)	Linearity (%)	Sensitivity (dBm)	Linearity (%)
100	-1.3668	80.87	-0.0750	77.95
90	-1.9750	70.37	-0.3693	85.59
80	-0.5518	86.04	-1.0593	71.95
70	-0.0950	89.04	-0.0979	84.99
60	-0.0939	90.97	-0.3264	71.07
<mark>5</mark> 0	-0.0771	92.07	-0.2993	71.46

The table 4.7 shows that the study's findings for various humidity percentages are presented. The output power levels for each optical light source, which are 1310nm and 1550nm, are displayed in Table 4.7. This table shows that 90% humidity is more sensitive than other humidity percentages at 1310nm, reaching a maximum value of -1.9750. At 80% humidity, the usage of an optical light source at a wavelength of 1550 nm is more sensitive than the other, which has a sensitivity of -1.0593.

4.3 Interaction for Humidity against Time

This section includes data that was gathered across a range of periods, from one minute to seven minutes.

4.3.1 1310nm and 1550nm wavelength observed for 1 minute



Table 4-8 Shows obtained data at 1 minute

Figure 4-7 Graph show results obtained at 1 minute

From the table 4.8, the output power of 1 minute is compared between 1310nm and 1550nm wavelength. The percentage of humidity used are 100%, 90%, 80%, 70%, 60%, and 50%. For 1310nm wavelength, the data obtained is decreases from -31.06 dBm at 100% humidity to -44.73 dbm at 50% humidity. As for 1550nm wavelength, the results shows

increases from -36.02 dBm at 100% humidity to -34.21 dBm at 50% humidity. Next, Figure 4.7 is the graph shows obtained at 1 minute and the gradient for 1310nm wavelength is 0.3103 while for 1550nm wavelength is -0.0163.

4.3.2 1310nm and 1550nm wavelength observed for 2 minutes

	Output power of 2 minutes (dBm)	
Percentage of	1310nm	1550nm
Humidity (%)		
100	-37.00	-36.45
90	45.19	-34.82
80	-48.01	-38.16
70	-44.91	-37.76
60	-45.02	-36.07
50	-44.98	-36.29
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Table 4-9 Shows obtained data at 2 minutes



Figure 4-8 Graph show results obtained at 2 minutes
From the table 4.9, the output power of 2 minutes is compared between 1310nm and 1550nm wavelength. The percentage of humidity used are 100%, 90%, 80%, 70%, 60%, and 50%. For 1310nm wavelength, the data obtained is decreases from -37.00 dBm at 100% humidity to -44.98 dbm at 50% humidity. As for 1550nm wavelength, the results shows slightly increases from -36.45 dBm at 100% humidity to -36.29 dBm at 50% humidity. Next, Figure 4.8 is the graph shows obtained at 2 minutes and the gradient for 1310nm wavelength is 0.1037 while for 1550nm wavelength is 0.0073.

4.3.3 1310nm and 1550nm wavelength observed for 3 minutes

	ALACTON ALA	
E.	Output power of 3	3 minutes (dBm)
Percentage of	1310nm	1550nm
Humidity (%)		
100	-39.95	-36.52
90 -	يېيىيى 46.50 يېيىيى مەر	-36.54 J
80 UN	IVERSITI T48,771IKAL MALAY	(SIA ME-38.98A
70	-45.08	-37.86
60	-45.21	-36.36
50	-44.98	-36.56

Table 4-10 Shows obtained data at 3 minutes



Figure 4-9 Graph show results obtained at 3 minutes

From the table 4.10, the output power of 3 minutes is compared between 1310nm and 1550nm wavelength. The percentage of humidity used are 100%, 90%, 80%, 70%, 60%, and 50%. For 1310nm wavelength, the data obtained is decreases from -39.95 dBm at 100% humidity to -44.98 dbm at 50% humidity. As for 1550nm wavelength, the results shows slightly increases from -36.52 dBm at 100% humidity to -36.56 dBm at 50% humidity. Next, Figure 4.9 is the graph shows obtained at 3 minutes and the gradient for 1310nm wavelength is 0.0503 while for 1550nm wavelength is -0.0042.

4.3.4 1310nm and 1550nm wavelength observed for 4 minutes

	Output power of 4	4 minutes (dBm)
Percentage of	1310nm	1550nm
Humidity (%)		
100	-40.47	-36.57
90	-46.95	-36.54

Table 4-11 Shows obtained data at 4 minutes

80	-49.11	-39.41
70	-45.15	-37.95
60	-45.27	-36.43
50	-45.17	-36.56



Figure 4-10 Graph show results obtained at 4 minutes

From the table 4.11, the output power of 4 minutes is compared between 1310nm and 1550nm wavelength. The percentage of humidity used are 100%, 90%, 80%, 70%, 60%, and 50%. For 1310nm wavelength, the data obtained is decreases from -40.47 dBm at 100% humidity to -45.17 dbm at 50% humidity. As for 1550nm wavelength, the results shows slightly increases from -36.57 dBm at 100% humidity to -36.56 dBm at 50% humidity. Next, Figure 4.10 is the graph shows obtained at 4 minutes and the gradient for 1310nm wavelength is 0.0414 while for 1550nm wavelength is -0.0053.

4.3.5 1310nm and 1550nm wavelength observed for 5 minutes

Output powe	er of 5 minutes (dBm)
1310nm	1550nm

Table 4-12 Shows obtained data at 5 minutes

Percentage of		
Humidity (%)		
100	-40.73	-36.57
90	-47.33	-36.82
80	-49.47	-39.49
70	-45.15	-37.97
60	-45.27	-36.48
50	-45.16	-36.64



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From the table 4.12, the output power of 5 minutes is compared between 1310nm and 1550nm wavelength. The percentage of humidity used are 100%, 90%, 80%, 70%, 60%, and 50%. For 1310nm wavelength, the data obtained is decreases from -40.73 dBm at 100% humidity to -45.16 dbm at 50% humidity. As for 1550nm wavelength, the results shows slightly decreases from -36.57 dBm at 100% humidity to -36.64 dBm at 50% humidity. Next, Figure 4.11 is the graph shows obtained at 5 minutes and the gradient for 1310nm wavelength is 0.0333 while for 1550nm wavelength is -0.0063.

4.3.6 1310nm and 1550nm wavelength observed for 6 minutes

	Output	power of 6 minutes (dBm)
Percentage of	1310nm	1550nm
Humidity (%)		
100	-40.88	-36.59
90	-47.54	-36.82
80	-49.58	-39.61
70	-45.20	-38.01
60	HALAYSIA -45.33	-36.50
50	-45.19	-36.69
TIM		
6 mi -36 -37 -38 -38 -39 -40	nutes at 1550nm V = -0.0059x - 36.929 R ² = 0.008	6 minutes at 1310nm 0 -20 y = 0.0301x - 47.879 R ² = 0.0375 -40 -60
0	50 100 150 HUMIDITY (%)	-30 20 70 120 HUMIDITY (%)

Table 4-13 Shows obtained data at 6 minutes

Figure 4-12 Graphs show results obtained at 6 minutes

From the table 4.13, the output power of 6 minutes is compared between 1310nm and 1550nm wavelength. The percentage of humidity used are 100%, 90%, 80%, 70%, 60%, and 50%. For 1310nm wavelength, the data obtained is decreases from -40.48 dBm at 100% humidity to -45.19 dbm at 50% humidity. As for 1550nm wavelength, the results shows slightly decreases from -36.59 dBm at 100% humidity to -36.69 dBm at 50% humidity. Next, Figure 4.12 is the graph shows obtained at 6 minutes and the gradient for 1310nm wavelength is -0.0059 while for 1550nm wavelength is 0.0301.

4.3.7 1310nm and 1550nm wavelength observed for 7 minutes

	ALC: UTA	
E.	Output power of '	7 minutes (dBm)
Percentage of	1310nm	1550nm
Humidity (%)		
100	-40.97	-36.61
.1.		+ +
90 -	يېڭنىڭ 47.54مايسىيا مال	-36.84
80 UN	IVERSITI T ^{49.62} IIKAL MALA	(SIA MEL ^{39.67} A
70	-45.26	-38.03
60	-45.40	-36.52
50	-45.25	-36.71

Table 4-14 Shows obtained data at 7 minutes



Figure 4-13 Graphs show results obtained at 7 minutes

From the table 4.14, the output power of 7 minutes is compared between 1310nm and 1550nm wavelength. The percentage of humidity used are 100%, 90%, 80%, 70%, 60%, and 50%. For 1310nm wavelength, the data obtained is decreases from -40.97 dBm at 100% humidity to -45.25 dbm at 50% humidity. As for 1550nm wavelength, the results shows slightly decreases from -36.61 dBm at 100% humidity to -36.71 dBm at 50% humidity. Next, Figure 4.13 is the graph shows obtained at 7 minutes and the gradient for 1310nm wavelength is 0.0303 while for 1550nm wavelength is -0.006.

4.3.8 Comparison UNIVERSITI TEKNIKAL MALAYSIA MELAKA

	131	.0nm	1550nm									
Time	Sensitivity (dBm)	Linearity (%)	Sensitivity (dBm)	Linearity (%)								
1	0.3103	80.44	-0.0163	14								
2	0.1037	52.17	0.0073	11.22								
3	0.0503	32.45	-0.0042	7.35								
4	0.0414	27.2	-0.0053	8.19								
5	0.0333	21.45	-0.0063	9.78								
6	0.0301	19.36	-0.0059	8.94								
7	0.0303	19.67	-0.0060	9								

Table 4-15 The data comparison between 1310nm &1550nm with different Time

The results for sensitivity and linearity against different times for 1310 wavelength and 1550 wavelength are shown in the table 4.15 above. The data supposed to proof the development of the optic microfiber in this project. Hence it can be concluded that 1310nm wavelength at the 1st minute is proven for its sensitivity which is 0.3103. Although, for 1550nm the best sensitivity is also at 1st minute which is -0.0163.

4.4 Average

In the section of comparisons below, the typical output power value (dBm). In order to compare and ascertain which of these two wavelengths is more sensitive, data for each humidity (%) was collected in table 4.16 for optical light sources with wavelengths of 1310 nm and 1550 nm. Based on diagram 4.14, both gradients of optical light sources are displayed. The 1310 nm optical light source is ideal for creating a microfiber humidity sensor since it is more sensitive to humidity. This may be demonstrated by comparing the gradient value, which is 0.9063 to the wavelength of the optical light source at 1550 nm, which is -0.2074.

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	Average output power (dBm)													
Percentage of	1310nm	1550nm												
Humidity (%)														
100	38.72	36.48												
90	44.00	36.17												
80	48.62	38.03												
70	45.05	32.42												

Table 4-16 Results for average output power (dBm)

60	45.18	36.02
50	45.07	36.24



4.5 Summary UNIVERSITI TEKNIKAL MALAYSIA MELAKA

For chapter 4, it explained the data obtained and analyzed them by Humidity Sensor by Optical Fiber by comparing between two wavelength which are 1310nm and 1550nm. Calcium Chloride is the substance that had been used on this project measured at different humidity and times. The results gained are obtained after a few errors happened hence it supposed to be the best result that achieved on this experiments. The goal of the experiments are to know which fiber will lead the best accuracy in order to measure humidity. By measuring the sensitivity and linearity, also after observing the best average data gained, the hypothesis is accepted.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The Development of Optical Microfiber Sensor for Humidity Detection was summarized in this chapter. The project is based on past research and literature reviews from a number of institutions on the use of optical fiber as a sensor in the medical field. The medical sensor's development is critical since the medical business requires accurate technology to save lives. The optical fiber cable is stripped, cleaved, and spliced as part of the project's technique. To accomplish the project, all of the approaches listed above are used. This project compares the accuracy of sensitivity of the humidity sensor employing optical fiber using Calcium Chloride. Meanwhile, the dehumidifier agents are being compared in terms of their ability to absorb moisture and water molecules in a confined space. The information is then collected and assessed depending on the test's repeatability. In terms of repeatability, each test has three cycles, all of which are carried out in the identical conditions and surroundings.

The data from this study concludes that relative humidity can be determined utilizing humidity sensors through optical fiber, since a minor change in the humidity level can be noticed by the experiment at the conclusion of the project. However, before being finished as a successful fiber optic sensor project for the medical business, constructing a humidity sensor based on optical microfiber will require a lot of growth and refinement.

5.2 Future Works

The creation of a humidity sensor using optical microfiber for the medical business requires several improvements before it is ready for medical usage. Among the suggestions are the following:

- A study of numerous types of dehumidifiers in diverse locations and situations.
- The use of optical fiber to create a long-lasting container for a humidity sensor.
- An optical light source that can output light while maintaining a steady connection throughout time.

• The development of a sterile and uncontaminated fiber cable.

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APPENDICES



Appendix A Laboratory where we finishing the project

Appendix B Testing the after splice fiber to see if laser passing through along the fiber



Table 5-1 GANTT CHART

													A (GA	. P NT	ER/ T C	ANC HAI	CAN RT)	IGA	N P	RO	JEK	PR	OJE	СТ	PLA	NN	IING	i																		
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Finding articles, books, and journal as reference for Literature Review	х	x	x	x	>	C						IWS	KAN N								-					_																	II WS			_
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Study the procedure of stripping and splicing.			1	100	<u>}</u>)	¢	x	х	х		SEMI								4																							SEMIN			
Finding research about dehumidifer agent in fiber optic sensor.					4.	11	in				х		2	x	x																															
Start the process of stripping and splicing of fiber optic.			5	1	N									4	1		-		4	1									х	x	1															
Run the experiment with 2 different dehumidifier agent.				1				-		-		1	Y					1					- 1		ę	2			/	2	x	x	х	×	()	x	x	х								
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Final checking for the project																																								х	х	х				



Appendix C Example of Appendix B