Faculty of Electronics & Computer Technology and Engineering

DEVELOPMENT OF OPTICAL MICROFIBER SENSOR FOR GLUCOSE DETECTION

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Bachelor of Electronics Engineering Technology (Telecommunications) with Honours

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DEVELOPMENT OF OPTICAL MICROFIBER SENSOR FOR GLUCOSE DETECTION

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in partial fulfillment of the requirements for the degree of
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DEDICATION

Alhamdulillah, all praise to Allah.
I dedicate this report to my beloved parents, ijbarah Abdallah and Balsam Mustafa , 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 glucose detection. The objective of this project is to study the operation and performance of a glucose sensor using optical microfiber technology, to develop the glucose sensor and test its sensitivity and performance in various glucose concentration tests, and finally, to analyze the performance of the glucose sensor in different environments and experimental conditions.

For this project, the optical microfiber was successfully fabricated with a different wavelengths (1310 nm and 1550 nm) were used for testing.

The key findings of this project are the sensitivity and linearity of the sensor, determined by comparing the gradient values and R^2 based on the graph obtained from OTDR (Optical Time-Domain Reflectometer) measurements. By analyzing the comparison results, the ideal wavelength for glucose sensing can be determined. Hence, the study successfully fulfills its objectives.

ABSTRAK

Penyelidikan ini menerangkan pembangunan sensor mikrofiber optik yang berkesan untuk pengesanan glukosa. Objektif projek ini adalah untuk mengkaji operasi dan prestasi penderia glukosa menggunakan teknologi mikrofiber optik, untuk membangunkan penderia glukosa dan menguji kepekaan dan prestasinya dalam pelbagai ujian kepekatan glukosa, dan akhirnya, untuk menganalisis prestasi penderia glukosa dalam persekitaran dan keadaan eksperimen yang berbeza.

Untuk projek ini, gentian mikro optik telah berjaya dibuat dengan panjang gelombang yang berbeza (1310 nm dan 1550 nm) telah digunakan untuk ujian.

Penemuan utama projek ini ialah kepekaan dan lineariti sensor, ditentukan dengan membandingkan nilai kecerunan dan R^2 berdasarkan graf yang diperoleh daripada pengukuran OTDR (Optical Time-Domain Reflectometer). Dengan menganalisis keputusan perbandingan, panjang gelombang yang ideal untuk penderiaan glukosa boleh ditentukan. Justeru, kajian ini berjaya memenuhi objektifnya.

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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 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.

1.2 Problem Statement

High standards are set for product quality in the medical sector. The need for an accurate and durable sensors system has increased in recent years due to the significant growth in optical microfiber technology and applications in the medical field. The standard electrical sensor equivalent needs to be swapped out for a wireless, lightweight material with better performance in order to improve the quality of accurate measurements.

1.3 Project Objective

The goal of this project is to provide an efficient and acceptable method for evaluating glucose 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 glucose sensor by using optical microfiber technology.

b) To develop the glucose sensor using optical microfiber and testing its sensitivity and performance in several glucose level tests.

c) To analyze the performance of glucose Sensor using optical microfiber in different experiments

1.4 Scope of Project

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

a) Testing with various glucose concentration levels.

b) Analyzing the microfiber optic sensor for glucose detection.

c) Maintaining a consistent light source in the optical fiber.

d) Differentiating the sensor output for various glucose concentrations in different levels.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the basic idea of microfiber optics and the microfiber optic sensor are covered. This project's primary sources include earlier work as well as supplemental materials like books, journals, and articles on the topic. This chapter concludes with a detailed description of the theory underlying and functioning of microfiber optic sensors. Additionally, this chapter provides an overview of all earlier research on the topic.

2.2 Microfiber Optic

Glass microfiber optics are minuscule strands of exceptionally pure glass, with a diameter comparable to that of a human hair. Transmitting light will messages across extensive distances as the optical microfibers are bundled together.

The outer covering of the cable, known as the jacket, serves to protect the bundles and consists of three distinct layers: buffer coating, cladding, and core. A plastic buffer coating is applied to the microfiber to safeguard it from moisture and damage. The external optical material encasing the core and reflecting light into it is known as cloaking. The slender glass core of the microfiber, responsible for the transmission and reception of light, constitutes the essential component of a microfiber optic cable.

There are two distinct types of microfiber optics: single-mode and multi-mode. The single-mode communication system features a reduced core size and effectively transmits infrared laser light over extensive distances. The multi-mode transmissions feature larger cores and are typically utilized for short-distance applications.

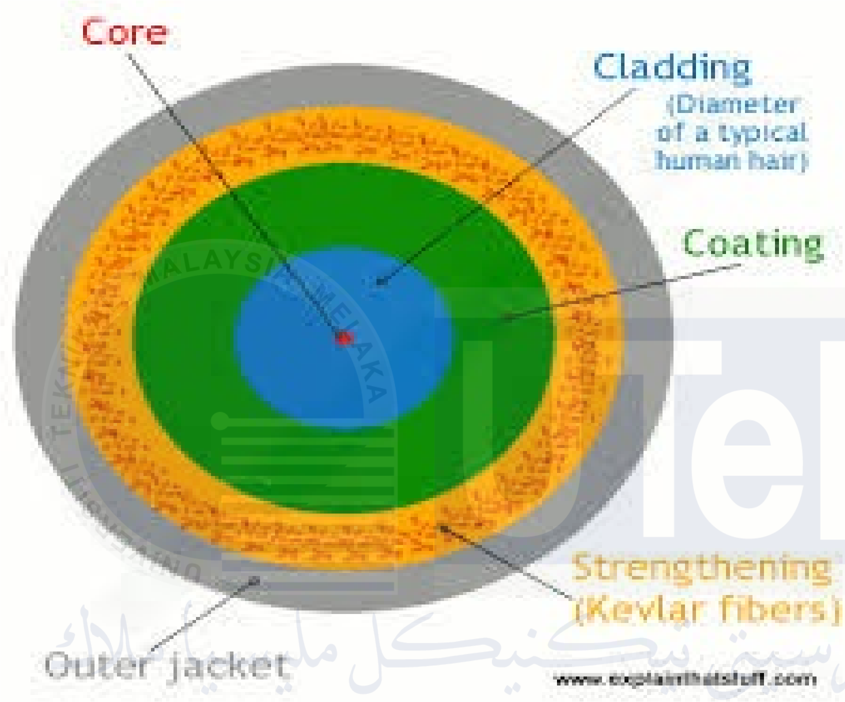


Figure 2-1 Maicrofiber Optic

Although fiber optics and copper wires have similarities, fiber optics are increasingly becoming the preferred choice for signal transport in communication systems and various applications. Fiber optics offer numerous advantages over copper, such as lower costs, a more streamlined design, and an increased capacity for data transmission. Optical fibers represent the pinnacle of efficiency in the transmission of digital data. The reason is that electricity was not present in the transmission, which consequently reduced the likelihood of fire sparks occurring. Fiber optic cables exhibit reduced size, lightweight characteristics, and enhanced flexibility.

2.3 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 8 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 Single Mode Fiber Optic

The requirement for high data speeds and minimal signal loss leads to the adoption of single-mode fibers in scenarios involving extended distances between repeaters and amplifiers. Furthermore, single-mode fiber is not affected by modal dispersion, unlike multimode fiber, because it allows the transmission of only one mode or ray (the lowest-order mode).

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.

2.4 Multi-Mode Fiber Optic

The concept of "multimode optical fiber" indicates that multiple light rays can be transmitted concurrently through a waveguide. The core size, being five to six times larger than that of single mode, allows for the utilization of more affordable electro-optic equipment while enabling the collection of increased light. The limitations on transmission distance and bandwidth have historically stemmed from the utilization of multiple modes or light channels operating in parallel within the fiber.

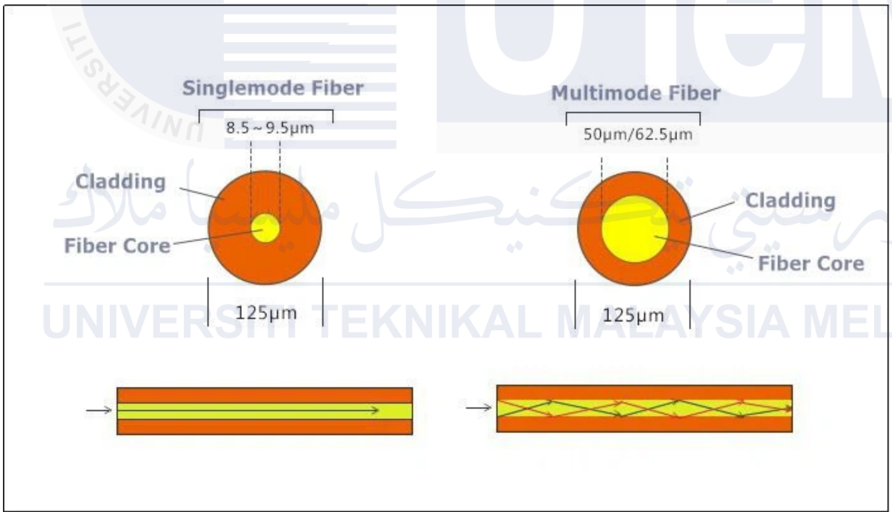


Figure 2-3Multi-Mode Fiber Optic

Multimode fiber exhibits greater attenuation compared to single-mode fiber due to its larger core diameter. The minimal attenuation of light in single-mode fiber cables is attributed to the small diameter of the fiber core. A standard multimode fiber used in telecommunications features a core diameter ranging from 50 to 62.5 micrometers and a cladding diameter of 125 micrometers. Consequently, the fiber might be able to propagate multiple modes.

A local area network (LAN) that needs high capacity (up to 1GHz) over short distances could gain advantages from using multi-mode fiber (under 3km). Several key advantages of multimode fiber include the following: Secondly, this problem presents a relatively straightforward challenge to address. The light is directly associated with it due to its larger core size. It can also serve as a source in conjunction with lasers and LEDs. Single-mode fiber exhibits reduced coupling losses compared to multi-mode fiber.

2.5 The Propagation of Light through Optical Fiber

The study of fiber optics involves examining the mechanisms by which light propagates through transparent optical fibers to arrive at its intended endpoint. Light is guided through fiber optic cables by the characteristics of the light itself and the design of the optical fibers. A fiber optic cable that transmits light energy is referred to as wave motion in the field of fiber optics. The concept of "wave motion" denotes the propagation of a repeating disturbance across a spatial domain, regardless of the presence of a physical medium.

2.6 Reflection and Refraction of light in Fiber Optic

Optical fiber is composed of several essential components. A fiber optic cable consists of several components: a core, an outer jacket, cladding, a buffer coating, and a strength member. The optic core serves as the central light-conducting component.

Due to the process of complete internal reflection, light is permitted to enter an optical fiber exclusively when it propagates through it. An optical fiber consists of a core that transmits light and a surrounding cladding that effectively confines the light within the core. A plastic buffer coating protects glass fibers from environmental factors, while also facilitating the processes of splicing and terminating.

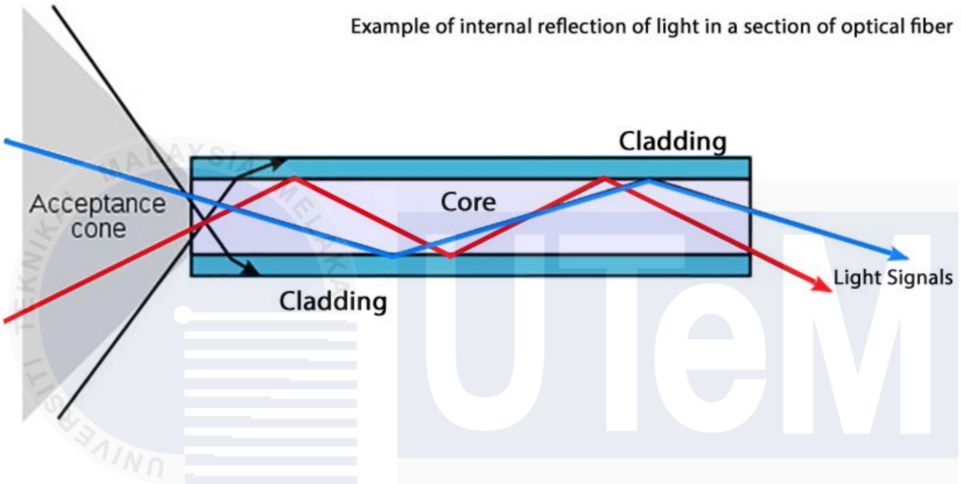


Figure 2-4 Reflection and Refraction of light in Fiber Optic

Light can be bent by altering the refractive index of glass, which quantifies the speed of light in the material (3x10^8 m/s). At angles exceeding a specific threshold, light undergoes refraction and is subsequently reflected from the surface. Optical fibers transmit light in the core through reflection by selecting core and cladding materials with a suitable index of refraction.

The specific angle at which internal reflection is fully achieved can be ascertained for each distinct fiber. A narrow beam of light will not be capable of reflecting into the core. The coating of the fiber will encapsulate it as a result. However, should it drop below that angle, it will be reflected into the core of the fiber and conveyed to the end of the fiber. The angle of total internal reflection, a standard metric in fiber optics, is utilized in determining the numerical aperture of fibers.

2.7 Advantages and Disadvantages

2.7.1 Advantages

a) Capable of transmitting signals over a considerable distance and supporting an exceptionally high data transmission rate:

Comparing the best copper conductor link to optical fiber cables, the attenuation of optical fiber cables is incredibly low. A low attenuation value of 0.1dB/km in the optical fiber cable allows the system to employ fewer repeaters or amplifiers while still maintaining high signal strength

b) Has greater bandwidth:

The carrier frequency range for optical cable is typically in the near infrared, which is in the range of 10-5 GHz. This is significantly higher than the bandwidth that is provided by coaxial cable by a factor of 500,000, making optical cable the superior choice. Optical fiber cable has the potential to be used for long-distance connections that can support extremely high data transfer rates.

c) Totally immune to electromagnetic interference (EMI):

Glass-fabricated cable ensures that the optical fiber transmission won't be disrupted by any type of electrical noise environment, including electromagnetic interference (EMI), because it is totally resistant to this type of noise.

d) Being of a small size and having a light weight:

The optical fiber core's diameter is so small that it's nearly impossible to measure, even though it's wrapped in a 125um-diameter layer of cladding. As a result of this, the optical cable is preferred over the coaxial wire.

e) Robust and flexible characteristics:

Even though it is constructed of glass or, in some cases, plastics, the protective layers around the core (the cladding, the coating, and the jacket) have been supporting its strength to the point where it can survive breaking or damage from extreme bending (a tiny radius), or from being twisted.

2.7.2 Disadvantages

a) Very expensive:

A long-distance optical fiber communication system can be expensive, especially when it comes to the expense of establishing a network. However, because of the high demand today, the system might be very cost-effective. The installation equipment may cost a lot of money to buy.

b) Difficult in handling:

A small diameter makes the splicing procedure tough to handle since engineers must exercise extreme caution to ensure that no breaking occurs throughout the process while it is uncoated.

c) Dangerous:

Because the optical fiber core is so small, it need special care and attention during handling, for fear that fiber fragments would enter the circulation and clot, or harm, vital organs.

d) Connectors must be inserted into cables with specialised knowledge:

Expertise is required in the fusion splicing of two fibers together, whether the two fibers are linked manually or by fusion. The engineer will need to pay for more training, which necessitates additional expenses.

2.8 Type of Fiber Optic Sensor

The telecommunications sector has experienced significant growth due to recent advancements in fiber-optic technology. The capability to convey gigabit data at light speed enhanced the research possibilities of optical fiber. The rapid and cost-effective advancement of optoelectronic components has led to the emergence of new devices. The recent advancements in fiber optic sensors have emerged from the integration of optical fibers with optoelectronic components. The phase, intensity, and wavelength of external disturbances can be detected rapidly owing to minimal material losses and enhanced sensitivity to these factors. The development of fiber optic sensors emerged as a result.

Optoelectronic and fiber optic sensor technology has emerged as a significant field in recent years. Fiber optic sensors were initially intended for use in these environments, and numerous components utilized were specifically engineered for that function. The advancement of fiber optic sensor technologies frequently occurred through the development and large-scale production of components for these companies. The increasing affordability and improved quality of components have led to a rise in the popularity of fiber optic sensors.

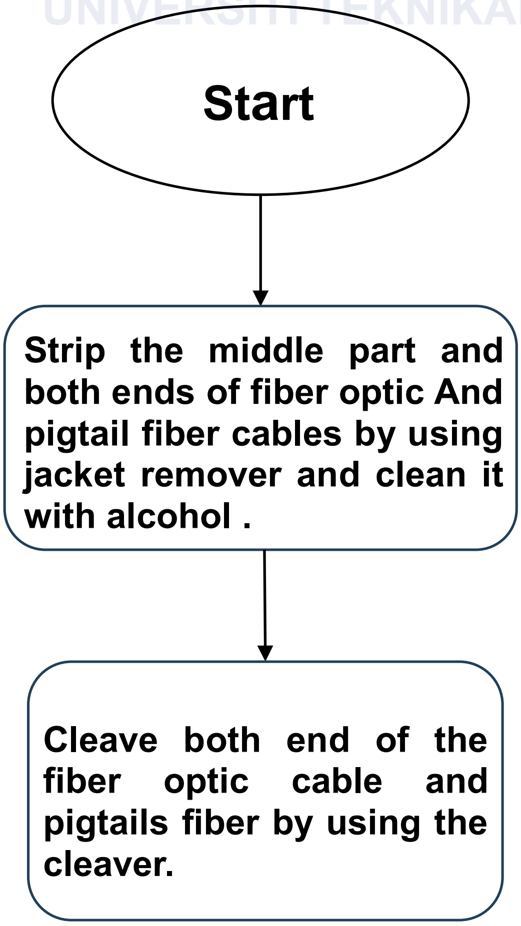
CHAPTER 3

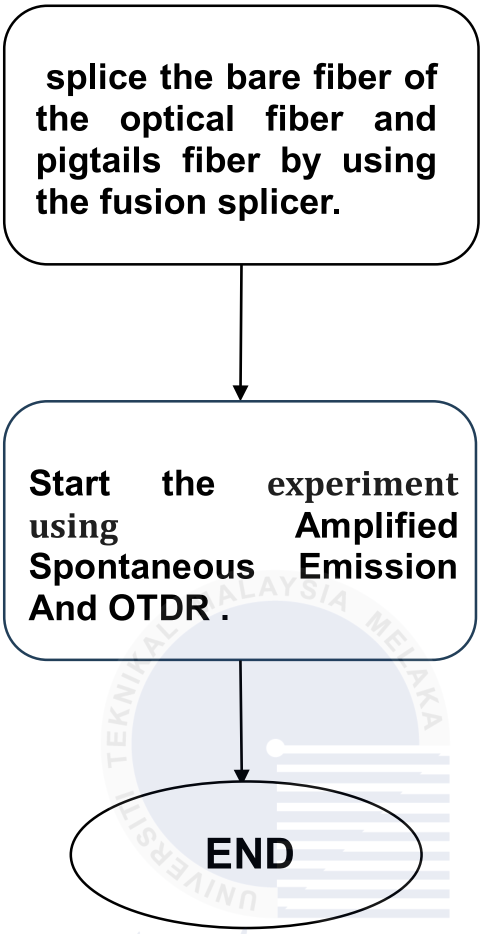
METHODOLOGY

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

3.2 Flow of Project





In designing and implementing a weather sensing project with a focus on sustainability, it is important to carefully select and evaluate the tools and technologies that will be used to collect and analyze data. This involves a range of methodological considerations, such as assessing the accuracy and reliability of sensors, evaluating the compatibility of different tools and software, and considering the environmental impacts of the project. Additionally, it is important to consider the social and economic implications of the project, such as ensuring that the data is accessible and understandable to diverse stakeholders and considering the costs and benefits of different tool selections. To support these methodological considerations, there are a range of approaches that can be used, such as conducting field tests to evaluate sensor accuracy, using open source software to promote transparency and accessibility, and conducting life cycle assessments to evaluate the environmental impacts of the project. By carefully selecting and evaluating tools for a weather sensing project, researchers and practitioners can ensure that their projects are effective, sustainable, and impactful.

3.3 Methodology

3.3.1 Stripping and cleaving of fiber optic cable

The protective polymer covering the optical fiber is removed in order to perform fusion splicing. The first step in the splicing method is to prepare both fiber ends for fusion, which includes removing or stripping each fiber's ends of any protective covering. A specialized stripping tool can be used to remove the coating from fiber optics. Stripping copper wire with copper wire strippers is comparable to stripping fiber with mechanical devices.

A mechanical splice, sometimes referred to as a fusion splice, is the most widely used method for connecting two optical fibers. As shown below, the fiber tips for optical fiber splicing techniques need to have a smooth end face perpendicular (90°) to the fiber axis. Additionally, a tool used in the fiber optic industry to cut (or cleave) the fiber in a clean 90° cut is called an optical fiber cleaver. The mechanical cleaver of fiber optic cable and the differences between a good and poor cleaving technique are shown in Figures and .

Figure 3-1 Stripping and cleaving of fiber optic cable

3.3.2 Fiber Optic Cable Splicing Procedure

Fiber optic splicing is the process of joining two fiber optic cables. As a result, the new cable can transfer data as quickly and effectively as a standard fiber optic link when installed correctly. Fusion splicing is more durable than mechanical splicing, despite the latter being less expensive. The fiber cores are fused using the fusion technique with less than 0.1dB of insertion loss and attenuation. Figure 3.5 shows the 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.

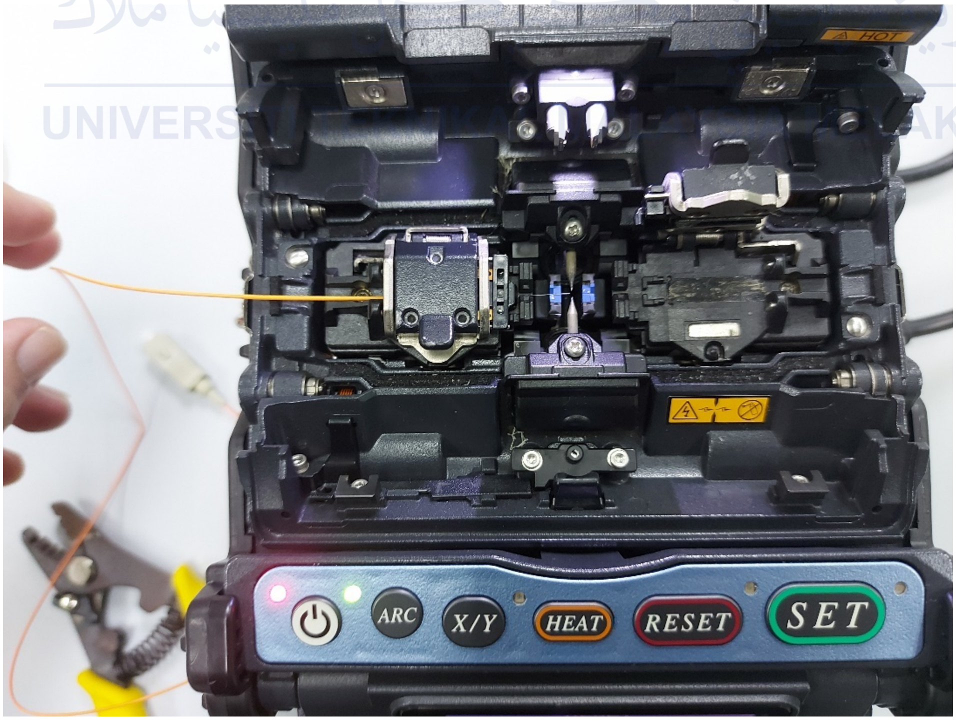


Figure 3-2 Fiber Optic Cable Splicing Procedure

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.

3.3.3 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.

3.3.4 Limitation of proposed methodology

Dirty connections are a big issue in fiber optics because they can lead to transceiver contamination, high reflectivity, and connection loss. According to network operators, half of all network failures are caused by dirty connections.

To make sure there is no contamination, the pigtail connection surface is cleaned using a lint-free wipe and 99 percent isopropyl alcohol. It has been demonstrated that isopropyl alcohol (IPA), a solvent that can be used to eliminate the majority of oily contaminants, poses no harm to fiber termination epoxies.

3.3.5 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 .

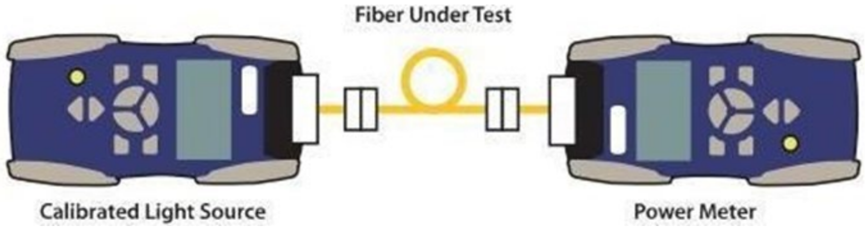


Figure 3-3 fiber under test

Continuous-wave light is sent from the source to the power meter via a power meter and a light source. The total span decreases as a result of the power differential. An insertion loss test mimics link operating conditions by injecting power into the fiber or cable being tested and using a power meter to measure the loss at the other end.

3.3.6 Chromatic Dispersion Test

Chromatic dispersion happens when different wavelengths move at different speeds due to the transmitters' non-zero spectral breadth. Since transmitters consist of multiple wavelengths traveling at varying speeds, pulse dispersion or spreading results from the variations in arrival times of each wavelength. The ps/nm scale is used to measure this phenomenon. Figure 3.15 illustrates how chromatic dispersion occurs in the fiber when longer wavelengths travel faster.

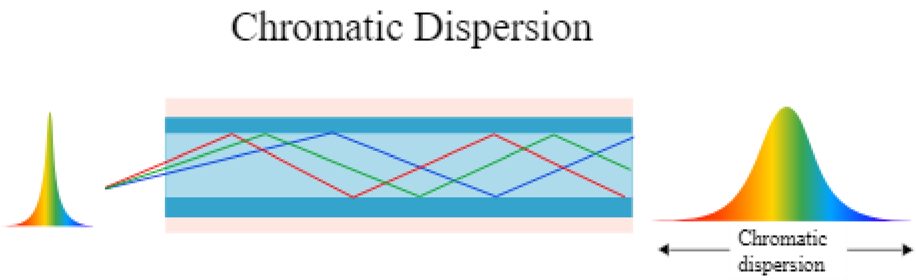


Figure 3-4Chromatic Dispersion Test

3.3.7 Polarization Mode Dipersion

The difference in arrival times of multiple polarization components of an input light pulse transmitted over an optical connection is known as PMD (Polarization Mode Dispersion). This light pulse can be split into two orthogonal polarization modes at any given time. These polarization modes propagate at different speeds due to the slow and fast axes created by the fiber's refractive index. Figure 3.14 shows the difference in arrival time.

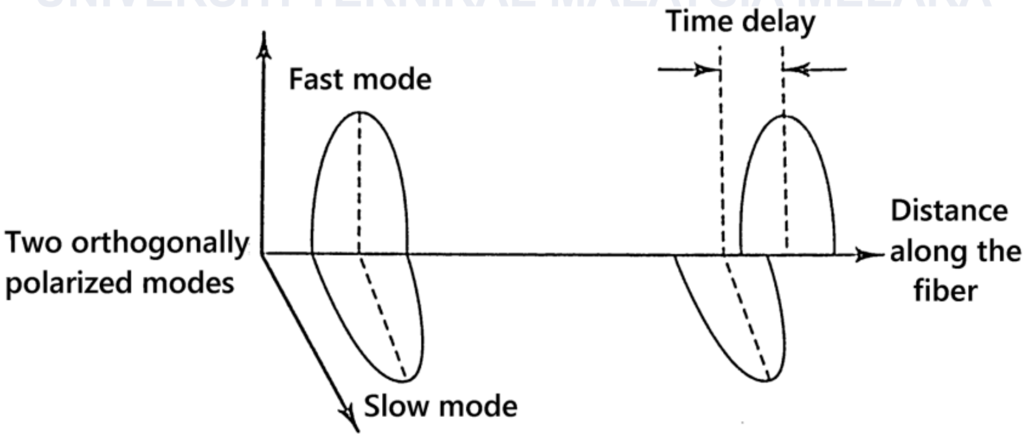


Figure 3-5Polarization Mode Dipersion

3.4 Equipment Used for the Experiment

these equipment are used to conduct an experiment or take measurements while collecting data.

Figure 3-6 Amplified Spontaneous Emission (ASE)

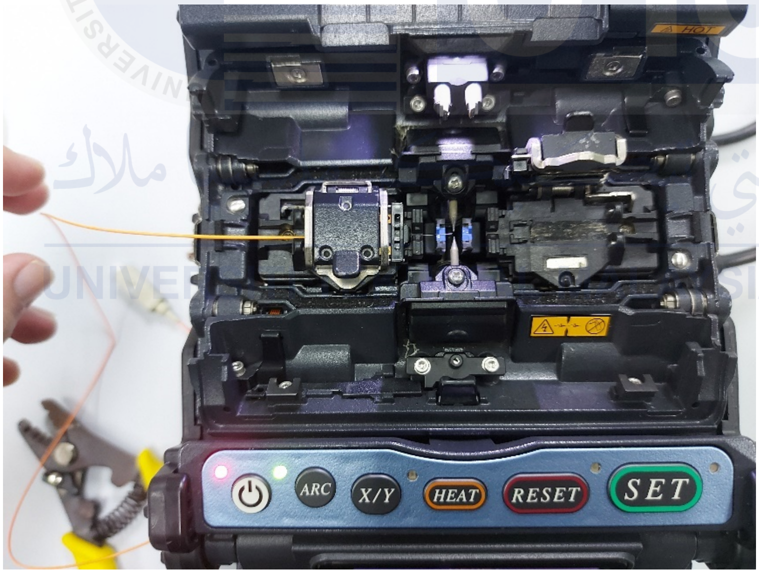


Figure 3-7 Splicing Machine

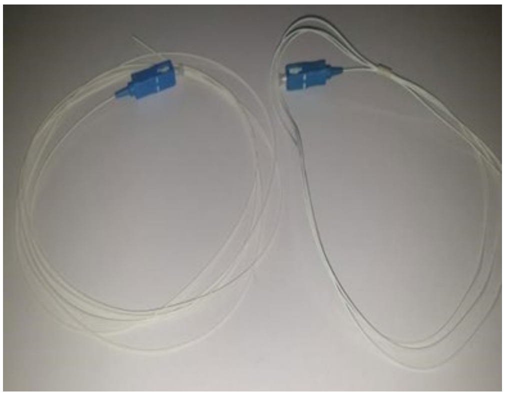


Figure 3-8 Fiber Pigtail

Figure 3-9 Cleaver

Figure 3-10 Stripper / Cutter

Figure 3-11 Alcohol Cleaning Pad

3.5 Summary

The methods employed to fulfill the project's goal is described 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.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter discussed the findings and data collected during the creation of an optical microfiber glucose 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.

4.2 Results and Analysis

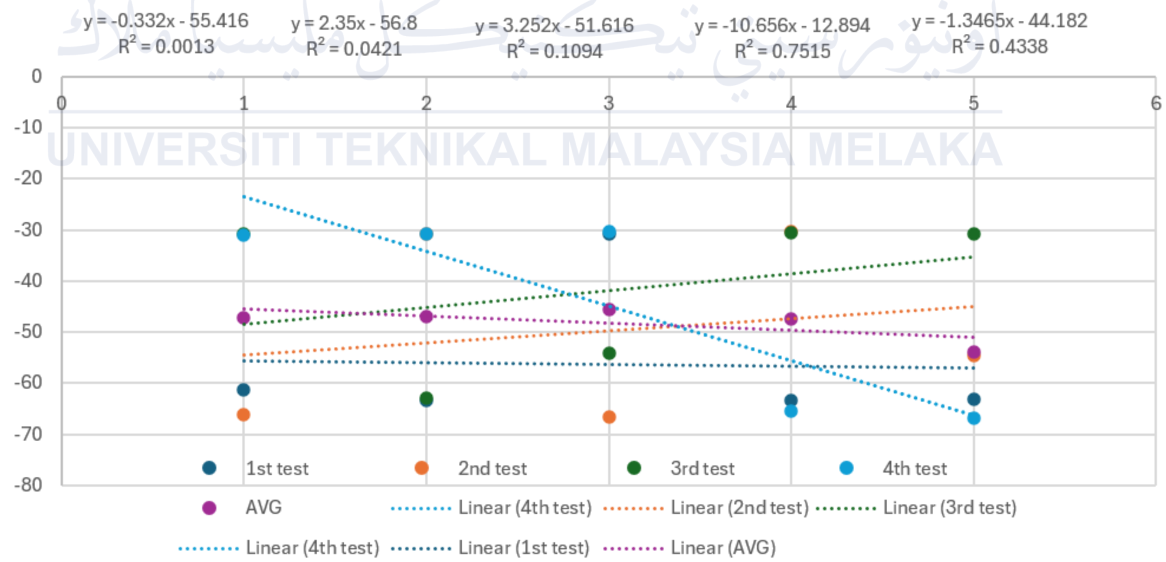
In this experiment, four single-mode fiber pigtails were coupled at the splice, with an unclad section in the middle of the transmission path. This setup was used to transmit a modulated light source to an Optical Time Domain Reflectometer (OTDR). Due to the partial absorption and scattering of light particles from the optical fiber core, the transmission from the light source was uneven.

The study utilized two different wavelengths, 1310 nm and 1550 nm, to analyze the variations in transmission. The duration of the experiment is one minutes, with results influenced by the glucose concentration applied during testing.

4.2.1 STRAIGHT SENSOR 1 RESULT FOR (1310nm , 1550nm)

Table 1 STRAIGHT 1 1550nm

		STRAIGHT 1	1550nm		
5g glucose	10ml water	20ml water	30ml water	40ml water	50ml water
1st test	-61.34	-63.49	-30.84	-63.29	-63.1
2nd test	-66.16	-30.89	-66.67	-30.35	-54.68
3rd test	-30.84	-62.95	-54.13	-30.65	-30.73
4th test	-30.91	-30.74	-30.37	-65.46	-66.83
AVG	-47.3125	-47.0175	-45.5025	-47.4375	-53.835

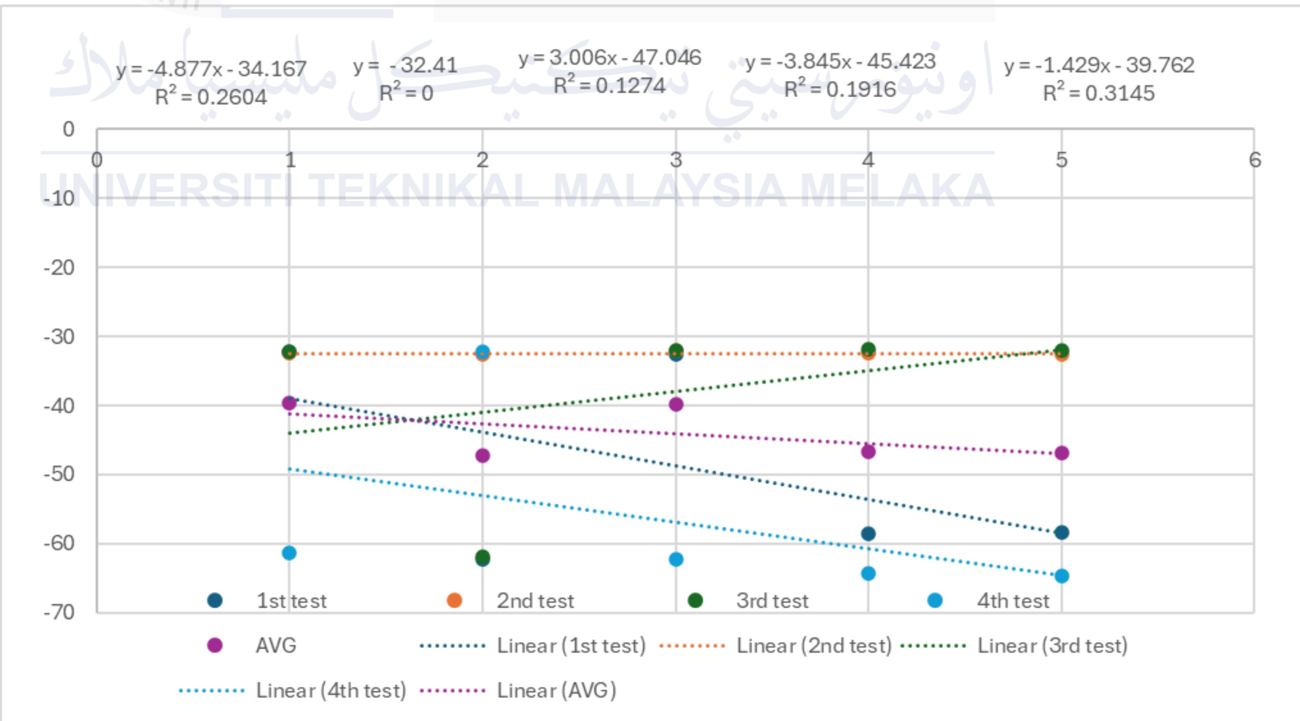


The table 1 shows wavelength (1550nm).there is good increase in sensitivity in test one, two and three which is 0.332 to 3.252 while for test number four we got the greatest increase which is 10.656, in all the test we got a good Linearity which is important to see that the sensitivity result is real.

From the figure , the graph showed that 1550nm wavelength for the first straight sensor, the average sensitivity result is 1.3465.

Table 2 STRAIGHT 1 1310nm

		ST1	1310nm		
5g glucose	10ml water	20ml water	30ml water	40ml water	50ml water
1st test	-32.16	-62.34	-32.51	-58.53	-58.45
2nd test	-32.46	-32.6	-32.03	-32.4	-32.56
3rd test	-32.17	-61.85	-32.1	-31.91	-32.11
4th test	-61.41	-32.23	-62.28	-64.24	-64.63
AVG	-39.55	-47.255	-39.73	-46.77	-46.9375



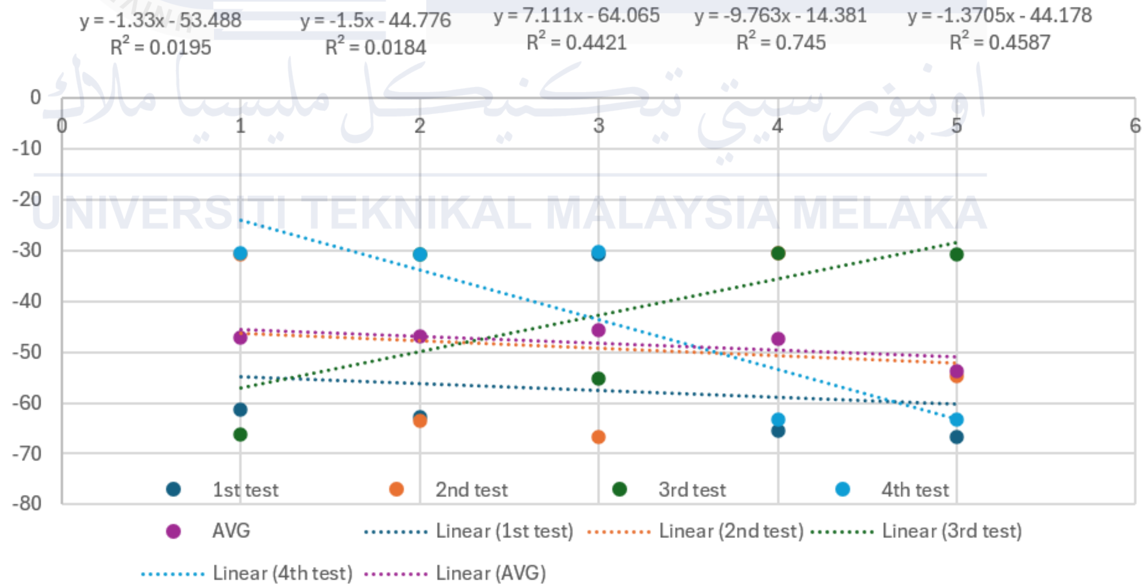
The table 2 shows wavelength (1310nm).there is good sensitivity in test one, three and four which is 4.877 to 3.845 while for test number two we got the greatest decrease which is 0, in all the test we got a good Linearity which is important to see that the sensitivity result is real.

From figure , the graph showed that 1310nm wavelength for the first straight sensor, the average sensitivity result is 1.429. when we look at the average sensitivity result in both wavelength (1550nm and 1310nm) they have almost the same result, that means the result well not be different in the straight sensor even if we change the wavelength.

4.2.2 STRAIGHT SENSOR 2 RESULT FOR (1310nm , 1550nm)

Table 3 STRAIGHT 2 1550nm

		ST2	1550nm		
5g glucose	10ml water	20ml water	30ml water	40ml water	50ml water
1st test	-61.43	-62.91	-30.81	-65.41	-66.83
2nd test	-30.88	-63.45	-66.64	-30.61	-54.8
3rd test	-66.21	-30.76	-55.33	-30.65	-30.71
4th test	-30.61	-30.88	-30.34	-63.31	-63.21
AVG	-47.2825	-47	-45.78	-47.495	-53.8875

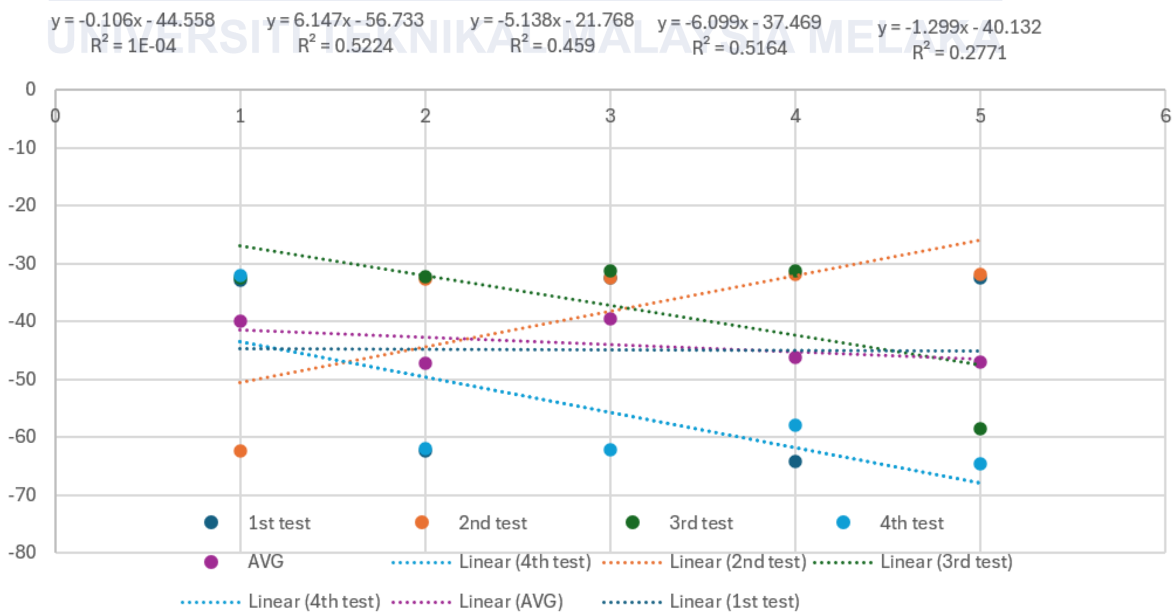


The table 3 shows wavelength (1550nm).there is good increase in sensitivity in test one, two and three which is 1.33 to 7.111 while for test number four we got the greatest increase which is 9.763, in all the test we got a good Linearity which is important to see that the sensitivity result is real.

From the figure , the graph showed that 1550nm wavelength for the second straight sensor, the average sensitivity result is 1.3705.

Table 4 STRAIGHT 2 1310nm

		ST2	1310nm		
5g glucose	10ml water	20ml water	30ml water	40ml water	50ml water
1st test	-32.89	-62.4	-32.41	-64.12	-32.56
2nd test	-62.34	-32.66	-32.53	-31.99	-31.94
3rd test	-32.43	-32.31	-31.23	-31.33	-58.61
4th test	-32.16	-61.91	-62.21	-57.88	-64.67
AVG	-39.955	-47.32	-39.595	-46.33	-46.945



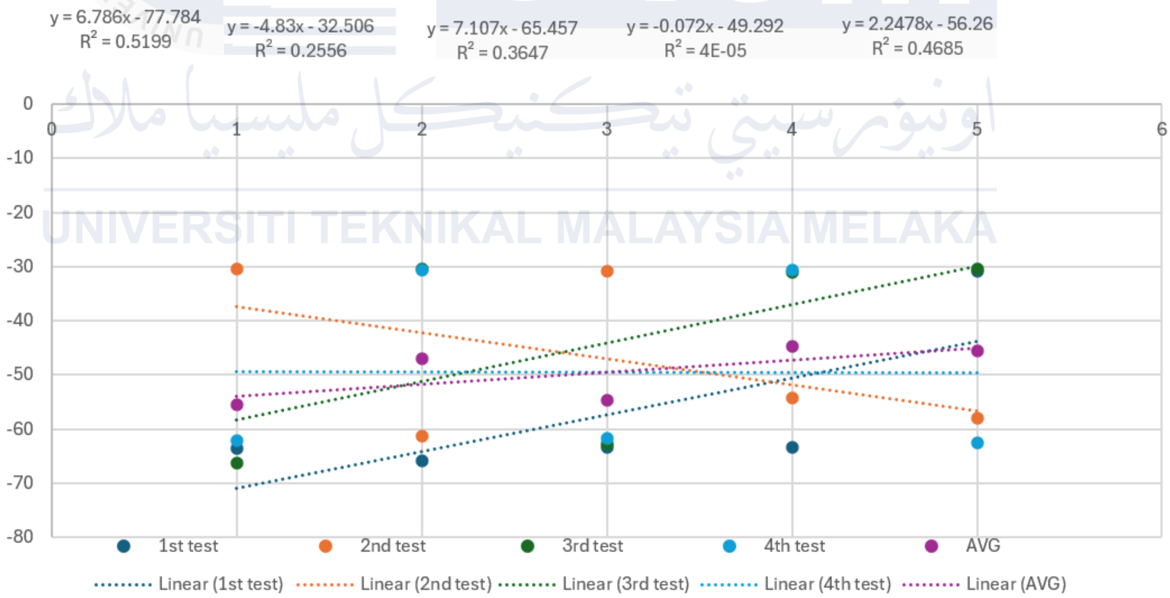
The table 4 shows wavelength (1310nm).there is good sensitivity in tests two, three and four which is 6.147 to 6.099 while for test number one we got the greatest decrease which is 0.106 , in all the test we got a good Linearity which is important to see that the sensitivity result is real.

From figure , the graph showed that 1310nm wavelength for the second straight sensor, the average sensitivity result is 1.299. when we look at the average sensitivity result in both wavelength (1550nm and 1310nm) they have almost the same result, that means the result well not be different in the straight sensor even if we change the wavelength.

4.2.3 LOOP SENSOR 1 RESULT FOR (1310nm , 1550nm)

Table 5 LOOP 1 1550nm

		LOOP1	1550nm		
5g glucose	10ml water	20ml water	30ml water	40ml water	50ml water
1st test	-63.53	-65.96	-63.36	-63.4	-30.88
2nd test	-30.46	-61.25	-30.88	-54.31	-58.08
3rd test	-66.2	-30.38	-62.75	-30.99	-30.36
4th test	-62.18	-30.61	-61.62	-30.57	-62.56
AVG	-55.5925	-47.05	-54.6525	-44.8175	-45.47

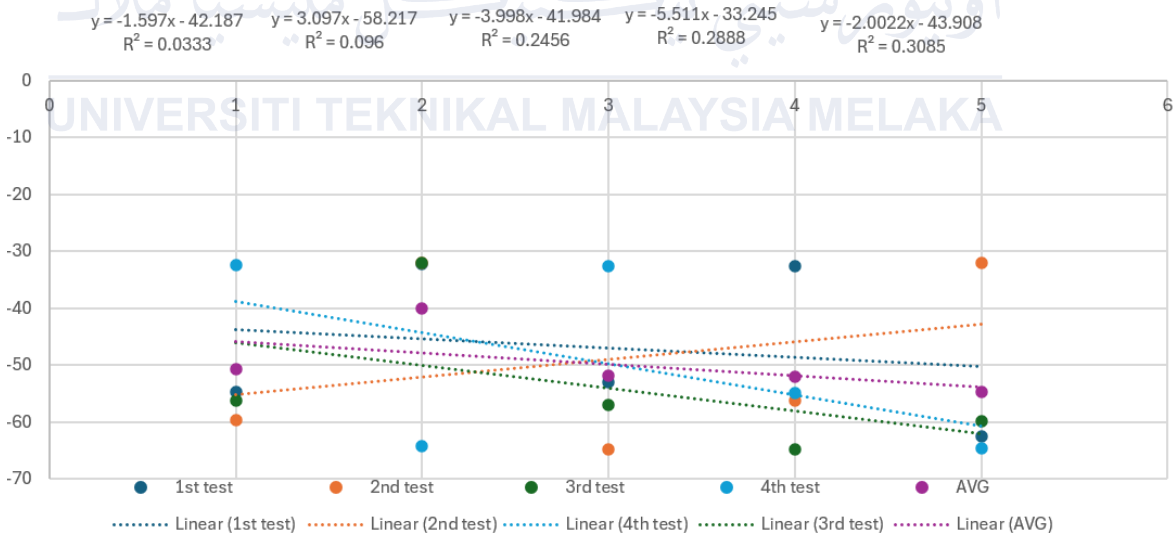


The table 5 shows wavelength (1550nm).there is good increase in sensitivity in test one, two and three which is 6.786 to 7.107 while for test number four we got the greatest decrease which is 0.072, in all the test we got a good Linearity which is important to see that the sensitivity result is real.

From the figure , the graph showed that 1550nm wavelength for the first loop sensor, the average sensitivity result is 2.2478.

Table 6 LOOP1 1310nm

		LOOP1	1310nm		
5g glucose	10ml water	20ml water	30ml water	40ml water	50ml water
1st test	-54.71	-32.12	-53.04	-32.53	-62.49
2nd test	-59.6	-31.95	-64.83	-56.32	-31.93
3rd test	-56.32	-31.94	-56.99	-64.72	-59.92
4th test	-32.46	-64.23	-32.61	-54.92	-64.67
AVG	-50.7725	-40.06	-51.8675	-52.1225	-54.7525



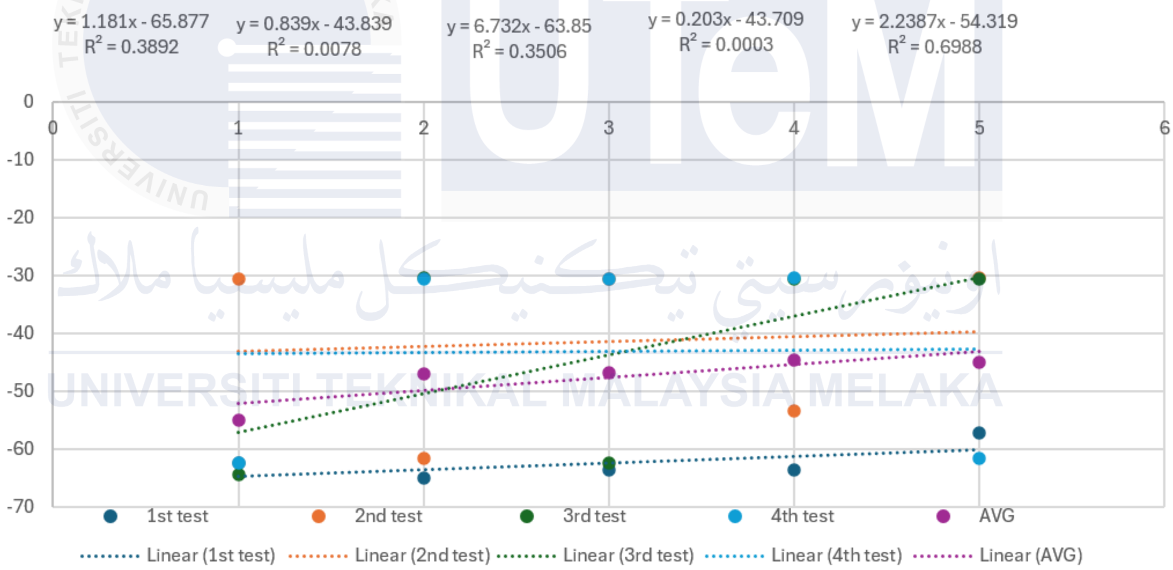
The table 6 shows wavelength (1310nm).there is good sensitivity in all tests one, two, three and four which is 1.597 to 5.511 while for test number four we got the greatest increase which is5.511, in all the test we got a good Linearity which is important to see that the sensitivity result is real.

From figure , the graph showed that 1310nm wavelength for the first loop sensor, the average sensitivity result is 2.0022 . when we look at the average sensitivity result in both wavelength (1550nm and 1310nm) they have different result, that means the result well be different in the loop sensor when we change the wavelength.

4.2.4 LOOP SENSOR 2 RESULT FOR (1310nm , 1550nm)

Table 7 LOOP2 1550nm

		LOOP2	1550nm		
5g glucose	10ml water	20ml water	30ml water	40ml water	50ml water
1st test	-62.43	-64.88	-63.64	-63.51	-57.21
2nd test	-30.57	-61.61	-30.54	-53.42	-30.47
3rd test	-64.34	-30.43	-62.32	-30.57	-30.61
4th test	-62.38	-30.62	-30.61	-30.43	-61.46
AVG	-54.93	-46.885	-46.7775	-44.4825	-44.9375

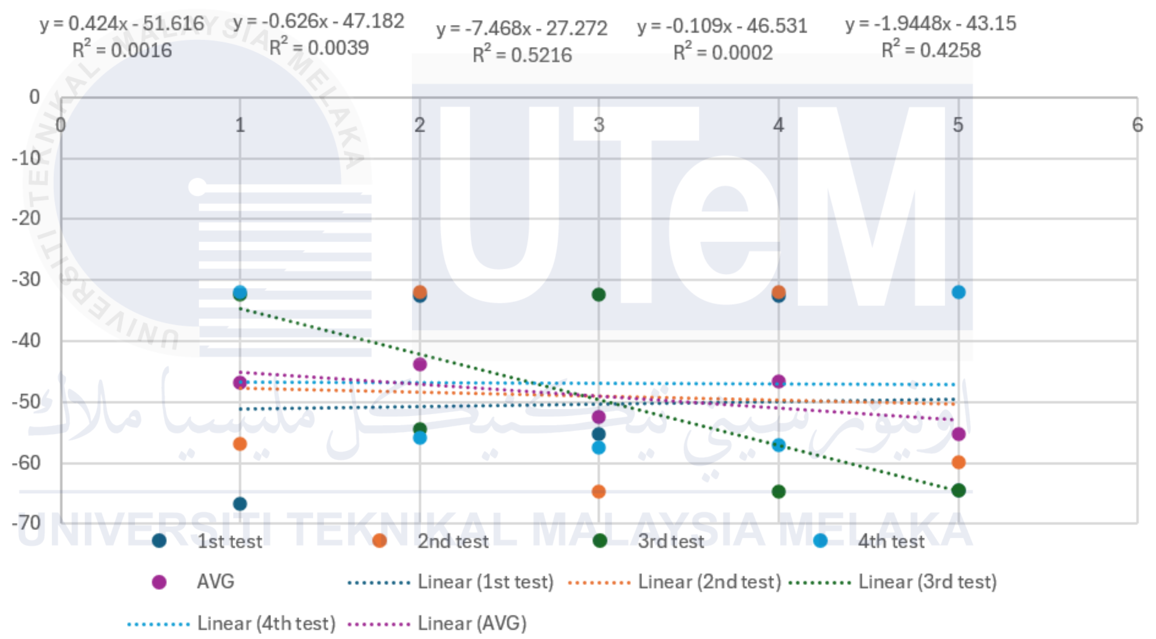


The table 7 shows wavelength (1550nm).there is good increase in sensitivity in test one and two which is 1.181 to 6.732 while for test number two we got the greatest decrease which is 0.839, in all the test we got a good Linearity which is important to see that the sensitivity result is real.

From the figure , the graph showed that 1550nm wavelength for the second loop sensor, the average sensitivity result is 2.2387.

Table 8 LOOP2 1310nm

		LOOP2	1310nm		
5g glucose	10ml water	20ml water	30ml water	40ml water	50ml water
1st test	-66.62	-32.67	-55.33	-32.53	-64.57
2nd test	-56.77	-31.94	-64.73	-31.98	-59.88
3rd test	-32.3	-54.43	-32.41	-64.77	-64.47
4th test	-31.93	-55.92	-57.51	-56.99	-31.94
AVG	-46.905	-43.74	-52.495	-46.5675	-55.215



The table 8 shows wavelength (1310nm).there is good sensitivity in test three which is 7.468 while for test number four we got the greatest decrease which is 0.109, in all the test we got a good Linearity which is important to see that the sensitivity result is real.

From figure , the graph showed that 1310nm wavelength for the second loop sensor, the average sensitivity result is 1.9448 . when we look at the average sensitivity result in both wavelength (1550nm and 1310nm) they have different result, that means the result well be different in the loop sensor when we change the wavelength.

4.2.5 AVERAGE RESULT

In the comparison section below, the typical output power values (dBm) are analyzed to determine which of the two wavelengths is more sensitive. To achieve this, data for each glucose concentration was collected in the Tables above for optical light sources operating at 1310 nm and 1550 nm.

Table 9 AVERAGE RESULT

	1550nm	1310nm
SENSOR	AVERAGE	AVERAGE
straight 1	1.3465	1.429
straight 2	1.3705	1.299
loop 1	2.2478	2.0022
loop 2	2.2387	1.9448

The results for sensitivity and linearity for 1310 wavelength and 1550 wavelength are shown in the table 9 above. The data supposed to proof the development of the optic microfiber in this project. Hence it can be concluded that 1550nm wavelength at the loop sensor is proven for its better sensitivity which is 2.2478 and 2.2387. Although, for 1310nm have less sensitivity it is still good .But in the straight sensor sensitivity almost the same in both wavelength. Looped fibers are expected to experience greater signal loss due to light escaping at bends in the fiber which mean better sensitivity as wee can see in the table 9.

4.3 Summary

Chapter 4 discusses the data obtained and analyzed using an optical fiber-based glucose sensor by comparing two wavelengths, 1310 nm and 1550 nm. Glucose was used as the test substance, and measurements were taken at different concentrations and time intervals. The results were obtained after addressing initial errors, ensuring that the most accurate data was achieved in this experiment. The primary goal was to determine which optical fiber wavelength provides the highest accuracy for glucose measurement. By evaluating sensitivity, linearity, and the best average data obtained, the hypothesis was confirmed.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The development of an optical microfiber sensor for glucose 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 development of medical sensors is critical, as the healthcare industry requires accurate technology to monitor glucose levels and improve patient outcomes. The optical fiber cable is stripped, cleaved, and spliced as part of the project's technique. To accomplish the project, all of these approaches are utilized.

This project compares the accuracy and sensitivity of the glucose sensor employing optical fiber using glucose solutions of varying concentrations. Meanwhile, different glucose-detecting agents are compared in terms of their ability to interact with glucose molecules in a controlled environment. The information is then collected and assessed based on the test's repeatability. Each test consists of three cycles, all conducted under identical conditions and surroundings to ensure consistency.

The data from this study concludes that glucose levels can be determined using optical fiber-based glucose sensors, as even minor changes in glucose concentration are detectable in the experiment. However, before being successfully implemented as a fiber optic sensor for medical applications, constructing a glucose sensor based on optical microfiber will require further development and refinement.

5.2 Future Works

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

- A study of various glucose-detecting agents in different environments and conditions.
- The use of optical fiber to create a durable and reliable structure for the glucose sensor.
- An optical light source that can output light while maintaining a stable connection over time.
- The development of a sterile and uncontaminated fiber cable to ensure accurate glucose detection in medical settings

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APPENDICES

Appendix A Example of Appendix A

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI TEKNOLOGI DAN KEJURUTERAAN ELEKTRONIK DAN KOMPUTER

CHECKLIST OF PSM FINAL REPORT SUBMISSION
BERU 4774 (BACHELOR DEGREE PROJECT II)

PSM2

Student Name: RABEE J.M.ABDALLAH

Matric Number: B082010470 Course: BERT

Supervisor Name: DR MD ASHADI BIN MD JOHARI

Project Title: DEVELOPMENT OF OPTICAL MICROFIBER SENSOR FOR GLUCOSE

No	Content	Page	Student Checklist (√/X)	Supervisor Checklist (√/X)
1	Cover page (CORRECT PROGRAMME & YEAR 2025)			
2	Report status confirmation form (SIGNED)			
3	Declaration (SIGNED)			
4	Approval (SIGNED)			
5	Dedication *(optional)*			
6	Abstract	i		
7	Abstrak	ii		
8	Acknowledgement	iii		
9	Table of Contents	iv		
10	List of Figures			
11	List of Tables			
12	List of Symbols and Abbreviations *(optional)*			
13	List of Appendices *(optional)*			
14	CHAPTER 1 – Introduction	1		
15	CHAPTER 2 – Literature Review			
16	CHAPTER 3 – Methodology			
17	CHAPTER 4 – Results and Discussion			
18	CHAPTER 5 – Conclusion and Future Works			
19	References			
20	List of publication and paper presented *(optional)*			
21	Appendices *(Optional)*			
22	Turnitin < 30%			

I acknowledge the acceptance of PSM Report from the above-mentioned student. I admit that the Report has been checked and fulfill the BERU 4774 (BACHELOR DEGREE PROJECT II) requirement.

Checked by:

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....
(Supervisor's Signature & Stamp)

Date: 20 / 02 / 2025