Characteristic Analysis Light Intensity Sensor Based On Plastic Optical Fiber At Various Configuration

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Abstract. This research discusses the light intensity sensor based on plastic optical fiber. This light intensity sensor is made of plastic optical fiber consisting of two types, namely which is cladding and without cladding. Plastic optical fiber used multi-mode step-index type made of polymethyl metacrylate (PMMA). The infrared LED emits light into the optical fiber of the plastic and is subsequently received by the phototransistor to be converted to an electric voltage. The sensor configuration is made with three models: straight configuration, U configuration and gamma configuration with cladding and without cladding. The measured light source uses a 30 Watt high power LED with a light intensity of 0 to 10 Klux. The measured light intensity will affect the propagation of light inside the optical fiber sensor. The greater the intensity of the measured light, the greater the output voltage that is read on the computer. The results showed that the best optical fiber sensor characteristics were obtained in U configuration. Sensors with U-configuration without cladding had the best sensitivity and resolution values of 0.0307 volts/Klux and 0.0326 Klux. The advantages of this measuring light intensity based on the plastic optical fiber instrument are simple, easy-to-make operational systems, low cost, high sensitivity and resolution.

1. Introductions

The rapid development of technology in the present era causes a very significant need for a sensor system that has reliability in detecting a parameter. Various sensor systems have been created by scientists. Up to the optical fiber technology which is a new breakthrough as a multi-function sensor system in various fields. Starting from the medical field, civil, communication, etc. As a sensor system, optical fibers can also be applied in various measuring areas for physical and chemical parameters, such as temperature sensors, pH sensors, electric current sensors and hydrogen detection sensors [1, 2].

Many research has been done using fiber optics as a sensor system in an attempt to develop it. As an example of sensor shift studies based on imperfection methods on optical fiber structures [3], the development of optical fiber-based sensors applied for measuring human respiration rates [7], the manufacture of load sensors using microbending methods on optical fibers with a certain distance [8], the use of plastic optical fibers as a medium for detection of load changes [9] and many other studies using fiber optics.
Fiber optic sensors have been developed to detect the effect of changes in the intensity of light on a particular light source. One example is a straightforward fiber optic configuration and U configuration for UV detection using Thorlabs SP1 spectrometer [10]. In addition, optical fiber sensors are also used to detect UV by utilizing a particular material that is bonded to a fiber optic configuration structure using a highly complex system as it passes through several processes to obtain materials that can be combined with optical fiber structures [11].

In this paper will be discussed about the light intensity sensor based on plastic optical fiber. Optical fiber is used as a medium for detecting changes in the light intensity of the measured light source used. Sensors are made with 3 configurations of straight configuration, U configuration and gamma configuration. Sensors are made to provide solutions for sensors in small sizes, simple systems, as well as sensitivity and resolution of good sensor measurements.

2. Experimental SET-UP

The plastic optical fiber is made of polymethyl metacrylate (PMMA) type of step index with coat, cladding, and core each other diameters of 2.2 mm, 1 mm, and 0.98 mm respectively used as transmission medium and detector of intensity change from source measurable light used. The core refractive index and the plastic optical fiber cladding are respectively 1.492 and 1.402 with NA numerical slot values of 0.5. The measured light source used is a white high power LED with a power of 30 Watt.

The light intensity sensor scheme of the plastic optical fiber is shown in figure 1. The sensor is made with 3 configurations of straight configuration, U configuration and the gamma configuration shown in figure 2. The U configuration sensor is made with some variations is the length with cladding and without cladding. Optical fiber is peeled at the curve area along 1 cm, 2 cm and 3 cm. In addition, there are also variations in diameter of bending 0.5 cm, 1.0 cm and 1.5 cm.

![Figure 1. Scheme of light intensity sensor based on plastic optical fiber.](image1.png)

![Figure 2. Sensor on straight, U, and gamma configurations.](image2.png)

Appropriate scheme in figure 1. The measured light source is placed perpendicular to the optical fiber sensor. The light signals propagating inside the core of the optic fiber will be passed to the phototransistor to be converted into electrical signals. To enlarge the electrical signal is used a differential amplifier circuit. Then the electrical signal in the form of analog signal is converted into digital signal using microcontroller to be readable on computer.
When the measured light source illuminates the optical fiber sensor, it will cause some light beam to enter into the fiber-optic core. The light entering the fiber-optic core will cause the intensity of light that was originally constant to increase. This increase in light intensity is proportional to the change in sensor output voltage. When measurements are made, the light intensity of the measured light source illuminating the optical fiber sensor is adjusted from the intensity of 0 Klux to 10 Klux with a change of 0.5 Klux.

3. Result and Discussion

The optical fiber sensor is made to measure the light intensity of a light source illuminating the optical fiber portion which is peeled by the measurement result of a voltage. Some beams of light from the measured light source illuminate the sensor into the fiber-optic core and cause the intensity of the original constant to increase. This change in light intensity is proportional to the sensor output voltage.

The result of the change in the output voltage of the plastic optical fiber sensor to the intensity change of the measured light source illuminating the sensor is shown in figure 3 below:

![Graph of the output voltage of the sensor on the change of light intensity with variation of length of peel (a) with cladding and (b) without cladding.](image)

Measurements using a U-configuration sensor with variations of peel shows the results where figure 3 shows that the higher the intensity of the measured light source the higher the sensor output voltage. The longer of the length of peel the greater the voltage change the sensor output. The characteristics of the light intensity sensor U configuration in the length of the peel variations are shown in table 1 below:

| Type of Sensor | Length of peel | Range (Volt) | Sensitivity (Volt/Klux) | Resolution (Klux) |
|---------------|---------------|--------------|-------------------------|-------------------|
| With Cladding | 1 cm          | 0.1030       | 0.0103                  | 0.0971            |
|               | 2 cm          | 0.1400       | 0.0140                  | 0.0714            |
|               | 3 cm          | 0.2010       | 0.0201                  | 0.0497            |
| Without Cladding | 1 cm        | 0.1490       | 0.0149                  | 0.0671            |
|               | 2 cm          | 0.2050       | 0.0205                  | 0.0488            |
|               | 3 cm          | 0.3070       | 0.0307                  | 0.0326            |

In table 1 above shows the range values, sensitivity and resolution of the sensors influenced by the length of peels of the fiber optic structure. The longer of the sensor peels the better the sensitivity and
the resolution results. The best results were obtained at length of 3 cm peel sensor without cladding with sensitivity value 0.0307 Volt/Klux and resolution of 0.0326 Klux.

The results of the light intensity sensor based plastic optical fiber testing for U configuration are shown in figure 4 below:

Figure 4. Graph of the output voltage of the sensor on the change of light intensity with the diameter of bending variation (a) with cladding and (b) without cladding.

Figure 4 shows the response of changes in sensor output voltage is higher when the intensity of light from white LEDs is greater. In the graph can be seen that the smaller diameter curve sensor U configuration, the greater the voltage change sensor output. The characteristics of the light intensity sensor U configuration are shown in table 2 below:

| Type of Sensor          | Diameter of bending | Range (Volt) | Sensitivity (Volt/Klux) | Resolution (Klux) |
|-------------------------|---------------------|--------------|-------------------------|-------------------|
| With Cladding           | 0.5 cm              | 0.2010       | 0.0201                  | 0.0497            |
|                         | 1.0 cm              | 0.1480       | 0.0148                  | 0.0676            |
|                         | 1.5 cm              | 0.1040       | 0.0104                  | 0.0961            |
| Without Cladding        | 0.5 cm              | 0.3070       | 0.0307                  | 0.0326            |
|                         | 1.0 cm              | 0.1840       | 0.0184                  | 0.0543            |
|                         | 1.5 cm              | 0.1260       | 0.0126                  | 0.0794            |

Table 2 above shows the range values, sensitivity and resolution of the sensors influenced by the diameter of bending sensor of the fiber optic structure. The smaller the diameter of bending sensor the better the sensitivity and the resulting resolution. The best results were obtained at 0.5 cm the diameter of bending without cladding sensor with a sensitivity value of 0.0307 Volt/Klux and a resolution of 0.0326 Klux.

Some configurations are made to produce sensors with the best sensitivity and resolution of the straight, U and gamma configurations. Each configurations using a sensor without cladding with a length of 3 cm peel. The response of the output voltage change to the change of light intensity for the straight configuration sensor, gamma configuration and U configuration is show in figure 7 below:
Figure 5. Graph of the output voltage of the sensor in straight configuration, gamma configuration and U configuration on the change of light intensity.

Figure 5 above is the result of comparison of straight configuration, U configuration of 0.5 cm diameter of bending, and gamma configuration of 1 cm in diameter of bending. Each configuration has a length of 3 cm each without cladding. The graph shows the greater the intensity of white LED light then the greater the sensor output voltage. Based on these graph, the U configuration sensor has the highest sensor output voltage change response compared to other configuration sensors.

Characteristics of light intensity sensor based on plastic optical fiber with straight configuration, U configuration and gamma configuration are shown in table 3 below:

| Configurations | Range (Volt) | Sensitivity (Volt/Klux) | Resolution (Klux) |
|----------------|-------------|-------------------------|-------------------|
| Straight       | 0.020       | 0.002                   | 0.500             |
| U              | 0.307       | 0.031                   | 0.033             |
| Gamma          | 0.135       | 0.014                   | 0.074             |

Table 3 shows that sensors with U configuration have the best sensitivity and resolution value compared to the straight configuration and gamma configuration. This is causes the U configuration has the smallest of the diameter of bending compared to other configurations. The smaller the diameter of the sensor indentation the better the sensitivity and resolution. The best results were obtained with sensitivity values of 0.031 Volt/Klux and resolution of 0.033 Klux.

The results of this study has consistent with result of previous studies on the comparison of sensitivity and resolution of load sensors based on plastic optical fiber using loop configuration. The addition of the load resulted in the smaller diameter of bending the sensor. The results show the smaller the diameter of bending the sensor the better the sensitivity and resolution [9].

4. Conclusion
The change in the sensor output voltage is proportional to the measured light source intensity change. The greater the intensity of the white LED light (measurable external light source) that illuminates the
optical fiber the larger the sensor output voltage. The longer of the peel and the smaller the diameter of bending, the sensitivity and the sensor resolution will get better. The result of measurement using light intensity sensor based on plastic optical fiber shows that U configuration sensor without cladding 3 cm length of peel on diameter of bending 0.5 cm has the best sensitivity of 0.031 volts/Klux and 0.033 Klux resolution.

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References
[1] Aranda A R M, Pensado M A B, Ceron E E A, Gómez L L C, Beltran G U, Rodriguez J A, García J C, Mondragón J J S, Pérez V I R 2013 Fiber Optic Pressure Sensor of 0–0.36 psi by Multimode Interference Technique Journal of Applied Research and Technology 11 695-701
[2] Lúcia B, Nélia A, João L P, Rogério N 2012 Optical Sensors Based on Plastic Fibers J. Sensor 12 12184-12207
[3] Arifin A, Hatta A M, Muntini M S, Rubiyanto A 2014 Bent of Plastic Optical Fiber with Structural Imperfection for Displacement Sensor Indian Journal of Pure & Applied Physics (IJPAP), NISCAIR Publication 52 520-524
[4] Arifin A, Hatta A M, Sekartedjo, Muntini M S, Rubiyanto A 2015 Long Range Displacement Sensor Based on SMS Fiber Structure and OTD Photonic Sensors 5 166-171
[5] Yingtian H, Yizhang W, Xiaoping W 2015 Novel Method Of Turbidity Compensation for Chemical Oxygen Demand Measurement by Using UV-Vis Spectrometry Sensor and Actuators B 393-398
[6] Dziuda L, Lewandowski J, Skibniewski F, Nowicki G 2012 Fiber-Optic Sensor For Respiration and Hear Rate Monitoring in The MRI Environment Procedia Engineering 59 1291-1294
[7] Marek K, Michel S, René M R, Luciano F B, Gian L B, Lukas J S 2014 An Optical Fiber-Based Sensor For Respiratory Monitoring Laboratory for Protection and Physiology 13 13088-13101
[8] Červeňová J, Iglarčík M 2013 Weight Measurements Using Microbending Optical Fibre Sensor and OTDR Proceedings of the 9th International Conference 243-246
[9] Arifin A, Yusran, Miftahuddin, Abdullah B, Tahir D 2017 Comparison of Sensitivity and Resolution Load Sensor at Various Configuration Polymer Optical Fiber The 6th International Conference on Theoretical an Applied Physics 1-6
[10] Ana V J, Bajic, Jovan S B, Dragan Z S, Miloš P S, Miodrag J, Milos B Z 2012 Simple and Low Cost Fiber-Optic Sensors for Detection of UV Radiation J. Telfor 4 2
[11] Ana V J, Dragan Z S, Jovan S B, Bojan M D, Zoran M, Miloš P S, Miloš B Z 2013 An End-Type Fiber-Optic UV Sensor Covered with Mixture of Two UV Sensitive Materials Engineering Materials 543 265-268