

Osnr Performance on Hand-Made Demultiplexer Using Thin-Film Filter and Splitter in Wdm-Pof Network Design for Short-Haul Communication System Applications

*Mohd Syuhaimi Ab-Rahman, Latifah Sarah Supian, Hadi Guna Safnal,
Mohd Hazwan Harun and Kasmiran Jumari*

Department of Electrical, Electronics and Systems Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia

Abstract: Polymer optical fiber has advantages compared to other alternatives communication media such as copper, coax cable and glass fiber. POF has bigger bandwidth compared to wireless communication network and POF also free from electromagnetic disruption. POF is suitable for communication system up to distance of 100 meters with data speed of 400 Mbps using polymer step-index type. Thus, POF is effective for short haul data transmission. Applications of POF has widen nowadays including the Ethernet network at home or usually known as fiber to the home (FTTH) and in also used in automotive system. To increase the bandwidth of the transmission system, wavelength division multiplexing technique or WDM is applied in this study using optical splitter. Several signals with different wavelengths are multiplexed and carried over a single fiber and demultiplexed at the end of the communication system to obtain the original signal to be directed to the receiver. The advantage of the device developed in this study is that it is easy to construct and inexpensive. Thin-film is used as filter and two main color wavelength used are red and green thin-films. The red thin-film will absorb any other wavelength other than $\lambda = 650$ nm and the green thin-film will absorb any other wavelength that is not around $\lambda = 510$ nm. Characterization is done to test the signal strength with the existence of noise. Optical to noise ratio (OSNR) is measured to determine the optimum distance of the demultiplexer can work effectively. In this study, the maximum distance is taken up to five meters and the signal degradation is small. Although the signal strength decreases linearly with the length of the fiber as the noise increases, the demultiplexer works efficiently for short haul communication system.

Key words: POF • Multiplexer • Demultiplexer • Thin-film • LED • OSNR • Short-haul communication • Splitter • WDM

INTRODUCTION

The demand for polymer optical fiber (POF) is getting higher since POF performance in sending the information or data through the optical cable is faster compared to other alternatives such as copper or coax cable. By using the multimode optical fiber, the signal transmission range from 10Mbps/sec to 10Gbits/sec [1]. However, high cost and complication of installing the optical fiber contributes to not many users that apply the POF system at home or in the industries. There are a lot of applications that use optical fibers for data transmission and automobile

industry for transmitting and receiving data. The demand in sending data in high capacity and bigger bandwidth is increasing these days. Thus, one of the effective solutions is by using WDM technique in the POF system. In theory, the technique enables several signals that carry different wavelengths to be transmitted through a single optical fiber without having any disruption between the signals. All the signals that are carried along the fiber will be separated at the end of the system so that each signal that carries certain data will be channeled to the respective receiver. The separation the signals is done by using multiplexing technique. There are some system that

Corresponding Author: Mohd Syuhaimi Ab-Rahman, Department of Electrical, Electronics and Systems Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia. Tel: +603-89216448. Fax: +603-89216146.

already use demultiplexer techniques in some of the commercialized devices, however, most of the devices that applied the techniques are hard to install and expensive.

In general, the communication system using polymer optical fiber is limited to the capacity ratio of 2Gbits/sec [1]. Therefore, new method is used to exploit the utilization of POF to the maximum in order to ensure more data can be sent in high speed and without any complication. By using WDM technique, no limitation or constraint found for the transmission capacity through the optical fiber [2].

The important components in this study are the multiplexer, optical splitter, LED source and demultiplexer. The multiplexer combines the intended signals to be transmitted where the multiplexer is placed before optical splitter. The optical splitter that is being used in this study is 1×3 . Optical splitter will carry the combined signals and at the end of each fibers of the optical splitter the combined signals will be directed to demultiplexer. Demultiplexer will separate the combined signals into the original signals so that the data carried by each wavelength can be sent to the user network. Some of the user networks that are using this application are internet network at home, telephone system network and video application system such as CCTV [3].

The demultiplexer used in this study is a hand-made demultiplexer by using thin-film color filter. By applying the concept of WDM technique, each color carries its own wavelength. Thus, the combined signals are separated by the wavelength that each of the color carries. Therefore, based on this simple understanding, a method to construct a simple demultiplexer is carried out by using colored transparent thin-film, connectors and sockets. This device is connected to the end of the optical splitter and demultiplex the signals carried where each of the colored thin-film will block any signal that carry different wavelength that is not similar to the color wavelength. Only the signal that carries the particular wavelength will be carried to the receiver. Two main LED sources used in this study are red ($\lambda = 650$ nm) and green ($\lambda = 510$ nm) with their respective wavelength. When the signals reach their destination, the demultiplexer device that utilized the colored transparent thin-film will separate the signals to its original ones and directed the signals to its respective user network.

The device is then tested and characterized for its effectiveness by measuring the insertion loss and power output for several samples of different colored thin-films for each red and green color. Optimum results that show the lowest loss and higher power output for each colored film is then selected to construct the demultiplexer.



Fig. 1: Thin-film attached to the plug assembly or socket using epoxy-resin



Fig. 2: Plug assembly attached with thin-film is secured by inserting the edge inside bulkhead receptacle

In this study, measurement of the signal strength with the attendance of noises is analyzed.

Specification of Design: The handmade 1×3 POF splitter is an optical device, which ended by 3 number of POF ports, while the other side ended by one POF port. The splitter can work bidirectional for the purpose of coupling signals or splitting signals. As an example, optical 1×3 splitter developed by the jointing of three PMMA POFs. The one end of the splitter is designed to be fused taper-twisted shape which enables to couple two optical pulse input signals. Each input and output is connected with POF connector.

The demultiplexer is designed by utilizing transparent colored thin-film as the main component of the device. The color filter device is connected at the end of the three fibers of the 1×3 taper-twisted splitter with red colored thin-film at one end and green colored thin-film at the other end. Each of the thin-film is attached to the single-position plug assembly or socket at one end as in Fig. 1. While the other end is connected with optical fiber with desired length. The attachment of the thin-film is then secured by inserting the one end to the single-position bulkhead receptacle as shown in Fig. 2. The other end of the bulkhead receptacle will be connected to optical fiber that is connected to the receiver.

MATERIALS AND METHODS

In the development process of colored thin-film filter, the samples of the thin-films are obtained from colored transparent thin-films. The colored thin-films are made from two type of plastics. 65% of its component is made from polycarbonate plastic and the rest is made from polyester dye. Guide on the energy spectrum reflected by each of the colored thin-film can be referred to the 'Spectral Energy Distribution' (S.E.D) provided. The first stage of selecting the thin-films that gives the optimum transmission of desired wavelength is by analysis of the S.E.D. The desired wavelength that shows the high peak of transmission and lowest base of other wavelengths is preferred and the sample colored thin-film is selected for further analysis.

In development process of 1×N splitter based on POF technology, multimode SI-POF type made of Polymethylmethacrylate (PMMA) 1 mm core size fully utilized in this paper, as PMMA is one of the most commonly used optical materials, due to its intrinsic absorption loss mainly contributed by carbon-hydrogen stretching vibration in PMMA core POF [4, 5].

Approach and Method: The first stage of the fabrication is the analysis of the S.E.D for each thin-film for red and green color. The peak that gives the optimum transmission for the desired wavelength is selected. Ten samples of each color are selected for further analysis. POF cables with length of 1 to 5 meters are connected to the plug assembly or socket. Then, the coarse end of the fiber connected to the plug assembly is refined by using sand papers. Epoxy-resin is then used to attach the small cut-up thin films to the end of the plug assembly and fibers and the attachments are left to dry as shown in the Fig. 3. Then, the attachment is secured by inserting the socket with thin-film into bulkhead receptacle as in Fig. 2. At the other end of the bulkhead receptacle is connected to a socket inserted with short length optical fiber. The optical fiber then is connected to the power meter for insertion loss and power output measurement. Red and Green LED sources will be injected through each of the 1-5 meter length optical fibers for the characterization analysis for each colored thin-film samples as shown in Fig. 4. Characterization analysis is done for each sample to develop demultiplexer device that can give optimum transmission for the desired wavelength with minimum loss. In this study, optical signal to noise ratio (OSNR) is focused on to analyze the signal strength when there is existence of noise in the system.

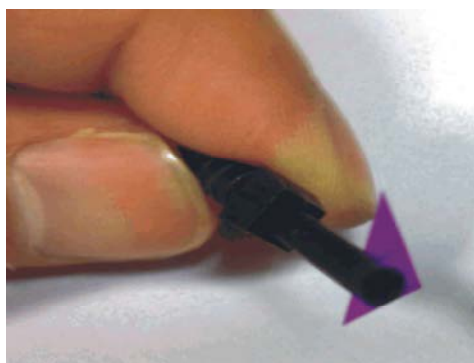


Fig. 3: Thin-film is attached to the end of plug assembly and fiber



Fig. 4: Both red and green LED sources are injected to both red and green thin-film respectively

Characterization: Characterization testing is done to identify thin-films that give optimum results with minimum loss and optimum transmission where the other undesired wavelengths are absorbed or blocked from being reflected pass through the thin-film filter. Optical signal to noise ratio testing is done to analyze the signals transmitted with the existence of noise in the short-haul communication system. Higher OSNR value shows the efficiency of the demultiplexer developed. OSNR is an important parameter because the value can show how much the signal strength degraded when the signal is transmitted through the optical fiber. High value shows the optimum performance of the demultiplexer where the signal transmitted has better signal strength than the noise distribution in the system. OSNR can be defined as $OSNR = 10 \log \frac{S}{N} dB$, where S is the signal reading (μW) transmitted through the fiber and N is the noise (μW) in the system. In this study, several optical fiber samples with different lengths are connected to optical fibers attached with red and green thin-films.

The other end of the various lengths optical fibers are connected to red and green LED sources while the end of optical fibers attached with red and green thin-films is connected to power meter for insertion loss and output power measurement. Optical fibers with length as short as 1 meter to fibers with length of 5 meters are measured for the insertion loss and output power for each color samples of the thin-films. Characterization analysis is done where the data collected from the power meter are plotted against the various length optical fibers.

POF with length range from one meter to five meters are measured and one end of the optical fibers are connected to the plug assembly or socket and the edge of the fibers are refined using sand papers. Red and green LED sources are injected through the optical fibers and the readings for the measurement of insertion loss and power output are analyzed. In this study, the reading of the green sample and red sample of the demultiplexer will be measured side by side. Three characterization testing situation are done which for the first situation, both the red and green LED sources are injected through the fibers at the same time. Second situation is only the red LED source is injected through while the third situation is only the green LED source injected through. Reference reading for the power meter is -20.4 dB. In theory, OSNR for the red thin-film demultiplexer can be defined as $OSNR = 10 \log \frac{\text{red LED source (S)}}{\text{green LED source (N)}}$ and same goes for green

thin-film demultiplexer where $OSNR = 10 \log \frac{\text{green LED source (N)}}{\text{red LED source (S)}}$. In this study, OSNR is measured by $OSNR = \frac{\text{red LED}_{\text{on}} \text{green LED}_{\text{off}}}{\text{red LED}_{\text{off}} \text{green LED}_{\text{on}}}$ for obtaining the

result when red thin-film is tested. Here the signal (S) is measured when green LED source is switched off and only red LED source is switched on. The noise (N) is measured when red LED source is switched off and only green LED source is switched on. The signal green LED source reflected pass through the red thin-film is measured using power meter. The green LED source or signal that reflected pass the red thin-film is classified as noise. The OSNR is measured using the above formula. Higher OSNR value shows that the thin-film is effective enough to filter out any undesired wavelength and let only the desired wavelength to be transmitted through the thin-film. This criteria is critical for demultiplexer development. Then, the signal strength is measured when both of the LED sources are injected at the same time. The reading of the red LED source that transmitted



Fig. 5: Red LED source is blocked from passing the green thin-film as on the left when red LED source is injected to both green and red thin-film

pass the red thin-film with the existence of the green LED source is measured. Lower reading value of OSNR is estimated compared when only red LED source is injected. The reading value is then analyzed when only green LED source is injected through the red thin-film.

Same characterization process is done for green thin-film. The OSNR is measured by $\frac{\text{green LED}_{\text{on}} \text{red LED}_{\text{off}}}{\text{green LED}_{\text{off}} \text{red LED}_{\text{on}}}$. The characterization testing is also

done when both of the red and green LED sources are injected at the same time through the green thin-film. As shown in the Fig. 5, reading is measured when the red LED source is injected and the signal transmitted through the red thin-film is recorded. Reading is also measured when the green LED source is injected through the red thin-film. The same process is done which the OSNR for the green thin-film is measured. All the readings from the measurement are plotted against the various lengths of the optical fibers. The analysis is done to obtain the optimum signal strength given by the hand-made demultiplexer with the optimum length as measured.

RESULTS AND DISCUSSIONS

As shown in Fig. 6, signal value decreases as the length of the optical fiber gets longer. Noise that existed in the fiber is bigger in the longer fiber compared to the short one, therefore, leads to the attenuation of signal that went through the fiber. The test shows that the length of the fiber does affect the signal strength carried through the fibers. The demultiplexer developed in this study is more effective in sending data through fiber with range of

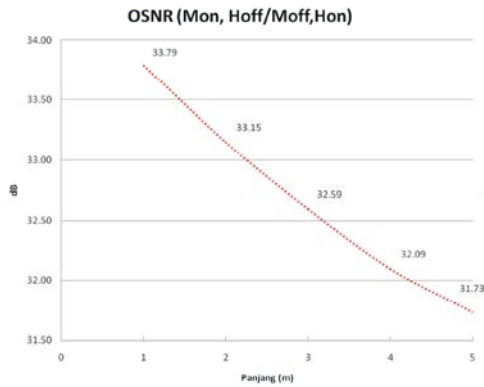


Fig. 6: OSNR measured at red thin-film with green LED source as the noise: Output power vs. length of fibers

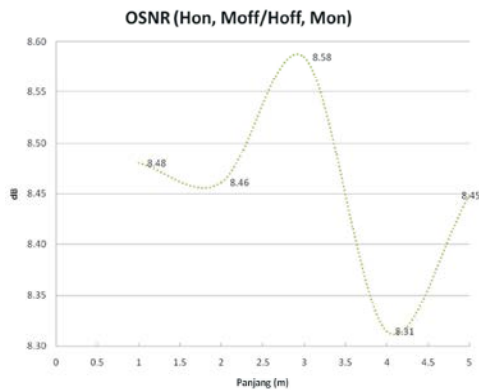


Fig. 7: OSNR measured at green thin-film with red LED source as the noise: Output power vs. length of fibers

length less than five meters. For the green thin-film with the red LED source injected as shown in Fig. 7, the length of the fibers with range of one to three meters show that the signal strength is better than fibers with length of four and five meters. Same factor affect the signal strength of the green LED source where the length of the fiber caused the signal carried through the fibers to degrade gradually. Although the signal attenuates through longer fibers, the data or signal can still be sent through the five meter fiber since the signal strength has not much different from the shorter ones.

CONCLUSIONS

In conclusion, the demultiplexer developed using transparent colored thin-film is effective to send data for short distance communication. The fabrication and characterization analysis has been done successfully to

develop demultiplexer with optimum performance for short communication purpose. Red wavelength source ($\lambda = 650 \text{ nm}$) is injected through the optical fiber attached with the red and green thin-film that acts as filter for the purpose of characterization to test for the signal strength with the existence of noise, which in this case the green LED source ($\lambda = 510 \text{ nm}$) within the connection. The analysis shows that the signal strength decreases as the length of the fibers increases. The demultiplexer developed using thin-films selected based on the characterization test in this study able to give optimum performance for the short haul communication system. Although the maximum distance of the transmission using the device developed has not yet determined, however, in the future, deeper study and research will be done to improve the performance. This device is not only effective for data transmission for short haul communication, but it is also easy to develop and inexpensive. Based on the analysis and characterization of the demultiplexer, the efficiency of the thin-film achieved 70% efficiency. Although the characterization shows some signal loss along the transmission, the measurement and test done on the data and video transmission depicts optimum performance based on the spectrum analyzer tool.

ACKNOWLEDGMENTS

The authors would like to thank Spectech Lab, Universiti Kebangsaan Malaysia for the support of this project.

REFERENCES

1. Horak, R., 2007. Telecommunications and Data Communication Handbook. Canada: John Wiley and Sons Inc.
2. Romeiser, M., 2006. Optical Fibers and RF: A Natural Combination. New Delhi: Prentice-Hall of India.
3. Ziemann, O., J. Krauser, P.E. Zamzow and W. Daum, 2007. POF Handbook: Optical Short Range Transmission Systems. Berlin: Springer.
4. Ab-Rahman, M.S., H. Guna, *et al.*, 2009. Cost-effective 1×12 POF-Based Optical Splitters as an Alternative Optical Transmission Media for Multi-Purpose Application. IJCSNS International Journal of Computer Science and Network Security, 9(3): 72-78.
5. Appajaiah, A., V. Wachtendorf, *et al.*, 2007. Climatic exposure of polymer optical fibers: Thermo-oxidative stability characterization by chemiluminescence. Journal of Applied Polymer Science, 103(3): 1593-1601.