Journal of Computer Science, 9 (4): 449-454, 2013
ISSN 1549-3636

doi:10.3844/jcssp.2013.449.454 Published Online 9 (4) 2013 (http://www.thescipub.com/jcs.toc)

Selection of Spectral Filters for Optical Demultiplexer Via Same Source Different Filters Testing Technique

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Received 2012-08-06, Revised 2012-09-25; Accepted 2013-05-09

ABSTRACT

This study aims to evaluate the effectiveness of selected color filter film for demultiplexer construction where only signals with certain wavelengths are allowed to pass through the demultiplexer while the other signal that carrying different wavelengths are absorbed. Characterization testing and analysis is done based on recorded data. Demultiplexer components are characterized by the Same Source at Different Filters (SSDF) and performance of transmitted signal are measured. The developed demultiplexer is effective in short range communication, using low cost components and simple techniques. Communication range for short range communication is maximized by combining wavelengths and send through a single strand of fiber by means of Wavelngth Division Multiplexing (WDM). Only signals with certain wavelengths are allowed to pass through the multiplexer. The rest are absorbed. Several measures are made to ensure efficiency, such as testing and measurement on parametres contributing to loss. Best filters are selected based on their ability to block certain wavelengths while letting others ro pass through efficiently. The blocking feature is important to avoid phenomena of crosstalk occurs in the system.

Keywords: Plastic Optical Fiber, Demultiplexer, Spectral, Filter, Output Power

1. INTRODUCTION

There are a lot of optical devices have been invented. Among them is the optical demultiplexer. According to Kartalopoulos (2000), optical demultiplexer is a device to receive from a fiber a beam consisting of multiple optical frequencies and separate it into its frequency components, then coupled in as many insdividual fibers as there are frequencies. Passive demultiplexers are based on prisms, diffraction gratings and spectral filters. This study discusses on filters selection for demultiplexer implementation.

Spectral filters allows particular electromagnetic wavelengths to pass through, while blocking the remainder. Spectral filters can be used to extract and sort wavelengths. Hence it is suitable for demultiplexer implementation. However, proper selection of filters are needed to ensure best efficiency.

1.1. Related Work

Pfenninger and Winzer (2006) had worked on the influence of filter bandwidth and flank steepness of Multiplexer (MUX) and Demultiplexer (DEMUX) in Dense Wavelength-Division Multiplexed (DWDM) systems in the presence of coherent WDM crosstalk. The approach this by investigating the MUX and DEMUX filter bandwidth on OSNR penalty for RZ, NRZ, CSRZ. They found that steeper filters tends to bring better OSNR values.

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Sanchis *et al*. (2010) proposed a microing demultiplexer filter for 60 GHz. They had also demonstrated experimentally a high Q factor of 33900. An SOI demultiplexer filter at 60 GHz is used. Their experimental result shown that two optical carriers separated by 60 GHz with extinction ratios above 20 dB and insertion losses is lower than 3dB in both ports.

Santos-Anguilar *et al*. (2011) designed and realized photonic filters, using segments of Polarization Maintaining Optical Fibers (PMF). The photonic filters are designed as optical retarders. Selective filtering of one and two modes on the spectrum of a longitudinal laser has been performed.

Igarashi *et al*. (2006) proposed a simple optoelectronic time-division demultiplexer based on selective spectral shift and spectral filtering. Their scheme has good receiver sensitivity of -33 dBm to -31 dBm at 40 Gbit/s. Their power penalty is measured 3 to 5 dB at BER = 10-9.

Fu and Zhu (2011) proposed, analysed and experimentally showed cost-effective demultiplexing approach for subcarrier multiplexed Radio-Over-Fiber (ROF) system. Experiment carried out by implementing a two-optical-source-based microwave photonic filter in an ROF downlink transmitting a 2.5-GHz subcarrier modulated with 150 Mb/s on-off keying. The peaks of the filter's frequency response can be used to get desirable subcarrier and the valleys of the filter can be used to suppress undesirable subcarrier frequency.

Ab-Rahman *et al*. (2011c) has demonstrate for the first time the POF devices can be fabricated by the skillful hand. The temperature, stress and splitting technique are the most important parameters to fabricate low loss device. With some modification the device can be used for the extended function such as demultiplexer which is fabricated from uniformity optical splitter (Ab-Rahman *et al*., 2011a). In WDM-POF system, many transmitters with different lights color to carry single information. For example, red light with 650nm wavelength modulated with Ethernet signal while blue, green and yellow lights carry image information, Radio Frequency (RF) and television signal, respectively. Wavelength Division Multiplexer is the first passive device required in WDM-POF system and it functions to combines optical signals from multiple different single-wavelength end devices onto a single fiber (Ab-Rahman *et al*., 2012b). Conceptually, the same device can also perform the reverse process with the same WDM techniques, in which the data stream with multiple wavelengths decomposed into multiple single wavelength data streams. The reverse process is called as de-multiplexing.

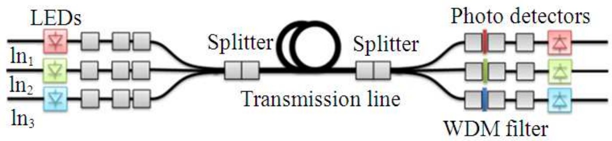

Fig. 1. Eco-friendly-WDM-POF network architecture using 1×3 splitter and color filters. The splitter can also be used as multiplexer and the splitter-filter combination work as a demultiplexer

Conceptually, POF splitter has similar function, operates to couple or combine several optical data pulse as a single coupled signal. Hence, the development of wavelength division multiplexer based on POF splitter is possible. A low-cost solution for POF-WDM system application will be presented.

A novel fused POF splitter will fabricated by a fusion technique as reported by Ab-Rahman *et al*. (2011b), as an effective transmission media to split and recombine a number of different wavelengths which represents different signals. Three different wavelengths will be fully utilized to transmit three different sources of systems; LAN connection Network, radio (audio) and video transmission system. Red LED which in 665 nm wavelength capable to download and upload data through Ethernet cable while green LED in 520 nm wavelength can transmit a video image generated from DVD player or CCTV system and blue LED with 470 nm wavelength represents an audio transmission system inside the house (Ab-Rahman *et al*., 2012a). Special filter will be placed between the splitter and receiver-end to make sure the entire WDM system can select a single signal as desired. For the filter design which able to eliminate unwanted signal and select the wavelength of the system as desired as shown in **Fig. 1**. Some parameters, such as optical output power, power losses, optical noise to ratio and crosstalk of the devices can be observed and not mentioning about the effect of filter placement and the efficiency of the WDM-POF system itself.

1.2. Objectives

The objectives of characterization and analysis testing are:

- To develop demultiplexer component and optical splitter that provide optimal results when applied to the data transmission systems
- To evaluate the effectiveness of selected color filter film for demultiplexer construction where only signals with certain wavelengths are allowed to pass through the demultiplexer while the other signals carrying different wavelengths are absorbed

- To find maximum distance of developed components where transmitted signal can be delivered quickly and effectively
- To ensure the developed components can deliver the best performance in short range communication system without lot of costs

Characterization testing and analysis are done based on recorded data. The developed demultiplexer components are categorized by Same Source Different Filters (SSDF). For final analysis, the outcomes are:

- The developed demultiplexer is effective to be applied in short range communication system by using low-cost components and implementation techniques that are not too complicated
- Maximum distance can be achieved for short range communications system by using the components developed
- Signals that carry different wavelengths are absorbed or prevented from being transmit through the developed demultiplexer with filter film. Only signals with certain wavelengths are allowed to pass through the demultiplexer

Signal transmitted through optical fiber and optical splitter by using LED light source is tested for the maximum distance that can be achieved for the purpose of data transmission. Parameters that have contributed to the loss of signals (which are carried by the components developed) are tested and measured. It is done to ensure the interference that exists in data transmission system does not affect the total emitted signal or reduced the performance of system that was developed in order to maintain the performance of signal transmission efficiency.

1.3. Same Source Different Filters (SSDF)

1.3.1. Characterization of the Prototype

Each optical fiber that used in this study should be ensured in order to transmit optical signals with low power loss. Power meter is used in order to measure the output power for optical fiber. **Figure 1** shows the insertion loss for each fiber where the length is measured between 1 and 10 m. Red LED light source is injected into each fiber and the readings will show that the higher of optical fiber length, the higher insertion loss rates is measured. This is because the transmitted signal starts to fade or weaken as the optical fibers are longer. Thus, the rate of transmitted signal will be decreases (attenuation).

Small insertion loss is detected in fiber of 2 m length and the readings will be higher due to the scattered signal that occurs in longer fibers.

Table 1. Insertion loss and output power loss when various sizes of fiber has attached to #4690 red filter film

Length (m)	Insertion loss (dB)	Output power loss (μW)
1	0.4	2.1
2	0.5	4.2
3	0.0	-0.2
4	0.7	5.0
5	0.5	3.7
6	0.1	-1.0
7	0.4	-1.8
8	0.4	2.6
9	0.8	3.8
10	0.4	-3.6

Sample of fiber for 1 m length has higher loss due to the fiber factor which is bending losses. However, the sample of optical fiber with 7 m length gives the highest rate of insertion loss. Imperfect connection between fiber and red LED light source will be one of factors, in which the signal loss has occurred. Fiber bending losses are also a factor which attributed for signal loss.

The value of output power for transmitted signal in each fiber is compared in **Fig. 2**. High value of output power is detected in optical fiber with 2 m length, thus it concluded that output power is decreased as the fiber length is increased. Although the output power is decreasing, however, the tested fiber optic can still be used in order to transmit the signals. Even the actual insertion loss is positive but negative sign (-) is used to differentiate with the output power and to shows the negative impact. **Figure 3** shows output power of red LED signal against various sizes of fiber optic length. **Figure 4** Insertion loss rate when red LED has injected through various fiber length that attached to #4690 red filter samples. The values are slightly bigger as compare to **Fig. 2**. The diffrence is the insertion loss of #4690 red filter. Output power for each fibers when red LED is injected through various fiber length that attached to #4690 red filter samples is shown in **Fig. 5**. **Figure 6** analyse the reduction on (a) the insertion loss and (b) output power when various sizes of fiber length attached to #4690 red filter films. The suiatbility of the filter used is determined by the rate of the insertion loss reduction. The highest rate gives meaning that the more loss has been attributed by the particular filter.

Table 1 shows the insertion loss rate (dBm) and a decline of output power (μW) for various sizes of fiber optic length. From the plotted values, fiber optics of 3 m length indicated the lowest loss rate and highest output power. However, the readings did not show a linear relationship between length of fiber with insertion loss and power output.

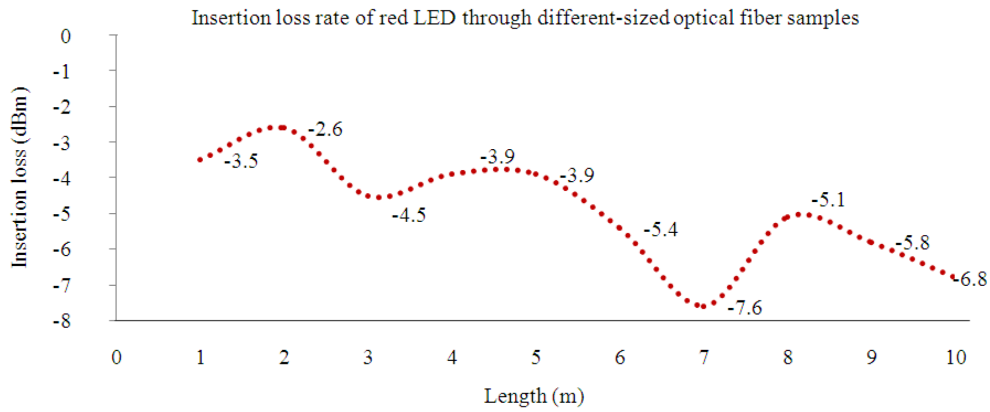

Fig. 2. Insertion loss rate of red LED signal against various length of fiber optic

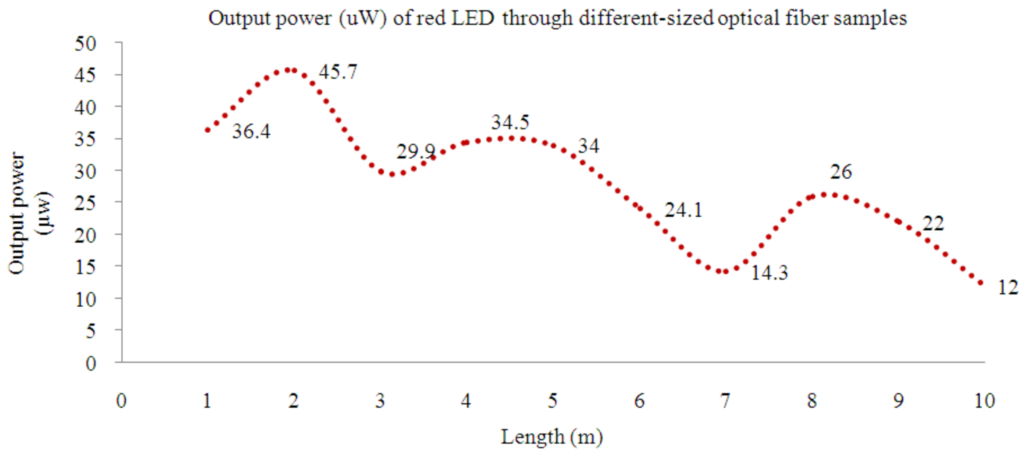

Fig. 3. Output power of red LED signal against various sizes of fiber optic length

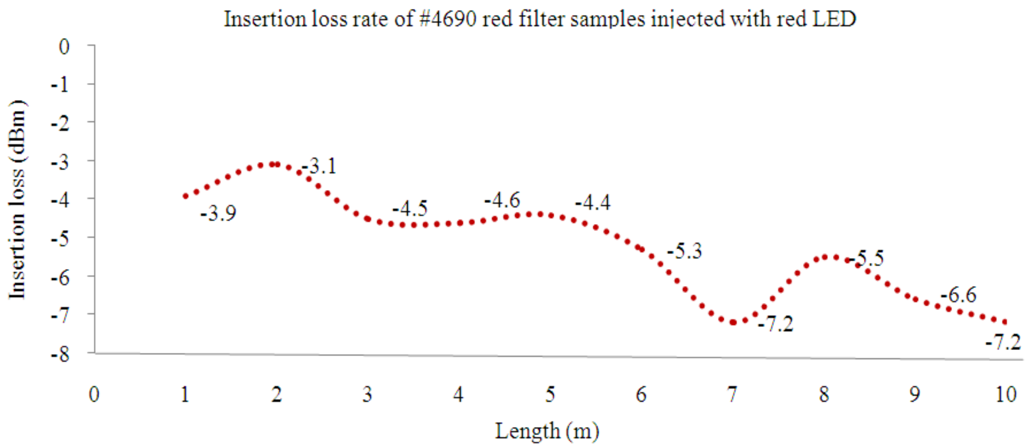

Fig. 4. Insertion loss rate when red LED has injected through various fiber length that attached to #4690 red filter samples

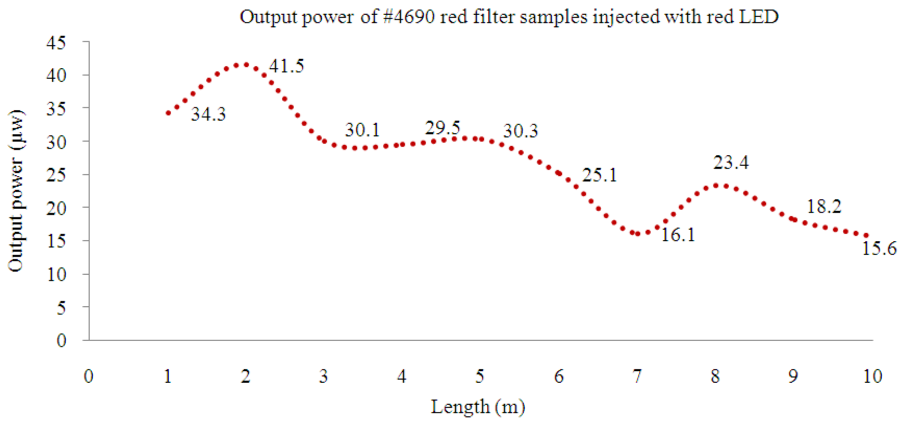

Fig. 5. Output power for each fibers when red LED is injected through various fiber length that attached to #4690 red filter samples

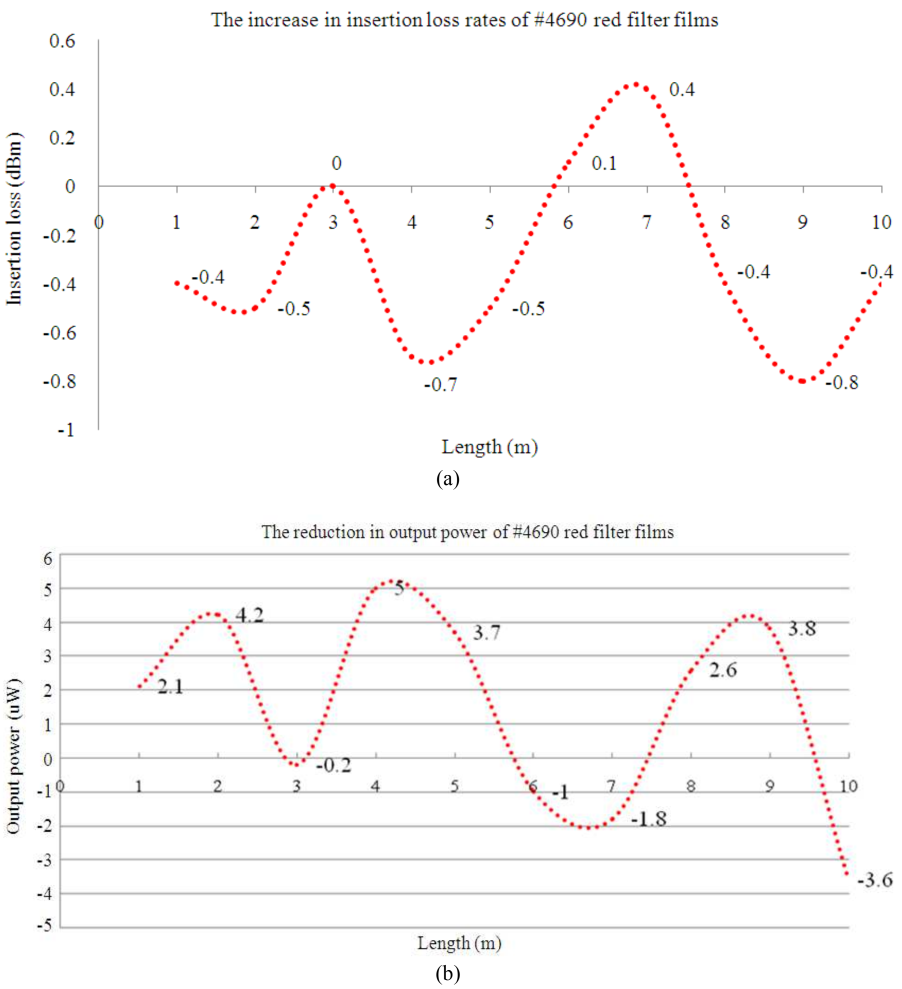

Fig. 6. Reduction in (a) the insertion loss and (b) output power when various sizes of fiber length attached to #4690 red filter films

This may be due to errors that occur during the connection between LED light source and imperfect fiber. Filter film that is not attached properly is also being a factor of errors that occur. Fiber surface that attached to improperly filter film will cause the transmitted signal through fiber to filter film and power meter decline. Epoxy-resin adhesive may also spread to the fiber surface which causes some signals carried by fiber fades or disappears.

2. CONCLUSION

Demultiplexer components are characterized by the Same Source at Different Filters (SSDF) and performance of transmitted signal are measured. The developed Demultiplexer is effective in short range communication, using low cost components and simple techniques. Communication range for short range communication is maximized by combining wavelengths and send through a single strand of fiber by means of Wavelngth Division Multiplexing (WDM). Only signals with certain wavelengths are allowed to pass through the multiplexer. The rest are absorbed. Several measures are made to ensure efficiency, such as testing and measurement on parametres contributing to loss. Best filters are selected based on their ability to block certain wavelengths while letting others ro pass through efficiently. The blocking feature is important to avoid phenomena of crosstalk occurs in the system. From the measurement we observed insertion of the RED filter used is less than 0.5dB and therefore the selective filter is suitable to be used for WDM communication using commercialized red LED.

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