New Optical Splitter Design for Network Scalability and Flexibility

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ABSTRACT

In this paper, we present the design of two optical splitter which are 2x3 optical splitter-combine and Multi Ratio Optical Splitter (MROS) based on waveguide with SU-8 polymer material. The technology ensures low cost fabrication and excellent performance as compared to conventional technique that uses fused coupler for optical splitter fabrication. Both optical splitter-combine and MROS are suggested to be used in passive customer access network FTTH-PON. The optical splitter-combine is used to variety the signals send to the premises and as for MROS, it is used in power management in minimizing the power loss. The problems arose such as the loss of output power is also discussed. The simulation result shows that factor such as wide-angle branching and refractive index will increase the output power loss. To obtain maximum power, the optimization of those parameters' value must be used. This designed optical splitter is operated at wavelength 1500 nm – 1600 nm. In this study, we characterized the trend of total output power with the effect of the parameters studied.

Keywords: Optical splitter-combine, Multi Ratio Optical Splitter, waveguide, SU-8 Polymer, parameters

INTRODUCTION

Fiber-to-the-home (FTTH) network is a network technology which uses fiber optic as a transmission medium to transmit Triple-play (data, voice and video) services. By using fiber optic, which has a very high broadband, FTTH network is capable to transmit data with higher capacity compare to the technology based on cuprum cable [8]. FTTH network plays an important role in reducing and solving the final access *Bottleneck* problem in broadband access network specifically in future optical access network [11]. Nowdays, FTTH network is recognized as the latest solution for various types of communication and multimedia services including telephone, high speed internet access, digital cable television (CATV) and video [2].

In the application of the FTTH, optical divider or the 2x3 optical splitter-combined is designed to solve the problem when different data transmission is required in the same house which in turn requires combination of transmission power from a different bandwidth and MROS has been designed in order to reduce the wastage of power.

The Beam Propagation Method (BPM) analysis is used to solve the scalar wave equations of polarizations transverse electric (TE) and transverse magnetic (TM). By using the beam propagation method employing the finite-difference method, the amplitude electric fields inside and outside of a slab structure can be analyzed. Beam propagation method, is a step by step technique for simulating the propagation of light in optical waveguides [5], [10]. BPM is a powerful tool for creating guided-wave optical devices using the mode combination approach like coupler, multiplexer and demultiplexer, splitter and optical combiners [1].

Waveguide is one of the important components in developing homogeneous optical device. Y-branch has a simple structure and yield high product fabricated with compact device with stable wide angle branching ratio and planar light wave circuit (PLC) [3].

SU-8 polymer is used as a waveguide material to produce optical switch device. SU-8 based on the *Epoxy* structure, strengthen the resistance system chemically with sensitive characteristic and High Aspect Ratio. SU-8 is used for the first time in the micro-electromechanical-system (MEMS) and microsystem structure which needs the non-conductive characteristic.

In this research, Y branch optical splitter-combine and MROS Y-branch was design to obtain the desired result using the beam propagation method. The research was done on a symmetrical Y branch optical splitter-combine to acquire an output power that is symmetry. This optical splitter-combine is design using the commercialized SU-8 material. Parameters such as refraction index, length and width of the waveguide as well as the wide-angle Y-branch have to be analyzed using the BPM-CAD simulation for the purpose of getting the optimal design.

PROPOSED APPLICATION

Optical splitter-combine

In the FTTH-PON network, signal towards the user is normally sharing the same wavelength which is 1480nm (voice & data signal) and 1550nm (video signal). If the application is widen through the increase of broadband and also additional new wavelength, this will cause the system to be complex. Hence, the easiest way is to distribute each Optical Line Terminal (OLT) to coordinate the different wavelength.

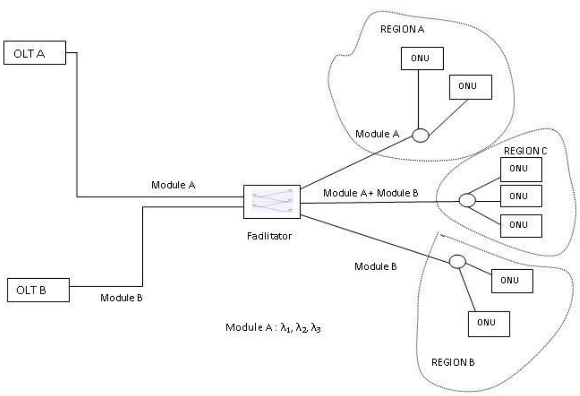

Figure 1. Optical splitter-combine device used as service facilitator which is offered by two different OLT.

Figure 1 illustrates the function of optical splitter-combine in the FTTH-PON network. OLT A provides different services from OLT B and the position of both of the OLT is far apart. Premises in area A will receive all of the services offer by OLT A and same goes with premises in area B which will only receive the services offers by OLT B. If there is another area say area C that will need the services offers by both OLT, it can be satisfied by the facilitator that is connected before the optical splitter. With the facilitator present, both services can be offered to area that requires it.

MROS device

Figure 2 shows the usage of optical segmentation in the transmitting network where the function is to divide the optical signal from OLT to premises. In reality, the distance from each premise to optical line terminal is not standardized so the multiple ratio optical splitters have been designed in order to avoid this problem. MROS divided the power which has been received into 10%, 20%, 30% and 40%. So the power losses during conveying the data can be reduced because the signal power is divided according to the distance of every house.

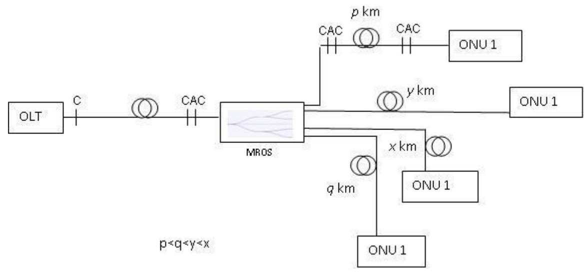

Figure 2. Optical splitter in FTTH network

RESULT AND DISCUSSION.

This analysis focused on the effect of parameters towards the output power. Figure 3a and 3b shows the propagation power along the waveguides for both optical splitters. Optical field at the end of waveguides propagation showed in Figure 4. The power that been produced is measured at every arm along MROS waveguides propagation is showed in Figure 5.

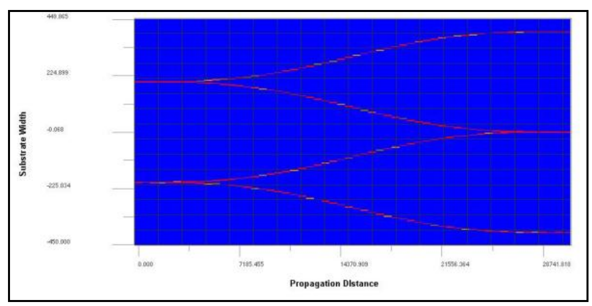

Figure 3a. Propagation power along the waveguide of 2x3 divider

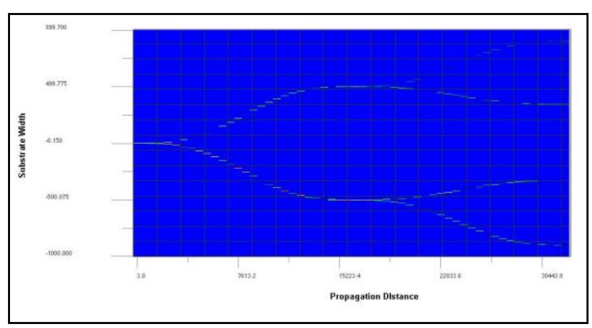

Figure 3b. Propagation power along the waveguide for MROS

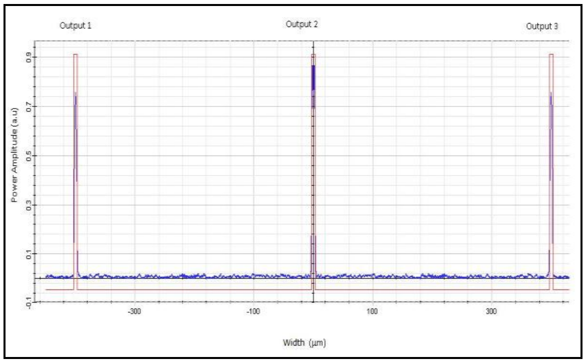

Figure 4a. Optical field of 2x3 divider at the end of waveguide propagation

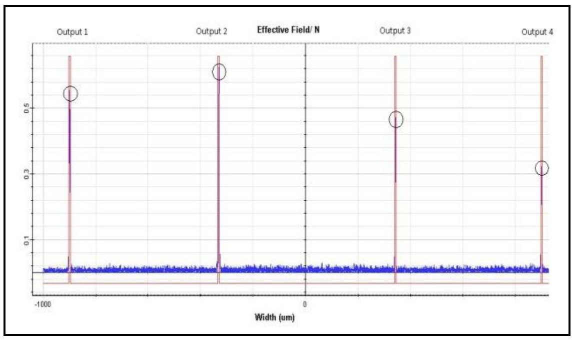

Figure 4b. MROS Optical field at the end of waveguides propagation

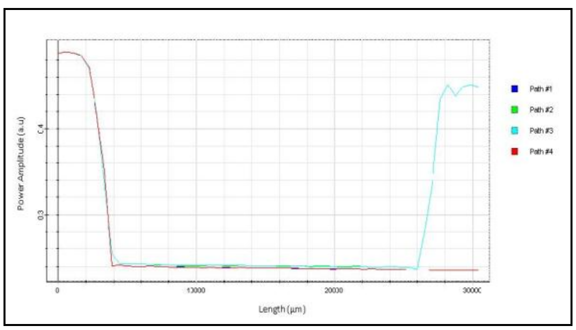

Figure 5a. Output power for each arm along the waveguide propagation of 2x3 divider

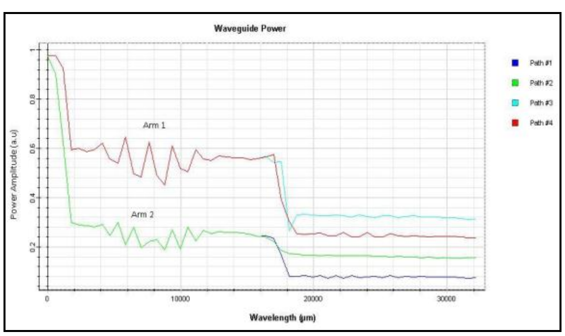

Figure 5b. Output power for each arm along the waveguide propagation of 2x3 divider

From the simulation result conducted using BPM_CAD, it was found that output power on each arm and the insertion loss are as follow:

<u>2x3 Optical-splitter combined</u>*:*

Output terminal 1 : 0.234985097563 ≈ 23 % (50% λ_1)

Output terminal 2 : 0.448802346314 ≈ 45 % (50% λ_1, 50% λ_2)

Output terminal 3 : 0.234985097563 ≈ 23 % (50% λ_2)

Total output power = 0.918772541 ≈ 91 %

Path loss, L = 10 log Po/Pin [1]

= -0.36 dB

Insertion Loss:

Output terminal 1 = 10 log Po1/Pin = -6.29 dB

Output terminal 2 = 10 log Po2/Pin = -3.47 dB

Output terminal 3 = 10 log Po3/Pin = -6.29 dB

<u>MROS</u>

Output 1: 0.074800207515 ≈ 7% (10%)

Output 2: 0.154832446992 ≈ 15% (20%)

Output 3: 0.312632040931 ≈ 31% (40%)

Output 4: 0.237388108523 ≈ 24% (30%)

Path loss, L = 10 log Po/Pin [1]

= -1.08 dB

Insertion Loss;

Output base 1 = 10 log Po1/Pin = -11.26 dB

Output base 2 = 10 log Po2/Pin = -8.10 dB

Output base 3 = 10 log Po3/Pin = -5.04 dB

Output base 4 = 10 log Po4/Pin = -6.24 dB

Analysis of output power was conducted by changing the value of wavelength, wide-angle branching and refractive index.

Wavelength

Four main wavelength been taken, which were 1310 nm (upstream), 1480 nm (downstream), 1550 nm (video) and 1625 nm which been used as the insertion test in FTTH. From the graph that been plotted (Figure 6), power loss increases when wavelength decrease for 2x3 optical splitter combine and as for MROS power loss increase when the wavelength decrease.

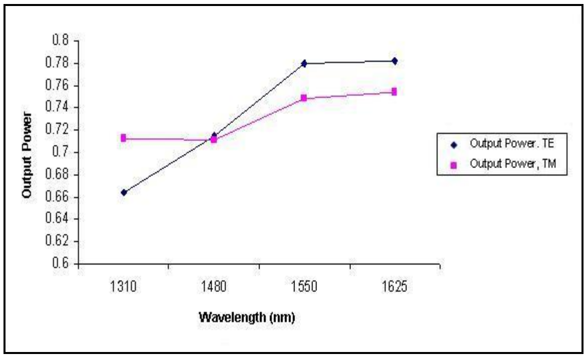

Figure 6a. Output power for the change of wavelength for 2x3 optical splitter-combine device

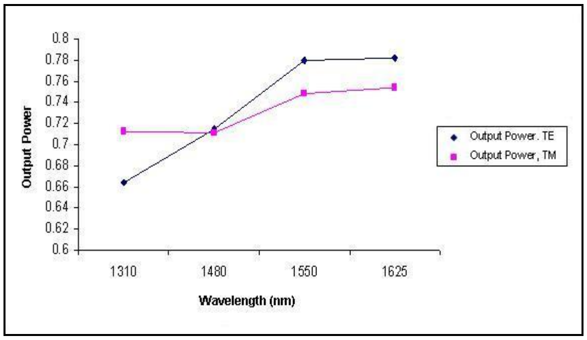

Figure 6b. Output power for the change of wavelength for MROS

Wide angle branching

The effect of changing the wide angle branching towards the output power was observed by changing the M value which is the width of branch opening. For the 2x3 optical splitter, the changes was observed for the M value between 160 µm until 260 µm with interval of 20 µm and for MROS, between 457 µm to 657 µm with the scale of 50 µm. From Figure 7a (2x3 optical splitter), it can be seen that the power decreases and increase at M value of 240 µm and decreases again afterwards and the maximum output power at wide-angle branching is at the M value of 260 µm.

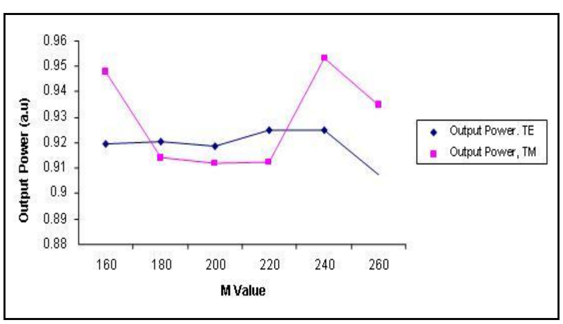

Figure 7a. Output power for the change of wide-angle branching for 2x3 optical splitter-combine.

Figure 7b (MROS) illustrates that the power losses is increasing with the increase in wide angle branching and the maximum power produced is at width angle opening 557 µm.

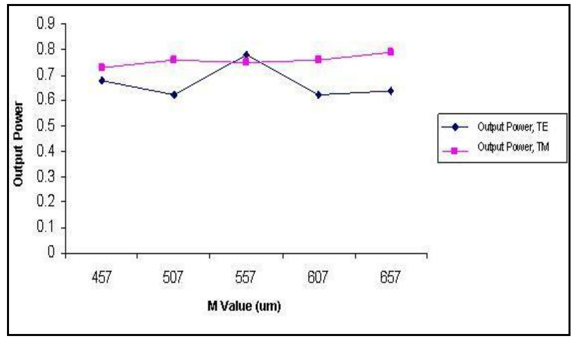

Figure 7b. Output power for the change of wide-angle branching for MROS

Refractive Index

The relative difference in refractive index is calculated with this formula: $\Delta = (n_1^2 - n_2^2) / 2\ n_1^2$, where n_1 is the core refractive index while n_2 is the cladding refractive index. The value of cladding refractive index which is substrate refractive index is 1.522 while the value of core refractive index with scale of 0.004. The result for the effect of refractive index towards output power for 2x3 optical splitter-combine can be seen in Figure 8a which shows that the output power decreases and power loss increases when the difference in relative refractive index increases. There is huge difference between output power of TE and TM at 0.0424 refractive index difference.

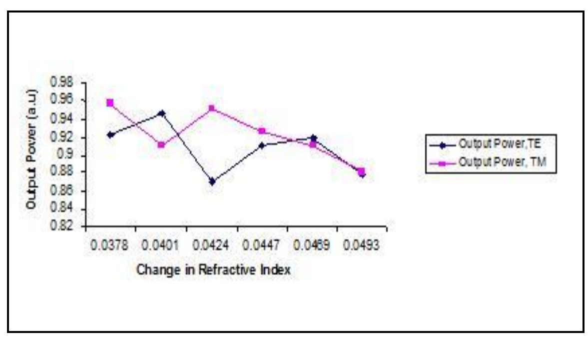

Figure 8a. Output power towards the change in refractive index for 2x3 optical splitter-combine.

As for MROS, the difference of power produced is small it showed that the losses of power increased when the difference of relative index is increased (Figure 8b). However, the increasing of core refractive index will change the power produced but in this situation the small changes output power. This shows that the refractive index that been developed is stable.

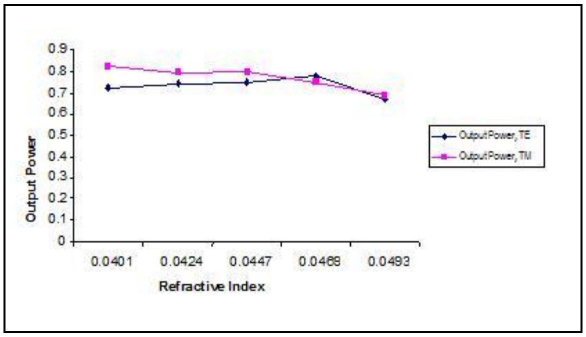

Figure 8b. Output power towards the change in refractive index for MROS.

CONCLUSION

This study is to introduce the design of two optical splitter which are 2x3 optical splitter-combined and Multi Ratio Optical Splitter (MROS). Some factors that were emphasized in the design process has been concluded in this study and points toward the optimum design of these two optical splitter. Result from the analysis of output power for both 2x3 optical splitter-combine and MROS found that the increase of the wide-angle branching will lead to the decrease of output power. Output power increases with the increase of wavelength. Based on the materials used to develop this device which is SU-8 polymer that operates at wavelength of 1550 nm and above, it was found that the maximum power is at the wavelength of 1625 nm. Other factors that need to be considered and can greatly influence the output power is the width of the waveguide. Width of the waveguide can't be too small because the propagation mode can't propagate in a narrow waveguide.

During characterization, there was loss of power at the optical splitter still can be accepted. The loss of power in the design is because of the waveguide bend. Other than that the loss of power is also occur in linear waveguide because of *Evanescent* mode.

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