Study of 1x4 Optical Power Splitters with Optical Network

Miss. Gayatri Y. Gurav[1], Prof. Maruti B. Limkar[2], Prof. Sanjay M. Hundiwale[3]

[1, 3]Dept. of Electronics and Telecommunication, ARMIET College of Engineering, Shahapur, Dist. Thane, India.
2 Dept. of Electronics Engineering, Terna College of Engineering, Nerul, India.

Abstract: *The optical Power splitters which allow for fiber connections are based on Different design techniques and fabrication process. The 1x4 optical power splitters have four output channels which are suitable for a number of network architectures by better adaptation to existing constructions like fiber cables and fiber management systems. The 4-level splitter can be used for cascading in the distributed network. The splitter cascade distributes the optical signal from one fiber to 16 subscribers via 4 splitting points in different locations but with equal signal levels for all 16 subscribers. This paper is aimed to provide reviews on different design techniques and fabrication process required while designing 1X4 optical power splitter.*

Keywords – *Design Techniques, Fabrication Process, Network, Optical Splitter, Power Splitter*

1. INTRODUCTION

In optical communication networking for Distribution purpose there is a need of 1-by-N optical power splitter. Typical Numbers of splitting will be from 16 to 256 or more. For low numbers of splitting, the splitter could be made as a fused bundle of optical fibers or as a Cascade of 1 -by-2 couplers or splitters. However, for large numbers of splitting, such devices will become very difficult to fabricate. The multi-mode interference (MMI) power splitters that are based on self imaging Effect (SIE) are of attractive performances, Such as compactness, low excess loss, wide Bandwidth and acceptable manufacturing tolerance. The fig. 1 represent the outer structure of basic optical splitter which split optical input signal in two optical output with 50% light level at both end.

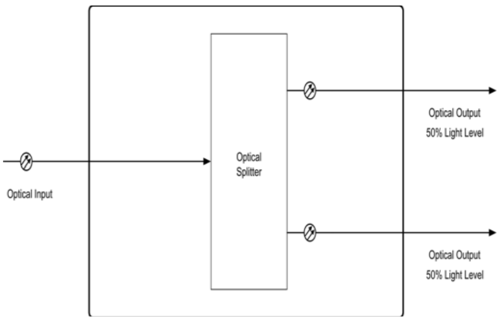


Fig. 1 basic optical splitter

MULTICORE optical fiber plays a significant role in dividing/Combining the optical power in optical fiber networks. A single power can be divided into several branches and can be routed to different locations. Several Approaches have been adapted to process and route the optical Power in branches. Among them, the most common approach is the fusion of several identical or non identical optical Fibers together by keeping mutual contact in the fusion region. This fusion process results in the tapered region of fused optical Materials, where exchange of powers occurs through proximity Coupling. It has been observed that splitters using fewer than six surrounding fibers are difficult to make, as one has to use Dummy fibers for example it may be difficult to make 1x4 power splitters using conventional optical fibers. However, 2x2, 4x4 and 1x7fiber couplers/splitters can be made by fusing conventional Optical fibers. In this optical network the need of optical power splitter arises. It is use to guide and split data traffic from one end to another end of the network.

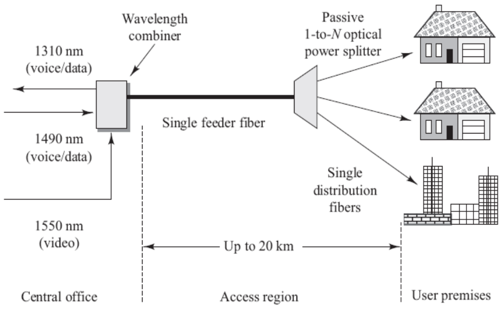


Fig. 2 optical network setup

Different optical terminals such as Optical Line Termination (OLT), Optical network termination (ONT), Optical network unit (ONU) were used in the optical splitting which is used to set up the optical network for the data communication. The optical splitting in the actual network is shown in the figure 3.

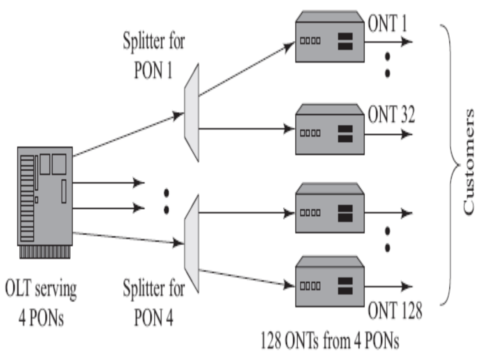


Fig 3 optical splitting in the network

2. OVERVIEW OF OPTICAL LAYER

To establish optical network the optical layer plays an important role. The optical layer is based on wavelength concept. The figure 4 shows the optical layer. It lies just above the physical layer of the TCP/IP Protocol.

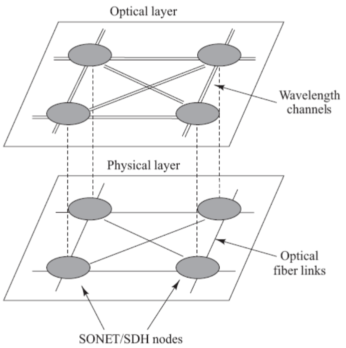


Fig. 4 optical layer

The physical layer used to provide physical connection between nodes where the optical layer used to provide ***light path services*** over the entire link. The optical layer process includes multiplexing, adding and dropping wavelengths, as well it support for optical switching. With the help of this optical layer different optical network can be developed.

3. DIFFERENT DESIGN AND FABRICATION TECHNIQUES OF 1X4 POWER SPLITTERS

For designing optical power splitter different methods and techniques were used. The most common used methods are as follows:

3.1 Device design and fabrication Method1

For designing of a 1x4 power splitter GaAs/GaAlAs double hetrojunction epitaxial layers structures were used.

n- $Ga_{08}Al_{02}As$	$<5x10^{15}/cm^3$	0.25µm
n- GaAs	$<5x10^{15}/cm^3$	1.5µm
n+ $Ga_{09}Al_{01}As$	$>2x10^{17}/cm^3$	1.7µm
n+ GaAs Substrate	$2x10^{18}/cm^3$	

Fig.5 epitaxial layers structure

All layers were n-type doped, except the GaAs waveguide core and $Ga_{0.8}Al_{0.2}$ As upper cladding layer, which were undoped. The thickness of GaAs waveguide core is 1.5µm; GaAlAs cladding layers are 0.25µm and 1.7µm respectively.

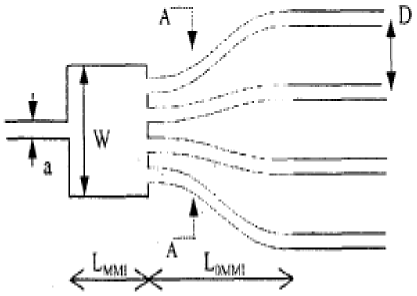


Fig. 6 top view of MMI 1x4 optical power splitter

The figure 6 shows top view of the MMI power splitter. According to designed requirement, we etch through the GaAs waveguide core and then deeply down to the GaAlAs lower cladding layer. Then the excess loss and imbalance for fixed W and varying L_{MMI} (as well vice versa) are calculated. The most critical parameter in the fabrication of the MMI power splitter is the MMI section width, [5] which is controlled to sub-micron.

The following figure 7 shows the measuring system for the output power.

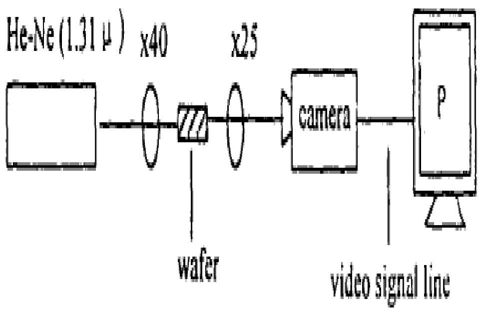


Fig.7 the measuring system

The light of a 1.31µm He-Ne laser is focused into the device by means of an x40 microscope objective lens. [1] The video signal outputted from camera is inputted into a PC and then the images on the output condition of the device can be shown in the PC screen. The related data of the video signal can also be processed in the PC. The output image of the optical power splitter picked up by PC. Then the relative distributive intensity outputted by the four output waveguides. The power imbalance of the optical power splitter is defined as following:

$$Imbalance = 10log\frac{P_{omax}}{P_{omin}}(dB)............ (1)$$

Where:

P_{omax}= maximum output power

P_{omin}= minimum output power

The following fig. 8 shows the relative distributive light intensity in the fiber.

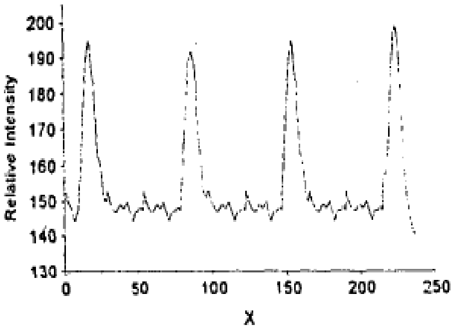


Fig. 8 The relative distributive light intensity

By referring to fig. and neglecting the background noise, we can calculate the power imbalance. It is nearly 0.155dB. [1] The power splitter will be designed for the second telecommunication window. Considering self-imaging effect and device compactness, the width (w) of multi-mode section is chosen.

The analysis of Ulrich shown that the shortest N-fold images of input field φ (y, 0) under center-fed condition at:

$$L_{MMI} = \frac{1}{N}\left(\frac{3L_{\pi}}{4}\right) = \frac{n_r W_e^2}{N\lambda} \ldots\ldots\ldots\ldots (2)$$

Where:

n_r= Effective refractive index of the wave guide core

W_e= Effective width of MMI section

In 1-by-4 optical power splitter,

For,

N=4, Width (w) = 40μm, λ = 1.31μm

We can obtain,

The length L_{MMI} = 1047μm

The low loss S- shaped curve single-mode waveguide were placed at the MMI section end. The center-to-center distance D between neighboring waveguides is chosen to 250μm to allow for fiber connections taken into account the typical cladding thickness of optical fibers of 125μm.The optical power splitter based on MMI coupler, which has compact size, is easy to monolithic integration with other optical devices. This designed structure has realized the requirement of power uniform splitting in fiber-optics communication system at wavelength of 1.31μm.

3.2 Device design and fabrication Method 2:

The 1x4 switch is based on a silicon-on-insulator circuit fabricated using a multi-project wafer run carried out by ePIXfab. An image of the complete IC is given in figure 9.

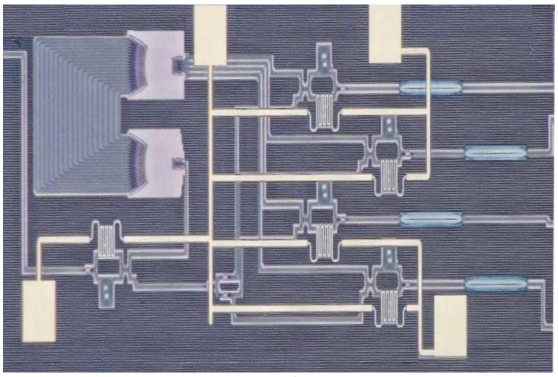
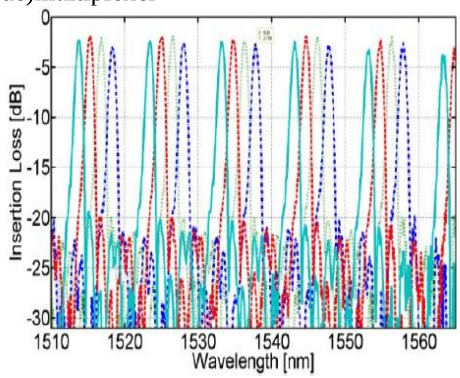


Fig. 9 Microscope image of the integrated 1x4 optically controlled remote switch

This silicon chip is further post processed to include the membrane InP switches, SU-8 inverted tapers and heaters as previously described [6]. The incoming input signal which contains the data and WDM labels is first de-multiplexed using a Mach Zehnder interferometer (MZI) into the data path (bottom of chip) and label path (top of the chip). The filtered out data signal is split into four by two consecutive 1x2 MMI splitter stages with each output of the splitter connecting to a separate chip output path. The WDM labels, which were de-multiplexed from the data signal, are sent to a 200 GHz channel spacing arrayed waveguide grating filter (AWG). After filtering, the four AWG outputs are multiplexed with the four copies of the data signal using an MZI multiplexer and sent to 4 separate membrane InP switches. The choice of active outputs is done by controlling which of the 4 WDM labels are active when the data packet arrives at the switches. The architecture allows for both uni-cast, multi-cast and broadcast operation as no space switching is involved.

4. DEVICE CHARACTERISTICS

The different components making up the integrated 1x4 switch were tested and characterized separately. The figure 10 shows optical performances of the AWG filter and MZI (de)multiplexer



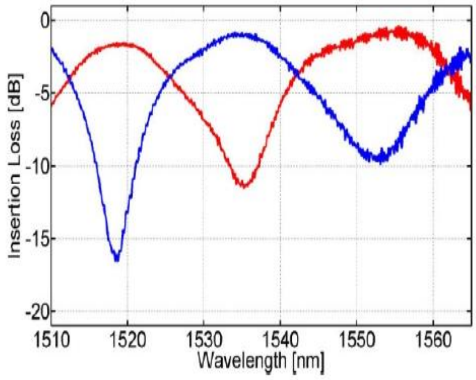


Fig 10 optical performances of the AWG filter and MZI (de)multiplexer

We show side by side the measured optical performance of the AWG filter and MZI (de)multiplexer periodic response of 200 GHz AWG; MZI (de)multiplexer through and cross transmission response. The AWGs were designed for 200 GHz channel spacing and a free spectral range (FSR) of 9.6 nm. Typical insertion loss measured on the AWG was 2.5 dB with a worst case channel cross talk of 17dB. While for normal operation 17dB channel cross talk may not be sufficient, the non-linear absorption response of the MIPS [7] makes 17dB more than enough. The MZI was designed with a FSR of 35nm.An extinction ratio of 10 dB and 1dB insertion losses were obtained. The full chip was also statically characterized for the extinction ratio (ER) of each output when the labels for other channels were present. This is to check for both the intrinsic ER of the membrane switch between the on and off states and the effect of the AWG cross talk on the eventual switch cross talk. In figure 3 we show the behavior of a single output of the switch (port number 2) while alternating the label wavelength as well as the ER for the other 3 ports for the on and off states. In this these experiments the label power was set to 0 dBm and the data signal was 8.5dBm (giving a total insertion loss >35 dB).
Figure 11: (Left) Port 2 extinction ratio for labels on and off and in the presence of other labels; (Right) Port 1, 3 & 4 extinction ratios with and without a label present

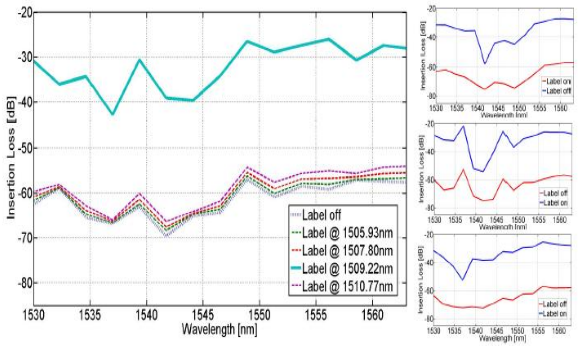


Fig. 11 Port 2 extinction ratios

It can be seen that the typical on-off ER of the switch is better than 25 dB at most wavelengths and better than 30dB for the wavelength range 1550-1560 nm were the data signal is placed (see red trace on fig. 2 (right)). It can also be seen that when a different wavelength for the label is used, the ER only degrades by 2-3 dB.

5. PERFORMANCE

The key performances of power splitters are excess loss and imbalance. In the fabrication process of the MMI power splitter the critical parameters are MMI Section width and length. We can use a finite difference beam propagation method (FDBPM) to simulate the evolution of the fundamental mode power of the input guide incoming device
The use of asymmetric splitter components in addition to symmetric components provides a high grade of flexibility when designing optical networks with a start topology setup. For 1x4 fiber coupler, the minimum coupling length required to transfer all input power in initial fiber to the other end. The AWG devices have very low excess loss of 0.5dB using 2 star splitters with 16 channels.
Overall, the 1x4 optical power splitters performs nearly the same as conventional broadband power splitters in terms of excess loss and uniformity but has some special features.

6. CONCLUSION

Intelligent Design and sophisticated manufacturing methods give these splitters exceptional quality and reliability and make them especially suitable for use under the harshest environmental conditions. Thereby they are compact, sturdy and long-term stable and can be produced in high yield and favorable quantities. In the Designing of Splitter multiple integrations offers a considerable reduction of required space and cost. The uses of splitter components provide a high grade of flexibility when designing optical networks with different topology setup.

7. ACKNOWLEDGEMENT

The authors would like to express gratitude to the people who helped and supported throughout this paper. The authors also like to thank the reviewers for their comments and suggestions to improve this paper.

REFERENCES

[1] Design and Fabrication of 1-by-4 MMI Power Splitter for Optical Communication Ma Huilian, Yang Jianyi, Zhou Qiang,Wang Minghua. *Communications, 1999,APCC/OECC 99, Fifth Asia-Pacific Conference*

[2] Giga-bit Transmission over Multimode Air-Clad Holey Fiber in a 1X4 PON Configuration Y. Kim, D. U. Kim, Y. Jeong, T. –Y. Kim, C. -S. Park and K. Oh *Department of Information and Communications, GIST, Korea,2006 IEEE*

[3] Coupling Characteristics of Multicore Photonic Crystal Fiber-Based 1 4 Power Splitters Shailendra K. Varshney, *journal of light wave technology, Vol. 27, No. 12, june 15,2009*

[4] K. Saitoh, Y. Sato, and M. Koshiba, "Coupling characteristics of dual core photonic crystal fiber couplers," *Opt. Express, vol. 11, no. 24, pp. 3188–3195, Dec. 2003*

[5] Design and Modeling of Symmetric Three Branch Polymer Planar Optical Power Dividers Václav PRAJZLER 1, Hynek TŮMA 1, Jarmila ŠPIRKOVÁ 2, Vítězslav JEŘÁBEK 1 Dept. of Microelectronics, *Radio engineering, Vol. 22, No.1 April 2013*