Comparison of the Performance of Photodetectors APD and PIN in a Hybrid TDM/WDM PON Network Designed in OPTIWAVE Simulation Environment

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ABSTRACT:
A hybrid TDM/WDM PON network with 64 users was designed by a bidirectional optical fiber in this paper. Having analyzed the performance of the hybrid network with regard to the importance of photodetectors as the first receiving block, the performance of photodetectors PON and APN for different fiber lengths are compared. All designing procedures were performed by optisystem software and measured values were represented and evaluated. As expected, the result showed that, due to an increase in the length of the fiber, the amount of noise increased and consequently, the signal to noise ratio decreased. However, it was found that the used topology was able to receive information in both upstream and downstream for fibers with a length up to 30 km and parameters of Q factor, the bit error ratio, and the signal to noise ratio are desired and acceptable for fibers of 30 km length. In addition, the values of simulations show that the performance of APD diode and the Q factor and BER obtained from APD is better than that of PIN which could be expected because APD is more sensitive than PIN.

KEYWORDS: PON network; Hybrid TDM/WDM PON; APD; PIN; OPTIWAVE.

1. INTRODUCTION

This document provides an example of the desired layout for a MJEE journal paper and can be used as a template for Microsoft Word versions 2003. It contains information regarding desktop publishing format, type sizes, and typefaces. Style rules are provided to explain how to handle equations, units, figures, tables, abbreviations, and acronyms. Sections are also devoted to the preparation of appendixes, acknowledgments, references, and authors' biographies. For additional information including electronic file requirements for text and graphics, please refer to www.mjee.org.

Due to the growing number of users and their communication needs on the one hand and the inability of copper lines and wireless approaches in response to this increasing trend on the other hand, a lot of attention is given to PON networks [1]. Passive optical networks (PON) are important because of the lack of restriction on the fiber transmission bandwidth and the reduced cost of broadband services. Like other FTTx networks, PON constitutes three main components of OLT in CO, some ONU and an ODN network (Figure 1). PON networks are called so due to the fact that the networks can't use active components in infrastructure. In fact, if RN in German FTTx networks is active, the network is called active optical network (AON); otherwise, in the case of using a passive RN, it will be called passive optical network [2].

From among the common multiplexing methods, TDM and WDM are used in PON networks. Due to restrictions in TDM-PON network, the network is used for short distances at low speeds with low number of users [3]. The WDM-PON network is able to provide services for a large number of users over long distances.

The price of these networks is, however, much higher than that of TDM-PON networks. Therefore, due to these different properties, TDM / WDM PON were proposed for the maximum use of optic fiber capacity and network optimization [5-7].

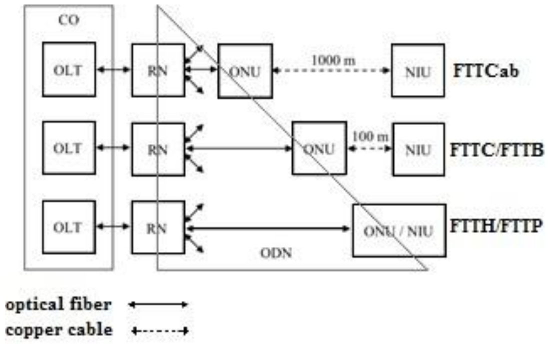


Fig. 1. Different types of FTTx architectures [4].

The combination of two techniques TDM-PON and WDM-PON has excellent transmission properties such as the ability to provide services to a large number of users, the ability to provide high-capacity services per user. Hybrid TDM / WDM PON (HPON) technique is also cost effective from the perspective of its economic aspects. In TDM / WDM PON, high splitting ratios are provided by TDM- PON and the large number of wavelengths by WDM-PON. Fig.2 depicts the structure of a HPON network. In the hybrid method, WDM technique is used to exploit the long distance between OLT and ONU. The signal is divided into separate wavelengths using an AWG demultiplexer. In the hybrid method, the time splitting demultiplexer is located in the nearest possible point to the target that is accessible to the network [3].

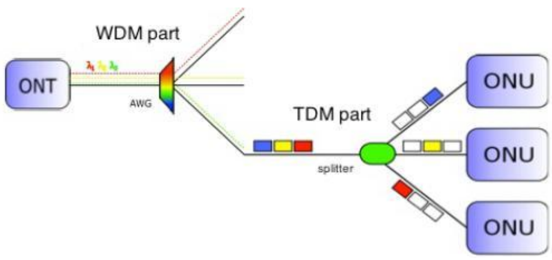


Fig. 2. Hybrid passive optical network.

This paper is an attempt in designing an optimal structure of the hybrid TDM / WDM PON (HPON) network using Fabry Perot (FP) laser. FP laser is used mainly for this reason that it can adjust its own wavelength with WDM input wavelength [3].

After the simulation of the designed topology and the analysis of its different parameters with the purpose of comparing the performance of different photodetectors, Q factor and bit error ratio are calculated for PIN and APD photodetectors.

In the second part of the article, the various parts of the designed topology such as photodetectors are described. The results of the simulation are presented in the third part and then the conclusion is given in Section IV.

2. DESIGNING THE TOPOLOGY IN OPTIWAVE

Figure 3 shows the general block diagram related to the topology simulated in this study. The block is divided into several main parts of upstream and downstream transmitters, upstream and downstream receivers and FP laser feed. 32 wavelengths with 100-GHz gap in each band have been used in this design.

The CW laser array is applied in the transmitter part that allows all 32 lasers be grouped together. CW laser makes the compatibility of lasers as simple as possible. CW laser output is turned into a single stream by an AWG that is configured as a multiplexer. Figure 4 shows the signal at the output of the AWG. This signal contains 32 waveforms with a distance of 100 GHz.

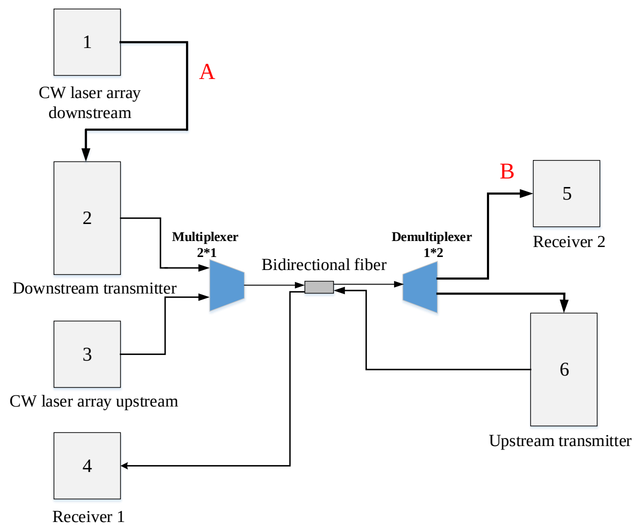


Fig. 3. general block diagram used in this study.

When the signal was multiplexed, consecutive filtering operations, strengthening and TDM multiplexing were exercised on it. These steps apply to each of the 32 channels. Figure 5 shows the FP laser circuit and how to use TDM multiplexer related to any one of the 32 channels. As seen in the figure, the input signal is generated by PRBS and is given to the input of RZ pulse generator. FP laser's output signal and the output signal of TDM transmitters are shown in figures 6 and 7, respectively.

When the signal was multiplexed, consecutive filtering operations, strengthening and TDM multiplexing were exercised on it. These steps apply to each of the 32 channels. Figure 5 shows the Fabry Perot laser circuit and how to use TDM multiplexer related to any one of the 32 channels. As seen in the figure, the input signal is generated by PRBS and is given to the input of RZ pulse generator. FP laser's output signal and the output signal of TDM transmitters are shown in figures 6 and 7, respectively.

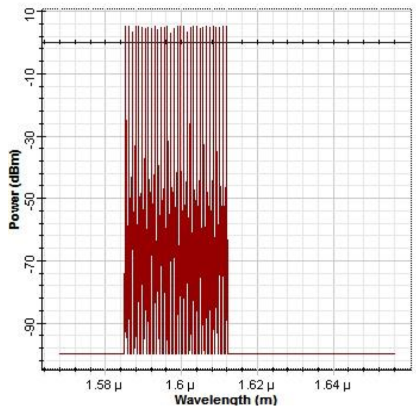


Fig. 4. Signal on CW laser array-downstream output.

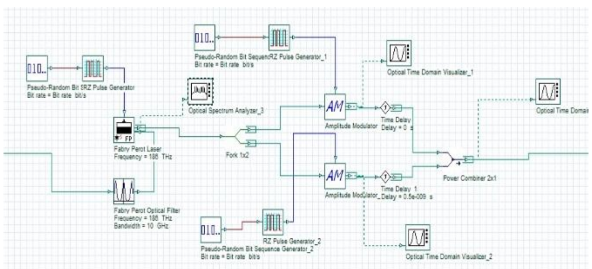


Fig. 5. Fabry-Perot laser and implementation of TDM multiplex.

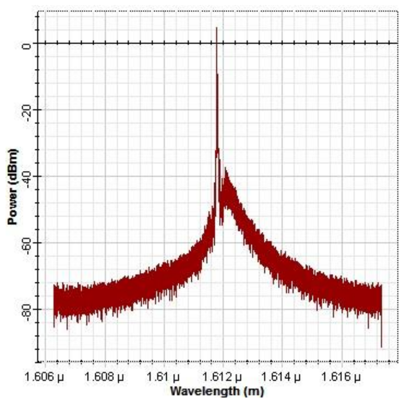


Fig. 6. Fabry-Perot output signal.

As mentioned earlier, FP lasers are mainly used because lasers are capable of adjusting their own wavelength with the input ones and are located at the upstream transmission instead of being placed in ONU in OLT. Since the above- mentioned designing is done in L and C frequency bands, AWG enters EDFA amplifiers for uplink transmission (EDFA amplifier has a uniform gain at the wavelength range of 1550nm, therefore it is the most suitable amplifier for this wavelength).

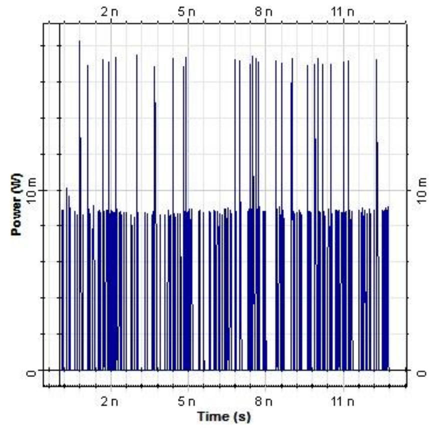


Fig. 7. Two channels in TDM output.

EDFA output signal related to FP laser feed of the upstream path (output of block 2 in Figure 4) accompanied with the signal of the data related to the downstream transmission (output of block 3 in Figure 4) must pass from bi-directional optical fiber simultaneously. An ideal 1*2 multi-multiplexer is used for the integration of the two streams. Figure 8 shows the output signal of the ideal multiplexer.

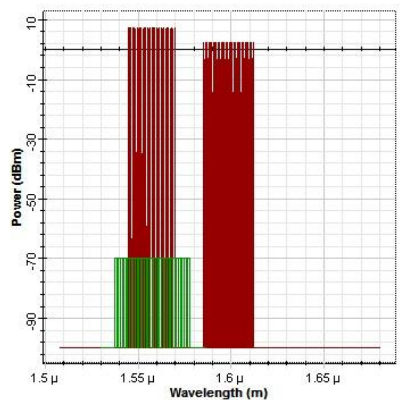


Fig. 8. Multiplexer output before line.

In the receiver, signal is splitted into separate wavelengths by an AWG that is this time configured as a demultiplexer. Each of the 32 AWG output streams is divided into two parts by a power divider and then both signals are modified in a similar way. Both are pushed at first into an APD diode that is set on the highest power to get a signal. After the diode, a low-pass filter and a 3R amplifier are used at the end of the path. The amplifier rebuilds and strengthens the form and the time basis of the signal (Fig. 9). The final element is a BER analyst. The analyst determines the exact properties of the signal after passing through the topology. Eye diagram in the receiver is represented in Figure 10. The output is obtained by RZ pulse generator for a fiber with a length of 5 km and 10 Gbps bit rate.

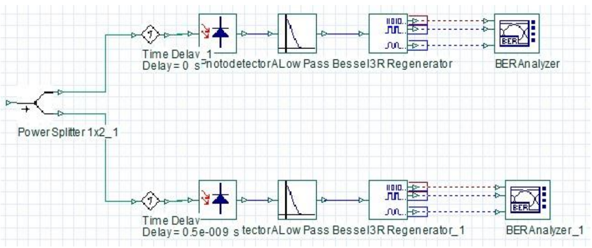


Fig. 9. Receiver circuit.

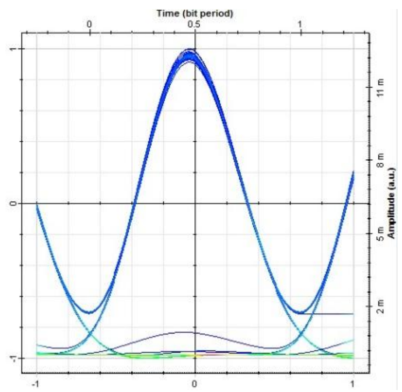


Fig. 10. Eye diagram showing the first channel of the topology with 10 Gbps on fiber length 5 km and RZ coding.

3. SIMULATION RESULT

3.1. Investigating the Designed Topology

Topology properties are carefully measured in this section. Parameters measured include the amount of power loss between the transmitter and receiver, as well as the evaluation of the quality of the output signal using parameters of Bit error rate and Q factor. Reduction in the output power level represents the power loss between two given points of topology. For the discussed topology, these points are shown by A and B in Figure 4. The values for Q factor, BER and Eye height are also achieved using BER analyst. Table 1 shows the measured values of these four parameters for fibers of length 5, 15 and 30 kilometers and the bit rate of 10 Gbps. Table 2 shows the values of these parameters for fiber with a length of 5 km and for bit rates of 2.5, 5 and 10 Gbps. To better understand the changes in the parameters, the curve of the changes is plotted in Fig.11. As it can be seen, an increase in the length of the fiber worsens the performance of the topology; however, the circuit's performance is desirable in fiber of up to 30 km, in which case the information are acceptably transmitted and received. A similar trend is also seen when the bit rate increases (figure 11. b).

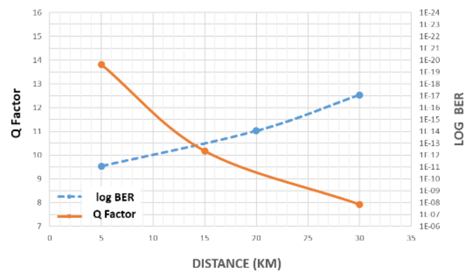
Table 1. Analysis of HPON network at different distance with 10 Gbps.

Distance (km)	5	15	30
Q factor	13.81	10.18	7.94
BER	$8.46*10^{-18}$	$9.12*10^{-15}$	$8.74*10^{-12}$
Drop of output level (dBm)	6.71	7.42	8.35
Eye height	$1.1*10^{-2}$	$8.3*10^{-3}$	$3.3*10^{-3}$

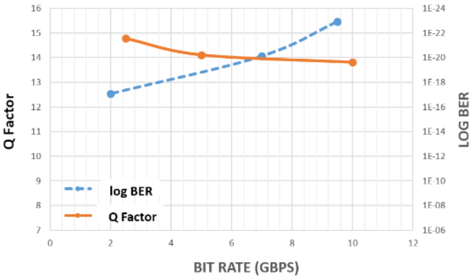
Table 2. Analysis of HPON network at different Bit Rate on fiber with a length of 5 km.

Bit Rate (Gbps)	2.5	5	10
Q factor	14.78	14.11	13.81
BER	$1.27*10^{-23}$	$7.84*10^{-21}$	$8.46*10^{-18}$
Drop of output level (dBm)	5.86	6.13	6.71
Eye height	$5.56*10^{-2}$	$3.9*10^{-2}$	$1.1*10^{-2}$

All results listed are related to downstream path and a quite similar trend are seen in upstream direction.



(a)



(b)

Fig. 11. Changes of different parameters of network: a) due to an increase in the length of fiber, b) due to an increase in the bit rate.

Q factor values of the upstream path are represented in figure 12. As it can be seen, the upstream path's performance is worse than that of the downstream path, but the difference in parameters is negligible.

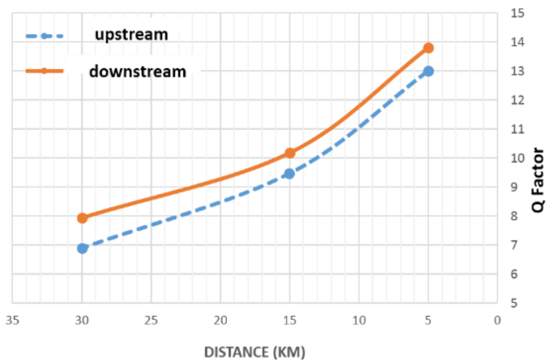


Fig. 12. Changes of Q factor as a result of increased fiber length in both upstream and downstream paths.

3.2. Comparison of the Properties of APD and PIN Diode

Photodetectors are one of the essential components of optical networks. photodetector is the first receiving block that converts the optical signal containing information into an electrical signal in a transmission line. Some common types of photodetectors include photodiode PN, photodiode PIN, APD avalanche photodiode and the metal-semiconductor-metal (MSM) detector. Special detectors of optical telecommunications are semiconductor photodetectors, mainly PIN and APD detectors [8-9].

As mentioned earlier, the first element placed in the receiver after AWG is an APD diode that is set to get the highest possible signal. To compare the quality of the received signal, APD diodes are used rather than PIN diodes.

Figures 13 and 14 show the Eye diagram of topology in question for different fibers (Figures 13 and 14 are related to APD diode and PIN diode, respectively). Values of different parameters while using PIN diodes and diode APD are compared in table 3 to 5. The parameters are measured at a rate of 10 Gbit/s on a 15 km path. As can be seen, the values of Q factor, BER and eye height obtained by APD diode are better than those achieved by PIN diode.

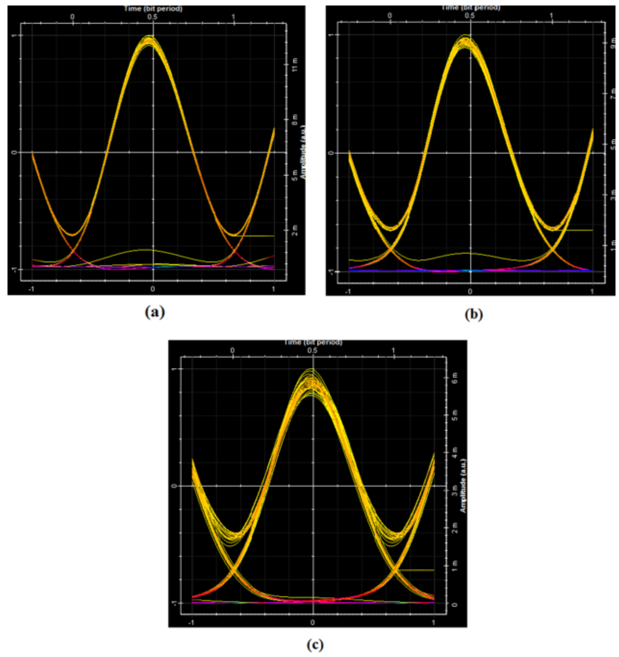


Fig. 13. Eye diagram for APD diode in bit rate of 10 Gbps for fibers with a length of: a) 2km, b) 15km and c) 30km.

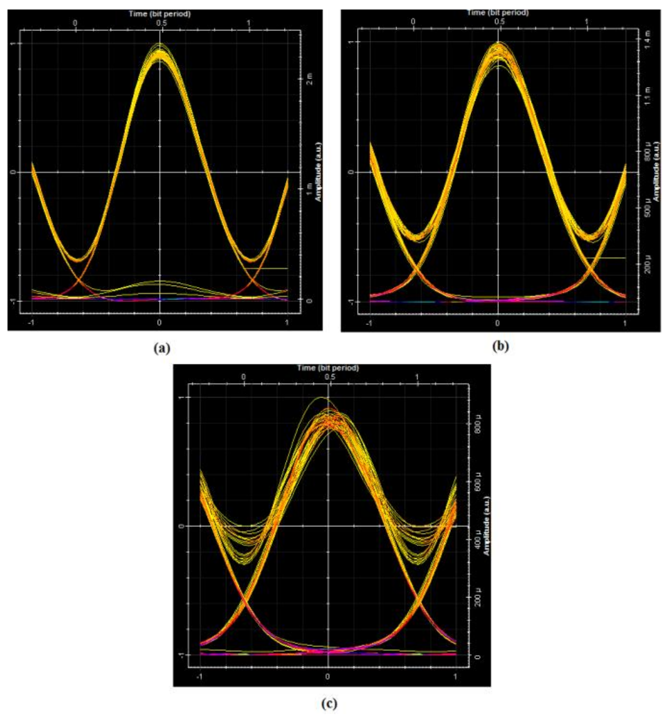


Fig. 14. Eye diagram for PIN diode in bit rate of 10 Gbps for fibers with a length of: a) 2km, b)15km and c)30km.

Table 3. Comparison of Q Factor in cases of APD and PIN.

	Q Factor	
	APD	PIN
2 Km	13.81	12.74
15 Km	10.18	9.26
30 Km	7.94	7

Table 4. Comparison of BER in cases of APD and PIN.

	BER	
	APD	PIN
2 Km	$8.46*10^{-18}$	$7.12*10^{-17}$
15 Km	$9.12*10^{-15}$	$5.46*10^{-13}$
30 Km	$8.74*10^{-12}$	$3.12*10^{-10}$

Table 5. Comparison of eye height in cases of APD and PIN.

	Eye height	
	APD	PIN
2 Km	$1.1*10^{-2}$	$2.3*10^{-4}$
15 Km	$8.3*10^{-3}$	$9.3*10^{-5}$
30 Km	$3.3*10^{-3}$	$2.7*10^{-5}$

In fact, it can be assumed that the most important benefit of APD is that it has current gain which, in turn, increases the receiver sensitivity. In other words, the gain results in more current in the output of the detector. Therefore the optic receivers become more sensitive which is a desirable feature leading to increased power of detector. In addition, APD is also in good condition in terms of response time and frequency band. In other words, the diode reacts to the optic pulse rapidly. For this reason, the calculated parameters for PIN diode are more desirable than those of APD. Furthermore, APD diode can set two parameters:

1. A gain with the value of 3;
2. Ionization quotas to the value of 0.9. Setting of other parameters in both diodes is done in the same way.

4. CONCLUSION

Given the importance of HPON networks in communications systems, this paper explores a descriptive topology for them. Modern parts such as FP laser and AWG are applied in the topology. Using AWG instead of the conventional dividers has the advantage that in AWG, increased number of output will not increase the amount of attenuation. Because of this feature, the proposed topology is very flexible in increasing the number of users. As expected, all parameters of power loss, and bit error rate and Q factor decreases with an. Despite these errors, however, the parameters measured are normal and the signal is properly transmitted. All the results obtained from the simulations are the expected results. Also, considering the importance of photodetectors as the first receiving block in the optical networks, the two main detectors applied in optical networks were compared. The results confirmed the theoretical assumptions. Due to more sensitivity of APD diode, output parameters were better than PIN diode. Despite APD was more advantageous than PIN, it can cause some problems such as creating a noise as a result of the avalanche multiplication of the diode. This problem has been fixed in the new APD structures. Other disadvantages of APD diodes are their complex structure and high cost. In spite of these defects, APD is still the most practical detector, its benefits outgrow its defects and is widely used.

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