Analysis on Design and Implementation of 4×10 Gb/s WDM-TDM PON with Disparate Receivers

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Abstract— *This article presents a design of wavelength division multiplexing/ Time division Multiplexing (WDM-TDM) in passive optical network with a data rate of 10 Gbps. The implementation has been carried out for varying link distance from 40km to 100km for 4 different wavelengths with a maximum of 32 supporting users with two different receiver photodiodes. The parameters such as BER and the Q-factor for PON network is being analyzed with the link distance. The BER is decreased as the distance of the network is increased when using the APD receivers than PIN receiver. Optimal value of BER is obtained for a distance of 97 Km in APD and 96 Km in pin receiver.*

Keywords—Passive Optical Network (PON), Wavelength division multiplexing (WDM), Time division multiplexing (TDM).

I. INTRODUCTION

As observed from the past few decades the requirement for the higher Bandwidth from the end users is increasing drastically. For providing higher bandwidth and also to be cost efficient with less maintenance requirement one has chosen PON to be a solution. This is due to the absence of electronic switches, routers etc.

WDM is considered as a key solution for the next generation as in such systems different wavelengths are used for each user, thus meeting high bandwidth demand of end users [2], [3]. So many researchers have observed the WDM, TDM and also the hybrid WDM-TDM PON. As to meet the requirement of higher bandwidth WDM is considered as a key solution as they provide different wavelengths for each user. TDM is not widely used now-a-days because it limits the number of users and also the bandwidth. Hence forth combining them the hybrid WDM-TDM PON has been deployed as they provide time division multiplexing when sharing the wavelength among the end users. Thus, such systems seems to be cost effective and also offer high bandwidth. In recent times, researchers have been showing interest in WDM-TDM PON. In such systems a number of wavelengths are deployed in the network and each wavelength is shared among end user using Time Division Multiplexing [3]. Raman and S.Singh [4] investigated the performance of the hybrid WDM-TDM system in the presence of the optical amplifier to increase the maximum number of users. This system was able to support 320 users up to 160km with a 1.25Gbps data rate. G.Talli and D.Paul [5] designed a 100km bi-directional PON with 10Gbps data rate in both directions and supporting 1:256 split with 17 TDM PONs each operating at different wavelengths.

In this paper we have proposed single-directional WDM-TDM PON with downstream part executed for maximum number of users and with minimum cost. This paper is organized as follows. Section 2 consisting of the System Architecture of WDM-TDM PON. In the next section the working of simulated architecture is described along with the details of the parameters used in the architecture. Followed by Section 4 wherein we have reported the simulation results and in section 5 conclusions are made.

II. SYSTEM ARCHITECTURE

The architecture of the proposed WDM-TDM PON is as shown in Fig.1. The downstream transmitters consist of a series of laser diodes which offer various wavelengths for the downstream data. The output signal of all the modulators is multiplexed and transmitted over a distribution link. The standard distribution link consists of a Single Mode Fiber (SMF) and also 2 EDFA (Erbium Doped Fiber Amplifier) Amplifiers which on a whole acts as an In-Line Amplifier case.

At the downstream receiver, signal is de-multiplexed and then transmitted to different ONU (Optical Network Unit) of 1km distribution SMF. At each ONU 2 stages of power splitters are used to distribute signal among all the 32 users.

III. SIMULATION ARCHITECTURE

Simulated Model of proposed WDM-TDM PON with an optical frequency of 191.4 THz is as shown in Fig.2. Four separate output binary sequences are generated by the PRBS block generator each of a data rate 10Gb/s. In the entire system there are four lasers being used each with 1550.91 nm, 1551.31 nm, 1551.72 nm, 1552.12 nm wavelengths respectively. The electrical signal generator is used to in converting binary sequence into electric signal. The output of each transmitter is applied to MUX (Multiplexer) block which multiplexes all the four signals into a single output optical signal.

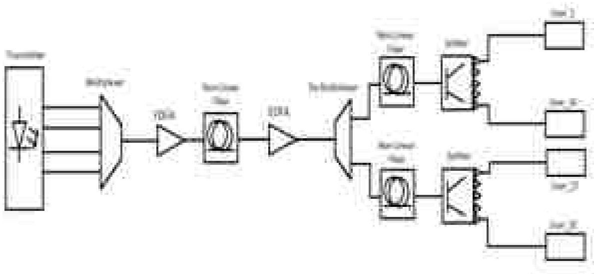

Fig.1: Architecture of PON

The initial frequency of the four optical channels are set according to the initial frequency of the filter inside the MUX. Henceforth after multiplexing the signal is transmitted over a distances of 40 Km, 60 Km, 80 Km, 100 Km SMF with loss followed by EDFA which generally acts as In-Line amplifier with gain of 30dB.

At the downstream receiver block the signal would be de-multiplexed and also transmitted to different ONU (s) present. The signal is further broadcasted for 16 users using a 1:16 splitter as shown from each of the two fibers present. The parameters used for simulation are tabulated as shown below.

TABLE I: PARAMETERS USED IN SIMULATED MODEL

Parameter	Value
OLT	
Bitrate	10 Gbps
Laser Peak Power	0 dB
Frequency Grid Spacing	50 GHz
Laser Wavelengths	1550.91 nm to 1552.12 nm
Modulation type	NRZ
MUX initial frequency	193.1 THz
EDFA Gain	30 dB
Distribution	Link
EDFA gain on downstream path	30 dB
Fiber dispersion Constant	0 ps/nm/Km
Fiber Loss	0.2 dB/Km
Fiber length	40 Km to 100 Km
ONU	
DEMUX initial frequency	193.1 THz
Distributed Fiber Length	10 Km

IV. RESULTS AND DISCUSSION

The data here is transmitted at 4 different wavelengths namely 1550.91 nm, 1551.31 nm, 1551.72 nm, 1552.12 nm with a frequency spacing of 50GHz. The results tabulated below are simulated with a pre-amplifier in the downstream distribution link.

TABLE II: BER FOR VARIOUS USERS (PIN)

Distance (km)	Downstream Users	BER	BER (dB)	Max Q-factor
40	32	1.24×10^{-36}	-359.06	12.5655
60	32	9.926×10^{-32}	-310.03	11.6393
80	32	9.49×10^{-20}	-190.22	8.9958
96	32	1.07×10^{-13}	-129.70	7.3201
100	32	0.00638	-21.95	2.3865

From Table II it is observed that as the link distance increases from 40 Km to 100 Km the BER values are seeing an increase and the proposed architecture can support up to 32 users with satisfactory values of BER till 96 Km beyond which they are not satisfactory. Also there is a gradual decrease in the maximum Q-factor values with increase in link distance.

TABLE III: BER FOR VARIOUS USERS (APD)

Distance (Km)	Downstream Users	BER	BER (dB)	Max Q-factor
40	32	4.22×10^{-41}	-403.74	13.3551
60	32	4.028×10^{-37}	-363.95	12.6560
80	32	7.374×10^{-17}	-161.32	8.2280
97	32	3.15×10^{-14}	-135.01	7.4653
100	32	0.00235	-26.29	2.8228

From Table III it is understood that BER values decrease and maximum Q-factor values decrease with increase in link distance. With APD in the receiver block the architecture gives satisfying BER values up to a maximum of 93 Km of link distance. Hence we can conclude that there exists a tradeoff between the link distance and the BER values and Q-factor values for a fixed number of supporting users.

Various analyses has been carried out namely Distance vs. BER, Distance vs. Q-factor and Q-factor vs. BER and the eye diagrams for two cases, using PIN and APD as the receiver diodes. Here the BER is plotted in its dB values. These analyses has been plotted using MATLAB software and are as follows:

Distance vs. BER:

Receiver as APD:

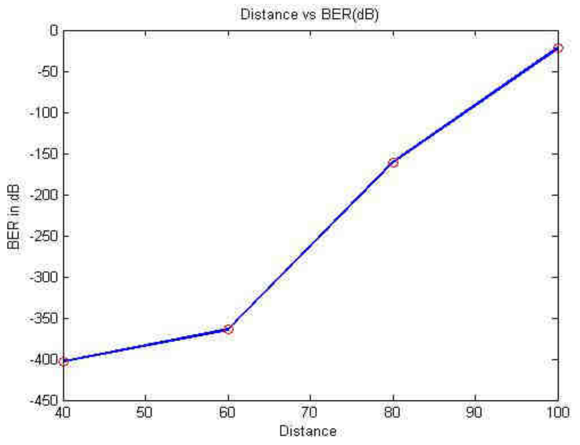

Fig.2: Dist. vs. BER

Receiver as PIN:

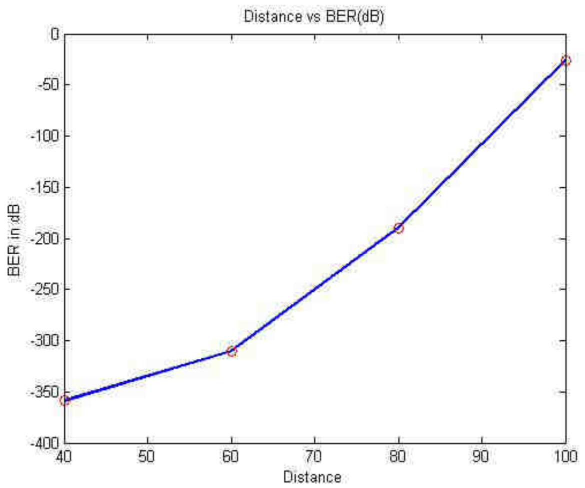

Fig.3: Dist. vs. BER

Distance vs. Q-factor:

APD:

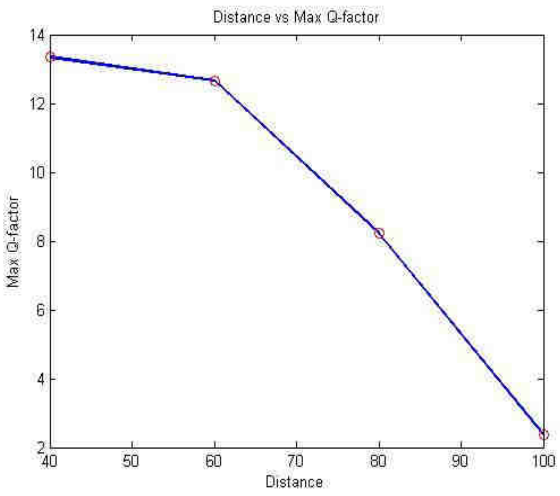

Fig. 4

PIN:

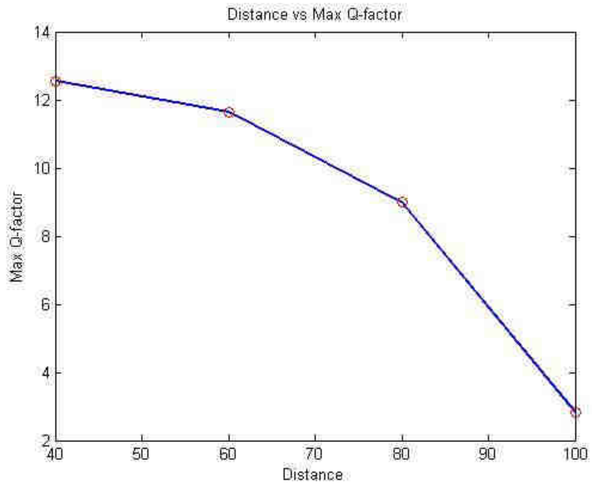

Fig. 5

Q-factor vs. BER:

APD:

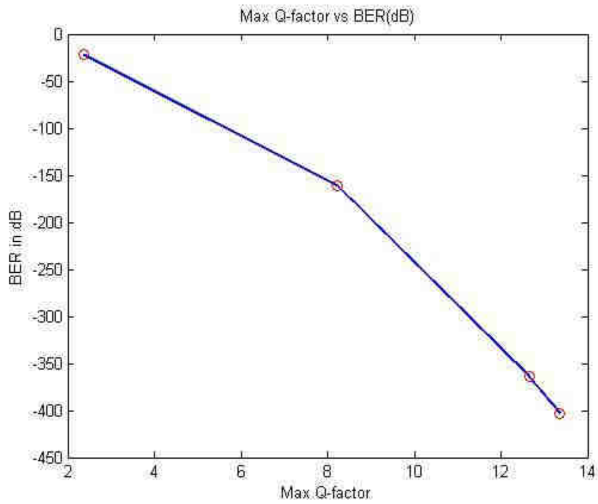

Fig. 6

PIN:

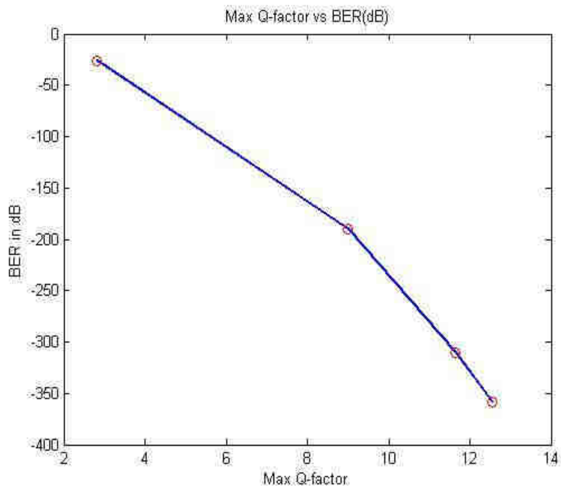

Fig. 7

Eye Diagrams for various fiber lengths and receivers:

PIN (40 Km)

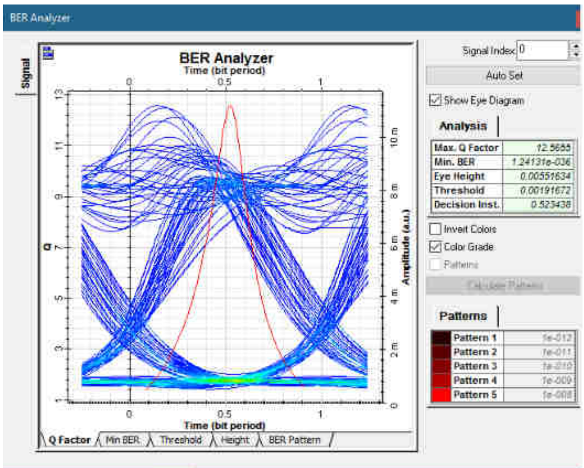

Fig. 8

PIN (60 Km)

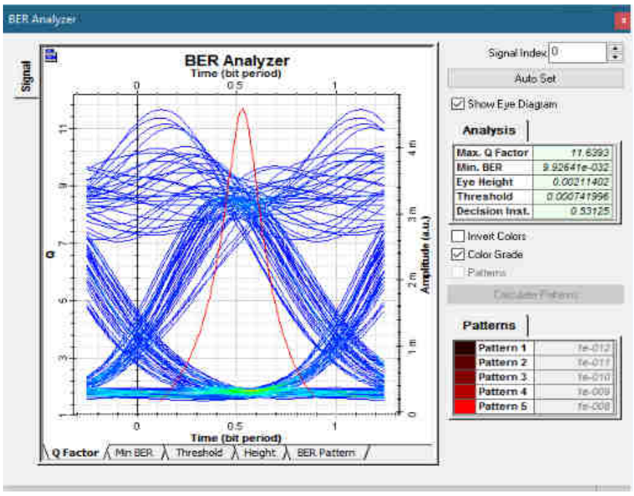

Fig. 9

PIN (80 Km)

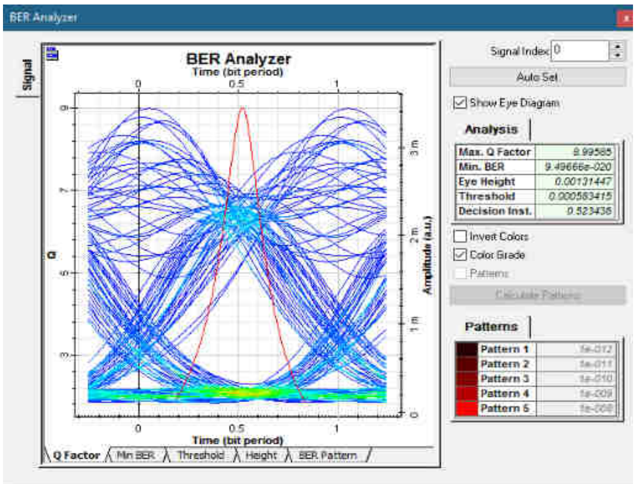

Fig. 10

PIN (100 Km)

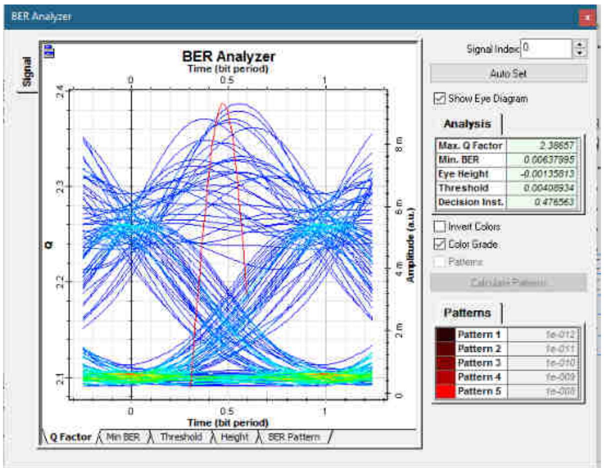

Fig. 11

APD (40 Km)

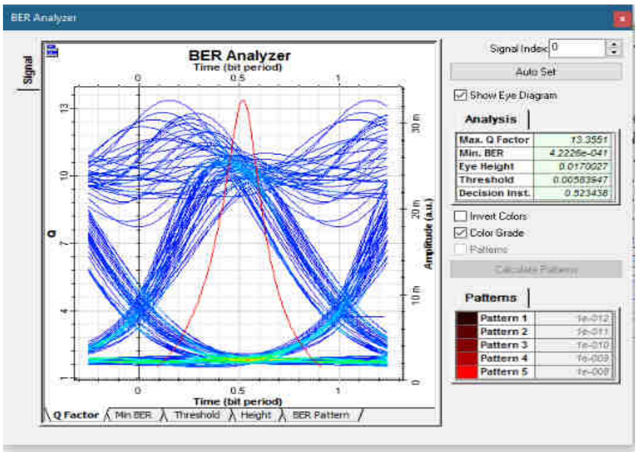

Fig. 12

APD (60Km)

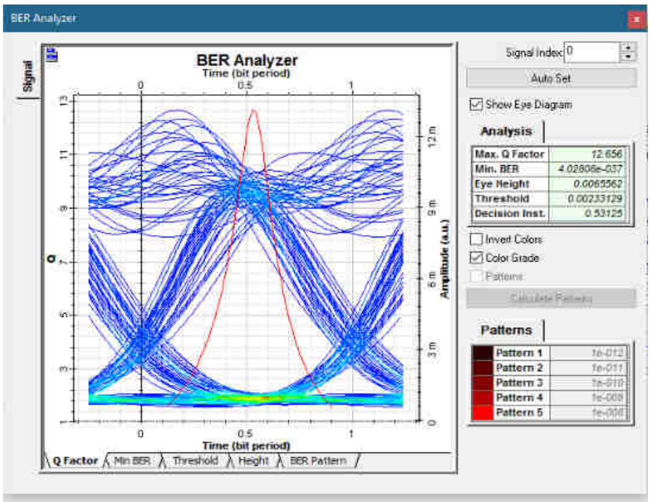

Fig. 13

APD (80 Km)

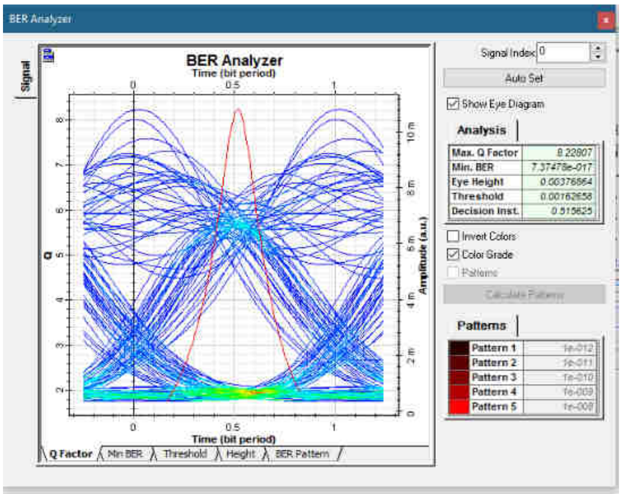

Fig. 14

APD (100 Km)

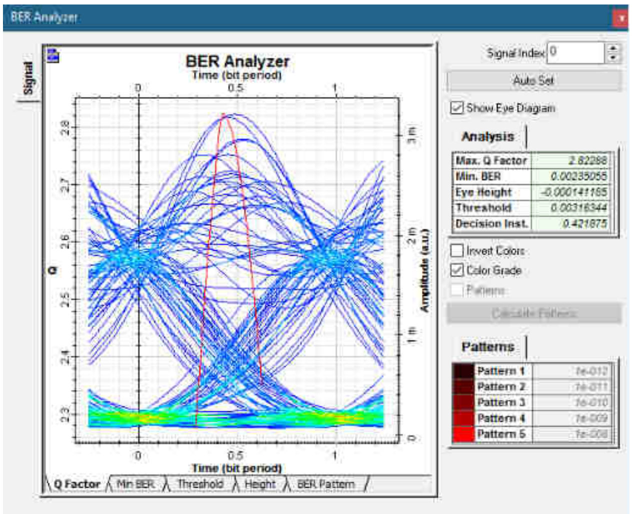

Fig. 15

V. CONCLUSION

In this paper we have proposed and demonstrated a cost effective WDM-TDM PON with downstream part implemented for 32 users at the end. From observing the graphical analysis, as the distance increases the BER value decreases and values are satisfactory till 97 Km for APD and 96 Km for PIN, while the APD receiver has better performance over PIN. From the Distances vs. Q-factor analyses, we can conclude that the distance is inversely proportional to Q-factor. From the analyses of Q-factor and BER we can say that Q-factor is inversely proportional to BER. We have also performed the analyses on eye diagrams for various distances. As we know that the eye's vertical opening in the diagram says about the intersymbol interference, as we can observe as the distance is gradually increasing the vertical opening of the eye is decreasing which clearly understands that the intersymbol interference is low for less distance and it increases with increase in distance. This is the case for both PIN and APD receivers.

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