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CRZ –An ideal choice for low BER in XG-PON Hybrid (DWDM-PON/ FSO) Network at 80 (8X10) Gb/s over 60 km fiber length in upstream transmission

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Abstract: In this paper, we have dealt with possibilities of exploring the right candidate from amongst the various types of modulation formats (RZ, NRZ & CSRZ), in XG-PON Hybrid (DWDM-PON/ FSO) Network. The purpose was to achieve low BER at high bit rates of 80(8X10) Gb/s over link distance of 60 km fiber length in upstream transmission from amongst the individual modulation formats. These modulation formats were evaluated with perspective to permissible limits of parameters Q-factor and BER in RSOA based Hybrid optical access networks.

Keywords: *DWDM, XG-PON, RSOA, FSO*

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1. Introduction

The Dense Wavelength Division Multiplexing (DWDM) is a technology which multiplexes multiple optical carrier signals on single optical fiber by using different wavelengths of laser light to carry different signals [1]. The DWDM puts together multiple signals and sends them at the same time along a fiber with a transmission taking place at different wavelengths [2]. In modern era of telecommunications, there is a sharp increase in the growth of internet and broadband services. To fulfill these demands, DWDM-PON is one of the most promising approaches. Currently DWDM technique (Figure 1) is being used for achieving higher data rates. In DWDM-PON, the different wavelengths chosen, each for a specific user, are multiplexed by the optical multiplexer on transmitting side and transmitted over fiber. On the receiving end, an optical splitter splits the received power in equal amount to each ONU (Optical Network Unit) maintaining the same BER.

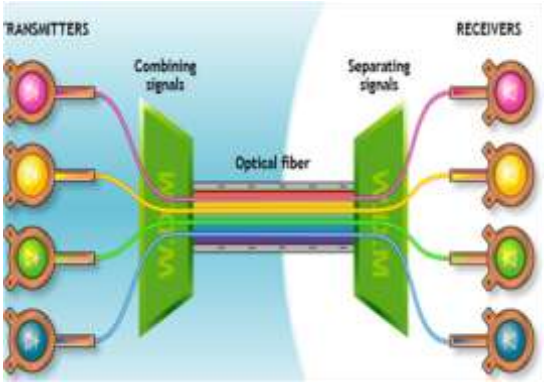

Figure1. Basic DWDM architecture [3].

However, in situations like a large disaster or in difficult deployment places where the installation cost is more, the alternative solution may be wireless link such as FSO, which provides flexibility and quick deployment of the system. Hence, the convergence of optical and wireless technologies gives rise to hybrid (DWDM-PON/ FSO) network. This hybrid network provides the benefits of high-capacity, flexibility, cost and energy efficient back-haul network. Figure 2 shows proposed hybrid network.

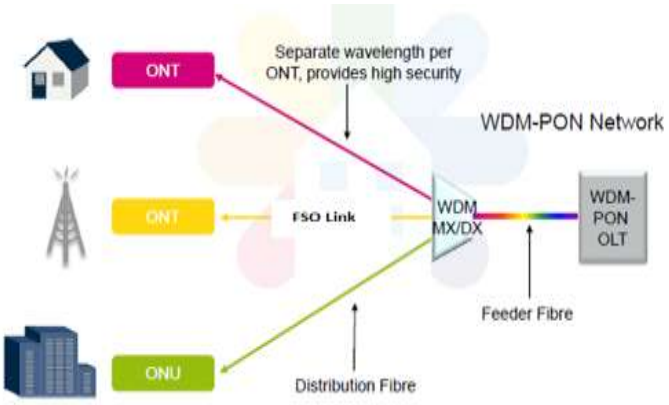

Figure2. Basic DWDM-PON architecture[3]

The FSO is an attractive last-mile access solution because of being able to offer considerable advantages over radio frequency communications such as large bandwidth, license-free spectrum and high security. Therefore the combination of DWDM-PON and FSO will facilitate the benefits of both optical and FSO links to fulfill the needs of the growing society.

Optical Wireless formally known as Free-space optics (FSO) is an optical communication technology in which typically a laser generated light beam propagates in the atmosphere to reach an optical receiver at a given distance , to transmit data. FSO is used where fiber optic cables cannot cater due to difficulty in establishing physical connection. It is used for both short and long ranges like building to building or inter satellites where laying of cables is impractical. [4] FSO tends to have some inherent benefits like immunity to electromagnetic interference (EMI) and interception between the transmitter and the receiver. FSO works on LOS communication hence any interception would generate an interruption of LOS, leading to

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the detection of the interception. This need for LOS, however makes the pointing and the alignment of the narrow laser beam extremely important to ensure the performance of the system. [5] FSO systems (in space and inside the atmosphere) have developed in response to a growing need for high-speed and tap-proof communication system. We have analyzed the performance of DWDM-PON/FSO-hybrid backhaul network while keeping in consideration various physical layer impairments of both optical fiber and free-space links. This paper consists of four sections. Starts with the introduction in section 1, section 2 describes the simulation setup. In section 3 result and discussion are shown. Finally, section 4 shows the conclusion.

2. Simulation Setup

Hybrid DWDM-PON provides high bandwidth for each user and supports multiple channels. Figure 3 shows the block diagram of simulation setup of bidirectional DWDM-PON for 8 channels.

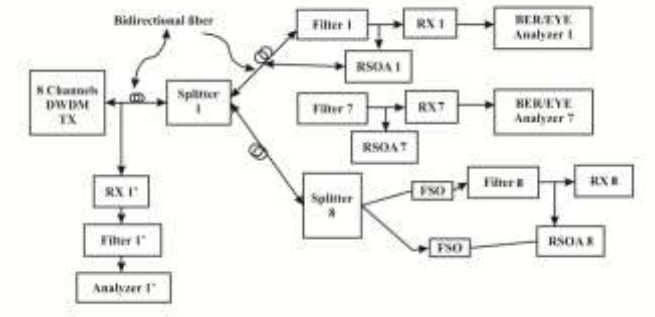

Figure 3: Block diagram of simulation setup of bidirectional DWDM-PON for 8 channels

The block diagram shows 8 DWDM channels transmitted each at -3dB input power and modulated by different modulation formats from optical line terminal (OLT) and multiplexed with the help of optical multiplexer and transmit through bidirectional fiber (BD). The output of BD fiber goes to splitter which separates each channel as transmitted from OLT and received by different receiver with filter bandwidth 3.5GHz. Now, again all channels are fed at -10dB input power inserted into reflecting semiconductor optical amplifier (RSOA). The RSOA re-modulates and re-amplify the signal and feed the signal back to bidirectional fiber. RSOA has the crucial task of re-modulating the received downstream signal with the new upstream signal which decides the effectiveness of the system. The high-pass filtering effect of the RSOA, which tends to be more pronounced at higher input powers, can be used to suppress the downstream signal.

Table 1: System Description

Parameters	Description
Number of channels	8
Channel spacing	0.4nm
Filter Bandwidth	3.5GHz in down link & 2.5GHz in up link
Data rate per channel in down stream	40GB/s
Data rate per channel in up stream	10GB/s
Pattern length	29
Modulation format in down stream	Varied
Modulation format in up stream	Varied
Bidirectional fiber length	40km + 20km

Optical Transmitter comprises of 8 Channels DWDM transmitters, which is amplified with EDFA at gain 20dB. The eight channel WDM transmitter is shown in figure 4.

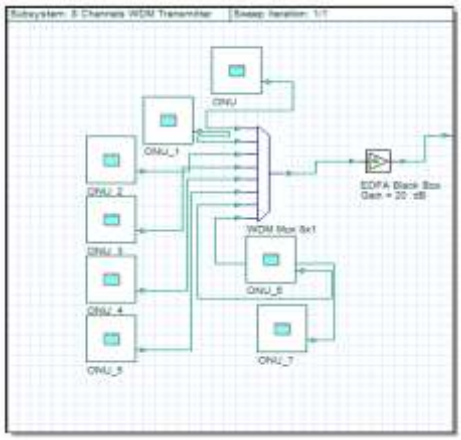

Figure 4: 8-channel DWDM transmitter

The channel spacing between the two adjacent wavelengths is 0.4nm whereas data rate per channel are set at 40Gbps and 10Gbps for downstream and upstream respectively. Thus the 8 channel DWDM transmitter is capable of transmitting at 320(40X8) Gb/s in downstream and 80(10X8) Gb/s in upstream. The Optical Line Terminal (OLT) components for single channel are shown in figure 5. External modulator is used for providing 180 degree phase shift to each channel [6].

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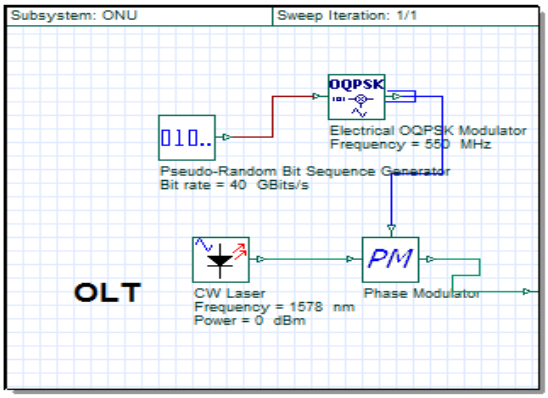


Figure 5: OLT components for single channel

The Semiconductor Optical Amplifier (SOA), as well as a Reflective SOA (RSOA) are highly nonlinear and can be used for signal amplification, signal modulation, and optical signal processing applications such as wavelength conversion, switching and optical time domain De-multiplexing. The RSOA has two input ports and one output port. The first input accepts optical signals, which can consist of one or more optical channels. The second input accepts an optional electrical modulation current. Finally, the output port generates the resulting output optical signal. RSOA does not support CW optical signals for re-modulation. All signals input to the RSOA must have identical time steps and number of data points, if the user connects an electrical modulation. In OptiSystem, RSOA has three ports i.e. Two Bidirectional Optical ports and one bidirectional Electrical Port. RSOA modulates and amplifies the signal.

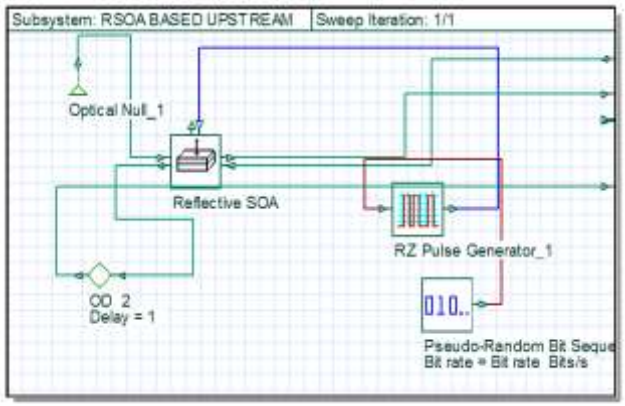


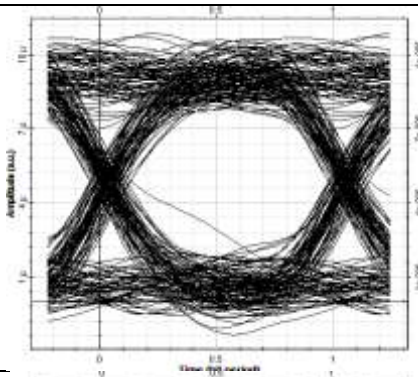
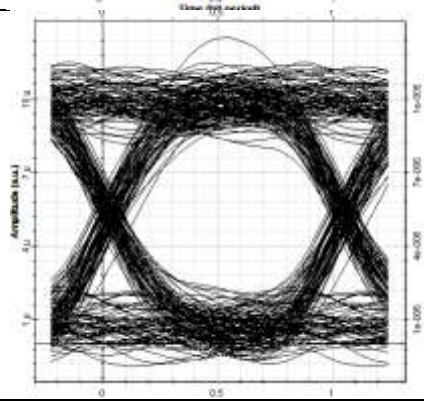
Figure 6: RSOA subsystem

The figure 6 shows the RSOA subsystem diagram. As per the system setup with the key parameters shown in table 1, the results and related discussion are summarized in the following section.

3. Result and Discussion

The work in this paper demonstrates high speed DWDM-PON/ FSO network. WDM-PON multiplexing of 8 channels having different wavelengths and each channel transmitting at the rate of 40 GB/s (downstream) and 10 Gb/s(upstream) have been simulated . The 8 DWDM channels were separated by 50GHz (0.4nm) as per standard International Telecommunication Union (ITU) [7]. Table 2 shows the BER values for channel 1 and channel 8 with their respective eye diagram.

Table 2: BER and Eye Diagram of Channel 1 & 8 for Upstream

Channel	BER	Eye Diagram
1(1578nm)	3.21e-11	
8(1581.2nm)	1.00e-13	

BER of the order of e-11 and e-13 has been analyzed for reflected wavelength of 1578nm and 1581.2nm respectively and the eye is open in both the cases.

Due to the carrier lifetime in the active layer, the modulation bandwidth of the RSOA is limited to GHz. Recently, there have been several attempts to operate these low bandwidth devices at 10-Gb/s and beyond using advanced modulation formats[8,9].To enhance the performance of the above mentioned designed system different modulation format were observed and improvement in BER value of channels 1 & 8 for CRZ modulation format is seen.

The results are shown in table 3.

Table 3: BER for different modulation formats at different wavelengths for (8X10)80GB/s at 60km fiber length in upstream transmission

S. No.	Wavelengths (nm)	Modulation formats		
		CRZ	RZ	NRZ
		BER	BER	BER
λ_1	1578	1.66E-20	3.21E-11	5.71E-09
λ_8	1581.2	1.86E-18	1.00E-13	2.42E-09

In upstream for channel 1 BER is 1.6632e-20, 3.21e-11 and 5.7146e-09 for CRZ, RZ and NRZ formats whereas for channel 8 it is 1.8573e-18, 1.e-13 and 2.4247e-09. It has been observed that CRZ is best for upstream direction.

4. Conclusion

A DWDM-PON and FSO based XG-PON network has been successfully implemented with the use of RSOA that offers cost minimization. It is demonstrated that RSOA based network can be implemented using CRZ modulation format for high upstream data rates of 80(8X10) Gb/s over link distance of 60km. It was investigated that by using CRZ modulation format, the BER was considerably reduced to 1.6632e-20 for fiber link and 1.8573e-18 for free space optical link.

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