Comparative study of different optical amplifiers for hybrid passive optical networks

RAKESH GOYAL[a,*], RAJINDER SINGH KALER[b], TARA SINGH KAMAL[c]
[a]*D.A.V. University, Jalandhar, Punjab, India*
[b]*Thapar University, Patiala, Punjab, India*
[c]*R. I. E. T., Abohar, Punjab, India*

In this manuscript, we have investigated different optical amplifiers like RAMAN, Semiconductor Optical Amplifier (SOA) and EDFA for bidirectional hybrid (WDM/ TDM) Passive Optical Networks (PONs) at 10 Gbps data rate with 128 numbers of Optical Network Units (ONUs). The performance of the system is enhanced with polarization modulation with 16-QAM technique. To make the system simple, a circulator is used for bidirectional transmission through the same fiber. The upstream data is transmitted at 1300 nm wavelength and downstream data is transmitted at 1550 nm wavelength. Various results for BER are shown at 40 and 50 KMs distance. It has been observed that EDFA amplifier shows better performance than SOA and RAMAN.

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1. Introduction

In current scenario, the numbers of subscribers of internet are increasing day by day [1]. The demand for huge bandwidth and high data speed is the main concern for the researchers [2]. These motivate the researchers towards the optical networks as fiber provides the largest bandwidth and suitable for long distance communications [3]. Passive Optical Networks (PONs) are the best choice for such type of access networks [4]. Hybrid (Wavelength division multiplexing/ time division multiplexing) PON is good postured to be one of the chief ladder in the evolution of access-metro optical networks [5]. In recent years, various techniques based PONs like Wavelength Division Multiplexing (WDM) PON [6], Time Division Multiplexing (TDM) PON [7] and hybrid (WDM / TDM) PON [8] have been believed the most promised solution for fiber-to-the-home (FTTH) systems [9].

Wei Han et al. [6] proposed a protection scheme for transmitters in WDM-PON. If any downstream transmitter encountered problems at the Central Office (CO), the interrupted communication was restored immediately by injecting a Fabry–Perot Laser Diode (FP-LD) with the upstream light wave corresponding to the failure transmitter. A 1:36 protection capability was implemented with a 2.5 Gbit/s downstream transmission capability over 10 km distance.

C. H. Wang et al. [7] proposed a new architecture for TDM-PON using externally injection locked FP-LDs in each Optical Network Unit (ONU). Four directly modulated 2.5 Gb/s FP-LDs were injection-locked by Continuous Wave (CW) carriers distributed from the Optical Line Terminal (OLT). The data was successfully transmitted up to 25 km standard single mode fiber (SMF) without dispersion compensation. The performance of the injection-locked FP-LD was also studied.

R. Goyal et al. [8] analyzed the performance and feasibility of a hybrid (WDM/ TDM) PON system with 128 ONUs. The triple play services (video, voice and data) were successfully transmitted up to a distance of 28 km to all ONUs.

Simranjit Singh et al. [10] compared 10 Gbps WDM systems at 16, 32 and 64 channels with EDFA, RAMAN and SOA amplifiers. It was demonstrated that when the dispersion was 2 ps/nm/km and the number of channels were less, then SOA provided better results and when dispersion was increased from 2 to 10 ps/nm/km, EDFA provided better results than SOA in the term of BER and output power.

In literature, we have studied various research works on PONs. Considering [6], a protection scheme for transmitters in WDM-PON was proposed using a FP-LD with a 2.5 Gbit/s downstream transmission capability over 10 km distance. In [7] TDM-PON is proposed with four directly modulated 2.5 Gb/s FP-LDs to transmit data up to 25 km, in [8] triple play services (video, voice and data) were successfully transmitted to a distance of 28 km to 128 ONUs. In this paper, we are presenting hybrid PON architecture with 10 Gb data rates and more transmission distance. Two different wavelengths 1550nm and 1300 nm are used for downlink and uplink data to avoid the use of extra tunable devices and reduce the effect of non linearity. Also, the non employment of various complex components like WSSs, FBGs and AWGs (those increases the complexity and cost of the network), is implemented for the sake of simplicity and flexibility. Further, the system is investigated with different types of optical amplifiers to find out the best suitable for the same.

This paper is organized into four sections. In section 1, introduction to hybrid PON is given. The system setup for hybrid PON is described in section 2. In section 3, results have been reported for the different amplifiers with respect to number of users. Finally, in section 4, conclusion is made.

2. System setup

The block diagram of hybrid PON with 128 ONUs is shown in Fig. 1. At the transmission section, pseudo-random data generator (PRBS) is used as data source to generate 10 Gbps data rate. Different amplifiers like EDFA, SOA and RAMAN are used and investigated their performance for the proposed system at 10 Gbps data rate.

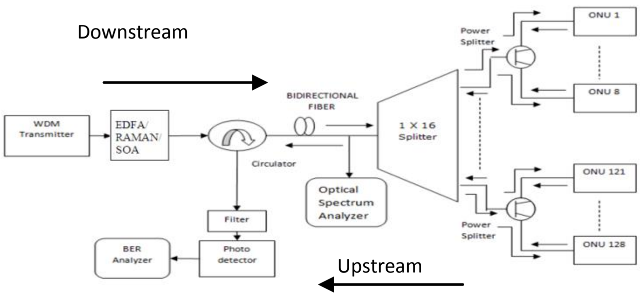

Fig. 1. Block diagram of system setup for hybrid PON with 128 ONUs

A circulator (with 3 dB insertion losses, 15 dB isolation) is employed for making possible bidirectional (upstream and downstream) data in same channel. For detection of the upstream data Bessel's filter and PIN photo detector are used. A wavelength of 1550 nm is used to transmit downstream data and 1300 nm for upstream data so that the impact of crosstalk can be minimized. The optical fiber with 0.2 dB/km attenuation and 16.75 ps/nm/km dispersion is used and simulation is done at different lengths. The block diagram of WDM transmitter is shown in Fig. 2.

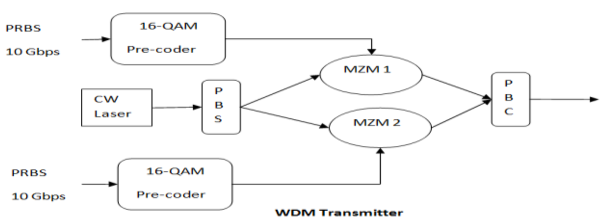

Fig. 2. The internal structure of WDM transmitter

The signal is generated using an electrical driver and CW laser source (with 193.1 THz frequency and 100 GHz channel spacing). The 16-QAM pre-coder with 5GHz electrical signal is used to modulate the signal with Mach-Zehnder (MZ) modulator (an excess loss of -3 dB). Non return to zero (NRZ) format is used for line coding. The optical signal from CW laser source is sputtered into two polarization beams viz. horizontal polarization and vertical polarization via Polarization Beam Splitter (PBS). These signals are further modulated using 16 QAM modulations with Frequency Fourier Transform (FFT) with size of 512 and cyclic prefix size of 8. The signals are transmitted to channel after combined through Polarization Beam Combiner (PBC).

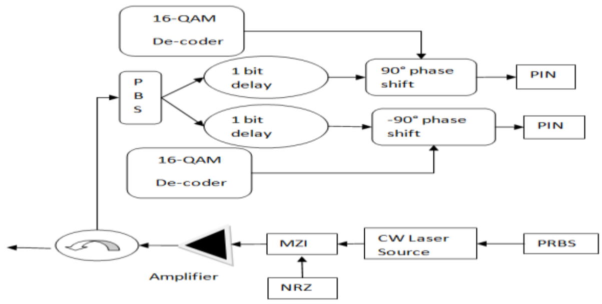

Fig. 3. The block diagram of ONU

The block diagram of ONU is shown in Fig. 3. The downlink signal is decoded with splitting it into two parts recovered using QAM decoder with 90° and -90° phase shift. PIN photo detector with Bessel filter is installed to detect the data. To transmit data to 128 ONUs, different passive optical splitters are used with different time delay parameters. 10 ps time delay is given to each ONU to receive the signal in each power splitter module. To keep the ONU simple and cost effective, PIN photo detector with Bessel filter is used for detection downstream data and CW laser source with PRBS data source are used to generate the upstream data. Various analyzers are used for observing the received power, Q factor and also for calculating BER.

3. Result and discussion

The hybrid PON system has been investigated for different optical amplifiers (RAMAN, EDFA and SOA) with respect to number of ONUs at 10 Gbps data rate at 40 and 50 KMs distances. The setup is simulated and investigated for performance parameters like Bit Error Rate (BER) with different number of ONUs. BER v/s No. of ONUs for EDFA, SOA and RAMAN amplifiers with 10 Gbps data rate at 40 KM is shown in Fig. 4.

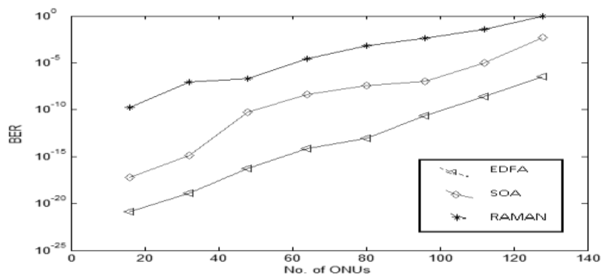

Fig. 4. BER V/s No. of ONUs with 10 Gbps data rate at 40 KM

As shown in the Fig. 4, it is evident that the BER increases with increase in the number of ONUs. The BER of 2.6×10^{-9} by EDFA with 112 ONUs, 3.6×10^{-8} by SOA with 96 ONUs and 9.2×10^{-8} by RAMAN by 48 ONUs are observed with 10 Gbps data rate at 40 KM. BER v/s No. of ONUs for EDFA, SOA and RAMAN amplifiers with 10 Gbps data rate at 50 KM is shown in Fig. 5.

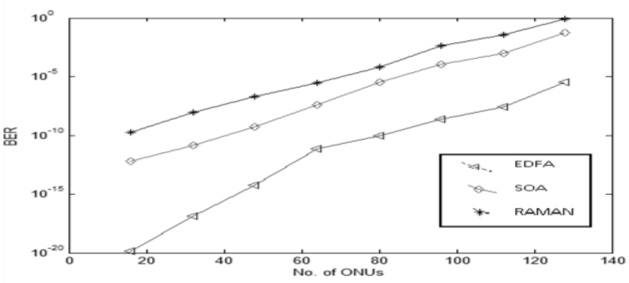

Fig. 5. BER V/s No. of ONUs with 10 Gbps data rate at 50 KM

As shown in the Fig. 5, it is evident that the BER increases with increase in the number of ONUs. The BER of 2.6×10^{-8} by EDFA with 112 ONUs, 4.1×10^{-8} by SOA with 64 ONUs and 9.2×10^{-9} by RAMAN by 32 ONUs are observed with 10 Gbps data rate at 50 KM.

4. Conclusions

In this paper, bidirectional hybrid (WDM/ TDM) passive optical network for different amplifiers at 10 Gbps data rate with 128 ONUs has been investigated. 1550 nm wavelength is used to transmit downstream data and 1300 nm is used for upstream data so that impact of crosstalk can be minimized. BER is observed for EDFA, SOA and RAMAN amplifiers for the system at 40 and 50 KM distances. It is shown that the data with 10 Gbps rate can be transmitted and received by 120, 96 and 48 ONUs up to 40 KM and 96, 64 and 32 ONUs up to 50 KM transmission distance with EDFA, SOA and RAMAN amplifiers respectively.

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*Corresponding author: er.rakeshgoyal@gmail.com