Investigation on polarization dependent bidirectional hybrid (WDM/TDM) utilizing QAM modulation with different amplifiers

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In this paper, we have demonstrated the performance of bidirectional hybrid Wavelength-Division Multiplexing/ Time-Division Multiplexing Passive Optical Networks (WDM/ TDM PONs) with 128 numbers of Optical Network Units (ONUs). Using polarization modulation technique in swing with QAM, system is being analyzed for RAMAN, Semiconductor Optical Amplifier (SOA) and EDFA amplifiers for utilizing its bandwidth at 5 Gbps data rate. It has been observed that EDFA amplifier shows enhanced performance than SOA and RAMAN amplifier for trimming down the consequence of crosstalk respectively for 80 KMs with above said ONUs.

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1. Introduction

Passive Optical Networks (PONs) are of high industrial and technical interest to deal with the ever increasing demand for high data traffic due to non requirement of electrical power at the Remote Nodes (RNs) [1]. Recently a number of studies and research has been carried out for improving cost efficiency and the performance of optical access networks [2-4]. To meet the above said criteria several aarchitectures have been proposed for Time Division Multiplexing PON (TDM-PON), Wavelength Division Multiplexing PON (WDM PON) and hybrid (WDM/ TDM) PON [5-7].

Ju Han Lee et al. [1] investigated the Continuous-Wave Super Continuum (CW SC) as a broadband wavelength-locking source for the implementation of extended-reach, colorless, WDM-PONs. The feasibility of the architecture was experimentally analyzed over a 60-km transmission fiber at 622 Mbit/s. Deeksha Kocher et al. [2] compared FTTH (Fiber To The Home) GEPON (Gigabit Ethernet Passive Optical Network) link design for 56 subscribers at 20 km reach at 2 Gbps bit rate. R. Goyal et al. [4] analyzed the performance and feasibility of a hybrid (WDM/ TDM) PON system with 128 optical network units (ONUs). The triple play services (video, voice and data) were successfully transmitted to a distance of 28 km to all ONUs. K. O. Kim et al. [8] proposed a hybrid PON consisting of a 2.5 Gb/s RSOA based 32 channel over a 50 km transmission distance. 1550 nm wavelength was used for uplink and downlink. G. Das et al. [9] proposed a hybrid PON architectures with 622 Mb/s based upon Wavelength Selective Switches (WSSs) with 256 subscribers over a distance of 70 KM. B. Neto et al. [10] proposed a hybrid PON based on a low power clamping provided by a DFB laser and a FBG. A transmission distance of 15 KM was achieved for 2.5 Gb/s data. Three EDF pump lasers peaking at 1470 nm, 1480 nm and 1490 nm were injected with 50/50 coupler.

Recently numerous studies revealed that above discussed WDM PON is being validated over a 60-km transmission fiber at data rate of 622 Mbit/s only [1]. Further, another purposed scheme of GEPON is designed for 56 subscribers with a length of 20 km at 2 Gbps bit rate while a hybrid PON consisting of a 2.5 Gb/s RSOA based 32 channel till 50 km length. Due to use of same wavelength for uplink and downlink, extra tunable devices are required. Moreover, the use of WSSs, FBGs and AWGs increases the complexity and cost of the network. By excluding these components, losses and power requirement is also being reduced. Further, by using two different wavelengths i.e. 1310 and 1550 nm for downlink and uplink respectively is capable for reducing the non-linearity effect. In turn of this, it also makes a feasible system without extra tunable devices. Further, the system is analyzed with different types of optical amplifiers to improve its performance and utilizing its bandwidth. Thus we achieve better results in terms of data rates, output power, quality factor and transmission distance.

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

2. System setup

The block diagram of system setup of hybrid PON is shown in Fig. 1. In the proposed architecture, 128 ONUs can communicate with the central office. The OLT consist of WDM transmitter with different amplifiers. To employ uplink and downlink in the same channel, a circulator (with 3 dB insertion losses, 15 dB isolation) is introduced in the channel. To detect the uplink data Bessel's filter and PIN photo detector are used at circulator's end. To reduce the impact of crosstalk (due to downlink and uplink signals in same channel), two separate wavelengths i.e. 1550 nm and 1300 nm are used for downstream and upstream signals respectively. The data is transmitted through fiber (having 0.2 dB/km attenuation and 16.75 ps/nm/km dispersion) with varying length in the channel.

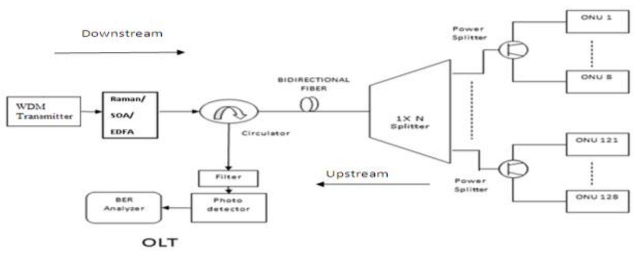

Fig. 1. Block diagram of system setup for hybrid PON with 128 ONUs.

The block diagram of WDM transmitter is shown in Fig. 2. It consists of the pseudo-random data generator (PRBS) data source (to generate 5 Gbps), QAM pre-coder with 5GHz electrical signal, CW laser source (with generation of laser beam at a frequency of 193.1 THz with 100 GHz channel spacing) and Mach-Zehnder (MZ) modulator. 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).

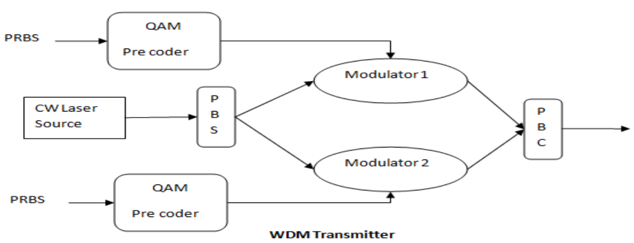

Fig. 2. The internal structure of WDM transmitter.

Passive optical splitters are included with fiber link to transmit the data 128 ONUs with different time delay parameters. At the ONU side, 10 ps time delay is specified to each ONU to receive the signal. 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.

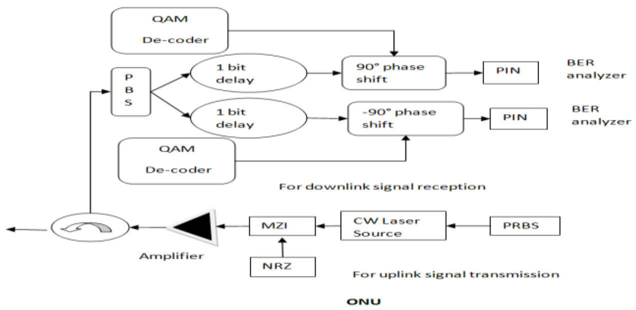

Fig. 3. The block diagram of ONU.

CW laser source and PRBS data source are used to spawn the upstream data. Various analyzers are used for observing the received power, Q factor and also for calculating BER. The proposed model is investigated for different amplifiers like EDFA, SOA and RAMAN at 5 Gbps data rate.

3. Result and discussion

In order to observe the performance of proposed hybrid PON system, the setup is simulated for different optical amplifiers with respect to number of ONUs at 5 Gbps data rate for different distances. The BER, Q factor and received optical power by varying number of ONUs at different optical fiber link length are calculated and represented graphically. Q factor v/s Number of ONUs for EDFA, SOA and RAMAN amplifiers at 70 KM with 5 Gbps data rate is shown in Fig. 4.

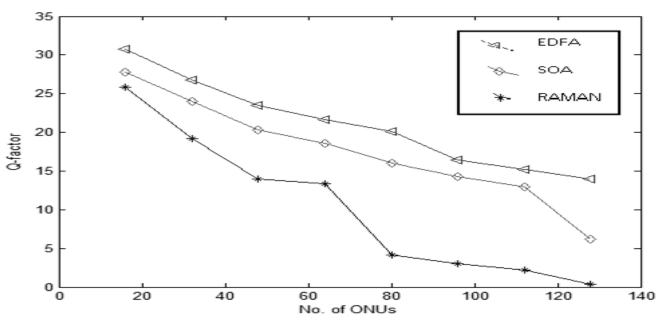

Fig. 4. Q factor V/s No. of ONUs at 70 KM with 5 Gbps data rate.

It is observed that the Q factor of 14, 6.2 and 0.4 dB with 128 ONUs is achieved by EDFA, SOA and RAMAN amplifiers respectively. It is also shown that Q factor is decreasing with the increase of ONUs. The data can be communicated with 120, 90 and 40 ONUs by EDFA, SOA and RAMAN amplifiers respectively with minimum acceptable Q factor [11]. BER v/s No. of ONUs for EDFA, SOA and RAMAN amplifiers at 70 KM with 5 Gbps data rate is shown in Fig. 5.

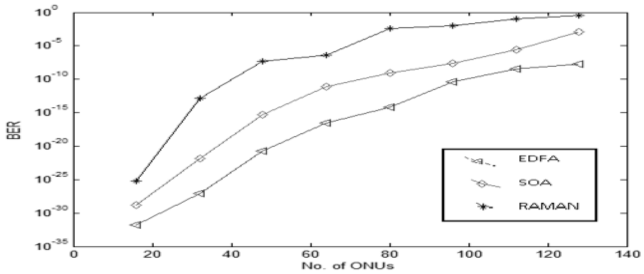

Fig. 5. BER V/s No. of ONUs at 70 KM with 5 Gbps data rate.

It is evident that the BER increases with respect to the number of ONUs. The number of ONUs ranges from 20 to 128 in this graph. The impact of different amplifiers is analyzed. The bit error rate is provided by EDFA is 3.8*10^(-9) with 112 ONUs, by SOA is 2.3*10^(-8) with 96 ONUs, by RAMAN is 5.4*10^(-8) with 48 ONUs. If we further increase the number of ONUs, then the BER crosses the maximum acceptable limit and hence system is not sufficient to transmit the data. Output Power v/s Number of ONUs for EDFA, SOA and RAMAN amplifiers at 70 KM with 5 Gbps data rate is shown in Fig. 6.

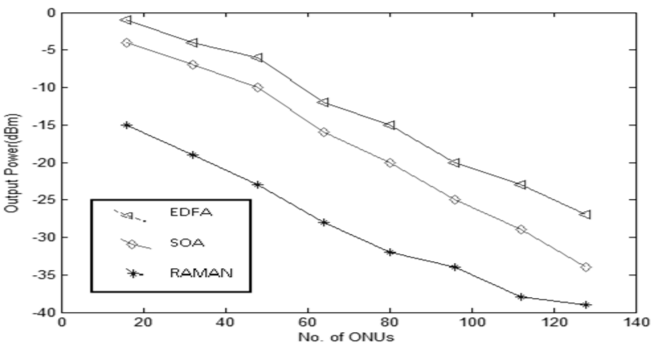

Fig. 6. Output Power V/s No. of ONUs at 70 KM with 5 Gbps data rate.

It is observed that the received optical power of -39, -34 and -27 dBm with 128 ONUs is achieved by EDFA, SOA and RAMAN amplifiers respectively. It is also shown that received power is decreasing with the increase in number of ONUs. Q factor v/s Number of ONUs for EDFA, SOA and RAMAN amplifiers at 80 KM with 5 Gbps data rate is shown in Fig. 7.

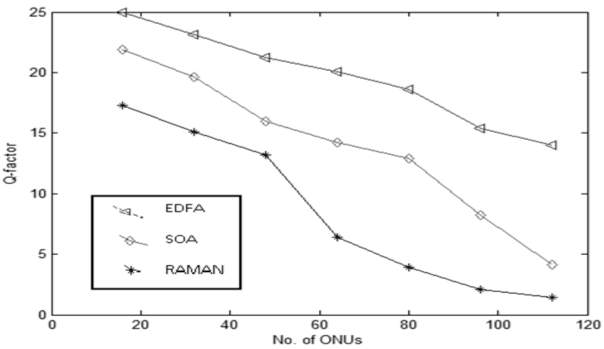

Fig. 7. Q factor V/s No. of ONUs at 80 KM with 5 Gbps data rate.

It is observed that the Q factor of 14.2, 4.1 and 1.4 dB with 112 ONUs is achieved by EDFA, SOA and RAMAN amplifiers respectively. It is also shown that Q factor is decreasing with the increase in number of ONUs. The data can be communicated with 110, 60 and 35 ONUs by EDFA, SOA and RAMAN amplifiers respectively with minimum acceptable Q factor. BER v/s No. of ONUs for EDFA, SOA and RAMAN amplifiers at 80 KM with 5 Gbps data rate is shown in Fig. 8.

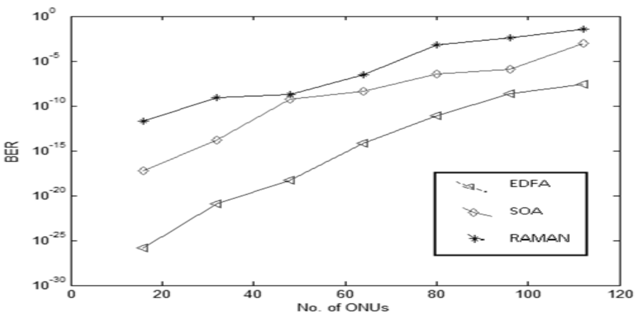

Fig. 8. BER V/s No. of ONUs at 80 KM with 5 Gbps data rate.

It is evident that the BER increases with respect to the number of ONUs. The number of ONUs ranges from 20 to 112 in this graph. The impact of different amplifiers is analyzed. The bit error rate is provided by EDFA is 2.3×10^(-9) with 96 ONUs, by SOA is 4.1×10^(-9) with 64 ONUs, by RAMAN is 1.9*10^(-9) with 40 ONUs. If we further increase the number of ONUs, then the BER crosses the maximum acceptable limit and hence system is not sufficient to transmit the data. Output Power v/s Number of ONUs for EDFA, SOA and RAMAN amplifiers at 80 KM with 5 Gbps data rate is shown in Fig. 9.

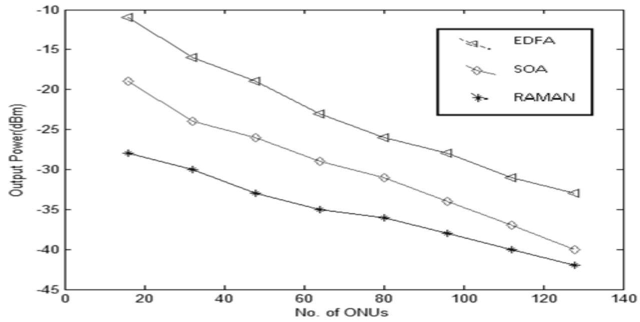

Fig. 9. Output Power V/s No. of ONUs at 80 KM with 5 Gbps data rate.

It is observed that the received optical power of -42, -40 and -33 dBm with 128 ONUs is achieved by EDFA, SOA and RAMAN amplifiers respectively. It is also shown that received power is decreasing with the increase of ONUs.

4. Conclusions

In this paper, bidirectional hybrid (WDM/ TDM) passive optical network for different amplifiers with 128 ONUs is investigated. The bandwidth utilization is achieved through polarization with 16–QAM modulation. Further, the impact of crosstalk is reduced by using different wavelength i.e. 1550 nm wavelength is for downstream data and 1300 nm for upstream data. BER, Q factor and received optical power are observed for EDFA, SOA and RAMAN amplifiers in the proposed model at 5 Gbps at 70 and 80 KM distances. It is shown that the data with 5 Gbps rate can be transmitted and received by 120, 90 and 40 ONUs up to 70 KM and 110, 60 and 35 ONUs up to 80 KM transmission distance with EDFA, SOA and RAMAN amplifiers respectively.

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