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Implementing a Long Reach Upstream and Downstream Data rate 100Gbps WDM-PON by using Directly Modulated RSOA

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Abstract

This paper presents Long Reach Wavelength Division Multiplexing Passive Optical Network (WDM-PON) system capable of delivering downstream 100 Gbit/s data and upstream 100 Gbit/s data on a single wavelength. The optical source for downstream data and upstream data is CW Laser at central office and reflective semiconductor optical amplifier (RSOA) at each optical network unit. We use four RSOAs at each optical network unit for the 100-Gb/s upstream transmission. The operating wavelengths of these RSOAs are separated by the free-spectral range of the optical demultiplexer at the central office and remote node (RN) for demultiplexing the WDM channels. We extend the maximum reach of this WDM PON to be 100 km by using Erbium-doped fiber amplifiers at the RN. Bit error rate, receiver sensitivity were measured to demonstrate the proposed scheme. In this paper Long reach and large data service aspects of a WDM-PON is presented. The results show that the error-free transmission can be achieved for all WDM channels with sufficient power margins.

Keywords: *Wavelength division multiplexing passive optical network (WDM-PON), Reflective semiconductor optical amplifier (RSOA), Erbium doped fiber amplifier (EDFA), Single mode fiber (SMF), Photo detector (PD), arrayed waveguide grating (AWG).*

I. Introduction

The fastest growing areas in telecom are broadband services and networks. The explosion of the Internet coupled with new video centric services has increased the demand for high bandwidth in access networks. Fiber to the home, based on a PON due to its high bandwidth, cost sharing of infrastructure, and absence of active components, is considered as a good solution to this demand [1]. Services such as IP high-definition video delivery, Voice-over-IP, social networking and cloud computing have pushed the demand for bandwidth even beyond what is achievable with today's gigabit PONs. WDM-PON is a promising candidate of the low- cost subscriber networks for the fiber-to-the-home systems. Its upgradability, large capacity and flexibility are its qualities that make it such a promising candidate. Wavelength-division- multiplexing transmits multiple data signals using different wavelengths of light through a single fiber. The objective of this work is to implement and propose low cost architectures for high speed performance of Passive Optical Network. [1] Due to the recent standardization activities of 100 Gigabit Ethernet (100 GbE), there have been growing interests in the 100-Gb/s passive optical network (PON) [1]. For example, it has been already demonstrated that 100-Gb/s PON can be realized by using the optical orthogonal-frequency-division-multiple access (OFDMA) technique [2][4]. However, it should be noted that these 100-Gb/s OFDMA PONs are not intended to deliver 100-Gb/s service to each subscriber. In other words, the term 100 Gb/s in this report indicates the maximum per- wavelength transmission speed. Thus, if we assume that this network is consisted of 10 optical

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network units (ONUs), it can provide only 10-Gb/s service to each subscriber on average.Ho-Chul Ji *et. al.*, [5] was experimentally demonstrated for the first time a cost-effective and colorless wavelength-division-multiplexed passive optical network which can provide a full- duplex 155-Mb/s bidirectional transmission over 20km SSMF. Downstream data transmitted on a single wavelength using Fabry-Perot laser diode (FPLD) as a source and upstream data directly modulated using refractive semiconductor optical amplifier (RSOA) and transmitted over 20km single mode fiber. In this experiment it found that FPLD can generate maximum output power at wavelength range from 1551 to 1553nm that is -10dBm, definitely received power for this wavelength range will be maximum. Wooram Lee *et. al.*, [6] was demonstrated for same distance that is 20km SSMF for 2.5Gb/s downstream and 1.25Gb/s upstream transmission. In this demonstration also FPLD is used as source for downstream transmission and RSOA works under gain saturation region over wavelengths from 1530 to 1560 nm, it employing wavelength independent in this wavelength range for upstream transmission. Ioannis Papagiannakis et.al.[7] was investigated WDM-PON with enhancement of up- stream transmission at 10 Gb/s using a low-bandwidth reflective semiconductor optical amplifier. The gain peak of RSOA is at 1510nm, and signal is transmitted over 30km SSMF at wavelength 1535nm. Further K. Y. Cho et. al. [3], proposed WDM-PON with 10Gb/s upstream and down- stream transmission. In this the bandwidth of RSOA is 2.2 GHz, and investigated for distance 20km, the optical power incident on the RSOA was -12 dBm and the upstream signal power received by the PIN receiver at the CO was -10 dBm.

In this work, we propose and demonstrate a long-reach wavelength-division-multiplexed (WDM) PON capable of providing 100-Gb/s service to each subscriber. For the cost effectiveness (as well as the colorless operation of ONUs), we implement this network in loopback configuration by using directly modulated reflective semiconductor optical amplifiers (RSOAs) operating at 25 Gb/s. Thus, the 100-Gb/s upstream signal is obtained by combining the outputs of four RSOAs at each ONU using the coarse WDM (CWDM) technique.

II. Operational principle

Figure 1 shows principle of the proposed WDM-PON. We are going to use Continuous wave (CW) laser as light source which generate light of difference wavelengths. At the central office, continuous wave (CW) optical signals at difference wavelength with specified peak power level are generated. In this paper, external modulation technique is used to improve the performance of communication system. In case of direct modulation technique, there is an unequal power distribution to each transmitted bits which affect largely on BER. In this paper, to avoid above drawback external modulation technique is used. The downstream data is externally modulated over continuous wave optical signal using Mach- Zehnder modulator as external modulator .The downstream data are transmitted over continuous wave optical signals and given to wavelength division multiplexing 1 (WDM 1) which is used for multiplexing of downstream signal of difference wavelengths. All these downstream signals are transmitted via EDFA 1, dispersion compensating fiber (DCF), single mode fiber (SMF) which is practically used and EDFA2. As shown in fig.1 EDFA 2 and DMUX 1 are used in Remote node. Downstream signals are transmitted via EDFA 1 and EDFA 2 to strengthen weaken signals ,to make it available for long distance and then after these are transmitted via DMUX 1 which is used for a purpose of demultiplexing of downstream signal and are transmitted to Optical Network Unit (ONU). The proposed network is implemented in loopback configuration. To generate the 100-Gb/s upstream signal, we use four butterfly-packaged RSOAs operating at 25 Gb/s at the ONU. Thus, we need to send a set of four seed light to each ONU from the central office (CO), we assume to use DMUX 1 and

DMUX 2 at the CO and RN, and the operating wavelengths of the seed light are separated by the free-spectral range (FSR) of the DMUX.

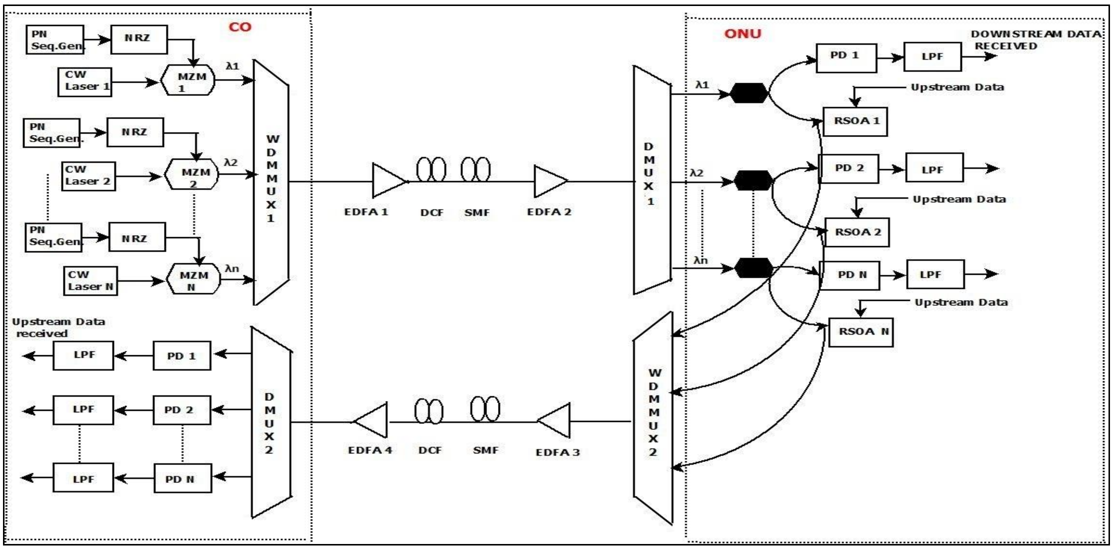

Figure 1. The Schematic Diagram of the Proposed WDM-PON

In ONU optical signal is splitted by splitter, half of optical signal is detected by APD photo-detector (PD) for reception of downstream data and output of APD photo-detector given to low pass Bessel filter. BER for downstream signals is observed and calculated at the output of Low pass Bessel filter. The other half of optical signal is injected by RSOA for remodulation of RSOA with the upstream baseband data. The RSOA is operating at the gain saturation region can squeeze out downstream baseband data, and enable the upstream data to be imposed directly upon downstream signal directly. Upstream data is directly modulated without an external modulator and amplified at the same time. A set of light can be sent to each ONU. At the ONU, this set of light is then directed to each RSOA which is modulated using the upstream data. The modulated outputs of these RSOAs are combined again by the WDM MUX 2 which are used for the purpose of multiplexing and sent back to the CO via EDFA 3, single mode fiber (SMF), DCF, and EDFA 4, then demultiplexed by using DMUX 2. The long-reach operation over 100-km long single-mode fiber (SMF) link is accomplished by using Erbium-doped fiber amplifiers (EDFAs) at the remote node (RN). We assume to use a pair of feeder fibers between the CO and RN to avoid the effects of Rayleigh backscattering. To secure the sufficient power budget needed for the long-reach application, we use EDFAs at the RN. The effect of chromatic dispersion (CD) is suppressed by designing the transmission link to have a slightly negative dispersion value by placing a dispersion compensation module (DCM) in front of the DEMUX 2 at the CO .At CO, upstream data signal is detected by APD photo-detector (PD) for reception of upstream data and output of photo-detector given to low pass filter.BER for upstream signals are observed and calculated at the output of Low pass filter.

III. Experimental set-up

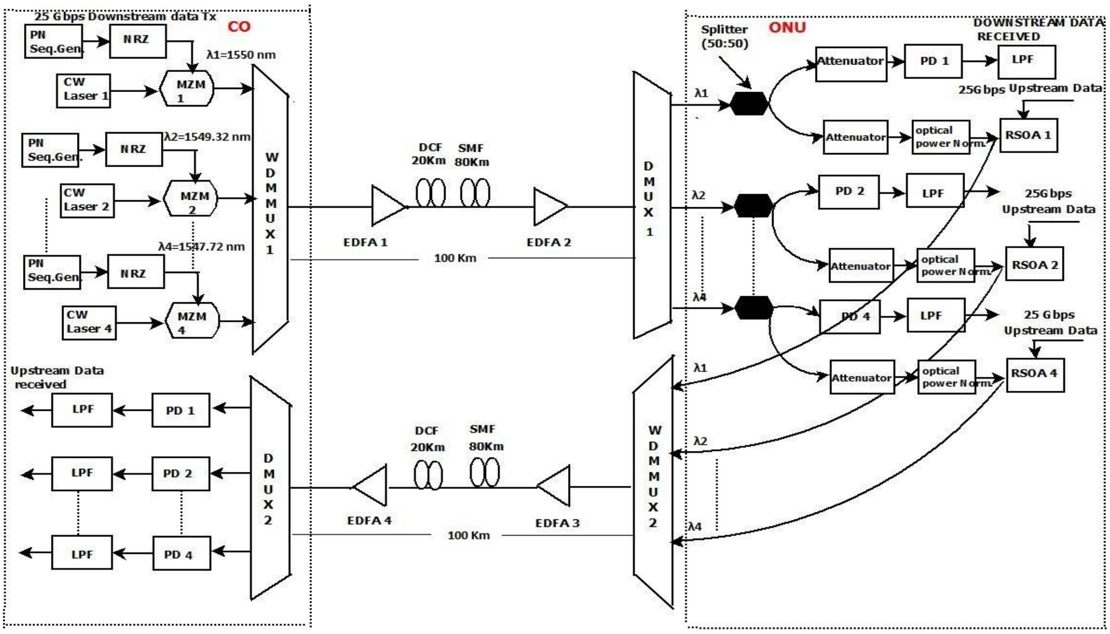

Figure 2. Experimental set-up for proposed scheme

We present 4 wavelength transmissions in this paper for sake of simplicity. Figure 2 shows the experimental setup used to demonstrate the 100-Gb/s, long-reach WDM PON by using directly modulated RSOAs. At the CO, we combined a set of four seed light (operating at 1547.72 nm, 1548.51, 1549.32, and 1550 nm). For downstream transmission, an NRZ baseband signal running at 25-Gb/s [pseudorandom bit sequence (PRBS) length of 2^7 *i.e.*, patter length of 128 bits]. Input optical power equal to 0 dBm is given to all optical sources in CO.CW Laser was externally modulated at downstream data equal to 25 Gb/s using Mach- Zehnder modulator as external modulator. Mach-Zehnder modulator has extinction ratio equal to 30 dB. All those four downstream signals are multiplexed by using WDM MUX 1.After multiplexing; those entire four signals are transmitted via single mode optical fiber which is mostly used for practical application. The loss 3dB is considered in WDM MUX 1.

These optical signals were amplified by the EDFA1 and EDFA 2.Each provide gain of 30 dB After travelling through SMF of length 80 km and 20 km dispersion compensating fiber (DCF). We have used pre compensation technique to reduce chromatic dispersion .A loss in SMF and DCF is 0.2 dB and 0.5dB respectively. The insertion loss of this DCF and SMF was compensated by using additional EDFAs at the RN. The DEMUX 1 was used with filter of type Trapezoidal which having filter BW equal to 2.50E+10 Hz and filter spacing equal to 1e+11 Hz. Further, all those two difference wavelengths signal are demultiplexed by DMUX 1 and which are given to 50:50 splitter .The insertion loss of DMUX 1 is equal to 3dB .The optical power received at the ONU was divided into 50% to the RSOA and 50% to the optical receiver by an optical splitter.APD photo-detector (PD) is used for reception of downstream data signal and output of photo-detector given to low pass Bessel filter which having filter BW Equal to 10^{09} Hz and filter order equal to 4 to get better signal to noise ratio. The APD is having quantum efficiency and dark current is equal to 0.8 and $1e^{-06}$ A. The other half of optical signal is injected by RSOA for remodulation of RSOA with the upstream baseband data 25 Gbps. As shown in fig.2 the attenuator and optical power normalizers used to provide sufficient input power to the optical signals which are applied to RSOA so that RSOA is operating at the gain saturation region can squeeze out downstream baseband data, and enable the upstream data to be imposed directly upon downstream signal directly .Further, all those four difference wavelengths signals are applied to respective RSOA. Among various solutions, the use of a reflective semiconductor optical amplifier (RSOA) in an ONU is a good candidate because this approach has the flexibility to assign a wavelength to the upstream signal, and the signal is directly modulated without an external modulator and amplified at the same time. These entire four difference wavelength signals which are given to respective RSOA are directly modulated without an external modulator and amplified at the same time and assigned a wavelength to the upstream signal by respective RSOA.

In Table 1 design parameters and their values for RSOA are shown. These parameters belong to input facet, output facet, and active region of RSOA model. These parameters are selected to give desired result. After modulation of RSOA with the upstream baseband data 25 Gbps, the modulated outputs of these four RSOAs are combined again by WDM MUX2. The multiplexed upstream data signals are passed via EDFA 3, SMF,DCF, and EDFA 4. To secure the sufficient power budget needed for the long-reach application, we use EDFA 4 at the CO. After travelling through SMF of length 80 km and 20 km dispersion compensating fiber(DCF). The feeder fiber is compensated dispersion by a length of dispersion compensating fiber. Here, post compensation technique is used to reduce chromatic dispersion. At CO, The DEMUX 2 was used with filter of type Trapezoidal which having filter BW equal to 2.50E+10 Hz and filter spacing equal to 1e+11 Hz. The insertion loss of DMUX 1 is equal to 3dB.Further, all those four difference wavelengths upstream signal are demultiplexed by DEMUX 2 at CO. Upstream optical signal is detected by APD photo-detector (PD) for reception of upstream data signal and output of photo-detector given to low pass Bessel filter Finally BER performance of upstream data signal is measured.

IV. Results and discussion

For performance measurement, we estimated the BER from the recovered data. Figure 3 shows the results for downstream data for four wavelengths.

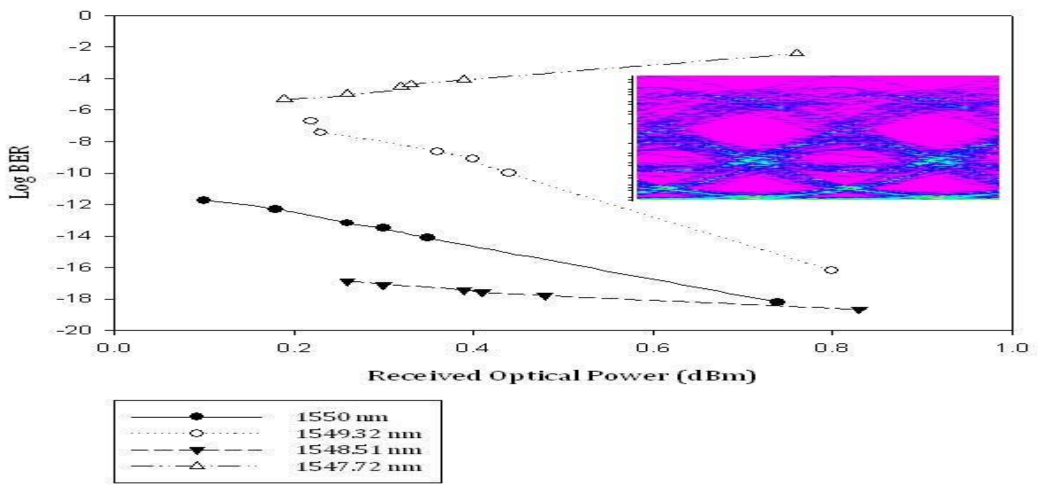

Figure 3. Transmission Performance of Downstream Data

The eye diagram is shown in Figure 3 for wavelength 1550 nm when transmitted power was 0dBm.We have varied the input transmitted power from 0dBm to -5dBm and note the down the BER and received optical power for four wavelengths .It is shown in Figure 3. The performance analysis for downstream data is done in Figure 3.

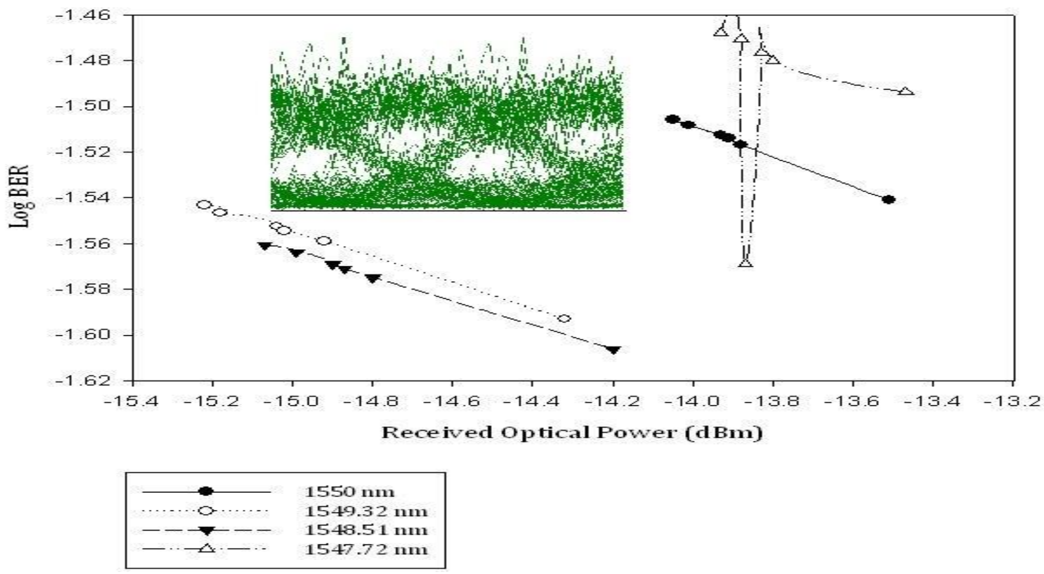

Figure 4. Transmission Performance of Upstream Data

Figure 4 shows the results for upstream data for four wavelength .The eye diagram is shown in Figure 4 for wavelength 1550 nm.

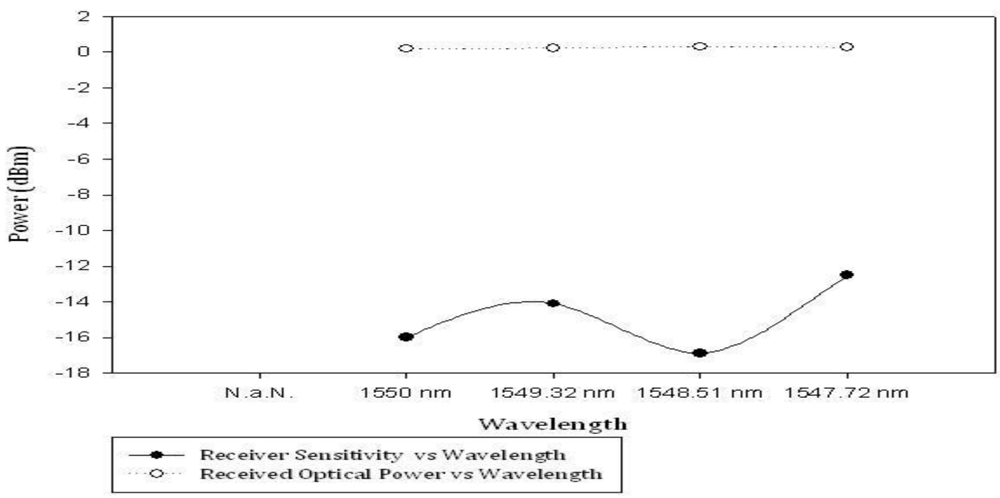

Figure 5. Receiver Sensitivities Measured for Downstream Data at the FEC Threshold of the RS(255, 239) Code (BER = 1×10−4*)* and the Optical Power Incident on the Receiver in the Setup shown in Figure 2

Figure 5 shows the receiver sensitivities measured for downstream data at the threshold 1×10−04 for the 4 CWDM channels together with their received powers . The received power was slightly different from channel to channel due to the wavelength dependence of the EDFA's gain, RSOA's gain, and loss of the CWDM filter. However, the power margins were >12 dB for all 4 CWDM channels. Fig.6 shows the receiver sensitivities measured for upstream data at threshold 2×10−02 for the 4 CWDM channels together with their received powers. However, the power margins were >4 dB for all 4 wavelength channels.

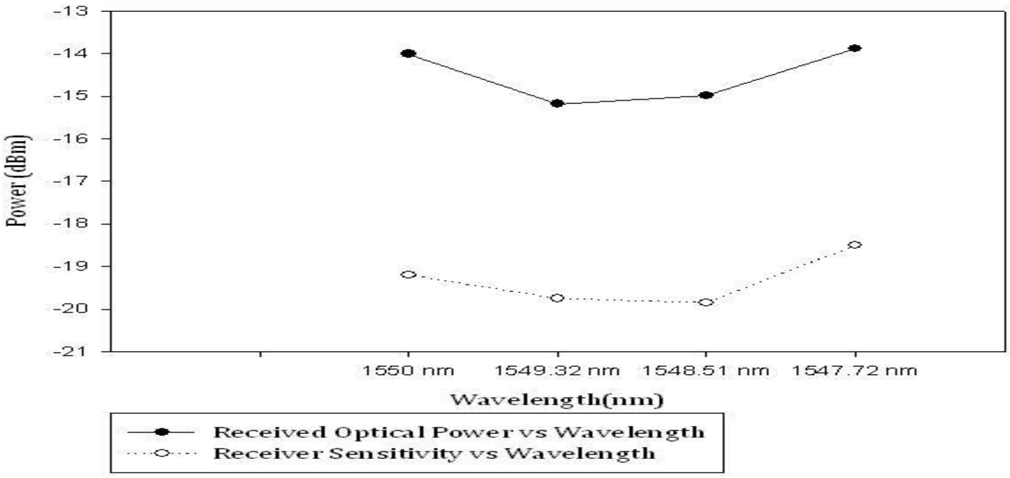

Figure.6 Receiver sensitivities measured for Upstream data at the threshold of (BER = 4×10−02*)* and the optical power incident on the receiver in the setup shown in Fig. 2.

References

[1] N. Cvijetic, D. Qian, and J. Hu, "100 Gb/s optical access based on optical orthogonal frequency-division multiplexing", IEEE Commun.Mag., vol. 48, no. 7, pp. 7077, Jul. 2010.

[2] K. Y. Cho, B. S. Choi, Y. Takushima, and Y. C. Chung, "25.78-Gb/s operation of RSOA for next-generation optical access networks", IEEE Photon. Technol. Lett., vol. 23, no. 8, pp. 495497, Apr. 15,2011.

[3] K. Y. Cho, Y. Takushima, and Y. C. Chung , "10-Gb/s operation of RSOA for WDM PON", IEEE Photon. Technol. Lett., vol. 20, no. 18, pp. 15331535, Sep. 15,2008.

[4] D. Qian, N. Cvijetic, J. Hu, and T. Wang , "108 Gb/s OFDMA-PON with polarization multiplexing and direct-detection",in Proc. Tech. Dig. OFC 2009, San Diego, CA, Mar. 2009, pp. 13, paper PDPD5

[5] T. Sugawara, et al., "High-speed optical/electrical devices and their integration for highly-efficient l00 GbE", in Proc. Tech. Dig. OFC 2010,San Diego, CA, Mar. 2010, pp. 13, paper OThS4.

[6] W. Lee et al, "Bidirectional WDM-PON based on gain-saturated reflective semiconductor optical amplifiers", IEEE Photon. Technol. Lett.,vol. 17, no. 11, pp. 24602462, Nov. 2005 .

[7] S. Park, G.-Y. Kim, and T.-S. Park, "WDM-PON system based on the laser light injected reflective semiconductor optical amplifier",Opt. Fiber Technol., vol. 12, no. 2, pp. 162169, Apr. 2006 .

[8] Laxman Tawade, '100 Gb/s Long- Reach WDM-PON Implemented By Using Directly Modulated RSOA', Microwave Optical Technology Letter (2013) Vol. 55, No.6, 1426-1430.

[9] Laxman Tawade, Sofien Mhatli , Rabah Attia ,'Bidirectional long reach WDM-PON delivering downstream data 20Gbps and upstream data 10Gbps using mode locked laser and RSOA', Optical Quantum Electron DOI 10.1007/s11082-014-9952-9.