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A Novel Design of Bidirectional WDM-PON by using Mode Locked Laser and RSOA

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Abstract

This paper presents Long Reach Wavelength Division Multiplexing Passive Optical Network (WDM-PON) system capable of delivering downstream 40 Gbit/s data and upstream 40 Gbit/s data on a single wavelength. The optical source for downstream data and upstream data is mode locked 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 40-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 117 km by using Erbium-doped fiber amplifiers at the RN. Bit error rate, 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).*

1. Introduction

The increasing demands for higher speed and advanced services in access networks require a bandwidth of above 50 Mbit/s for next-generation services to end users [1]. The use of technologies based on optical fibers can easily achieve bandwidths higher than 100 Mbit/s and at the same time can reduce maintenance and repair costs [1, 2]. In terms of cost, a passive optical network (PON) is very attractive because there are no active components in the trans- mission line. A PON system typically consists of an optical line terminal (OLT) in a central office (CO), a remote node RN), and optical network units (ONUs). There are limitations on the transmission capacity and number of users of time-division multiplexing (TDM) PONs with splitters, but they are easy to install, are small, and require no electricity [3]. On the other hand, a wavelength division multiplexing (WDM) PON with arrayed waveguide gratings (AWGs) assigns a different wavelength channel to each end user, so the bandwidth can be high. In addition, it is far superior to TDM PONs in security [3, 4] and potentially cost effective [5]. The development of colorless ONUs is a key is- sue in WDM PON technologies to reduce the system cost dramatically. Among various solutions, the use of a reflective semiconductor optical amplifier (RSOA) in an ONU is a good candidate The long reach wavelength division multiplexing passive optical network (WDM-PON) with reflective optical network unit (R-ONU) have attracted more attention recently. This transport system, which integrate the advantages of hybrid dispersion compensating

Raman/EDFA[6-9] amplifier and colorless ONU, have been developed with expectations for fiber optical communications that require high-speed bit rate, higher capacity and low cost in architecture. In such way, the long reach optical links must to suffer from the limitation of fiber loss, chromatic dispersion and noise. Furthermore, the unnecessary laser source in each ONU will increase capital expenditures of the system. Therefore, we integrated the hybrid Raman/EDFA amplifier and the colorless optical network units. In this letter, we proposed the technique of dispersion compensating Raman/EDFA hybrid amplifier with double-pump in feed-forward Raman amplifier cascade EDFA for secondary signal amplification.

The hybrid amplifier is designed to enhance the signal power and compensated the fiber dispersion over a wide wavelength range, besides, to demonstrate the colorless concept in optical network unit. Here, the signal re-modulation by reusing the downlink wavelength for generating the uplink signal can also transmit over 50 km bi-directional fiber. In our proposed approach, the power budget and the sensitivity will be improved. And the data stream of symmetrical 10-Gb/s transmitted both for down/uplink with low bit error rate (BER) values were obtained. The objectives of project are To design an reflective semiconductor optical amplifier (RSOA) based on ONU with downlink signal in colorless WDM-PON. To simplify the complicated bidirectional long reach WDM-PON system, by using hybrid amplifiers. To simulate the design using OPTSIM version-13 software. To enhance the signal sensitivity in transmission. To lower the Bit Error Rate. This transport system integrate the advantages of hybrid dispersion compensating Raman/EDFA amplifier and colorless ONU, with expectations for fiber optical communications that require high-speed bit rate, higher capacity and low cost in architecture.

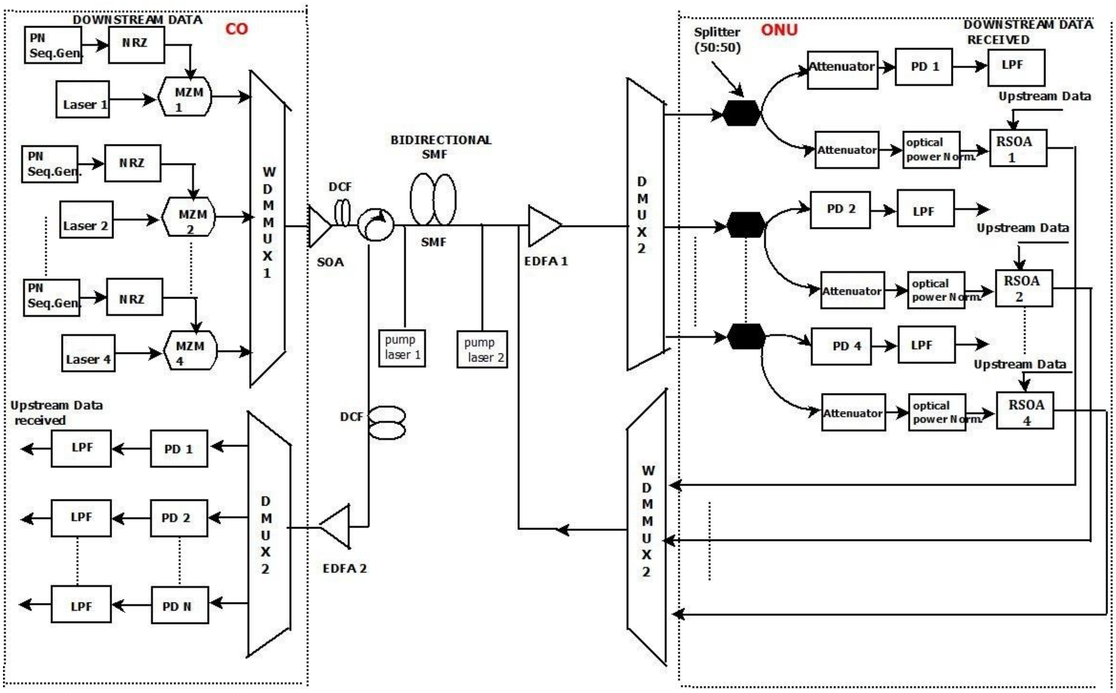


Figure 1. The Schematic Diagram of the Proposed WDM-PON [10-11]

2. Operational Principle

Fig.1 shows principle of the proposed WDM-PON. We are going to use mode locked laser as light source Which generate light of difference wavelengths. At the central office, mode locked laser 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 semiconductor optical amplifier (SOA) ,Dispersion compensating fiber (DCF) ,single mode fiber (SMF) which is practically used and EDFA1 .As shown in fig.1 EDFA 1 and DMUX 1 are used in Remote node. Downstream signals are transmitted via EDFA 1 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 40-Gb/s upstream signal, we use four RSOAs operating at 10 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. 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. 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 single mode fiber (SMF), DCF, and EDFA2 then demultiplexed by using DMUX 2. The long-reach operation over 117-km long fiber link is accomplished by using Erbium-doped fiber amplifiers (EDFAs) at the remote node (RN).

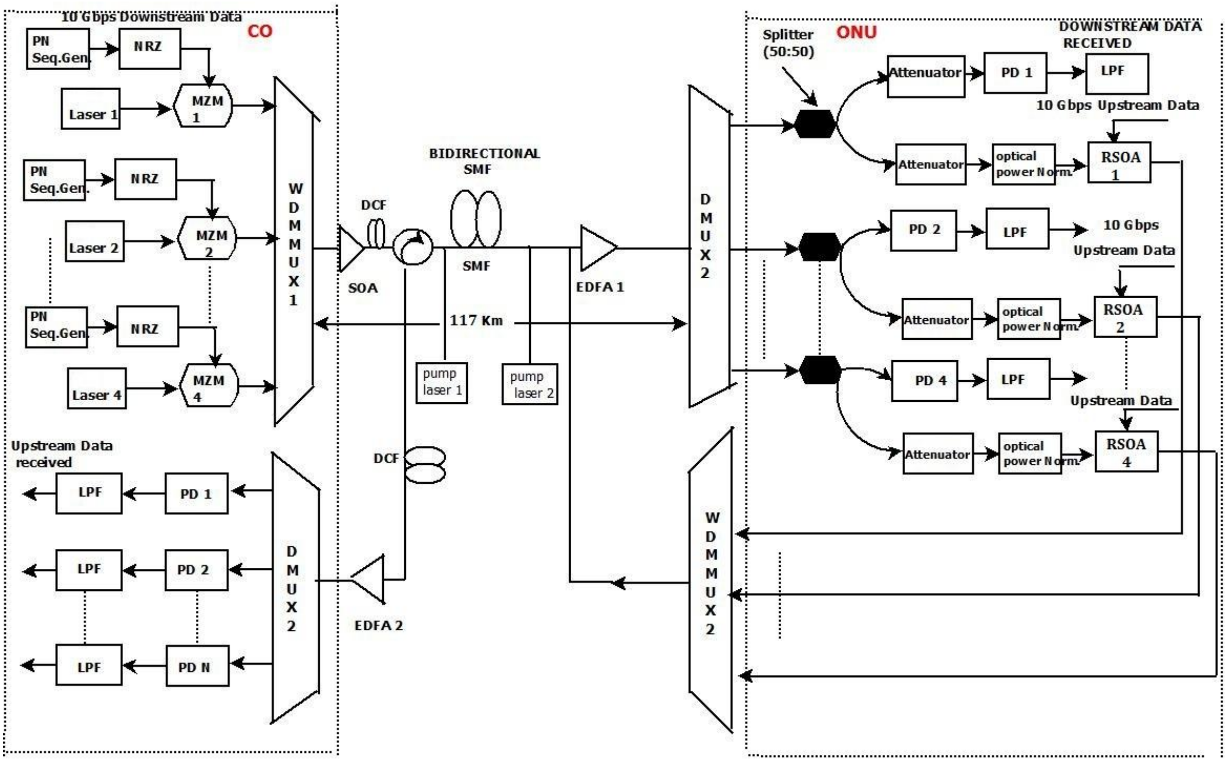


Figure 2. Experimental Set-up for Proposed Scheme

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.

3. Experimental Set-up

Here as shown above in fig.2 ,we have implemented a bidirectional wdm –pon in Optsim software version13.We are using a mode locked laser i.e.soliton pulse generator as a light source.There is 4 optical sources are used which having wavelength 1550.12 nm,1549.32nm,1548.51nm,and 1547.72 nm.We are using pn sequence generator which generate a digital binary data of 10 Giga bits per second(10Gbps).All this binary data given to NRZ Modulator .The output of NRZ is electrical signal which is information signal which superimposed on light which is carrier. This modulation is called external modulation .There is Mach- Zehnder modulator is used as external modulator. The output of these 4 Mach- Zehnder modulator is optical signal which is carrying information signal (10Gbps) which is multiplexed by using wdm mux 1.The combined data is 40 Gbps which is transmitted through fiber. This multiplexed data is transmitted through Semiconductor optical amplifier (SOA), DCF of length 20 km ,bidirectional single mode fiber (SMF) of length 97 km,and Erbium doped fiber amplifier (EDFA 1).We are designing a raman amplifer at the bidirectional single mode fiber with 2 pump laser .One pup laser is having wavelength 1435 nm and power of 0.17w which is used for co pumping and another laser of 1460 nm with input power of 0.14 w is used for counter pumping. this data is demultiplxed by using demux 1 .The length of SMF is 50 km .The distance between Central office (co) and Optical network unit (ONU) is 117 km.These 4 optical signal of different wavelength which each is carrying data of 10 Gbps is separated by demux 1 .The each optical signal is further proceed to splitter which split the incoming optical signal 50% optical signal proceed to receiver where optical to electrical conversion is done and the transmitted 10 Gbps downstream signal is received and the performance analysis is done by comparing the transmitted bits with received bit which is nothing but bit error rate(BER) calculated. Q-factor ,BER ,eye diagram and eye height can be measured using the eye diagram analyzer. The remaining 50 % optical signal is given to RSOA .we are going to reutilize the wavelength so that we can reduces the number of optical source in the ONU that why we called it coloureless ONU. RSOA is having two input one is optical signal and another one electrical signal i.e.10 Gbps Upstream data.The RSOA which modulate the 10Gbps data on optical signal.This is performed for 4 RSOA.The modulated data ie.(10Gbps*4=40 Gbps)which is upstream data which is multiplexed by wdm mux 2 and transmitted through bidirectional single mode fiber (SMF), DCF and EDFA 2.Then this optical signal is demultiplxed by Demux 2 and demultiplxed optical signal is given to respective receiver and proceed to receiver where optical to electrical conversion is done and the transmitted 10 Gbps downstream signal is received and the performance analysis is done by comparing the transmitted bits with received bit which is nothing but bit error rate(BER) calculated. q-factor ,BER ,eye diagram and eye height can be measured using the eye diagram analyzer.

4. Results and Discussions

We estimated the BER from the recovered data. Fig. 3 shows the results for downstream data for four wavelength .The eye diagram is shown in fig 7 for wavelength 1547.72 nm and 1548.51 nm when downstream data transmitted power was 0dBm. The eye diagram is shown in fig 8 for wavelength 1547.72 nm and 1548.51 nm when upstream data was transmitted.

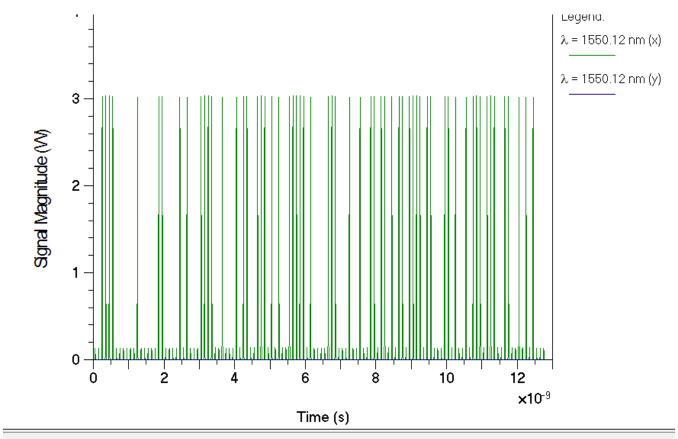


Figure 3. Transmitted Downstream Data

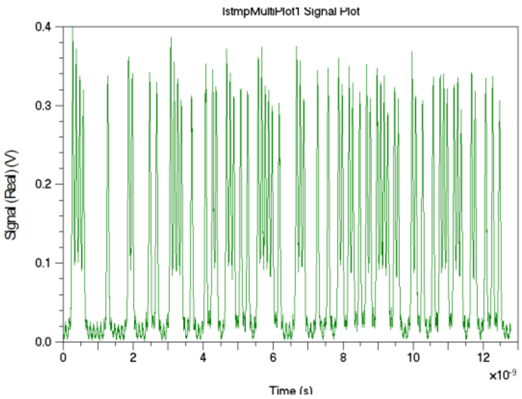


Figure 4. Received Downstream Data

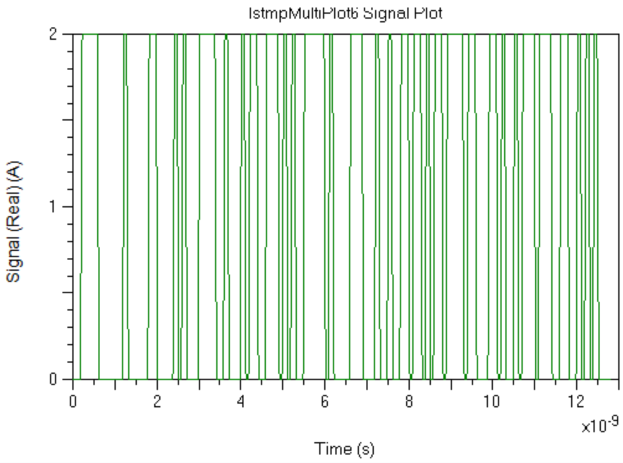


Figure 5. Transmitted Upstream Data

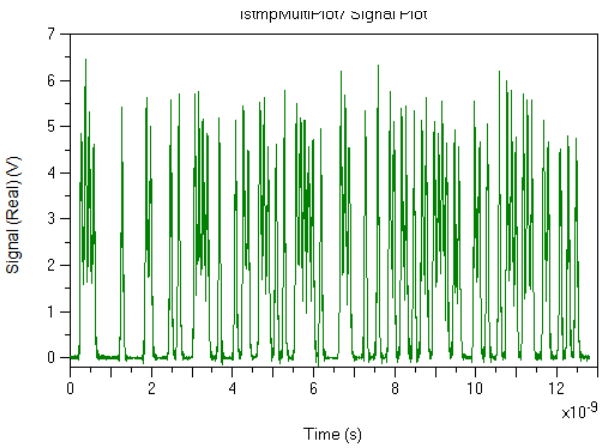


Figure 6. Received Upstream Data

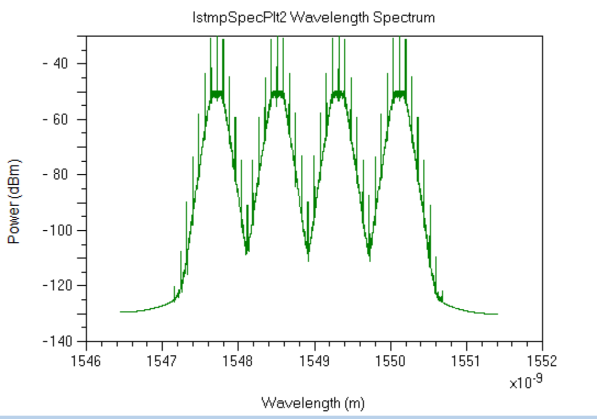


Figure 7. Multiplexed Downstream Data Signal at the Output of wdm mux 1

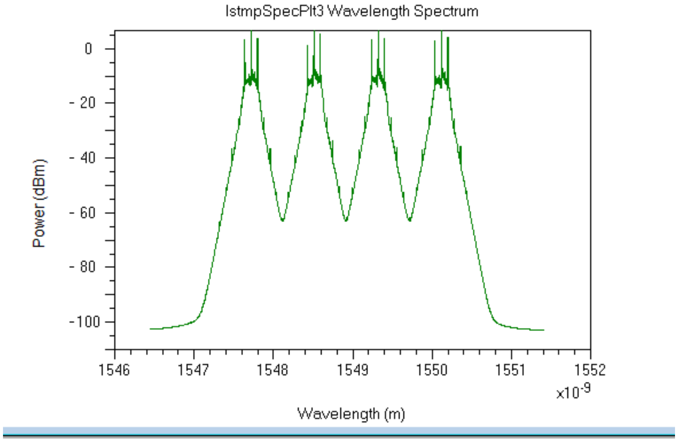
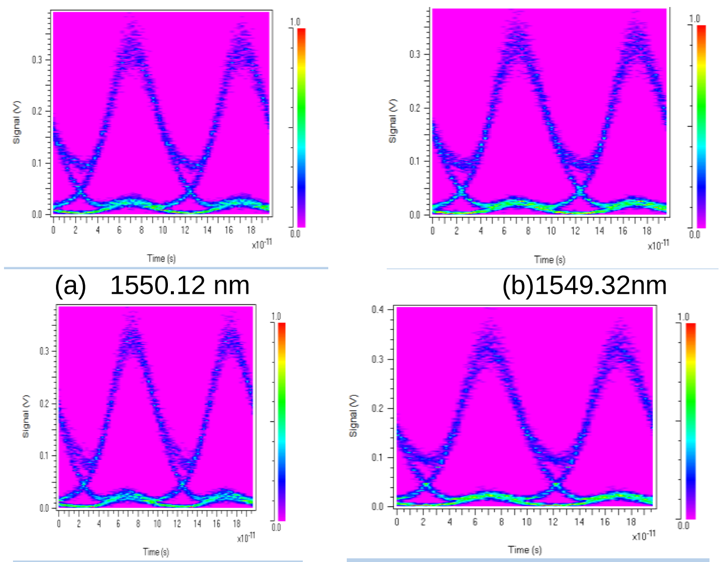


Figure 8. Multiplexed Upstream Data Signal at the Output of wdm mux 2



(a) 1550.12 nm (b)1549.32nm

(c) 1548.51nm (d)1547.72 nm

Figure 9. Eye Diagram for Downstream Data signal at Input Optical Power 0 dBm

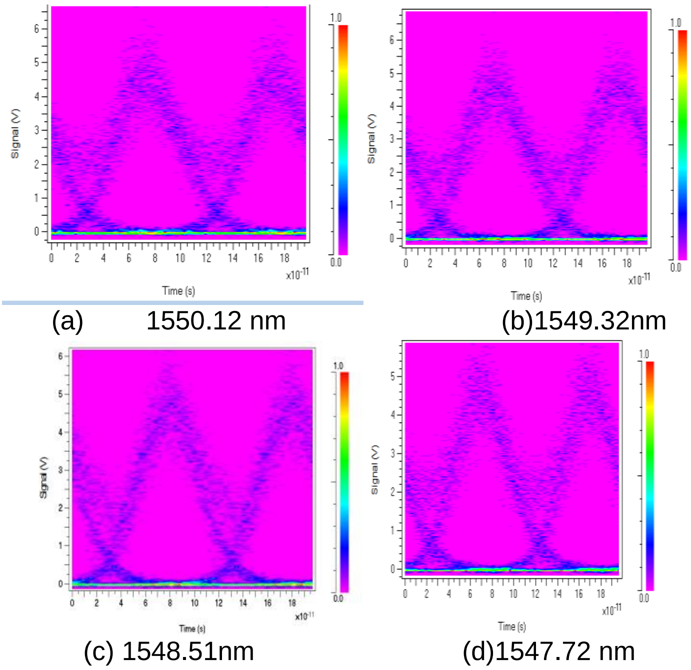


Figure10. Eye Diagram for Upstream Data Signal at Input Optical Power 0 dBm

DOWNSTREAM DATA PERFORMANCE ANALYSIS

INPUT OPTICAL POWER	RECEIVED OPTICAL POWER FOR DIFFERENT WAVELENGH				BER				Log BER			
(dBm)	1550.12 n	1549.32 nm	1548.51 nm	1547.72 nm	1550.12 n	1549.32 nm	1548.51 nm	1547.72 nm	1550.12 r	1549.32 nm	1548.51 nm	1547.72 nm
o dBm	-14.906	-15.735	-15.795	-20.704	1.47E-57	6.86E-59	3.28E-63	2.44E-57	-5.68E+01	-5.82E+01	-6.25E+01	-5.66E+01
-2 dBm	-20.704	-21.532	-22.36	-24.926	2.96E-43	1.29E-44	1.26E-47	1.89E-45	-4.25E+01	-4.39E+01	-4.69E+01	-4.47E+01
-4 dBm	-24.017	-27.745	-28.261	-28.157	3.12E-31	6.54E-32	4.23E-34	1.39E-32	-3.05E+01	-3.12E+01	-3.34E+01	-3.19E+01
-6dBm	-28.157	-28.965	-33.913	-32.298	4.24E-22	2.04E-22	8.42E-24	1.09E-22	-2.14E+01	-2.17E+01	-2.31E+01	-2.20E+01
-8 dBm	-30.642	-36.439	-34.783	-35.611	1.96E-15	1.37E-15	2.14E-16	1.07E-15	-1.47E+01	-1.49E+01	-1.57E+01	-1.50E+01

Note :Received Optical Power is in dBm unit

Figure 11. Downstream Data Performance Analysis

UPSTREAM DATA PERFORMANCE ANALYSIS

INPUT OPTICAL POWER (dBm)	RECEIVED OPTICAL POWER FOR DIFFERENT WAVELENGH				BER				Log BER			
	1550 nm	1549.32 nm	1548.51 nm	1547.72 nm	1550 nm	1549.32 nm	1548.51 nm	1547.72 nm	1550 nm	1549.32 nm	1548.51 nm	1547.72 nm
o dBm	-10.776	-11.594	-12.422	-13.251	1.33E-11	1.04E-11	2.07E-12	1.30E-11	-1.09E+01	-1.10E+01	-1.17E+01	-1.09E+01
-2 dBm	-14.907	-12.008	-12.836	-14.079	1.19E-11	1.14E-11	1.56E-12	1.18E-11	-1.09E+01	-1.09E+01	-1.18E+01	-1.09E+01
-4 dBm	-15.735	-13.251	-14.079	-14.907	2.10E-11	1.24E-11	4.53E-12	2.08E-11	-1.07E+01	-1.09E+01	-1.13E+01	-1.07E+01
-6 dBm	-16.573	-14.079	-15.735	-16.573	5.27E-11	4.21E-11	1.58E-11	5.11E-11	-1.03E+01	-1.04E+01	-1.08E+01	-1.03E+01
-8dBm	-17.391	-14.493	-15.999	-17.391	2.03E-10	1.74E-10	8.15E-11	2.17E-10	-9.69E+00	-9.76E+00	-1.01E+01	-9.66E+00

Note :Received Optical Power is in dBm unit

Figure 12. Upstream Data Performance Analysis

5. Conclusion

It is successfully demonstrated that wavelength division multiplexing passive optical network (WDM-PON) system can be successfully implemented for 117 Km. It delivers downstream 40-Gbps data and upstream 40-Gbps data on a single wavelength. We have experimentally demonstrated the upstream link of 40-Gb/s, 50-km reach WDM PON implemented by using directly modulated RSOAs. For this experiment, we mounted the RSOA. The results show that the error-free transmission can be achieved for all WDM channels with sufficient power margins. Since the colorless modulators are used, the advantage can reduce the laser source and stabling at the ONU. From the serial discussion we also found that the novel hybrid amplifiers not only can simply the complicated of bi-directional long reach WDM-PON system, but also can enhance the signal sensitivity in transmission.

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