ISSN: 0975-766X
CODEN: IJPTFI
Available Online through
Research Article
www.ijptonline.com

CARRIER-REUSE USING RSOAIN TWDM-PON FOR BROADCAST AND MULTICAST TRANSMISSION

S. Rajalakshmi[1], Dr. T. Shankar[3]
[1]Assistant Professor (Senior), School of Electronics Engineering, VIT, University, Vellore, Tamil Nadu, India – 632014.
Associate Professor, School of Electronics, Engineering, VIT, University, Vellore, Tamil Nadu, India – 632014.
Email:srajalakshmi@vit.ac.in

Received on: 18.10.2016 *Accepted on: 11.11.2016*

Abstract

The WDM-PON is a promising candidate to meet the rapidly increasing bandwidth demand for enterprises and households. In the proposed architecture we make use of the cyclic property of arrayed waveguide grating(AWG), splitting capabilities of optical power splitter as well as splitting properties of the delay interferometer(DI) and also the reflective capabilities of the fiberbragg grating(FBG). In the design of the proposed architecture we make use of eight 10Gb/s downlink unicast channel, one 10Gb/s broadcast channel and eight 2.5Gb/s uplink unicast channel. The performance matrices to be analyzed include: How the operation condition of the SOA of the broadcast channel affect the transmission performance of the broadcast and the unicast channel. The effect of DI extinction ratio on the BER performance for both downlink and uplink data transmission. The interference from the broadcast to the unicast channel. Receiver sensitivity at each ONUs. Power budget and network stability.

Keywords: Wavelength Division Multiplexing WDM-PON, (Arrayed Waveguide Grating) AWG, Delay Interferometer (DI), Fiber Bragg Grating (FBG).

Introduction

In this project, a broadcast multicast-capable WDM-PON architecture, based on the carrier-reuse scheme reported in [16] is proposed. A broadcast channel is multiplexed with the downlink unicast channels in the central office (CO). Since broadcast and multicast data uses separate wavelengths, a NRZ modulation format instead of DPSK can be used, which would simplify detection of broadcast data at each ONU. At the RN, an optical splitter for splitting the broadcast signal and an AWG for routing and overlaying the broadcast channel onto the unicast channels are employed such that the broadcast channel and a dedicated downlink unicast channel can be transmitted to each ONU simultaneously.

Naturally, this WDM-PON can support multicast services, since each ONU can receive the common broadcast channel. The multicast function can be implemented either in the medium access control (MAC) layer or in the Internet Protocol (IP) layer, similar to the current multicast-capable. E-PON or G-PON using IP multicast addresses through a single wavelength channel. There is no need to change the configuration of physical connections for multicast services.

Wavelength Division Multiplexed Passive Optical Network(WDM-PON) architecture which comprises of WDM Mux/DeMux, tunable receivers, tunable transmitter. C-band WDM-PON prototype is demonstrated/simulated to provide 20Gb/s downstream and 20Gb/s upstream bandwidth[1]. Optical Network Unit (ONU) that is colourless and employs a reflective semiconductor optical amplifier (RSOA) as optical source and uses a feedback process to use itself light and get the seed signal[2]. The recent trends in fiber access passive optical networks include Ethernet Passive Optical Network (EPON), Gigabit Passive Optical Network (GPON) and Wavelength

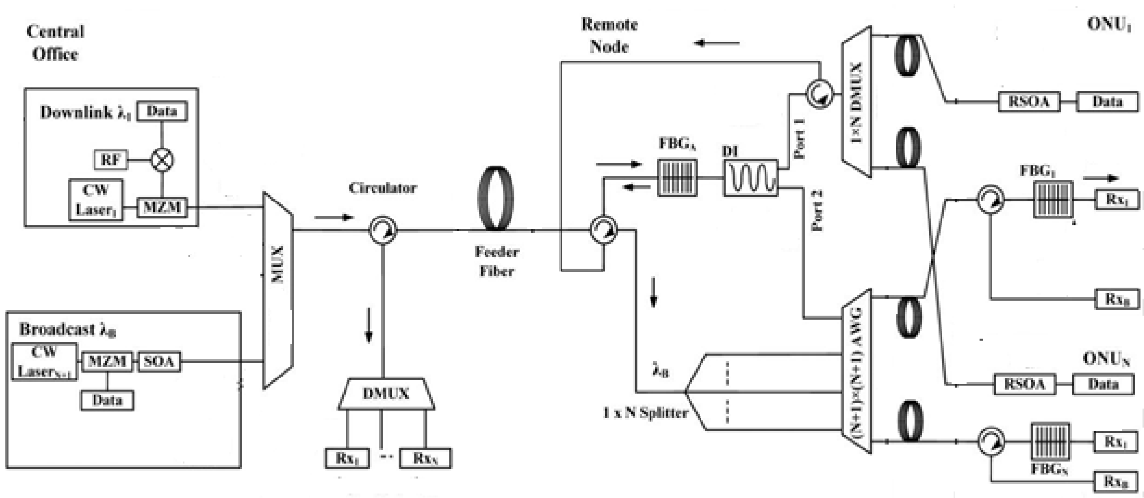
Division Multiplexing Passive Optical Network (WDM PON).PON such as GPON and next generation WDM PON discusses key technological aspects, and challenges of GPON, and next generation WDM PON and aims to provide insights to a reader by doing a comparative study of the two fiber access passive networks on the basis of cost, capacity and flexibility[3].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(in this paper[4]. New next generation (NGPON) standards (10 Gigabit-PON (XG-PON) and 10 Gigabit Ethernet-PON (10G-EPON)) are based on time division multiplexing (TDM-PON) which also has its limitations. In this paper hybrid TDM-WDM PON architecture is proposed to meet the requirements of NG-PON[5]. The design includes spectral preemphasis and offset optical filtering to increase the effective bandwidth of a commercial 2.2 GHz reflective semiconductor optical amplifier based optical network unit. We realize symmetric 10 Gb/s transmission over a 20 km single feeder PON with optical line terminal launch powers from 1 to 9 dBm. We also demonstrate the ability of these SCM WDM PONs to with stand the effects of upstream impairments[6]. The high-speed WDM PON operating at per-wavelength speed of > 10 Gb/s by using reflective semiconductor optical amplifiers (RSOAs) and the digital coherent detection technique. We also evaluated the maximum operable speed of the RSOA-based WDM PON by using the classical Shannon theorem[7]. We here transmit one unicast data, one multicast data and two broadcast data transmission to each ONU. With the help of single frequency reflection capacity of FBG and cyclic wavelength distribution property of the AWG a unicast/multicast data and broadcast data is transmitted to each ONU[8].The investigation of high speed 8-channel spectrum-sliced DWDM PON system with efficient CD compensation methods like dispersion compensating fiber (DCF) and fiber Bragg grating (FBG). It is shown that CD compensation has an important role for guaranteed downstream optical link performance and maximum transmission line length of high speed SS-DWDM PON system[9].The multicast function can be implemented in a higher layer, similar to the current multicast-capable E-PON or G-PON using IP multicast addresses through a single wavelength channel. Thus, there is no necessity for reconfiguration of physical connections for multicast services[10]. The optical carrier of a phase-modulated injection optical signal at one slope of the filter response, phase-modulation to intensity-modulation conversion is achieved, leading to the generation of a UWB signal having a power spectrum meeting the FCC-specified spectral mask [11]. The baseband data are also carried on the optical carrier after subcarrier modulation. This residual data introduce crosstalk when the optical carrier is separated from subcarriers and reused for uplink data modulation [12]. WDM-PON mitigates the complicated time-sharing and power budget issues in time division-multiplexed PON (TDM-PON) by providing virtual point-to-point optical connectivity to multiple end users through a dedicated pair of wavelengths[13].The differential-phase-shift-keying multicast data is modulated on the same optical downstream carrier with the inverse return-to-zero point-to-point data signal, thus additional light sources are saved[14]. The differential phase-shift keying multicast signal is superimposed onto all point-to-point non return-to-zero (NRZ) signals. By adjusting the extinction ratios of the individual NRZ point-to-point signals, multicast can be realized and only the designated optical network units can properly receive the multicast data.[15]. the impact of fiber nonlinearity and modulation format on equalization is also investigated. The main objective of this paper is to present an overview and a comparison of the performances rather than a detailed explanation of the principles of the different equalization schemes[16].

Design Methodology

The proposed architecture can be divided into three sections, Central Office (CO), Remote node(RN), optical network Unit (ONU). We make use of eight 10 GB/s downlink unicast channel, one 10 GB/s broadcast channel and eight 2.5 GB/s uplink unicast channel, they are muxed using a AWG. At the remote node, the broadcast signal is split into N number of ONUs in the network. AWG at the RN overlaid with a unicast channel and then simultaneously transmitted to an ONU. The same AWG is used to separate the unicast channels, i.e., no additional AWG is required. At the central office each unicast downlink NRZ data stream is modulated onto a radio frequency (RF) subcarrier, which is further modulated onto an optical carrier by means of a Mach–Zehnder modulator (MZM), to generate the subcarrier modulated (SCM) signal. N downlink SCM modulated unicast channels and one broadcast channel are mixed by a WDM Multiplexer (MUX). The combined signals are transmitted over a feeder fiber to the RN. The broadcast signal is to be split into N equal parts at the RN. SOA used to boost the power of the broadcast channel before it is multiplexed with the unicast channels and transmitted to the RN via a feeder fiber (20 km).

Fig 1 shows the schematic diagram of proposed architecture. At the RN, FBG is used to reflect the broadcast channel, in order to separate the broadcast channel and the downlink SCM modulated unicast channels. The reflected broadcast signal is then split into N equal parts by an optical splitter, and then each part is launched into an AWG from the 2nd to the (N+1)th input port. The power splitter introduce.

Fig 1.Schematic Diagram of the Proposed Architecture.



High insertion loss which is compensated by the gain of a semiconductor amplifier. An optical delay interferometer (DI) is used to separate all optical carriers and subcarriers of the SCM modulated downlink unicast signals, which is much more cost-effective than the method of dedicated filtering for each downlink unicast signal at each ONU.

The free spectral range (FSR) of the DI is twice the subcarrier frequency and the WDM channel spacing of the carriers should be an even integer multiple of the subcarrier frequency, so that all the optical carriers appear in one output port of the DI, and all optical subcarriers emerge at the other output of the DI. The individual uplink unicast signals are then transmitted to the RN where they are multiplexed and sent back to the CO via the same feeder for uplink data detection.

The separated subcarriers are launched into the 1st input port of the AWG. Due to the cyclic routing property of the AWG, all the output ports except the (N+1)th port would have two channels: the common broadcast channel and a downlink unicast channel. Each pair of broadcast channel and downlink unicast channel from each output port is fed into the corresponding ONU for data detection via another distribution fiber. In each ONU, a uniform FBG together with an optical circulator (OC) is used to separate the broadcast channel from the downlink unicast channel for respective data detection. Since an identical FBG can be used in every ONU, all ONUs can be made colorless. The two distribution fibers between the RN and each ONU, it can be readily extended to the case where there is only one distribution fiber by using a larger AWG in the RN and employing a coarse WDM coupler at each ONU. Since broadcast/multicast is incorporated in this architecture, naturally the overall cost would be increased. However as compared to the architecture without broadcast/multicast the increased cost is expected to be small. An identical FBGs used in the new architecture, each ONU only requires one FBG to separate the broadcast wavelength from the unicast wavelength. Table 1 shows the parameters used.

Table-1. Schematic Parameters used.

Parameters	Values
Data Rate Multicast	10Gb/s 10Gb/s
Data Rate Broadcast	2.5Gb/s
Unicast frequency	193.1 to 194.22 THz
Unicast channel spacing	160 GHz
Broadcast frequency	195.66 THz.
Subcarrier RF frequency	20 GHz
PRBS data	10 Gb/s
Feeder fiber	20 km
Single mode fiber	16.8 km
SM Dispersion	16ps/nm/Km
Dispersion compensation fiber	3.2 km
DCF Dispersion	84ps/nm/Km
FBG wavelength	195.66 THz
FBG reflectivity	0.99999
DI Extinction ratio	40 GHz
FSR	0.025 ns
APD Gain	3
APD Responsivity	0.9 A/W
APD Dark current	10 nA
RSOA Current	50 mA

Results and Discussion

SOA Input verses Output Power:

The input power for SOA is found by varying bias current. The Fig2 shows the output power of SOA increases as its input power is increased only up to a certain point and then the output became constant, thus dividing the SOA into saturation and non-saturation region.

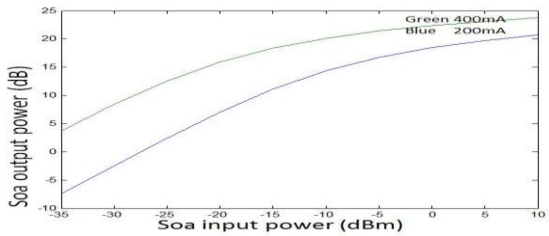


Fig 2.SOA Input versus Output power (dBm).

The power splitter introduces insertion loss and to compensate for this loss the broadcast signal is amplified at CO using SOA. Thus an evaluation of the impact of the operating conditions of the SOA on the BER of the broadcast channel and the unicast channels is performed.

SOA Input Power Verses Gain

The gain of SOA was plotted against its input power as shown in fig3. Initially the gain remains constant that is there is almost zero or negligible variation in gain with the increase in input power.

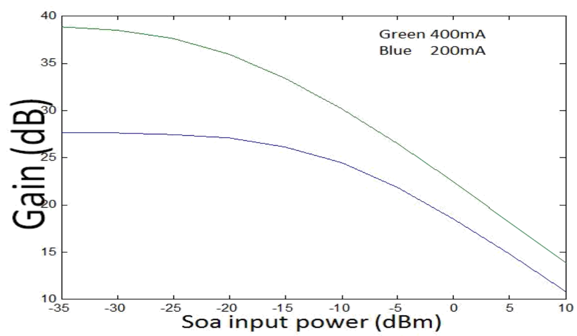


Fig3 SOA Gain (dB) verses Input power (dBm)

For a bias current of 600mA, gain saturation occurs when the SOA input power is 16.2dBm and the corresponding output saturation power being 11.1dBm. The extinction ratio (ER, i.e., the on/off power ratio) of the SOA output modulated signal were plotted against its input power at the bias current of 600mA. As expected the ER of the SOA output signal rapidly degrades as the SOA input power increases in the saturation region.

Effects of the Di Extinction Ratio (ER)

The carrier-reuse, residual downlink data on the optical carriers exists after the SCM modulated signals, introducing considerable crosstalk when the optical carriers are reused for uplink data modulation. Performance evaluation of the effect of the ER of the DI on the OCSR which in turn influences the BER significantly. The output OCSR at port 1 would increase, which benefits the reuse and re-modulation of the carrier for uplink data transmission; while the output OCSR at port 2 would reduce, which benefits direct detection of downlink data carried on the sub-carriers. The output OCSRs at port 1 and port 2 of the DI are affected considerably by the DI extinction ratio (ER).The difference between the output OCSR at port 1 and the output OCSR at port 2 increases with the DI ER.

Receiver Sensitivity Analysis in ONUS

Broadcast Signal Receiver Sensitivity: The receiver sensitivity of the broadcast signal at each ONUs was measured by varying the SOA input power. The receiver sensitivity of broadcast channel increases with increase in the SOA input power and reaches at its best when the output power from the SOA reaches maximum and beyond this the receiver sensitivity of broadcast channel degardes. Fig4 shows the receiver sensitivity of broadcast carrier.

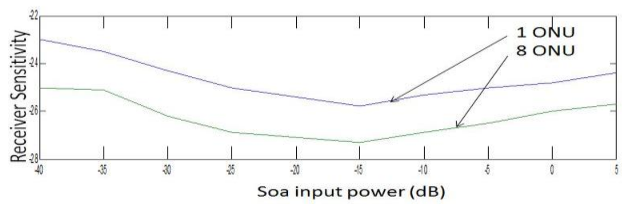


Fig-4: Receiver Sensitivity of Broadcast Carrier.

Downlink Unicast Channel Receiver Sensitivity

The receiver sensitivities of the downlink unicast channel and the uplink unicast channel slightly degrade as the SOA input power increases. This is mainly because of the interference of the broadcast channel on the unicast channels. The interference of the broadcast channel on the downlink unicast channel increases with the SOA input power. Fig5 shows the down link channel receiver sensitivity.

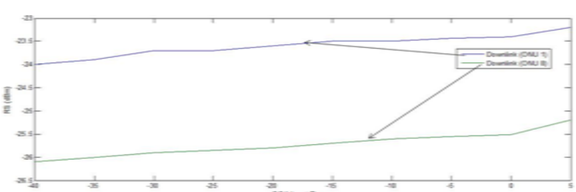


Fig-5: Receiver Sensitivity of Downlink Channel.

Fig 6 shows the receiver sensitivity of uplink channel. The receiver sensitivities for the broadcast channel, downlink unicast channel and uplink channel at different ONUs was evaluated. The mean values of the receiver sensitivities of broadcast transmission, downlink transmission, and uplink transmission are -25.59dBm, -25.97dBm and 30.29dBm, respectively are obtained.

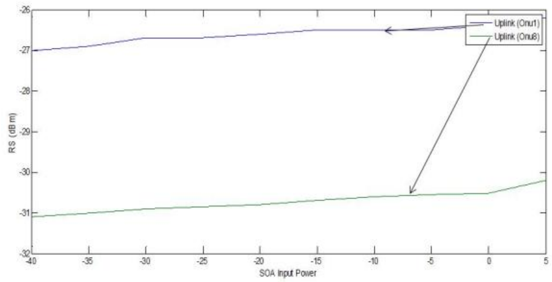


Fig 6: Receiver Sensitivity of Uplink Channel.

Power Budget and Scalability Analysis

An evaluation of the power budget requirements for the case of 8 ONUs is been carried out. Increasing the laser output power or adjusting the input OCSR are two options to meet the power budget for the downlink and uplink unicast channels. Use of an SOA or an EDFA to boost the power of the broadcast channel before it is multiplexed with the downlink unicast channels, ensuring its operation in the light gain-saturation region, is a practical way to meet the power budget requirement for the broadcast channel. For the input of OCSR at the transmitters is set at 10 dB. The downlink power are estimated as follows: 3 dB from each MUX/DMUX; 0.6 dB from each circulator; 5.35 dB from the 20 km feeder fiber; 2.2 dB from the DI (for both the carriers and the subcarriers); 0.1 dB for transmission and 0.5 dB for reflection from each FBG; 0.2 dB for each 1 km distribution fiber; 17.55 dB from the 1*8 splitter (being splitting loss of 15.05 dB excess loss of 2.5 dB) for the broadcast signal only; 4.5 dB from the AWG.

The power of the broadcast channel and average power of each downlink unicast channel launched into the system (before the MUX) are 11.48dBm and -3.57dBm, respectively, and the link loss for the broadcast signal and the down link subcarrier signals are 33.99 dB and 17.24 dB, respectively.

The received broadcast optical power and the downlink subcarrier optical power are -22.51dBm (11.48dBm - 33.99dB) and -20.81dBm. The effect of the number of ONUs on the loss for broadcast channel, downlink unicast channels and uplink unicast channels. (-3.57dBm –17.24 dB), respectively, sufficient for downlink data detection, since the worst receiver sensitivities among all ONUs at 10^-9BER are - 25.02dBm and -25.33dBm for the broadcast signal and the downlink unicast signal, respectively.

The receiver sensitivity of uplink transmission improves as the seeding power of RSOA increases. The average received carrier power (the seeding power of RSOA) at all ONUs is -13.93dBm, which is sufficient to achieve a good receiver sensitivity for uplink transmission. For the uplink transmission, the average uplink unicast signal power transmitted out of all ONUs is about 1.85dBm, below the trigger for stimulated Brillouin scattering. As the uplink loss is about 13.94 dB, the received optical power which is more than sufficient for uplink data detection, since the worst uplink receiver sensitivity among all ONUs at10^-9 BER is-29.83dBm

The power budget is acceptable for the proposed architecture for 8 unicast channels and one broadcast channel. The number of downlink/uplink unicast channels increases proportionally to the number of ONUs. Let be the number of ONUs; the power splitter loss increases with, while the loss of other components generally remains unchanged. The power splitter loss is dB plus excess insertion loss (typically 2 to 3 dB).

The maximum allowable loss for the broadcast channel is about 36.5 dB (being 11.48dBm–(-25.02dBm). The power loss for the broadcast channel increases with the number of ONUs. When the number of ONUs exceeds 64, the power budget for the broadcast channel cannot be met, unless an SOA or EDFA with output saturation power greater than 11.48dBm is employed.

BER Evaluation

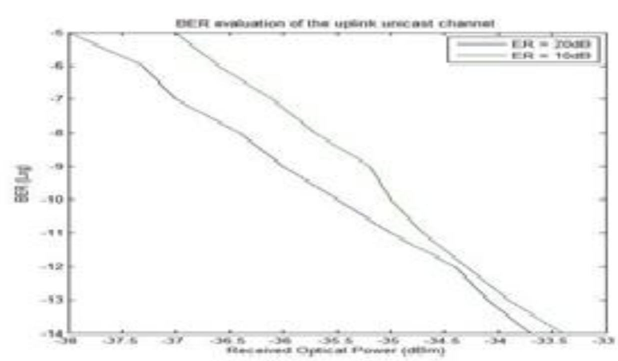


Fig7. BER Vs uplink optical Power received.

Fig7 shows the BER performance of uplink received power. To maintain a satisfactory BER performance, the number of ONUs is also limited by the available wavelength band and the data rate. For the proposed architecture operating at 10Gb/s for the downlink transmission, the frequency spacing between a carrier's center frequency and its subcarrier's frequency must be 20 GHz (or higher) to avoid interference. As the spacing between a carrier's center frequency and the outer boundary of the subcarrier reaches round 30 GHz, the frequency spacing between each carrier's centre frequency has to be at least 80 GHz to maintain good BER performance. If the operating wavelength band is from 1530nm to 1570 nm, the total available bandwidth is about 5THz. Thus, up to 61 unicast channels and 1 broadcast/multicast channel can be supported. Down link received power is shown by fig8.

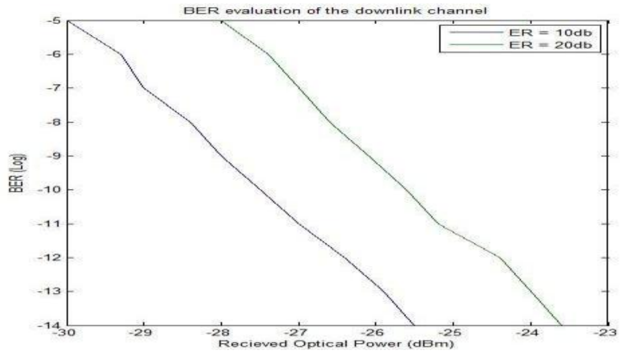


Fig-8: BER Vs Downlink optical Power received.

Conclusion

A broadcast multicast-capable WDM-PON architecture based on carrier-reuse scheme was designed and evaluated. In the designed WDM-PON, a separate NRZ broadcast channel is multiplexed with the NRZ downlink unicast channels. Results shows that this scheme can work effectively with one 10Gb/s broadcast channel and eight 10Gb/s downlink unicast channels, and eight 2.5Gb/s uplink unicast channels. The advantage of this architecture is that the broadcast channel causes limited interference to the downlink uplink unicast channels, and each ONU only uses a single wavelength for both downlink and uplink unicast transmissions. Further, the components and their settings in each ONU are identical, yielding colourless operation.

The effect of the OCSR of the SCM modulated signal on the BER performance can be mitigated by an increase of the DI extinction ratio. The receiver sensitivity also improves as the DI extinction ratio increases. The power budget and scalability of the designed WDM-PON were found to be feasible.

Reference

1. Kachhatiya, V.; Prince, S. "Conventional Band (C-band) Wavelength Division Multiplexed Passive Optical Network (WDM-PON)", 2014 International Confcerence on Communications and Signal Processing (ICCSP), Year: 2014, Pages: 377 - 381, DOI: 10.1109/ICCSP.2014.6949866.

2. Henning, L.F.; do CarmoR. Medeiros, M.; Monteiro, P.; de A P Pohl, A. "Colourless ONU based on self seed signal RSOA in a WDM-PON", 2014 16th International Telecommunications Network Strategy and Planning Symposium (Networks), Year: 2014, Pages: 1 - 6, DOI: 10.1109/NETWKS.2014.6959216.
3. Satyanarayana, K.; Abhinov, B. "Recent trends in future proof fiber access passive networks: GPON and WDM PON",2014 International Conference on Recent Trends in Information Technology (ICRTIT), Year: 2014, Pages: 1 - 5, DOI: 10.1109/ICRTIT.2014.6996129.
4. Latha, D.; Muthumani, I.; Sivanantharaja, "A.Long-reach upstream >100-Gb/s by using directly modulated RSOAs for WDM PON", 2013 International Conference on Information Communication and Embedded Systems (ICICES), Year: 2013, Pages: 685 - 690, DOI: 10.1109/ICICES.2013.6508307.
5. Abdalla, M.E.; Idrus, S.M.; Mohammad, A.B."Hybrid TDM-WDM 10G-PON for high scalability next generation PON", 2013 8th IEEE Conference on Industrial Electronics and Applications (ICIEA), Year: 2013Pages: 1448 - 1450, DOI: 10.1109/ICIEA.2013.6566595.
6. Buset, J.M.; El-Sahn, Z.A.; Plant, D.V. "Experimental Demonstration of a 10 Gb/s Subcarrier Multiplexed WDMPON", IEEE Photonics Technology Letters, Year: 2013, Volume: 25, Issue: 15, Pages: 1435 - 1438, DOI: 10.1109/LPT.2013.2266615.
7. Chung, Y.C, "High-speed coherent WDMPON for next-generation access network ", 2013 15th International Conference on Transparent Optical Networks (ICTON), Year: 2013, Pages: 1 - 4, DOI:10.1109/ICTON.2013.6602825.
8. Pandey, G.; Agarwal, N.; Goel, A." WDM PON enhanced capacity architecture for unicast, multicast and broadcast through efficient sideband carrier modulation" 2012 Ninth International Conference on Wireless and Optical Communications Networks (WOCN), Year: 2012, Pages: 1 - 6, DOI: 10.1109/WOCN.2012.6335542.
9. Spolitis, S.; Bobrovs, V.; Ivanovs, G.Reach Improvement of Spectrum-Sliced Dense WDM-PON System 2012 Seventh International Conference on Broadband, Wireless Computing, Communication and Applications (BWCCA), Year: 2012, Pages: 296 - 301, DOI: 10.1109/BWCCA.2012.56.

10. Feng Zhang; Wen-De Zhong; Zhaowen Xu; Tee Hiang Cheng; Michie, C.; Andonovic, Ivan , "A Broadcast/Multicast-Capable Carrier-Reuse WDM-PON", Journal of Lightwave Technology, Year: 2011, Volume: 29, Issue: 15, Pages: 2276 - 2284, DOI: 10.1109/JLT.2011.2158986.
11. S. Pan and J. Yao, "A UWB over fiber system compatible with WDM-PON architecture," IEEEPhoton. Technol. Lett., vol. 22, no.20, pp. 1500–1502, Oct. 2010.
12. Z. Xu, Y. J. Wen, W. D. Zhong, T. H. Cheng, M. Attygalle, X. Cheng, Y. K. Yeo, Y.Wang, and C. Lu, "Characteristics of subcarrier modulation and its application in WDM-PONs," J. Lightw. Technol., vol. 27, no. 12, pp. 2069–76, Jun. 2009.
13. G.-K.Chang, A. Chowdhury, Z. Jia, H.-C.Chien, M.-F.Huang, J. Yu, and G. Ellinas, "Key technologies of WDM-PON for future converged optical broadband access networks," IEEE/OSA J. Opt. Commun. Netw., vol. 1, no. 4, pp. C35–C50, 2009.
14. N. Deng, C.K.Chan, L. K. Chen, and C. Lin, "AWDM passive optical network with centralized light sources and multicast overlay," IEEE Photon. Technol. Lett., vol. 20, no. 2, pp. 114–116, Feb. 2008.
15. Y. Zhang, N. Deng, C. K. Chan, and L. K. Chen, "A multicast WDM-PON architecture using DPSK/NRZ orthogonal modulation," IEEE Photon. Technol. Lett., vol. 20, no. 17, pp. 1479–1481, Aug. 2008.
16. H. Bulow, F. Buchali, and A. Klekamp, "Electronic dispersion compensation," IEEE/OSA J. Lightw. Technol., vol. 26, no. 1, pp. 158–167, Jan. 2008.