Optik 125 (2014) 5141–5143

ELSEVIER

Optik

journal homepage: www.elsevier.de/ijleo

Optimal design of 32 channels spectrum slicing WDM for optical fiber access network system

Abdel Hakeim M. Husein[a,*], Fady I. El Nahal[b]

[a] *Al-Aqsa University, Physics Department, P.O. Box 4051, Gaza, Gaza Strip, Palestine*
[b] *Islamic University of Gaza, Electrical Engineering Department, Gaza, Gaza Strip, Palestine*

ARTICLE INFO

Article history:
Received 7 September 2013
Accepted 26 April 2014

Keywords:
Dense wavelength division multiplexing (DWDM)
Passive optical network (PON)
Spectral slicing
Fiber-to-the-Home (FTTH)

ABSTRACT

In this article, the spectrum sliced dense wavelength division multiplexed passive optical network (SS-DWDM–PON) has been investigated as a power efficient and cost effective solution for optical access networks. In this work an AWG demultiplexer is used to operate as slicing system. The high speed SS-DWDM system has been realized and investigated for 32 channels with data rate up to 3 Gb/s using broadband ASE source (LED). The 3 Gb/s signals both non-return-to-zero (NRZ) and return-to-zero (RZ) were demonstrated in 40 km optical fiber link with BER < 10^{-12}. The results obtained here demonstrate that SS-DWDM is well suited for Fiber-to-the-Home (FTTH) network.

1. Introduction

Future access networks will have to meet the ever increasing demand to large capacity. Wavelength-division-multiplexing–passive optical networks WDM–PONs are key solution for high network capacity thanks to its easy management, network security, protocol transparency, and easy upgradability [1,2]. General WDM systems include several transmitter lasers operating at different wavelengths, which need to be wavelength selected for each individual channel operated at a specific wavelength [1,3]. It increases complexity of network design, cost and wavelength management [4–6]. For that reason the spectrum sliced dense wavelength division multiplexed passive optical network (SS-DWDM–PON) has been promised to be cost effective and power efficient solution for optical access networks to satisfy the growing worldwide demand for higher transmission capacity [7,8].

Spectrum slicing optical systems benefit from the same advantages as WDM, while employing low cost incoherent broadband light sources such as broadband amplified spontaneous emission (ASE) source or light-emitting diode (LED) [7]. The method of spectrum-slicing is a cost-efficient, suitable and undertaking solution for transmitter in optical line terminal (OLT) of DWDM–PON systems [2]. In this technology, the low cost LED is used to play the role of light sources instead of costly laser diodes. Since LED has very broadband spectrum then this spectrum can be sliced spectrally into many independent signals with equal channel spacing. Spectral slicing is an attractive DWDM technique that provides a means of sharing a multi-wavelength optical source amongst many users [9]. Literature survey reveals that the selection of optimum channel spacing between the two sliced spectral is a very critical task [10]. Currently channel spacing of 0.8 nm is widely used in SS-WDM system [11]. Therefore, 0.4 nm channel spacing SS-DWDM system has been studied and investigated in this work. Then selecting 0.4 nm channels spacing in our system is preferable for narrow band SS-DWDM system.

In this paper, we have investigated a 32-channel SS-DWDM system using LED as a multi-wavelength source and 0.4-nm channel spacing for a short haul transmission. We have examined the efficiency of narrow band DWDM system for FTTH by simulation. We can increase the capacity of the system by reducing the channel spacing but this leads to a severe cross-phase modulation (XPM) problem [10,11]. In order to remain this effect under tolerance level, we choose 0.4-nm channel spacing. In this research, the proposed performance investigation was carried out using non-return-to-zero (NRZ) and return-to-zero (RZ) format at 3 Gb/s.

2. SS-DWDM system architecture

The proposed architecture of 32-channels spectral-sliced DWDM system with 0.4-nm channel spacing is shown in Fig. 1. The low cost broadband light source light emitting diode (LED) is sliced into 32-channels using arrayed-waveguide grating (AWG) demultiplexer (DMUX). The LED operation wavelength started

---

* Corresponding author. Tel.: +970 82871829/599 165 678.
E-mail address: hakeim00@yahoo.com (A.H.M. Husein).

http://dx.doi.org/10.1016/j.ijleo.2014.04.076

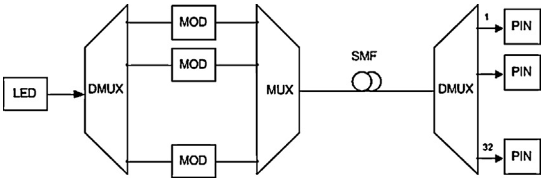

Fig. 1. The architecture of operational principle of spectrum sliced system broadband light source demultiplexer.

from 1549.78 nm. The DC power is used as the input power for the light source. The average input power of light source is from 1 to 6 dBm. The LED emits between −1.283 dBm and 9.51 dBm input power for the system with bit rates of 3 Gb/s. After that optical slices are modulated using Mach–Zehnder modulator (MZM). Then the channels are multiplexed by an AWG MUX to combine the entire modulated signal. The sliced signals are modulated by the $2^{15} - 1$ pseudorandom bit sequence and then the modulated signal transmitted over 40 km standard single mode fiber (SMF). Then the signal is demultiplexed and the signals are detected by PIN photo detectors. The attenuation loss of the fiber is 0.25 dB/km and the insertion loss is 0.2 dB. The eye-diagram analyzers (BER) investigate the performance of each channel signal. The simulation was carried out at data rate of 3 Gb/s for a 40 km distance with standard SMF. A SMF was chosen to minimize the dispersion effect. The dispersion slope of DSF at wavelength 1550 nm is 0.075 ps/nm^2 km respectively. The average fiber loss is about 0.2 dBm including the splicing loss. The noise generated at the receivers is set to be random and totally unconnected. The system insertion loss, including multiplexer and demultiplexer is considered as 0.25 and 2 dBm, respectively.

3. Results and discussion

The system was simulated using a commercially available software tool [12]. The results of the simulations are presented here. The eye patterns for output 32 were plotted for RZ and NRZ in Figs. 2 and 3, respectively. The system performance has been characterized using the bit-error-rate (BER) against the received optical power. The BER versus optical received power curves were plotted for both RZ and NRZ formats respectively as shown in Fig. 4. The eye diagrams illustrate that the proposed system performs well and suitable for FTTH at bit-rates of 3 Gb/s. However the eye for the NRZ format is more open and less distorted compared with the RZ formatting. Moreover, Fig. 4 shows that the NRZ format SS-DWDM system performs slightly better than the RZ system. For example, it can be seen from Fig. 4 that to achieve the same BER of 10^{-12} a 4 dBm extra power is required for the RZ format compared with NRZ format. The results show that the proposed spectrum sliced WDM system with NRZ formatting is cost effective and well suited for FTTH network.

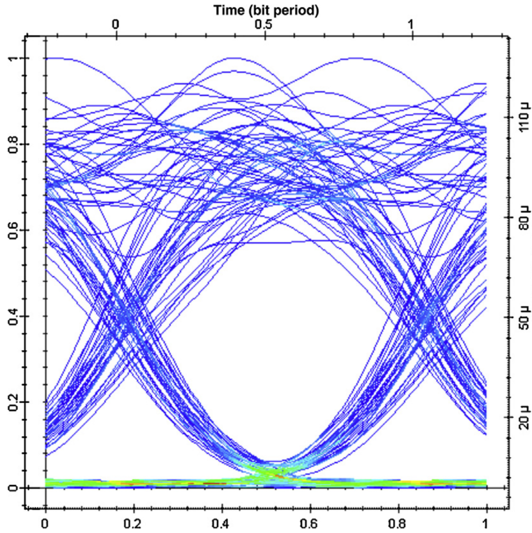

Fig. 2. The eye diagram of NRZ at 3 Gb/s.

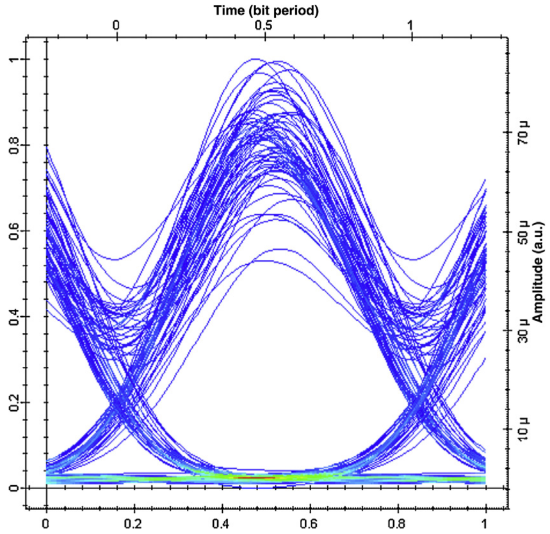

Fig. 3. The eye diagram of RZ at 3 Gb/s.

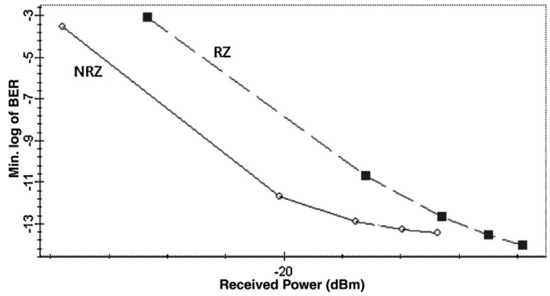

Fig. 4. BER curves measured at ch.32 for 40-km SMF and 0.4-nm channel spacing for NRZ and RZ formats.

4. Conclusion

A high-speed SS-DWDM–PON system have been realized and investigated where a broadband ASE source (LED) is used. A new model of a demultiplexer used to operate as slicing system for 32 channels over 40 km fiber length, with one LED laser source. It was found that the performance of investigated SS-DWDM–PON system is completely sufficient to provide transmission of information with data rate of 3 Gb/s per channel with BER < 10^{-12} over the 40 km long fiber optical line. Therefore, the proposed system would be promising solution and cost effective for the next generation optical access networks, such as Fiber-to-the-Home (FTTH).

References

[1] K. Lee, D.S. Lim, M.Y. Jhon, H.C. Kim, P. Ghelfi, T. Nguyen, et al., Broadcasting in colorless WDM–PON using spectrum-sliced wavelength conversion, Opt. Fiber Technol. 18 (2) (2012) 112–116.

[2] Z.A. El-Sahn, W. Mathlouthi, H. Fathallah, S. LaRochelle, L.A. Rusch, Dense SS-WDM PON over legacy PONs: smooth upgrade of existing FTTH networks, IEEE J. Lightwave Technol. 28 (10) (2010) 1485–1495.

[3] F.I. El-Nahal, A.H.M. Husein, Bidirectional WDM–PON architecture using a reflective filter and cyclic AWG, Optik 122 (2011) 1776–1778.

[4] B.H. Choi, S.S. Lee, The effect of AWG-filtering on a bidirectional WDM–PON link with spectrum-sliced signals and wavelength-reused signals, Opt. Commun. 284 (24) (2011) 5692–5696.

[5] H.J. Thiele, R.I. Killey, P. Bayvel, Influence of transmission distance on Xpm induced intensity distortion in dispersion managed amplified fiber links, Electron. Lett. 35 (1999) 408–409.

[6] S. Kaneko, J. Kani, K. Iwatsuki, A. Ohki, M. Sugo, S. Kamei, Scalability of spectrum-sliced DWDM transmission and its expansion using forward error correction, J. Lightwave Technol. 24 (3) (2006) 1295–1301.

[7] S. Spolitis, G. Ivanovs, Extending the reach of DWDM–PON access network using chromatic dispersion compensation, in: IEEE Swedish Communication Technologies Workshop (Swe-CTW 2011), art. no. 6082484, 2011, pp. 29–33.

[8] M. Zimgibl, C.H. Joyner, L.W. Stulz, C. Dragone, H.M. Presby, I.P. Kaminow, LarNet, a local access route 1 network, IEEE Photon. Technol. Lett. 7 (1995) 215–217.

[9] J.S. Lee, Y.C. Chung, D.J. DiGiovanni, Spectrum-sliced fiber amplifier light source for multi-channel WDM applications, IEEE Photon. Technol. Lett. 5 (1993) 1458–1461.

[10] M. Shtaif, M. Eiselt, R.W. Tkach, T.H. Stolen, A.H. Gnauck, Crosstalk in WDM systems caused by cross-phase modulation in erbium-doped fiber amplifiers, IEEE Photon. Technol. Lett. 10 (12) (1998) 1796–1798.

[11] N. Ahmed, S.A. Aljunid, R.B. Ahmad, H.A. Fadil, M.A. Rashid, Investigate Spectrum-Sliced WDM System for FTTH Network. ICSECS 2011. Part III. CCIS 181, Springer-Verlag Berlin Heidelberg, 2011, pp. 728–734.

[12] OptiSystem Software Program, V. 11, OptiWave Company, Canada, 2012.