ISSN ONLINE (2395-1680)
DOI: 10.21917/ijme.2015.0006

INVESTIGATION ON PCRR BASED ADF IN 10 GBPS CWDM NETWORKS

S. Robinson[1] and R. Nakkeeran[2]
[1]*Department of Electronics and Communication Engineering, Mount Zion College of Engineering and Technology, India*
E-mail: mail2robinson@gmail.com
[2]*Department of Electronics Engineering, Pondicherry University, India*
E-mail: nakkeeranpu@gmail.com

Abstract

In this paper, a four channel Coarse Wavelength Division Multiplexing (CWDM) network is designed by incorporating the proposed and designed Two Dimensional (2D) Photonic Crystal Ring Resonator (PCRR) based Add Drop Filter (ADF). The performance parameters of the network such as the received output power, Bit Error Rate (BER) and Q factor are examined for the bit rate of 10 Gbps over the fiber length of 50 km and 400 km. The observed sensitivity of the receiver is -19 dBm. Also, the receiver sensitivity of the dropped channel is increased while increasing the channel distance; however, it is decreased and maintained constant for added channel.

Keywords:

CWDM, Point to Point Networks, Photonic Band Gap, Bit Error Rate

1. INTRODUCTION

The rapid and global spread of the internet is accelerating the growth not only the backbone networks but also the enterprise, metro/access and regional networks. The Dense Wavelength Division Multiplexing (DWDM) system has been employed to meet the explosive demand (to support 1 Tbps) for backbone or long haul networks. Since, the channel spacing (1.6 nm, 0.8 nm, 0.4 nm and so on) of DWDM system is extremely narrow, it requires highly stringent laser source along with thermal coolers and optical amplifiers which increases the overall system cost [1]. In addition, it is necessary to employ costly packaging techniques to prevent the wavelength drifting due to temperature variation. Therefore, the DWDM system is not a better choice for metro/access networks as it increases the overall cost.

In contrast to DWDM, the Coarse Wavelength Division Multiplexing (CWDM) system has recently emerged as a cost-effective solution for networks requiring fairly high bit rates (1-40 Gbps), at minimal cost with unamplified point to point transport of several wavelengths over moderate distances (0-500 km). As its name implies, CWDM standard (ITU-T G.694.2) wavelengths are spaced 25 to 50 times more coarsely (i.e., 20 nm) than DWDM system, thus allowing more relaxed specifications for the fabrication, selection and testing of the optical components in the link[1, 2] which will greatly reduce the system cost.

The Add Drop Filter (ADF) is one of the devices, which receives prime consideration for CWDM systems to add/drop a required wavelength channel without disturbing other channels arriving along with it. In eight-channel ITU-T G. 694.2 CWDM system, the eight wavelengths (λ) are used to add/drop the channels over the range from 1471 nm to 1611 nm with 20 nm channel spacing[3] and the passband width of the channel is 13 nm (±1.5 nm). In the literature, the optical filter for CWDM metro access networks is reported using arrayed waveguide grating [4, 6] and Mach-Zehnder Interferometers (MZI)[7]. The overall dimension of the reported filter is in the range of centimeters (cm) which will not suitable for Photonic Integrated Circuits (PICs) and future optical networks. To overcome this issue without deteriorating the performance, the optical filter (ADF) is designed using Photonic Crystals (PC).

Typically, PC based optical devices have attracted great interest due to their compactness, speed of operation, long life period and suitability for PICs. Generally, PCs are patterned nanostructure or artificial materials in which a periodic variation of the material dielectric constant (refractive index) in one, two and/or three dimensions resulting Photonic Band Gap (PBG). By introducing the defects, it is possible to break the periodicity in turn localize the light in a PBG region [8, 9]. This leads to the design the PC based optical active and passive devices in the PBG region [10]. Recent years, many PC based optical devices are proposed both theoretically and experimentally. To name a few, add-drop filters [11, 12], power splitters [13], multiplexers and demultiplexers [14, 15], triplexers [16], switches [17], directional couplers [18], bandstop filters [19], bandpass filters [20, 21] etc.

In this paper, a four channel CWDM network is designed, initially, for demonstration purpose and the circular Photonic Crystal Ring Resonator (PCRR) based ADF proposed by the authors [12] for ITU-T G 694.2 CWDM system is incorporated in the CWDM network for examining its performances. The received output power, Bit Error Rate (BER) and Q factor of the network are examined at the bit rate of 10 Gbps for 50 km and 400 km fiber link.

2. POINT TO POINT CWDM TRANSMISSION SYSTEM

The four channel CWDM system which consists of transmitter, channel and receiver is shown Fig.1. Though the ITU-T G 694.2 CWDM system proposed [3] for eight channels, here, we have considered first four channels for demonstration purpose.

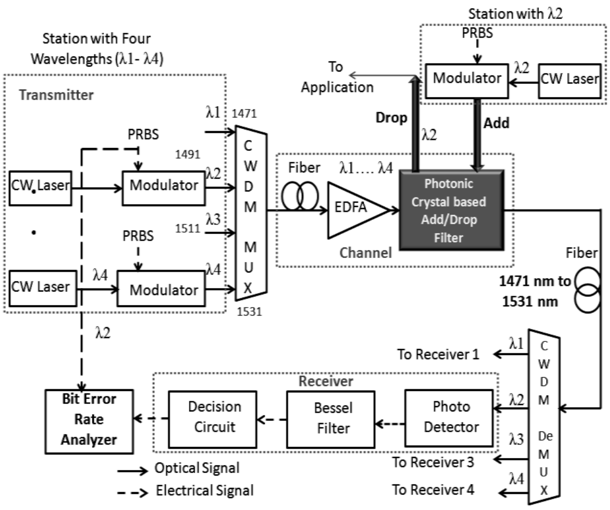

Fig.1. Four channel CWDM transmission system

In transmitter, data are converted into electrical signals and coded to the NRZ (Non Return Zero) modulation format, then converted into optical signals. A wavelength channel is assigned for optical signal for transmission by means of a transmitter and launches the resulting optical signal into the optical fiber. The signal from different wavelength channels are combined and coupled into a fiber by 4 × 1 CWDM multiplexer and the signal is amplified using Erbium Doped Fiber Amplifier (EDFA) after an every transmission distance of 100 km. The proposed and designed circular PCRR based ADF centered at 1491 nm [12] is inserted in the link to drop/add a required channel as desired by any station. The normalized transmission spectra of PCRR based ADF is shown in Fig.2, where the inset depicts the schematic structure, 3D view and electric field distribution [12]. The performance parameters of the proposed ADF are verified by CMT analysis [22]. The information carrying channel can be dropped based on the destination address, which is possible through the drop port of the ADF and it can also be possible to add a new channel with the same wavelength using the add port of the same ADF.

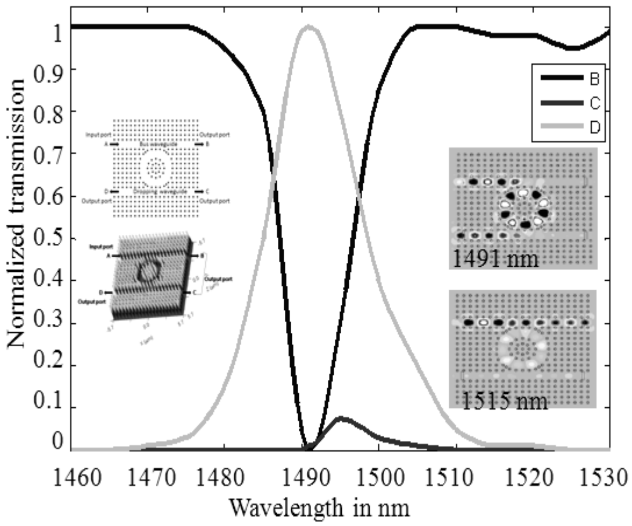

Fig.2. Normalized transmission spectra of circular PCRR based ADF

The 4 × 1 CWDM demultiplexer separates all the CWDM channels and directs them into the individual channel receiver, which in turn converts an optical signal into an electrical signal and reaches their respective destination thus the entire transfer process is completed. The receiver comprises of a photo detector that generates an electric current, a filter (Bessel) to minimize noise in the amplified electrical current, and a decision circuit to determine whether the transmitted bit is 1 or 0 in each bit interval. Finally, the BER of the concern channels are estimated by comparing the obtained output signal with the input signal.

The input optical signal is arriving from the transmitter to the receiver through fiber. The incoming channels are amplified and the desired channel is dropped or added by the drop or add port of the ADF. The resonant wavelength and Q factor of the PCRR based ADF are 13 nm and 114.6 [12], respectively, which is designed and simulated using Fullwave simulator, Rsoft.

3. SIMULATION RESULTS AND DISCUSSIONS

The effect of BER with respect to the received power and Q factor of the CWDM network for back to back connection, drop port at 0 km, 50 km and 400 km, and add port at 0 km, 50 km and 400 km fiber, are shown in Fig.3(a) and Fig.3(b), respectively. The input power range is identified to estimate the BER is -15 dBm to -20 dBm for 0 km, -5 dBm to -10 dBm for 50 km and 0 dBm to -5 dBm for 400 km.

The receiver sensitivity (minimum average optical power required to achieve a certain BER at a particular data rate, it is usually measured at a BER of 10-12 for good CWDM system performance) is -19 dBm. The receiver sensitivity for the channel at drop port increases while increasing the distance, however, it decreases and/or maintained constant for add port as the channel from add port is not arriving for long distance. Obviously, the Q factor increases linearly while decreasing the BER which is shown in Fig.3(b). The increases in the input power increases the Q factor which in turn reduces the BER. In general, Q factor is to be greater than 7 to get a sufficient BER i.e., 10-12.

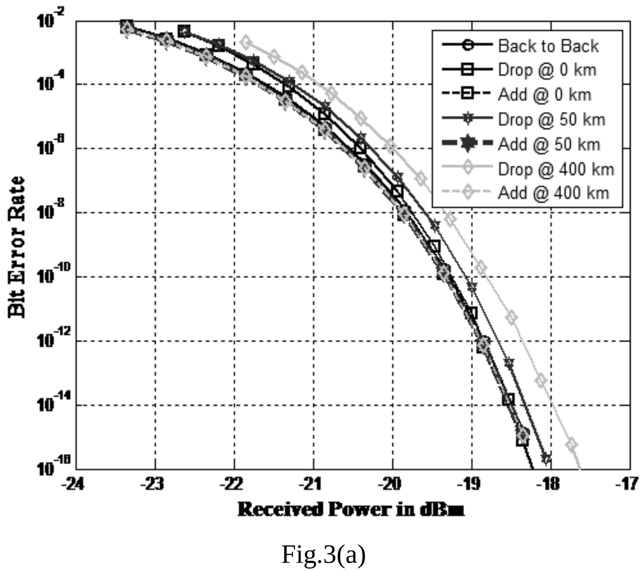

Fig.3(a)

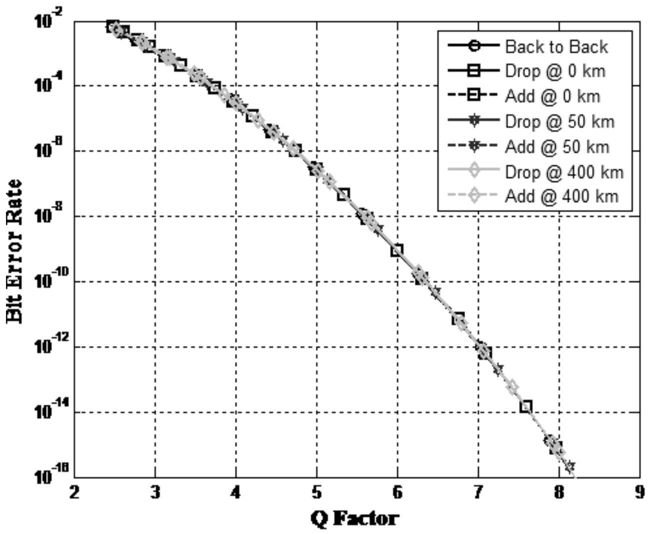

Fig.3(b)

Fig.3. BER performance of 10 Gbps CWDM systems with respect to (a). Received power and (b). Q factor at 1491 nm

4. CONCLUSION

A four channel CWDM network is designed and Photonic Crystal Ring Resonator based Add Drop Filter that is centered at 1491 nm is incorporated in the network. The network performance parameters such as received output power, BER and Q factor of the CWDM network is evaluated. The performance of the network is investigated for the bit rate of 10 Gbps over the fiber length of 50 km and 400 km. The minimum receiver power required to get a desired BER is to be -19 dBm. It is observed that the average received power of the drop port increases while increasing the fiber distance whereas it decreases and/or maintained constant for add port, to get sufficient BER of the system. This attempt may be useful to incorporate the PC based devices into the networks for Photonic Integrated Circuits.

REFERENCES

[1] H. Kawata, H. Nakamura and T. Sugie, "Service multiplexing systems with wide passband WDM technology for access networks", *Institute of Electronics, Information and Communication Engineers Transactions on Communications*, Vol. E83-B, No. 10, pp. 2348-2354, 2000.

[2] J. A. Richard, "CWDM: A lower cost alternative for increased capacity", *Photon Spectra*, Vol. 37, No. 5, pp. 62-64, 2003.

[3] ITU-T Recommendation G 694.2, "Spectral grids for WDM applications: CWDM wavelength grid", Available in http://www.itu.int/rec/T-REC-G.694.2-200312-I.

[4] Chemmanda John Leo, Pamidighantam V Ramana and Krishanmachari Sudharsanam, "Design of polymer arrayed waveguide grating for access networks and CWDM applications", *IEEE 5th International Conference on Electronics Packaging Technology Conference*, pp. 647-651, 2003.

[5] Heng Cherng Woei, Nazarina Abdul Rahman and Sahbudin Shaari, "Conventional arrayed waveguide grating with 4 channel structure design for CWDM", *IEEE International Conference on Semiconductor Electronics*, 2004.

[6] Min-Ching Lin, Tien-Tsorng Shih, Pei-Hao Tseng, Kuei-Ming Chu, Chieh Hu and Wood-Hi Cheng, "High-performance and low-cost 40-Gb/s CWDM optical modules", *IEEE Transactions on Advanced Packaging*, Vol. 23, No. 3, pp. 644-649, 2009.

[7] Y. Inoue, M. Oguma, T. Kitoh, M. Ishii, T. Shibata and Y. Hibino, "Low crosstalk 4-channel coarse WDM filter using silica based planar-lightwave-circuit", *Proceedings of IEEE Conference on Optical Fiber Communication*, pp. 75-76, 2002.

[8] E. Yablonovitch, "Inhibited spontaneous emission on solid-state physics and electronics", *Physical Review Letters*, Vol. 58, No. 20, pp. 2059-2062, 1987.

[9] S. John, "Strong localization of photons in certain disordered dielectric superlattices", *Physical Review Letters*, Vol. 58, No. 23, pp. 2486-2489,1987.

[10] J. D. Joannopoulos, Steven G. Johnson, R. D. Meade and J. N. Winn, "*Photonic Crystal: Modeling the Flow of Light*", Princeton university press, 1995.

[11] Z. Qiang, W. Zhou and Richard A. Soref, "Optical add-drop filters based on photonic crystal ring resonators", *Optics Express*, Vol. 15, No. 4, pp. 1823-1831, 2007.

[12] S. Robinson and R. Nakkeeran, "Two dimensional Photonic Crystal Ring Resonator based Add Drop Filter for CWDM systems", *Optik – International Journal for Light and Electron Optics*, Vol. 124, No. 6, pp. 3430-3435, 2013.

[13] A. Ghaffari, F. Monifi, M. Djavid and M. S. Abrishamian, "Analysis of photonic crystal power splitters with different configurations", *Journal of Applied Science*, Vol. 8, pp. 1416-1425, 2008.

[14] G. Manzacca, D. Paciotti, A. Marchese, M. S. Moreolo and G. Cincotti, "2D photonic crystal cavity-based WDM multiplexer", *Photonics and Nanostructures - Fundamentals and Applications*, Vol. 5, No. 4, pp. 164-170, 2007.

[15] M. Djavid, A. Ghaffari, F. Monifi and M. S. Abrishamian, "Heterostructure wavelength division demultiplexers using photonic crystal ring resonators", *Optics Communications*, Vol. 281, No. 15-16, pp. 4028-4032, 2008.

[16] Tien-Tsorng shih, Yaw-Dong Wu and Jian-Jang Lee, "Proposal for compact optical triplexer filter using 2-D Photonic crystals", *IEEE Photonics Technology Letters*, Vol. 21, No. 1, pp. 18-20, 2008.

[17] Qiong Wang, Yiping Cui, Jiayu Zhang, Changchun Yan and Lingling Zhang, "The position independence of heterostructure coupled waveguides in photonic-crystal switch", *Optik – International Journal for Light and Electron Optics*, Vol. 121, No. 8, pp. 684-688, 2010.

[18] M. K. Moghaddam, A. R. Attari and M. M. Mirsalehi, "Improved photonic crystal directional coupler with short length", *Photonics and Nanostructures - Fundamentals and Applications*, Vol. 8, No. 1, pp. 47-53, 2010.

[19] S. Robinson and R. Nakkeeran, "Bandstop filter for photonic integrated circuits using photonic crystal with circular ring resonator", *SPIE - Journal of Nanophotonics*, Vol. 5, No. 1, pp. 1-14, 2011.

[20] S. Robinson and R. Nakkeeran, "Investigation on parameters affecting the performance of the two

dimensional photonic crystal based bandpass filter", *Optical and Quantum Electronics*, Vol. 43, No. 6-10, pp. 69-82, 2012.

[21] S. Robinson and R. Nakkeeran, "Investigation on Two Dimensional Photonic Crystal Resonant Cavity based Bandpass Filter", *Optik – International Journal for Light and Electron Optics*, Vol. 123, No. 5, pp. 451-457, 2012.

[22] S. Robinson and R. Nakkeeran, "Coupled Mode Theory analysis for Photonic Crystal Ring Resonator based Add Drop Filter", *SPIE - Optical Engineering*, Vol. 51, No.11, pp. 1-6, 2012.