# Investigation of DWDM system using bidirectional optical add/ drop multiplexer (B-OADM) including the fiber non linearity effect

TARANDEEP SINGH, HARMANJOT SINGH, RAKESH GOYAL[a,*]
*Punjabi University, Patiala, Punjab, India*
[a]*D.A.V. University, Jalandhar, Punjab, India*

In this paper, we have investigated dense wavelength division multiplexing (DWDM) system for fiber non linearity effects based on sixteen bidirectional optical add/drop multiplexers (B-OADMs). To perform bidirectional transmission, circulator is used in BOADM. Semiconductor Optical Amplifier (SOA) is employed with each OADM to boost up the signals to longer distance. A length of 100 Km distance of dispersion compensating fiber (DCF) is inserted between each B-OADM to achieve 1500 Km total distance of the proposed network. Four channels with frequency 193.1THz at 50GHz spacing are used to transmit data at various data rates i.e. 2.5, 5 and 10 Gbps. Various performance parameters such as for different data rates to investigate the system performance in the term of BER and Q factor and output power in 2D and 3D graphical representation.

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*Keywords*: B-OADM, DWDM, non linear effect, SOA, crosstalk

## 1. Introduction

Due to the advancements in optical technology, the dense wavelength-division multiplexing (DWDM) not only can fully utilize the fiber bandwidth, but also can increase the capacity and transmission distance of the fiber link [1]. In current optical fiber communication systems, DWDM transmission with 10 Gb/s wavelength channels at 50 GHz channel spacing is an International Telecommunication Union (ITU) standard for long-haul and metropolitan networks [2,3]. Fibers grating based devices seem to be promising candidates for OADMs since they have the characteristics of small volume, inherently low loss, spectrally selective and easy to be coupled with optical fiber systems. An important technical issue for OADM design is the reduction of crosstalk, which can severely degrade system performance [3-5].

With the recent significant advances in wavelength routing devices and optical switches, OADMs will play a critical role in enabling greater connectivity and flexibility in DWDM networks for multi-wavelength signals locally transmitting/extraction (i.e., the add/drop operation) as well as signal routing and network (re)configuration (i.e., the cross-connect operation) at the HUB and access node (AN) [1,6]. One of the main limitations for the transparent networks with a large number of nodes is the signal degradation due to transmission through multiple OADMs. The degradation is mainly from (1) the spectral filtering due to narrowing of the overall filter pass band and (2) the group delay introduced by the impact of filter phase response. This dispersion leads to pulse distortion, ultimately resulting in transmission performance degradation, and it limits the bit rate [2]. OADM using a fiber Bragg grating (FBG) and Mach–Zehnder fiber Bragg grating (MZFBG) still required two working fiber paths to support both protection as well as bidirectional transmission. Nevertheless, a single-fiber bidirectional self-healing ring has been emerging to not only double the transmission capacity in the operating mode and provide the self-healing function without protection in the transmission path, but also reduce the required amount of optical fiber by half [3,7]. In this investigation, we have proposed DWDM system for fiber non linearity effects based on sixteen B-OADMs. To perform bidirectional transmission, circulator is used in BOADM. SOA is employed with each OADM to boost up the signals to longer distance. A length of 100 Km distance of DCF is inserted between each B-OADM to achieve 1500 Km total distance of the proposed network. Four channels with frequency 193.1THz at 50GHz spacing are used to transmit data at various data rates i.e. 2.5, 5 and 10 Gbps. This paper is organized into four sections. In Section 1, introduction to optical networks and OADM is described. In Section 2, the system setup for proposed DWDM network using B-OADM is described. In Section 3, results and discussion have been reported. Finally in Section 4, conclusions are made.

## 2. System setup

The block diagram of proposed system setup of DWDM network using B-OADM is shown in Fig. 1. Sixteen B-OADMs with center frequency 193.1THz are installed to make a ring structure. The length between each OADM is kept 100 Km. SOA with 4 dB gain is also installed with all OADM to boost up the signals. Each B-OADM consists of Transmitter array and Receiver array.

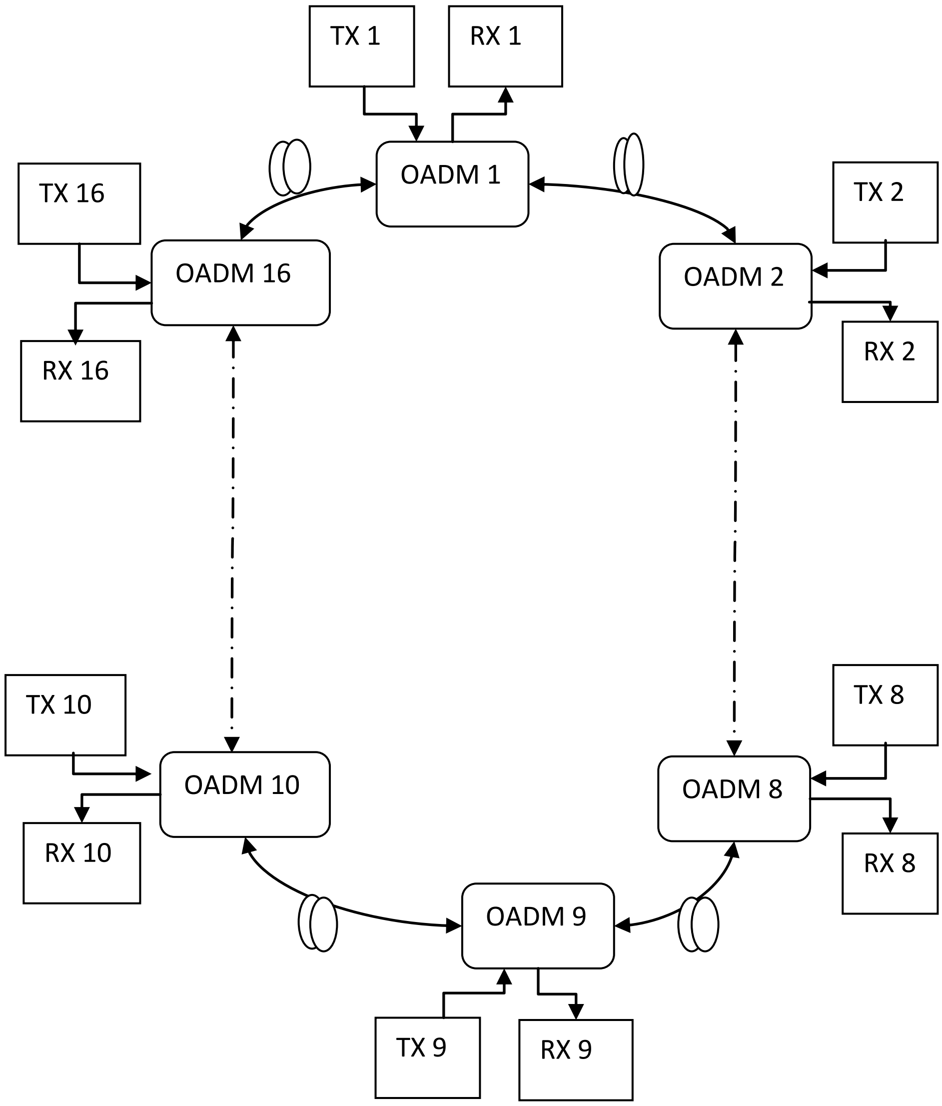


*Fig. 1. Block diagram of DWDM network using B-OADM.*

The internal structure of transmitter array is shown in Fig. 2. It consists of four wavelength channels to send the data to different users at 193.1 THz wavelength with spacing 50 GHz, data source, electrical driver, laser source, filter and modulator. CW laser source with 10 MHz line width and different data rates are generated by Pseudo Random Binary Sequence Generator (PRBS) and directly fed to non return to zero (NRZ) electrical driver which generates for each input bit, this electrical coded signal fed to Bessel's filter.

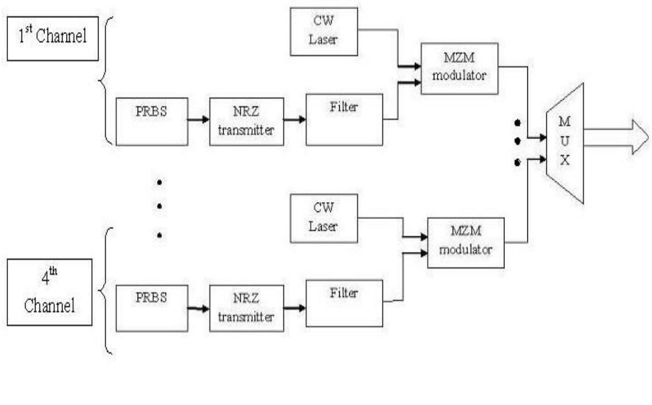


*Fig. 2. Internal structure of transmitter array.*

The signals from data source and CW laser are fed to Mach-Zehnder modulator with 30 dB extinction ratio. The output from the Mach-Zehnder modulator is multiplexed by 4:1 multiplexer with 3dB insertion loss then passed through the B-OADM.

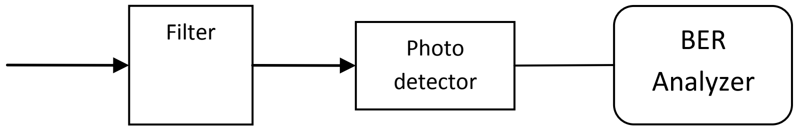


*Fig. 3. Block diagram of Receiver.*

The block diagram of receiver is shown in Fig. 3. To receive the data from B-OADM, the signal is passed through Bessel filter to avoid the channel interference. PIN photodiode is used to detect the signal. Various result and performance analyzers are used to investigate the system performance. Then various simulation parameters are set to investigate the system setup such as by varying bit rate, channel spacing, input power and length of fiber. The various results at each node like BER and Q-factor are observed at signal analyzer.

## 3. Result and discussion

In order to observe the performance of the proposed system, the setup is simulated for different data rates. Various result parameters like BER, Q factor and output power at different data rates for added and dropped wavelengths at various B-OADM nodes are observed. The graphical representation of Q factor in 2D and 3D with respect to number of nodes at various data rates i.e. at 2.5, 5 and 10 Gbps for added wavelengths to B-OADM without non linearity effect is shown in Fig. 4.

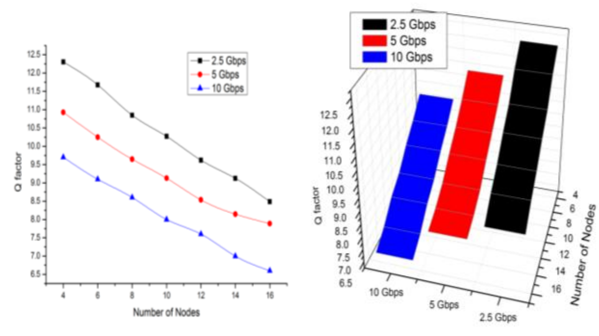


*Fig. 4. Q Vs number of nodes at 2.5, 5 and 10 Gbps data rates for added wavelengths to B-OADM without non linearity effect in (a) 2D and (b) 3D.*

It is evident that the Q-factor gets decreased with the increase in number of nodes. It is observed that the Q factor of 12.3 to 8.4 by 2.5 Gbps, 10.9 to 7.8 by 5 Gbps and 9.7 to 6.6 by 10 Gbps is achieved at 4$^{th}$ to 16$^{th}$ nodes respectively. It is also mention here that there is 100 km distance between each node making a total system at 1500 km distance. The graphical representation of Q factor in 2D and 3D with respect to number of nodes at various data rates i.e. at 2.5, 5 and 10 Gbps for dropped wavelengths to B-OADM without non linearity effect is shown in Fig. 5.

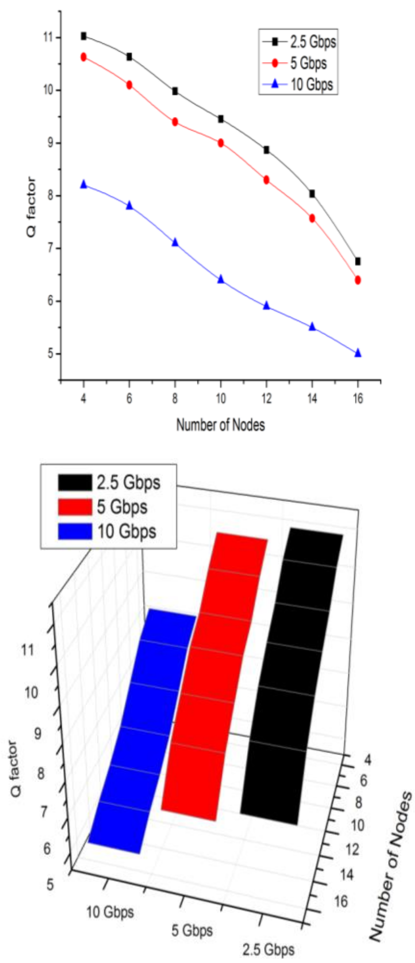


*Fig. 5. Q Vs number of nodes at 2.5, 5 and 10 Gbps data rates for dropped wavelengths to B-OADM without non linearity effect in (a) 2D and (b) 3D.*

It is observed that the Q factor of 11.03 to 6.7 by 2.5 Gbps, 10.6 to 6.4 by 5 Gbps and 8.2 to 5 by 10 Gbps is achieved at $4^{th}$ to $16^{th}$ nodes respectively. The Q factor is decreasing due to increase in the distance; there is 1500 km distance between $2^{nd}$ and $16^{th}$ nodes. It is evident that the Q-factor gets decreased with the increase in number of nodes. The graphical representation of Q factor in 2D and 3D with respect to number of nodes at various data rates i.e. at 2.5, 5 and 10 Gbps for added wavelengths to B-OADM with non linearity effect is shown in Fig. 6.

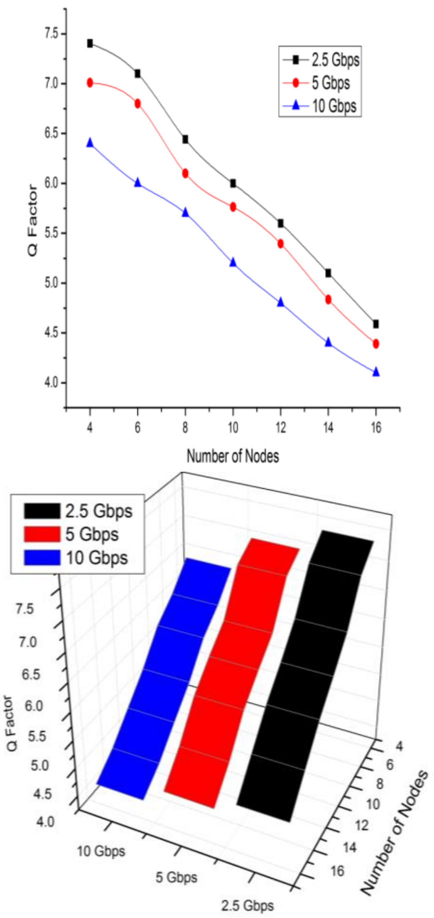


*Fig. 6. Q Vs number of nodes at 2.5, 5 and 10 Gbps data rates for added wavelengths to B-OADM with non linearity effect in (a) 2D and (b) 3D.*

It is evident that the Q-factor gets decreased due to the non linearity effect and with the increase in number of nodes. It is observed that the Q factor of 7.4 to 4.5 by 2.5 Gbps, 7.01 to 4.3 by 5 Gbps and 6.4 to 4.1 by 10 Gbps is achieved at $4^{th}$ to $16^{th}$ nodes respectively. It is also mention here that there is 100 km distance between each node making a total system at 1500 km distance. The graphical representation of Q factor in 2D and 3D with respect to number of nodes at various data rates i.e. at 2.5, 5 and 10 Gbps for dropped wavelengths to B-OADM with non linearity effect is shown in Fig. 7.

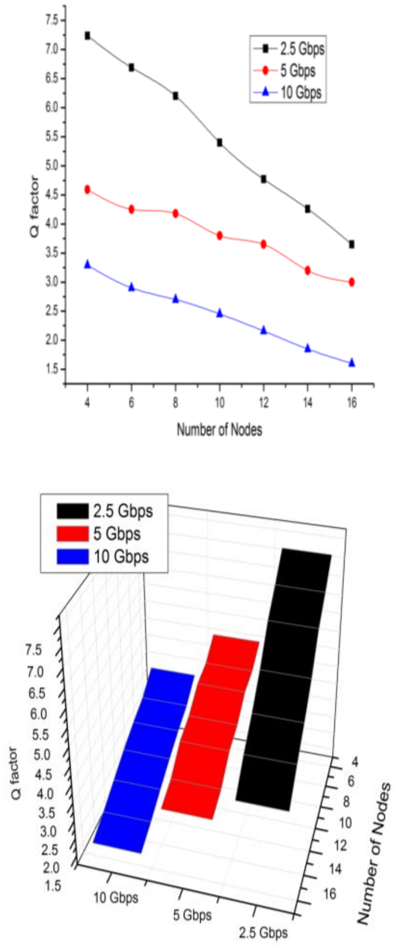


*Fig. 7. Q Vs number of nodes at 2.5, 5 and 10 Gbps data rates for dropped wavelengths to B-OADM with non linearity effect in (a) 2D and (b) 3D.*

It is observed that the Q factor of 7.2 to 3.6 by 2.5 Gbps, 4.59 to 3 by 5 Gbps and 3.29 to 1.6 by 10 Gbps is achieved at $4^{th}$ to $16^{th}$ nodes respectively. The Q factor is decreasing due to increase in the distance; there is 1500 km distance between $2^{nd}$ and $16^{th}$ nodes. It is evident that the Q-factor gets decreased with the increase in number of nodes. The BER versus number of nodes at 2.5, 5 and 10 Gbps data rates for added wavelengths to B-OADM without nonlinearity is shown in Fig. 8.

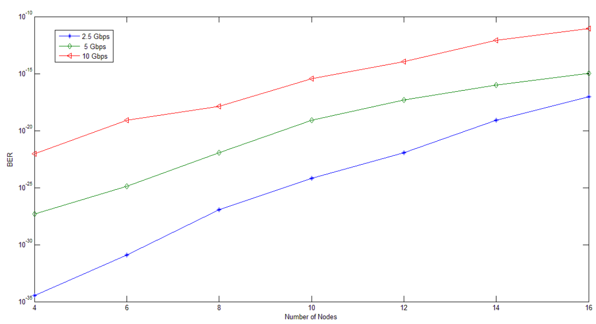

*Fig. 8. BER Vs number of nodes at 2.5, 5 and 10 Gbps data rates for added wavelengths to B-OADM without non linearity effect.*

As shown in the above figure, the BER increases with respect to the number of nodes due to increase in transmission distance of 100 km per node. The bit error rate varies from 3.47*10^(-35) to 9.1*10^(-18) by 2.5 Gbps, 5.1*10^(-28) to 1.01*10^(-15) by 5 Gbps and 8.9*10^(-23) to 9.1*10^(-12) by 10 Gbps at 4$^{th}$ to 16$^{th}$ nodes respectively for added wavelengths without nonlinearity effect. The BER versus number of nodes at 2.5, 5 and 10 Gbps data rates for dropped wavelengths to B-OADM without nonlinearity is shown in Fig. 9.

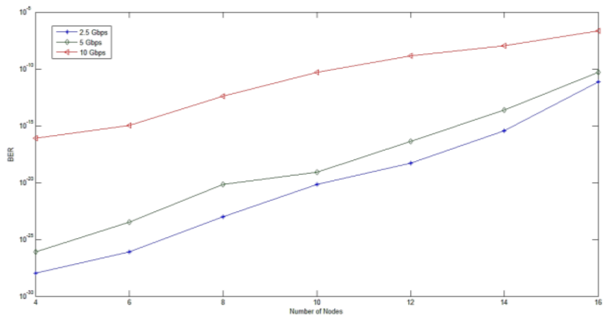


*Fig. 9. BER Vs number of nodes at 2.5, 5 and 10 Gbps data rates for dropped wavelengths to B-OADM without non linearity effect.*

As shown in the above figure, the BER increases with respect to the number of nodes due to increase in transmission distance of 100 km per node. The bit error rate varies from 1.1*10^(-28) to 6.9*10^(-12) by 2.5 Gbps, 7.67*10^(-27) to 4.9*10^(-11) by 5 Gbps and 7.9*10^(-17) to 2.2*10^(-7) by 10 Gbps at 4$^{th}$ to 16$^{th}$ nodes for dropped wavelengths respectively without nonlinearity effect. The BER versus number of nodes at 2.5, 5 and 10 Gbps data rates for added wavelengths to B-OADM with nonlinearity is shown in Fig. 10.

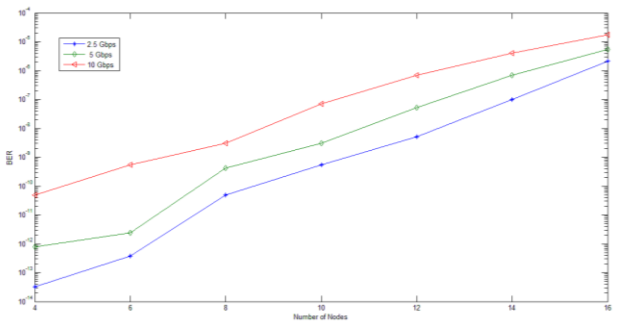


*Fig. 10. BER Vs number of nodes at 2.5, 5 and 10 Gbps data rates for added wavelengths to B-OADM with non linearity effect.*

As shown in the above figure, the BER increases with respect to the number of nodes due to increase in transmission distance of 100 km per node. The bit error rate varies from 3.2*10^(-14) to 2.12*10^(-6) by 2.5 Gbps, 7.9*10^(-13) to 5.53*10^(-6) by 5 Gbps and 4.9*10^(-11) to 1.75*10^(-5) by 10 Gbps at 4$^{th}$ to 16$^{th}$ nodes respectively for added wavelengths with nonlinearity effect. The BER versus number of nodes at 2.5, 5 and 10 Gbps data rates for dropped wavelengths to B-OADM with nonlinearity is shown in Fig. 11.

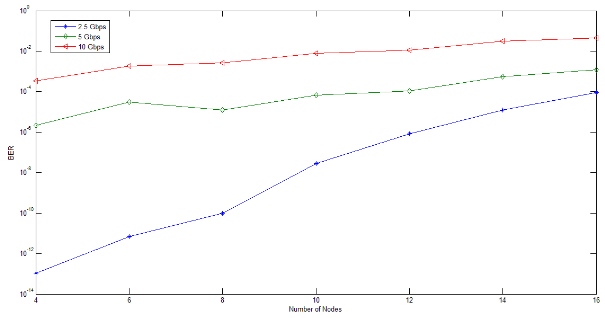


*Fig. 11. BER Vs number of nodes at 2.5, 5 and 10 Gbps data rates for dropped wavelengths to B- OADM with non linearity effect.*

As shown in the above figure, the BER increases with respect to the number of nodes due to increase in transmission distance of 100 km per node. The bit error rate varies from 1.1*10^(-13) to 8.9*10^(-5) by 2.5 Gbps, 2.12*10^(-6) to 1.2*10^(-3) by 5 Gbps and 3.4*10^(-4) to4.5*10^(-2) by 10 Gbps at 4$^{th}$ to 16$^{th}$ nodes respectively for dropped wavelengths with nonlinearity effect. The output power versus number of nodes at 2.5, 5 and 10 Gbps data rates for added wavelengths to B-OADM without nonlinearity is shown in Fig. 12.

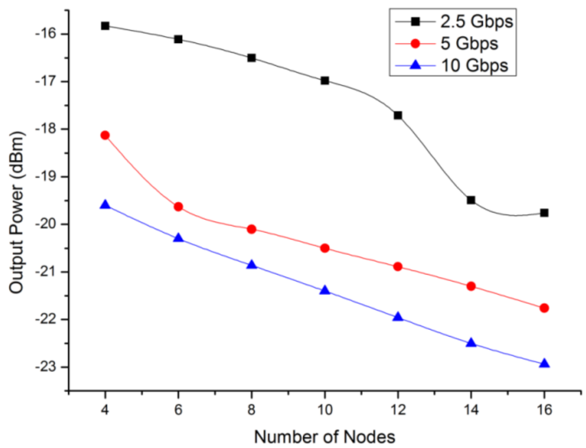


*Fig. 12. Output Power Vs number of nodes at 2.5, 5 and 10 Gbps data rates for added wavelengths to B- OADM without non linearity effect.*

It is observed that the output power received is not same for all the nodes but in decreasing order due to increase in transmission distance of 100 km per node. The optical output power of -15.83 to -19.76 by 2.5 Gbps, -

18.13 to -21.76 by 5 Gbps and-19.6 to-22.94 by 10 Gbps in dBm at 4th to 16th nodes respectively for added wavelengths without nonlinearity effect. The output power versus number of nodes at 2.5, 5 and 10 Gbps data rates for dropped wavelengths to B-OADM without nonlinearity is shown in Fig. 13.

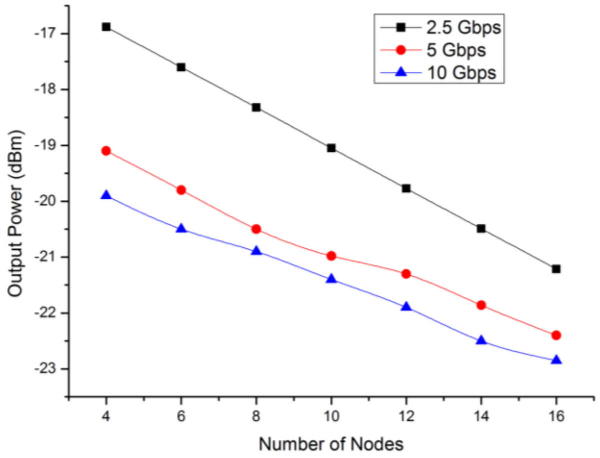


*Fig. 13. Output Power Vs number of nodes at 2.5, 5 and 10 Gbps data rates for dropped wavelengths to B-OADM without non linearity effect.*

It is observed that the output power received is not same for all the nodes but in decreasing order due to increase in transmission distance of 100 km per node. The optical output power of -16.88 to -21.21 by 2.5 Gbps, -19.1 to -22.4 by 5 Gbps and -19.9 to -22.85 by 10 Gbps in dBm at 4th to 16th nodes respectively for dropped wavelengths without nonlinearity effect. The output power versus number of nodes at 2.5, 5 and 10 Gbps data rates for added wavelengths to B-OADM with nonlinearity is shown in Fig. 14.

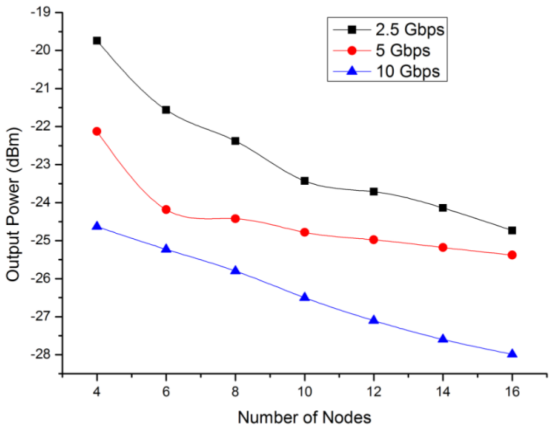


*Fig. 14. Output Power Vs number of nodes at 2.5, 5 and 10 Gbps data rates for added wavelengths to B- OADM with non linearity effect.*

It is observed that the output power received is not same for all the nodes but in decreasing order due to increase in transmission distance of 100 km per node. The optical output power of -19.74 to -24.73 by 2.5 Gbps, -22.13 to -25.38 by 5 Gbps and -24.63 to -27.99 by 10 Gbps in dBm at 4th to 16th nodes respectively for added wavelengths with nonlinearity effect. The output power versus number of nodes at 2.5, 5 and 10 Gbps data rates for dropped wavelengths to B-OADM with nonlinearity is shown in Fig. 15.

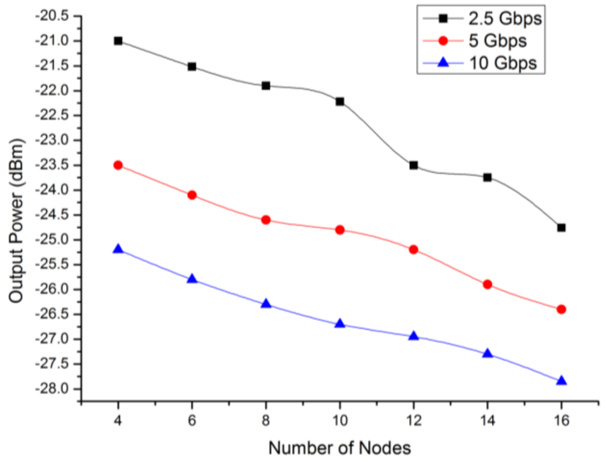


*Fig. 15. Output Power Vs number of nodes at 2.5, 5 and 10 Gbps data rates for dropped wavelengths to B-OADM with non linearity effect.*

It is observed that the output power received is not same for all the nodes but in decreasing order due to increase in transmission distance of 100 km per node. The optical output power of -21 to -24.76 by 2.5 Gbps, -23.5 to -26.4 by 5 Gbps and -25.2 to -27.85 by 10 Gbps in dBm at 4th to 16th nodes respectively for dropped wavelengths with nonlinearity effect.

## 4. Conclusion

In this paper, we have investigated DWDM system for fiber non linearity effects based on sixteen bidirectional B-OADMs. To perform bidirectional transmission, circulator is used in BOADM. SOA is also employed with each OADM to boost up the signals to longer distance. A length of 100 Km distance of DCF is inserted between each B-OADM to achieve 1500 Km total distance of the proposed network. Four channels with frequency 193.1THz at 50GHz spacing are used to transmit data at various data rates i.e. 2.5, 5 and 10 Gbps. Various performance parameters such as for different data rates to investigate the system performance in the term of BER and Q factor and output power.

## References


[1] Chia-Hsiung Chang, Tsair-Chun Liang, Chien-Yu Huang, Optics Communications, **282**, 4518 (2009).
[2] Kamaljit Singh Bhatia, R. S. Kaler, T. S. Kamal, Rajneesh Randhawa, Optik, **124**, 117 (2013).
[3] Sanjeev Dewra, R. S. Kaler, Optik, **124**, 347 (2013).
[4] Kamaljit Singh Bhatia, T. S. Kamal, Optik, **124**, 1907 (2013).
[5] Hwan Seok Chung, Sun Hyok Chang, Kwangjoon Kim, Optical Fiber Technology, **15**, 431 (2009).
[6] Vishal Sharma, Ramandeep Kaur, Optik, **124**, 3112 (2013).
[7] T. Sabapathi, R. Gowri Manohari, Optik, **125**, 18 (2014).
[8] Rakesh Goyal, R. S. Kaler, Optical Fiber Technology, **18**(6), 518 (2012).
[9] Rakesh Goyal, R. S. Kaler, Optoelectron. Adv. Mater. – Rapid Comm. **8**(7-8), 663 (2014).


* Corresponding author: er.rakeshgoyal@gmail.com