Performance analysis of DWDM system with dynamic ROADM based on PLC and WSS

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This paper presents an investigation on the planar lightwave circuit (PLC) and Wavelength Selective Switch (WSS) based Reconfigurable Optical Add Drop Multiplexer at 16 × 10 Gbps with 100 GHz channel spacing. The influence of increase in length of fiber has been investigated to evaluate the performance of optical communication system. The dynamic power transient with dynamic EDFA is also studied which equalizes power variations. It is found that the signal can be transmitted with acceptable optical output power (-34 dBm) using dynamic ROADM based on PLC and WSS up to maximum transmission distance of 462 Km with three dynamic EDFA's.

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1. Introduction

Dense wavelength-division-multiplexing (DWDM) technology is well-known for its dramatic increase in transmission capacity, and its flexibility in optical networking [1-2]. The tremendous growth of the high speed Internet and data traffic has created an enormous demand for transmission bandwidth of dense wavelength division multiplexed optical communication systems [3-4]. Erbium-doped fiber amplifiers (EDFA) plays a key role as power boosters, optical repeaters and preamplifiers in long distance optical fiber communications systems [5]. In a WDM optical network system, it is necessary to add or drop different wavelengths and optical add drop multiplexer (OADM) is one of the key components to enable greater connectivity and flexibility of the network [6]. An optical add/drop multiplexer is a device which is used in WDM system for multiplexing and routing different channels carrying wavelength of light from a single mode fiber (SMF) [7]. A Reconfigurable Optical Add/Drop Multiplexer (ROADM) can automatically terminate wavelengths from one optical cable to another. Wavelengths can be routed across the network at the optical layer or ''dropped'' at traffic access points to provide service [8]. A two-degree ROADM is like a location on a highway with off and on ramps to drop off and accept local traffic. It terminates an incoming DWDM fiber, drops specified wavelengths, and in most cases blocks these wavelengths from propagating further, adds local wavelengths, equalizes the combined traffic of passed-through and added wavelengths, and provides an exit for this traffic toward the next ROADM node. A multidegree ROADM is like an interchange where highways meet. It is used for interconnecting DWDM rings or for mesh networking. It accepts and rearranges wavelengths from the multiple fibers entering and leaving the multidegree node, as well as adding and dropping local wavelength traffic [9]. Optical Wavelength Selective Switches (WSS) are essential devices for high-capacity optical network systems based on reconfigurable optical add–drop multiplexing (ROADM) [10]. In a ROADM network, the WSSs can add and drop optical signals or let them pass through without converting them to electrical signals [11].

Planar lightwave circuit (PLC) technology is ideally suited to wavelength switching functions as it combines very low loss wavelength filters based on arrayed waveguide grating (AWG) technology with high performance switches based on the thermo optic effect in Mach–Zehnder interferometers. PLC technology is a solid-state technology with the potential for low costs due to the lack of critical optical alignments and the low-cost nonhermetic packaging [12].

C.A. Al Sayeed et al. [13] proposed architecture for ROADM subsystem that integrates the best features of the latest available ROADM designs. The proposed ROADM subsystem denoted as hybrid roadm subsystem exhibits a low insertion loss (7 dB for express channels) than existing roadm's while offering simplification and cost benefit. A metro network testbed had been configured to demonstrate and compared the performance of the propose hybrid ROADM module against currently available ROADM subsystems. Kiyo Ishii et al. [14] proposed an efficient reconfigurable optical add–drop multiplexer ring connecting node architecture that utilizes waveband routing; it achieved a small footprint and excellent cost effectiveness. The key component devices were implemented using planar lightwave circuit technologies and their performances were verified in experiments. Yuta Goebuchi et al. [15] demonstrated the basic elements of a full matrix optical switching circuit using a hitless wavelength-selective switch (WSS). It is a multi wavelength channel-selective switch consisting of cascaded hitless WSS, and a multiport switch. These switching elements were based on the individual thermo optic tuning of double series-coupled microring resonators, and could switch arbitrary wavelength channels without blocking other wavelength channels during tuning. The fundamental switching operations, such as four switching states from a three-wavelength selection to a zero-wavelength selection and multiport switching characteristics, were successfully demonstrated.

The investigation presented in [13] is restricted to bit rate of 2.48 Gbps. We have extended the work to higher bit rate of 10 Gbps with improvement in optical transmission distance using ROADM based on planar lightwave circuit and wavelength selective switch.

The paper is organized into four sections. Section 1 presents the introduction. Section 2 presents the simulation system set-up and the description of its components. Section 3 includes the discussion of the results for the network. Section 4 presents the conclusion about the feasibility of the system.

2. Simulation set up

The simulation set up consists of three stages i.e. transmitter, Reconfigurable optical add drop multiplexer and receiver. The transmitter block consists of sixteen channels, each of them operating at its own frequency ranging from 193.1 to 194.6 THz. Each transmitter includes a Data Source, NRZ coder, Modulator and a Continuous Wave Laser. Data source generates a binary sequence of data stream which is customized by baud rate, sequence type. The output from the driver and laser source is passed to the optical amplitude modulator. Modulation driver here generates data format of the type NRZ rectangular with a signal dynamics i.e. low level -2.5 and high level +2.5. The sixteen channels are spaced at 100 GHz and each channel is having 4mW input power. The Emission frequency of first channel is 193.1THz. The system set up is shown as in Fig. 1.

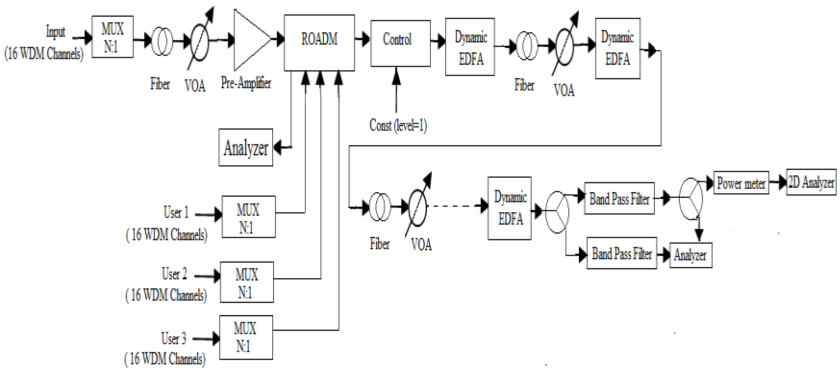

Fig. 1. System set up of DWDM system with dynamic ROADM

This set up illustrates the impact of dynamic traffic changes on the system performance. It supports 16 WDM channels and provide colorless add drop ports. The Reconfigurable Optical Add Drop Multiplexer (ROADM) is used to add/drop and switch channels. This causes dynamic power changes (as the no. of transmitted channels varies or the power of the add and drop channels is different). The impact of these transients can be mitigated with a single feed forward (constant input power). This is shown by observing the power variation for surviving channel with or without control Scheme at the receiver. The Control Scheme simulates a non ideal optical switch or gate, a drive of 0 turns the switch off, a drive of 1 turns it on. The preamplifier is power controlled amplifier with maximum gain of 20 dB and noise figure of 5dB. The dynamic EDFA can cope with variations in operating conditions that are frequently encountered in practical WDM networks. The dynamic EDFA utilizes a passive Gain Equalizing filter which is followed by a variable attenuator of 4dB for automatic power control of an EDFA. The fiber length of EDFA is 16 m. The forward pump power and pump wavelength are 200 mW and 980 nm.

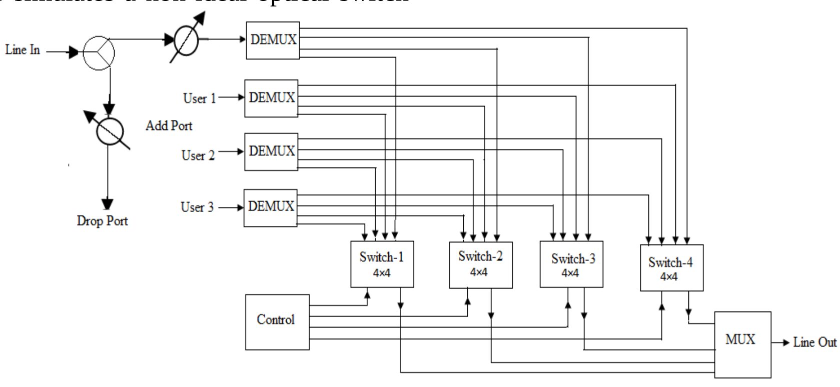

Fig. 2. Architecture of ROADM using PLC and WSS

Fig. 2 shows the Architecture of ROADM using PLC and WSS. The functional technologies of our proposed architecture depends on multiplexers and demultiplexers, 4× 4 optical switches, and variable optical attenuator(VOA). The incoming optical signals are usually brought to the Line-In input port. A fraction of the input signal is diverted towards drop port. The rest of the input signal is carried towards demultiplexer that separates into N channels. The wavelength-selective switch (WSS) is capable of demultiplexing, multiplexing, and switching DWDM wavelengths between one, or multiple input fiber ports, and one or more output fiber ports. The dynamic power transients are obtained at the analyzer whereas the received optical power is received through power meter at the 2D analyzer.

3. Results and discussions

To illustrate the performance of ROADM based on PLC & WSS the impact of dynamic transients is studied by utilizing dynamic EDFA's which equalizes the power variations among the channels and received optical output power is recorded at first channel obtained at 16×10 Gbps with 100 GHz channel spacing. Fig. 3 to 5 depicts the Dynamic transient response after three, five and seven dynamic EDFA's with the surviving channels. The variations in number of EDFA's in the network affect the dynamic power transients. The power variations are more with less number of dynamic EDFA's. To mitigate the effects of power transients on optical networks, a method based on Dynamic EDFA's where heads and tails are joined to the beginning and end of a traffic block is proposed. EDFA optical power transients can be significantly reduced with more no. of dynamic EDFA's. The power transients represent a major limitation to the performance of optical networks, whenever channels are added or dropped. The dynamic characteristics (speed, duration, and amplitude) of such power transients depend on the total number of EDFAs in the network. If some channels are dropped, the power in the surviving channels may surpass the threshold above which the fiber nonlinearities cannot be neglected any longer. If channels are added, the power in the surviving ones diminishes, and may fall below the receiver sensitivity.

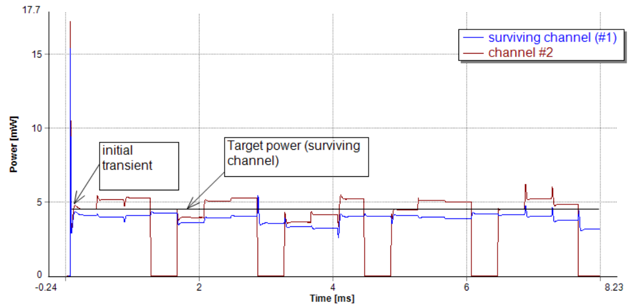

Fig. 3. Dynamic transient response after three dynamic EDFA

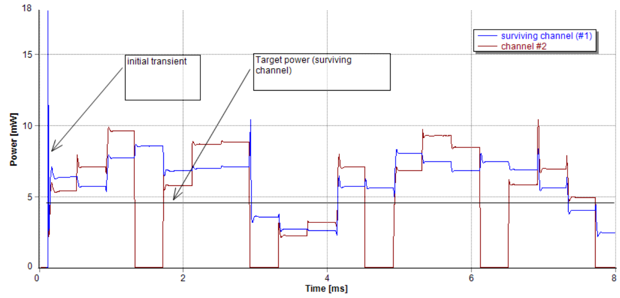

Fig. 4. Dynamic transient response after five dynamic EDFA

When channels are added or dropped by network's reconfiguration or failure, the power of the surviving channels decreases or increases due to cross saturation in the amplifiers. Power excursion of surviving channels can cause signal distortion by nonlinear effects or degradation of optical signal to noise ratio (OSNR).

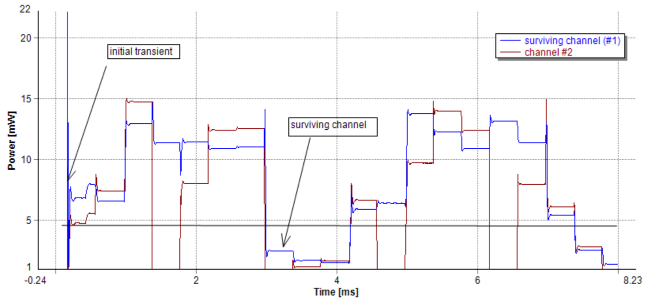

Fig. 5. Dynamic transient response after seven dynamic EDFA

The amplitude of transients increases with the number of amplifiers in a chain and power transients are reduced using more number of dynamic EDFA's. We have introduced a method of mitigating power transients called dynamic EDFA's where heads and tails are added to traffic blocks in order to gradually increase or decrease the average power on the channel. Dynamic EDFA does not require the addition of expensive and specialized electro-optic components or high-power lasers.

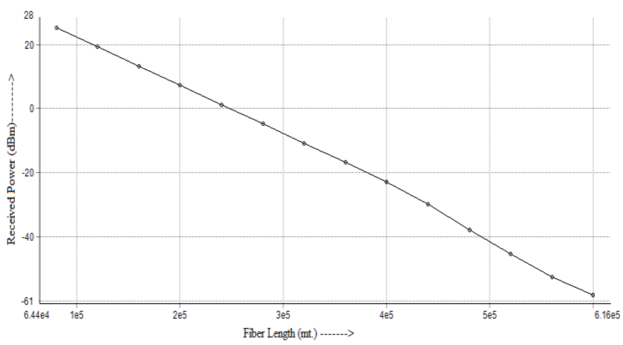

Fig. 6. The Received power vs. fiber length

The Received power vs. fiber length graph is shown in Fig. 6. As we increase the length of fiber, the received power decreases. The signal can be transmitted with acceptable optical output power (-34 dBm) using dynamic ROADM based on PLC and WSS up to maximum transmission distance of 462 Km with three EDFA's. Our result shows improvement over results reported in [13] in terms of optical transmission distance and bit rate.

4. Conclusion

The performance of Reconfigurable Optical Add/Drop Multiplexer based on PLC and WSS is obtained for 16× 10 Gbps with 100 GHz channel spacing. This paper demonstrates the power transient effects caused by the addition or deletion of channels. The add-drop of the channels causes transient effects in the surviving channels. Such transient effects are mitigating using the Dynamic EDFA component with the surviving channels. It is observed that the signal can be transmitted with acceptable optical output power (-34 dBm) up to maximum transmission distance of 462 Km with three dynamic EDFA's. The proposed ROADM based on PLC and WSS can also be applied with less channel spacing. Therefore with this approach, high bit rate & less channel spacing are achieved and applicable for DWDM system.

References

[1] C. A. Brackett, IEEE J. Sel. Areas Commun. **8**, 948 (1990).
[2] Simranjit Singh, Rajinder Singh Kaler, Optical Engineering **54**(10), 1 (2015).
[3] Simranjit Singh, R. S. Kaler, IEEE Photonics Technology Letters **25**(3), 250 (2013).
[4] Simranjit Singh, R. S. Kaler, IEEE Photonics Technology Letters **26**(2), 15 (2014).
[5] Simranjit Singh, Gauravpreet Singh, Gurpreet Kaur, Ramandeep Kaur, Rajinder Singh Kaler, Optoelectron. Adv. Mat. **9**(7-8), 944 (2015).
[6] M. Mahiuddin, M. S. Islam, J. Networks **7**(3), 450 (2012).
[7] Sanjeev Dewra, R. S. Kaler, Optik **124**, 347 (2013).
[8] Conrado Borraz-Sánchez, Diego Klabjan, Computer Networks **57**, 2013 (1443).
[9] Jonathan Homa, Krishna Bala, Xtellus, IEEE Communications Magazine, July 2008.
[10] Patinharekandy Prabhathan, Zhang Jing, Vadakke Matham Murukeshan, Zhang Huijuan, Chen Shiyi, IEEE photonics technology letters **24**(2), 15 (2012).
[11] Tomomi Sakata, Fumihiro Sassa, Mitsuo Usui, Junichi Kodate, Hiromu Ishii, Katsuyuki Machida, Yoshito Jin, Precision Engineering **37**, 897 (2013).
[12] M. P. Earnshaw, M. Cappuzzo, E. Chen, L. Gomez, A. Griffin, E. Laskowski, A. Wong, Foy, J. Soole, IEEE Journal of Selected Topics In Quantum Electronics **11**(2), (2005).
[13] C. A. Al Sayeed, A. Vukovic, O. W. W. Yang, Heng Hua, IET Optoelectron **1**(4), 178 (2007).
[14] Kiyo Ishii, Osamu Moriwaki, Hiroshi Hasegawa, Ken-ichi Sato, Yoshiteru Jinnouchi, Masayuki Okuno, Hiroshi Takahashi, IEEE photonics Technology letters **22**(7), 1 (2010).
[15] Yuta Goebuchi, Tomoyuki Kato, Yasuo Kokubun, IEEE photonics technology letters **19**(9), 1 (2007).

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