Australian Journal of Basic and Applied Sciences, 3(2): 1177-1184, 2009
ISSN 1991-8178

Determination of the Suitable Injection Signal and Internal Gain for Optical Cross Add and Drop Multiplexer in Survivable Optical Ring Network

Mohammad Syuhaimi Ab-Rahman and Muhd Fauzi Aminuddin Shazi Shaarani

Computer and Network Security Research Group, Department of Electrical, Electronic & Systems Engineering, Faculty of Engineering and Built Environment Universiti Kebangsaan Malaysia
43600 UKM Bangi, Selangor, Malaysia

Abstract: In this paper, we introduced a new architecture of asymmetrical optical switch device which is expected to have vast applications in optical communication and monitoring system. It has many excellent features such as low crosstalk, lossless properties and multifunctional. The multifunctional device means the integration of single functional devices onto single architecture and Optical Cross Add and Drop Multiplexer (OXADM) achieved the point with its unique architecture. With the use of micro-electro-mechanical systems (MEMs) technology, it has minimized the effects of crosstalk and return loss. With the accumulation feature, asymmetrical OXADM has widened its application to fiber-to-the-home (FTTH) and network security system. The main function of OXADM is to reconfigure the optical channel path while implementing add and drop function simultaneously. This paper highlights on the determination of best injected signal amplitude and internal amplifier's gain for OXADM in ring optical network. Indetermination of new added signal will contribute to the signal inhomogeneities and generate the worst quality at the receiver. Therefore we introduced the method to determine the best level of injection signal by intersection of bypassing signal with the new added signal to ensure the system work properly. Lastly we prove the technique feasibility by measuring the BER values of OXADM node in ring optical network.

Key words: Optical Cross Add and Drop Multiplexer (OXADM), injection signal, internal gain, ring network"

INTRODUCTION

The increase of capacity in transmitting data over 10 Gbps has limited the use of coaxial cable as medium for data transmission. Hence, fiber optic technology has been opted to fulfill the requirement for wide band transmission. Introducing WDM into the fiber optic technology has made it the transmission medium without limits that offers few advantages including higher capacity and speed, ability for transmitting long distance data and a better signal quality (Palais, 2005). Information transmitted in the domain optic is transferred via point line to point using synchronous optical networking (SONET) / synchronous digital hierarchy (SDH) equipment to create ring and mesh topology network. In this network, the needs of the devices for add drop operation and cross-connecting optical line are executed by OADM and OXC respectively (Rahman, *et al.,* 2004; Mutafungwa, 2000). These two devices have wide application in optical world and have a same basic structure, but both having different characteristics. OADM handled different signal carrier at each of its base, meanwhile OXC operates the same signal carrier (Eldada and Nunen, 2000; Mutafungwa, 2000). Therefore, both devices have been used at different location for different functions. But if the function of both devices is merged together, the application of optical technology will be tremendously widened.

The explosive requirement of bandwidth and new randomly nodes presence have led to a demanding of flexible, efficient, survivable and multifunctional device to support all of network topologies and functions (Eldada and Nunen, 2000). The introducing of new architecture of switching device that is designed to overcome drawbacks that occur in migration is expected. The device is called OXADM which uses the combination concept of OXC and OADM (Rahman, *et al.,* 2006; Rahman, *et al.,* 2008). It enables the operating wavelength on two different optical trunks to be switched to each other while implementing add and

Corresponding Author: Mohammad Syuhaimi Ab-Rahman, Computer and Network Security Research Group, Department of Electrical, Electronic & Systems Engineering, Faculty of Engineering and Built Environment Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia

drop function simultaneously. Here, the operating wavelengths can be reused again as a carrier of new data stream. The concept is similar to the other optical switch device (Kirihara, *et al.,* 1993). The wavelength transfer between two different cores of fiber will increase the flexibility, survivability and also efficiency of the network structure. To make device operational more efficient, MEMs switches are used to control the mechanism of operation such as wavelength add/drop and wavelength routing operation. As a result, the switching performed within the optical layer will be able to achieve high-speed restoration against failure/degradation of cables, fibers and optical amplifiers (Rahman, *et al.,* 2006; Rahman, *et al.,* 2008; Rahman, *et al.,* 2006).Previously, two restoration schemes have been proposed to provide survivability in ring and mesh metro network which are been activated according to the condition of failure by means of linear, multiplex and ring protection (Rahman, *et al.,* 2006; Rahman, *et al.,* 2006; Rahman, *et al.,* 2007). The migration of topology will be easier and reduce the restructuring process by eliminating the installation of new nodes because OXADMs are applicable for both types of topologies beside providing efficiency, reliability and survivability to the network (Rahman, *et al.,* 2006; Rahman, *et al.,* 2007).

OXADM – Next generation of ADM device:

OXADMs are elements which provide the capabilities of add and drop function and cross connecting traffic in the network, similar to OADM and OXC. OXADM consists of three main subsystem; a wavelength selective demultiplexer, a switching subsystem and a wavelength multiplexer. Each OXADM is expected to handle at least two distinct wavelength channels each with a coarse granularity of 2.5 Gbps of higher (signals with finer granularities are handled by logical switch node such as SDH/SONET digital cross connects or asynchronous transfer mode (ATM) switches.

There are eight ports for add and drop functions, which are controlled by four lines of MEMs switch. The other four lines of MEMs switches are used to control the wavelength routing function between two different paths (see Figure 1a).The functions of OXADM include node termination, drop and add, routing, multiplexing and also providing mechanism of restoration for point-to-point, ring and mesh metropolitan and also customer access network in FTTH. With the setting of the MEMs optical switch configuration, the device can be programmed to function as another optical devices such as multiplexer, demultiplexer, coupler, WSC, OADM, WRB an etc for the single application (Rahman, *et al.,* 2008; Rahman, *et al.,* 2008). In ring architecture, OXADM perform as a node and the function is similar to the parallel connection add drop multiplexer (ADM) in which the drop port of one ADM is connected to Add port and vice versa. The architecture is depicted in Figure 1b and 1c (Eldada and Nunen, 2000). The designed 4-channels OXADM device is expected to have maximum operational loss of 0.06 dB for each channel when device components are in ideal condition (Rahman, *et al.,* 2008). The maximum insertion loss when considering the component loss at every channel is less than 6 dB. In the transmission using SMF-28 fiber, with the transmitter power of 0 dBm and sensitivity –22.8 dBm at a point-to-point configuration with safety margin, the required transmission is 71 km with OXADM (Rahman, *et al.,* 2008).

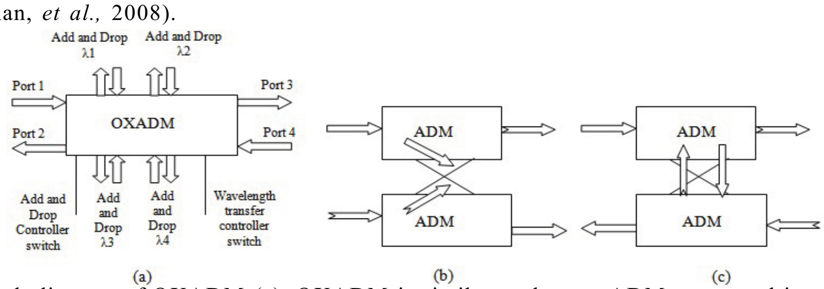

Fig. 1: The block diagram of OXADM (a). OXADM is similar to the two ADM connected in parallel, which the drop port connected to add port and vice versa. This enable the cross-connecting (b) and U turn mechanism (c) can be implemented

The asymmetrical OXADM architecture consists of 3 parts; selective port, add/drop operation and path routing. Selective port permits only the interest wavelength going through and acts as filter. With the switch configuration, add and drop function can be activated in second part of OXADM architecture. The signals are then re-routing to any port of output. The signals can also be accumulated on one path and exit at any output port (Rahman, *et al.,* 2006; Rahman, *et al.,* 2008).

Injection Signal in Add Port:

Figure 2 shows the BER profile on the reduction of new input power during add/drop operation. From the figure, the BER profile can be divided to two main parts, separated by the line of the threshold point. The increase of the reduction (smaller power) causes the BER profile to recover until its threshold point (reduction at 16dB), which then continues to further reduce itself. The power measured at this point is the suitable power of added new signal to OXADM.

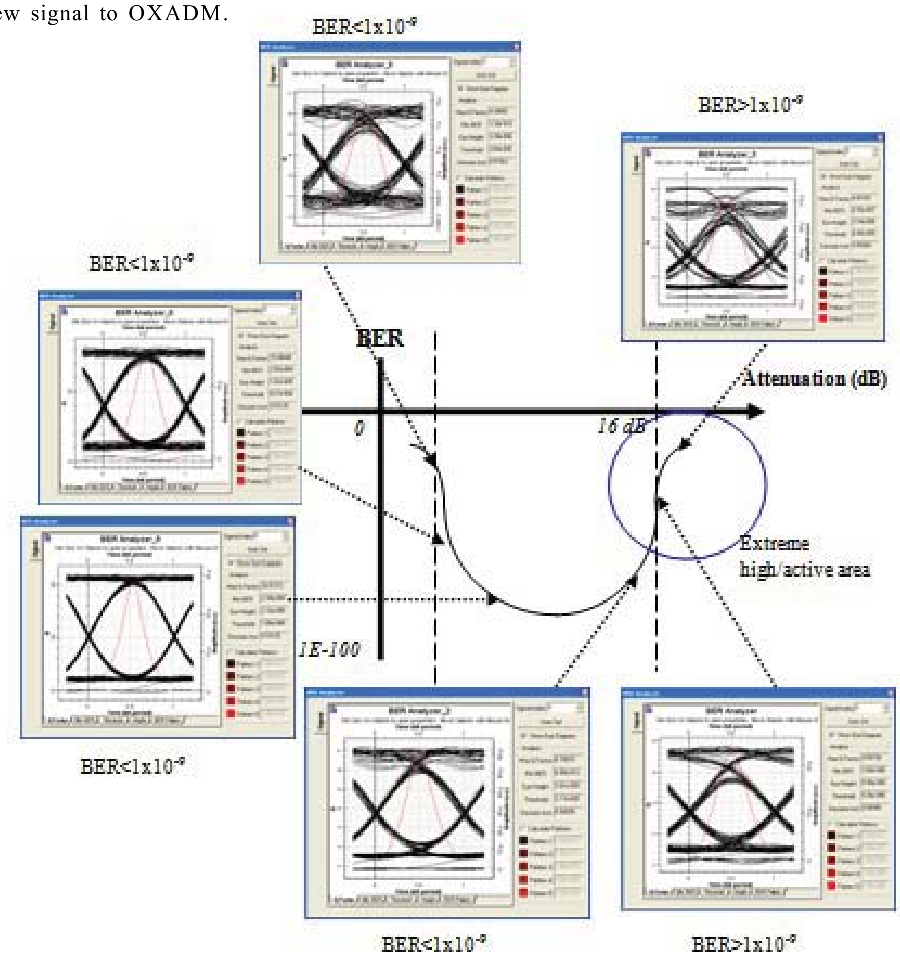

Fig. 2: Profile of BER on reduction of new input power during add/drop operation. The increase of the attenuation causes the BER profile to recover until its threshold point (reduction at 16dB), which then continues to further reduce itself.

Through the BER profile, the area suited for new input power is identified in order to make it at the same level as power of other carriers making a direct path through the nodes. An ideal input power can be obtained by determining the intersection between the power profile of the direct path carrier and the new input signal carrier (additional terminals) as shown in Figure 3. Its BER profile is next shown in Figure 4. It is found that an ideal input power for the metropolitan ring network will be at -22dBm.

Gain of Internal Amplifier:

The simulation aims at obtaining the optimum value for the power multipliers of the internal amplifier for the protection of directional ring towards the west at different transmission rates. Three different transmission rates are being chosen for this simulation: 1.25, 2.5, and 5 Gbps. The values of the ideal internal multipliers for each rate is determined in this testing. Sensitivity of the receiver is set at -25 dBm (1530 nm) for a transmission of 2.5 Gbps (Thermal noise = 3.1347 x 10^{-23} W/Hz).

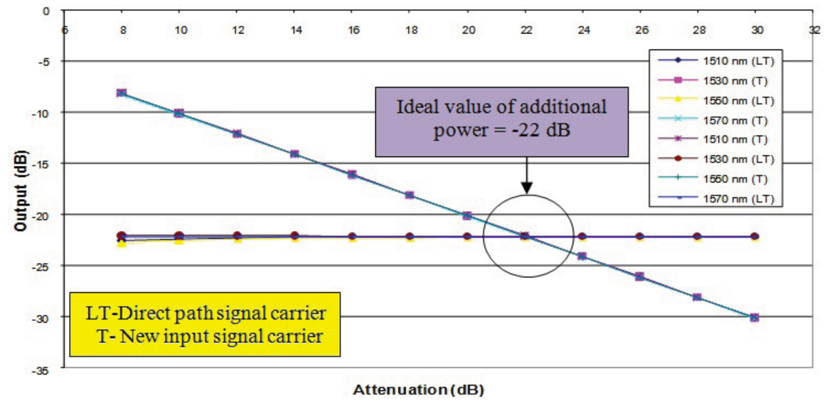

Fig. 3: Ideal new input power obtained from the intersection between the power profiles of the direct path carrier and the new input signal carrier at the additional terminal. Data transmission rate is at 2.5 Gbps.

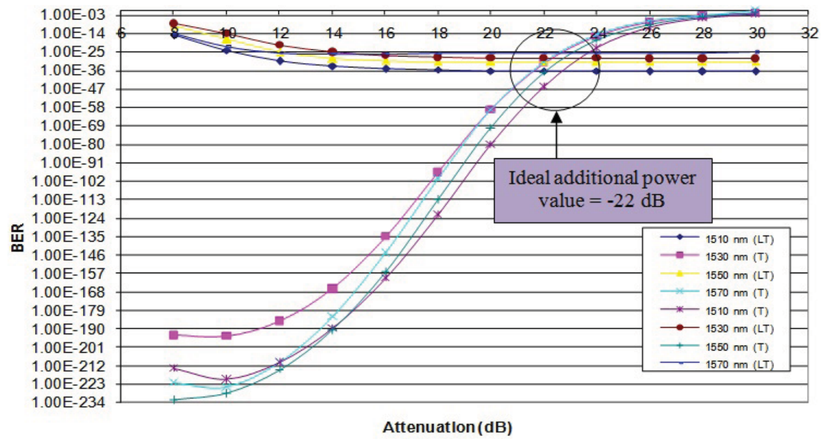

Fig. 4: The overlapping of BER profiles between the direct path carrier and the new input signal carrier ensures that the power and BER performance maintains at a similar level.

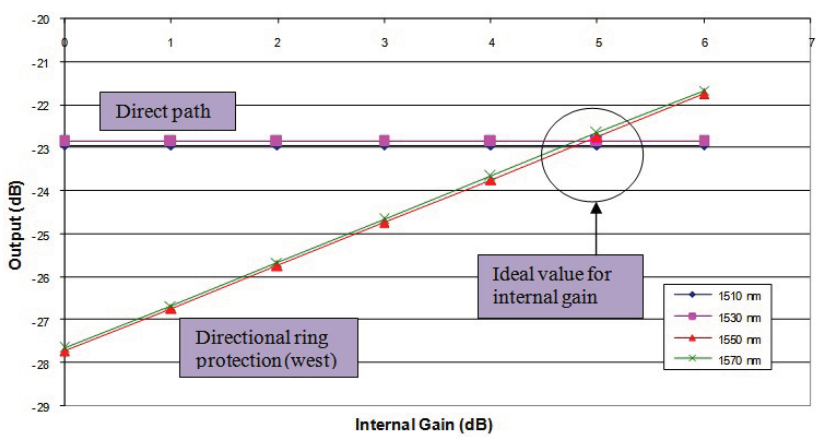

Fig. 5: Effects of the internal multiplier towards the output power at the directional ring protection towards the west scheme at a transmission rate of 1.25 Gbps.

As seen in Figure 5, a suitable gain value at a transmission rate of 1.25 Gbps for a directional ring protection scheme (west) is at 5dB, which provides a similar value of power in terms of magnitude with the direct path signal operation (output power = -22.84 dB). This is the intersection point on both the graphs.

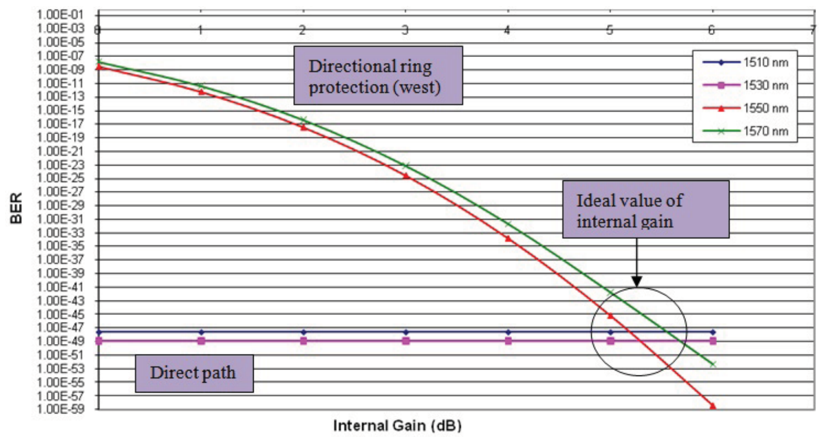

Fig. 6: Effect of internal multipliers towards the BER profile performance in a directional ring protection (west) at a transmission rate of 1.25 Gbps.

The effects it has towards the BER performance at a transmission rate of 1.25 Gbps is shown in Figure 6 above. At an internal gain value of 5.5 dB, it gives an almost similar BER value and it is satisfactory for both operations (BER < 1×10^{-47}).

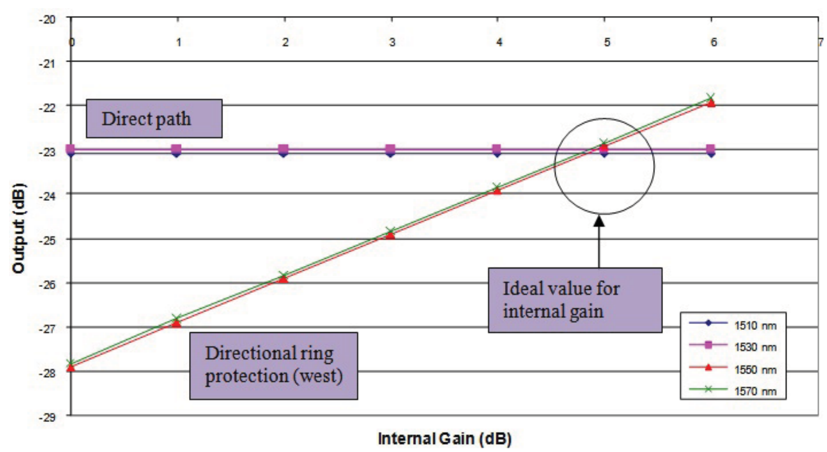

Fig. 7: Effects of the internal gain towards the output power at the directional ring protection towards the west scheme at a transmission rate of 2.5 Gbps.

The suitable value of internal gain for the operation of directional ring protection (west) at a rate of 2.5 Gbps is at 5 dB, giving a similar value of output power with the direct path signal operation (Output power = -22.98 dB). This is based on the intersection point on both graphs shown in Figure 7. This value is found to be the same as the one discovered in Figure 5.

The effect of the internal gain on the BER performance at a transmission rate of 2.5 Gbps is shown in Figure 8. At an internal gain value of 5.5 dB, it gives an almost similar BER value and it is satisfactory for both operations (BER < 1×10^{-19}).

The suitable value of internal gain for the operation of directional ring protection (west) at a rate of 2.5 Gbps is at 5 dB, giving a similar value of output power with the direct path signal operation (Output power = -23.37 dB). This is based on the intersection point on both graphs shown in Figure 9. This value is found to be the same as the one discovered in Figure 5 and Figure 7.

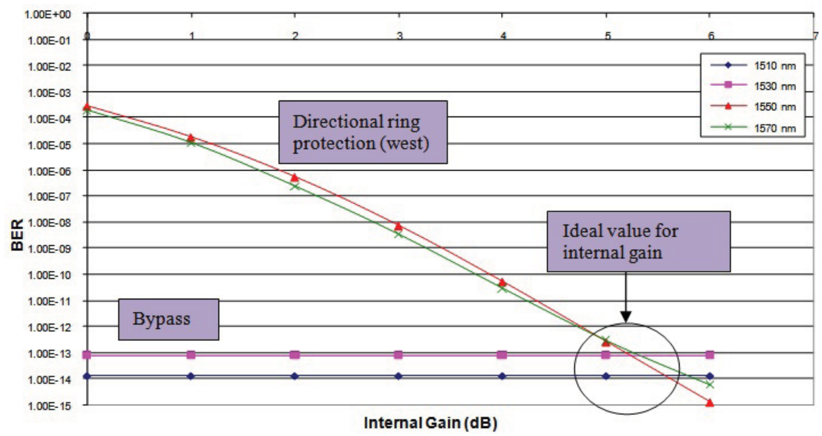

Fig. 8: Effect of internal multipliers towards the BER profile performance in a directional ring protection (west) at a transmission rate of 2.5 Gbps.

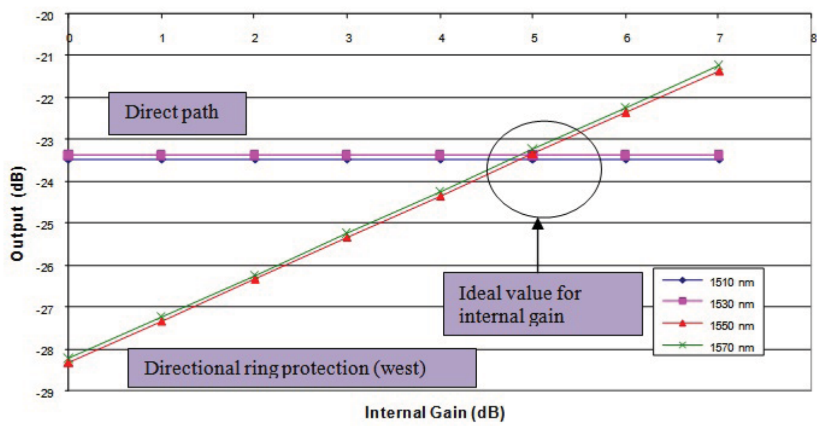

Fig. 9: Effects of the internal multiplier towards the output power at the directional ring protection towards the west scheme at a transmission rate of 5 Gbps.

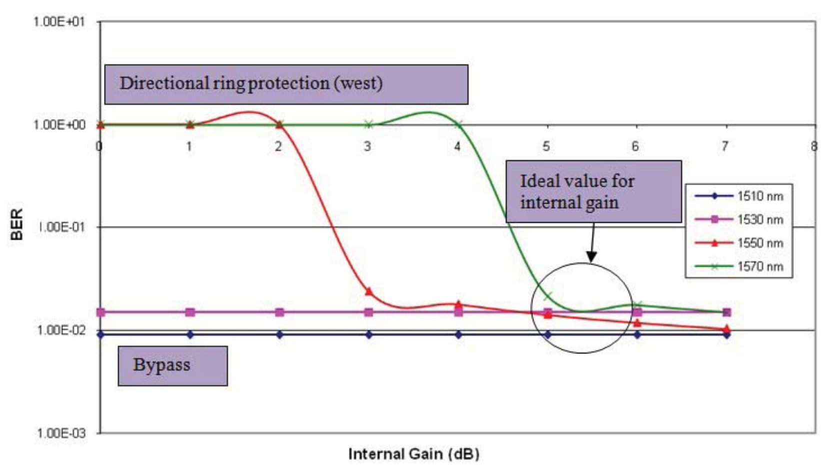

Fig. 10: Effect of internal multipliers towards the BER profile performance in a directional ring protection (west) at a transmission rate of 5 Gbps.

Even though the increase of data transmission rate will reduce the measured BER performance, but based on Figure 10 shows that the intersection of the main operations for OXADM occurs at 5.5 dB (BER<$1x10^{-2}$). However, in order to increase the performance of BER, either the sensitivity has to be increased or the value of the amplifier gain used has to be increased (Saleh and Teich, 1991).

From the observations made based on Figure 5 until Figure 10, it can be said that the value for the internal amplifier will be at 5.5 dB to obtain a uniform BER performance with the direct path signal transmission, or any other operations at different rates of data transmission. Therefore, an optimum value that can be deduced here will be at 5 dB.

Conclusion:

In this paper, we introduced a new architecture of asymmetrical optical switch device named as Optical Cross Add and Drop Multiplexer (OXADM) which is expected to have vast applications in optical communication and monitoring system. It has many excellent features such as low crosstalk, lossless properties and multifunctional. OXADM perform the cross-connecting and 'U' turn mechanism simultaneous with add and drop function to increase the survivability and flexibility in ring optical network. This objective of this study is to determine the best injected signal amplitude and internal gain for OXADM in ring optical network to avoid generation of worst quality at the receiver due to signal level inhomogeneities. Therefore we define the suitable level of injection signal by intersection of bypassing signal with the new added signal to ensure the system work properly. Meanwhile the internal amplifier gain of OXADM will be 5.5 dB to obtain the symmetrical bidirectional throughput power. Our next step is concentrating on development of OXADM using the thin film technique that can be called waveguide based optical device. This is expected to have mass production, lossless, low crosstalk and enable to integrate with other optical devices (Kirihara, *et al.,* 1993; Rahman, *et al.,* 2004).

ACKNOWLEDGEMENT

This project is supported by Ministry of Science, Technology and Environment, Malaysia Government, through the National E-Science Project fund 01-01-02-SF0493 and Research University Grant fund UKM-GUP-TMK-07-02-108. The work was also been done in Photonic Technology Laboratory at Institute of MicroEngineering and Nanoelectronics (IMEN), Universiti Kebangsaan Malaysia (UKM), Malaysia.

REFERENCE

Eldada, L., J.V. Nunen, 2000. Architecture and performance requirements of optical metro ring nodes in implementing optical add/drop and protection functions, Telephotonics Review.

Kirihara, T., M. Ogawa, H. Inoue, K. Ishida, 1993. Lossless and low-crosstalk characteristics in an IP-based 2x2 optical switch. IEEE Photonics Technology Letter, 5(9): 1059-1061.

Mutafungwa, E., 2000. An improved wavelength-selective all fiber cross-connect node," IEEE Journal of Applied Optics. pp: 63-69.

Palais, J.C., 2005. *Fiber optic communication*; Prentice Hall:New Jersey.

Rahman, M.S.A., Ehsan, A.A., S. Shaari, 2006. Mesh upgraded ring in metropolitan network using OXADM. Presented at the 5th ICOCN/ATFO International Conference on Optical Communications and Networks & the 2nd International Symposium on Advances and Trends in Fiber, Chengdu, China, 225-227.

Rahman, M.S.A., A.A. Ehsan, S. Shaari, 2006. Survivability in FTTH PON access network using optical cross add and drop multiplexer switch. *Journal of Optical Communication (JOC)*. 27(5): 263-269.

Rahman, M.S.A., H. Husin, A.A. Ehsan, S. Shaari, 2006. Analytical modeling of optical cross add and drop multiplexing switch. Presented at the ICSE IEEE International Conference on Semiconductor Electronics, pub. IEEE Malaysia Section, 290-293.

Rahman, M.S.A., M.F. Ibrahim, 2008. OXADMs: Comparison With the Existing Device. Presented at the 2nd AMS Asia International Conference on Modelling and Simulation, Kuala Lumpur, Malaysia, 283-290.

Rahman, M.S.A., A.A.A. Rahni, M.D. Zan, K. Jumari, S. Shaari, M.F. Ibrahim, 2008. OXADMs: the next generation of optical switching devices. Presented at the 5th WOCN International Conference on Wireless and Optical Communication Network, (in CD).

Rahman, M.S.A., S. Shaari, 2004. Modeling of planar lightwave circuit OADM for CWDM. Presented at the Proceeding 2004 Postgraduate Conference, Selangor, Malaysia, 116-120.

Rahman, M.S.A., S. Shaari, 2006. OXADM restoration scheme: approach to optical ring network protection. Presented at the ICON IEEE International Conference on Networks, Singapore, 371-376.

Rahman, M.S.A., S. Shaari, 2007. Survivable Mesh Upgraded Ring in Metropolitan Network, *Journal of Optical Communication (JOC),* 28(3): 206-211.

Rahman, M.S.A., 2080. The proposal of OXADM application in FTTH network. *Journal of Optical Communication (JOC)*. In-press.

Rahman, M.S.A., H.F.A. Wahab, 2008. Development of optical multifunctional switch. Presented at the 2nd HUT_ICCE International Conference on Communications and Electronics, Vietnam, 454-460.

Tzanakaki, A., I. Zacharopoulus, I. Tomkos, 2003. Optical add/drop multiplexers and optical cross-connects for wavelength routed network, Presented at the ICTON International Conference on Transparent Optical Networks, 41-46.