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ORIGINAL ARTICLE

OSNR Measurement on Single Function of Optical Cross Add and Drop Multiplexer (OXADM): Experimental versus Analytical

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Mohammad Syuhaimi Ab-Rahman: OSNR Measurement on Single Function of Optical Cross Add and Drop Multiplexer (OXADM): Experimental versus Analytical

ABSTRACT

In this paper we have introduced the new architecture of optical switch that embedded many functions on single device. With the use of MEMs technology has minimized the effect of crosstalk and return loss. The asymmetrical architecture of OXADM consists of 3 parts; selective port, add/drop operation, and path routing. Selective port permits only the interest wavelength pass through and acts as a filter. While add and drop function can be implemented in second part of OXADM architecture. The signals can then be re-routed to any port of output or/and perform an accumulation function which multiplex all signals onto one path and then exit to any interest output port. This will be done by the third part. We demonstrate fiber-to-fiber low crosstalk (60 dB ON/OFF ratio) and low return loss (40 dB ON/OFF ratio) of 2x2 OXADM optical switch with detail experimental set up explanation. Finally, the existing switches (e.g directional coupler and OXC) and OXADM switch are compared. Finally we proposed one graph to verify the result gain from the experimental by the analytical result. Both results show the agreement for every points measured with respect to the input power variation.

Key words: New architecture, optical switch, asymmetrical, hybrid device, OSNR.

Introduction

A photonic space division switching network is one of the most promising switching systems with ultralarge data throughput that are expected to be realized in the near future (T. Kirihara, *et al*., 1993). The introducing of new architecture of switch device that is designed to overcome drawbacks that occur in wavelength management in expected. The device is called optical cross add and drop multiplexing (OXADM) which use combination concept of optical cross connect (OXC) and optical add and drop multiplexing (OADM) (M.S.A. Rahman, *et al*., 2006). Its enable the operating wavelength on two different optical trunks to be switched to each other and implementing accumulating function simultaneously. Here, the operating wavelengths can be multiplexed together and exit to any interested output port. 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 which had been proposed in (M.S.A. Rahman, *et al*., 2006; M.S.A. Rahman, S. Shaari 2006). We had proposed previously 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 provide efficiency, reliability and survivability to the network (M.S.A. Rahman, *et al*., 2006).

Oxadm Device:

OXADMs are element which provide the capabilities of add and drop function and cross connecting traffic in the network, similar to OADM and OXC (A. Tzanakaki, *et al*., 2003; E. Mutafungwa, 2000; L. Eldada & J.v.

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Nunen 2000). 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 ATM switches. There are eight ports for add and drop functions, which are controlled by four lines of MEMs optical switch. The other four lines of MEMs switches are used to control the wavelength routing function between two different paths. 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, wavelength converter (with fiber grating filter configuration), OADM, wavelength round about an etc for the single application. The designed 4-channel OXADM device is expected to have maximum operational loss of 0.06 dB for each channel when device components are in ideal condition (M.S.A. Rahman, *et al*., 2006). 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 (M.S.A. Rahman, *et al*., 2006). The 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.

Oxadm optical switch:

The control switch for OXADM optical switch is used to change the path of incoming from the input port. When the control switches in ‘off’ state, no switching occurs and the signal pass through the device as seen from the Figure 1 a. But when the control switch B is ‘on’ state, the signal from the input 1 will be switch to Output 2 (see Figure 1 b). The accumulation function occurs which multiplex all the signals from the inputs together and exit at the Output 2. This will be the same if the control switch A is in ‘on’ state but the output is at Output 1 in contrast to the control switch B is in reverse state (see Figure 1 c). If both switches are in ‘on’ state, the signal will be switched to exchange their output port and works as an OXC device (see Figure 4 b). The functional of an OXADM optical switch can be summarized through the truth functional table shown by Table 1. The incoming signals from the back will be switched to neighbor output port or pass through the device. This is shown in Figure 2.

Device Comparison:

The OXADM optical switch device will be compared with two existing switching devices; directional coupler switch and optical cross connect (OXC). The non-selective directional coupler switch has two states and one control element. It has fixed number of input and output port which is two. The wide bandwidth signal comes from the input port with switch to either one of output ports. It works bi-directional with symmetrical function (Palais, J.C. 2005). Figure 3 shows the mechanism of switching for directional coupler switch in normal (a) and active condition (b) & (c). The application of DC switch is to control the signal path in WDM network and optical storage; and can also perform the function of OADM in optical distributed network. OXC is the directional coupler witch but with many ports. The functional of OXC is cross-connecting between output and input port (Figure 4) (E. Mutafungwa, 2000). Same with OXADM, the OXC is selective device but it does not have accumulation feature. In contrast with OXADM, OXC works bi-directional with symmetrical function. The application of OXC is as a switching device in mesh network configuration and also in optical storage. Table 2 summarizes the differences of OXADM with DC and OXC.

Experimental Setup:

Two parameters have been studied experimentally to ensure the interference of uninterested signal is minimized. The experimental set up to measure the crosstalk at two ports of OXADM has been carried out and the results are redrawn in Figure 5 and Figure 6 respectively. The crosstalk value is bigger than 60 dB means the interested wavelength is in safety mode and the transmitted data can be interpreted at any receiver end. The other parameter should be considered for bi-directional device is return loss. Return loss is the disturbance of uninterested signal against the direction of interested signal. The return loss is measured and the result is shown in Figure 12. The value is 40 dB which is higher than minimum safety value. Both experimental have shown that the OXADM optical switch has a good and acceptable value of crosstalk and return loss.

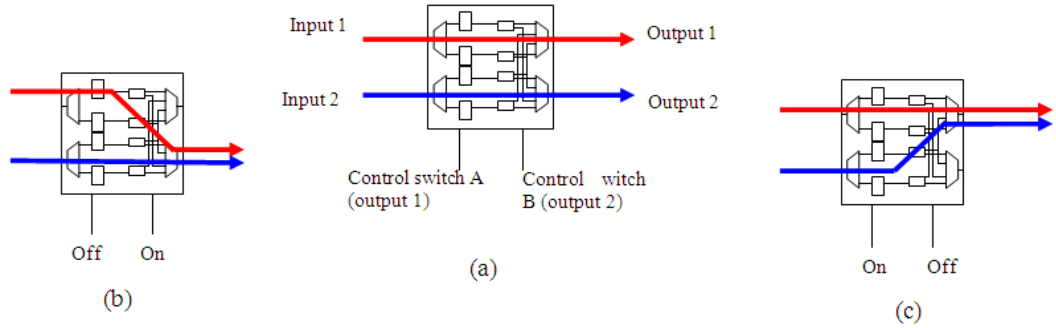

Fig. 1: OXADM optical switch works as re-configurable output port multiplexer. (a) Normal condition. (b) Switch B activated – Accumulation signal on output 2. (c) Switch B activated - Accumulation signal on output 1.

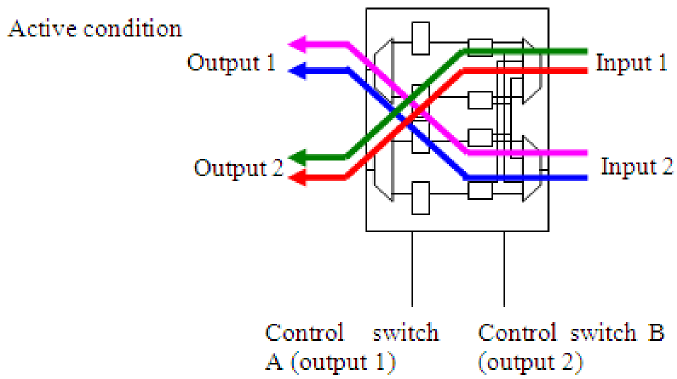

Fig. 2: OXADM optical switch works as 2x2 demultiplexer. When the switch is activated, the signal will be switched to any output port.

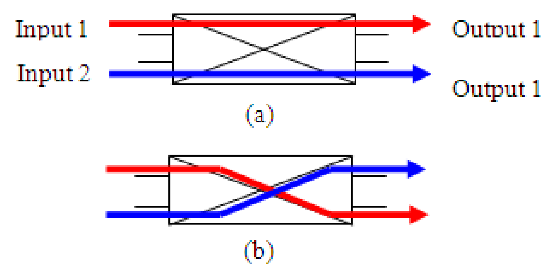

Fig. 3: Switching mechanism of directional coupler optical switch, a) normal (b) activate.

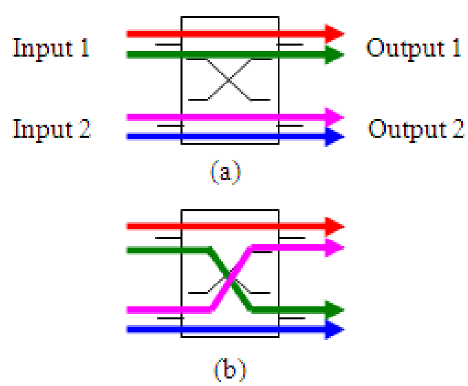

Fig. 4: Switching mechanism of OXC, a) normal (b) activate.

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Table 1: The truth table of OXADM optical switch

Switch A	Switch B	Output 1	Output 2
0	0	λ_A	λ_B
1	0	$\lambda_A + \lambda_B$	X
0	1	X	$\lambda_A + \lambda_B$

0 = Off λ_A = Signal enters input 1
1 = On λ_B = Signal enters input 2
X = No signal

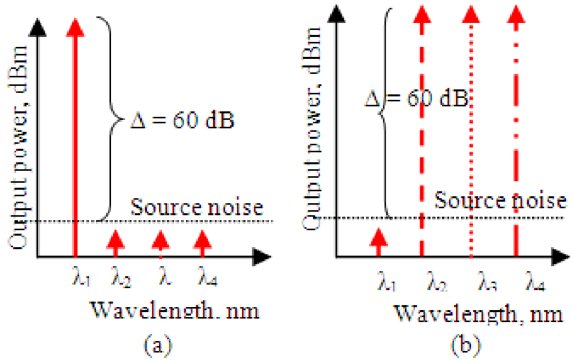

Fig. 5: Redrawing of measured output signal for single wavelength switching configuration. (a) Port 1 (b) Port 2

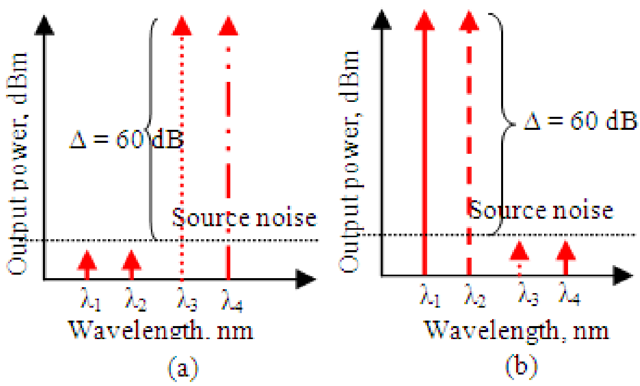

Fig. 6: Redrawing of measured output signal for double wavelength switching configuration. (a) Output 1 (b) Output 2.

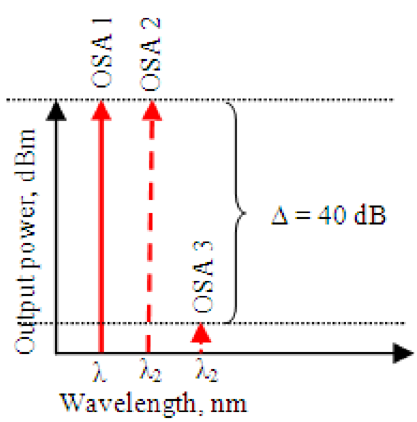

Fig. 7: Redrawing of measured output port at every port for configuration 2 for return loss measurement. Return signal coming out from the input port is routing to OSA 3 using optical circulator.

Experimental Result:

The OXADM device is characterized by using two tunable light sources and two optical spectrum analyzer. The experimental set up is shown in Figure 9 below. The designed 4-channel OXADM device is expected to have maximum operational loss of 0.6 dB for each channel when device components are in ideal condition. The maximum insertion loss when considering the component loss at every channel is 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 (M.S.A. Rahman, S. Shaari, 2004).

The testing is also carried out for every function of OXADM. The function includes bypass, add and drop, path exchange and also functional combined. The operating wavelength is 1510 nm and the results shows the OSNR value for this function is 20 dB (bypass), 32.9 dB (drop), 28,95 dB (add), path exchange (20 dB), add & path exchange (30 dB). Each measurement result is indicated in Figure 10 to Figure 13. The multiplexed input signal is also applied and the result shown in Figure 14 and Figure 16. For bypass and path exchange function, the OSNR values are bigger than 20 dB. This can be concluded that the level of signal is 20 dB higher than noise level. The 20 dB indicates the safety value for the signal to noise ratio.

Table 2: *Comparison between OXADM, DC and OXC*

Features	OXADM	DC	OXC
Selective	Yes	No	Yes
Accumulation	Yes	No	No
Scalability	Yes	No	Yes
Symmetrical function	No	Yes	Yes

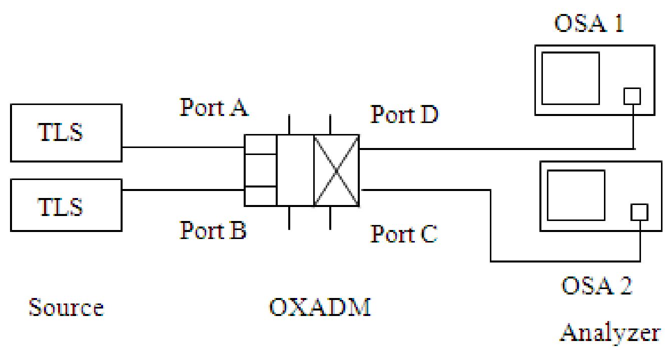

Fig. 9: Experimental set up block diagram

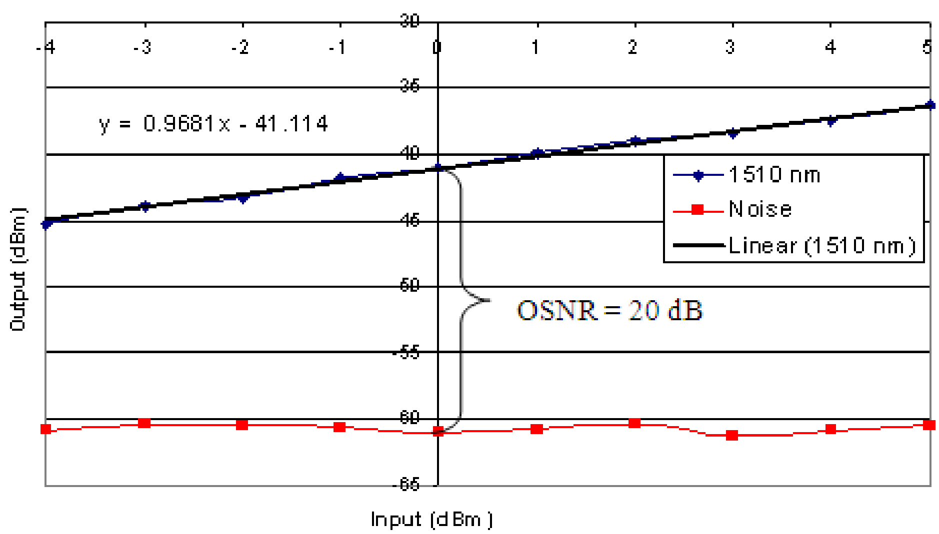

Fig. 10: The measured output power for bypass operation at single operating wavelength.

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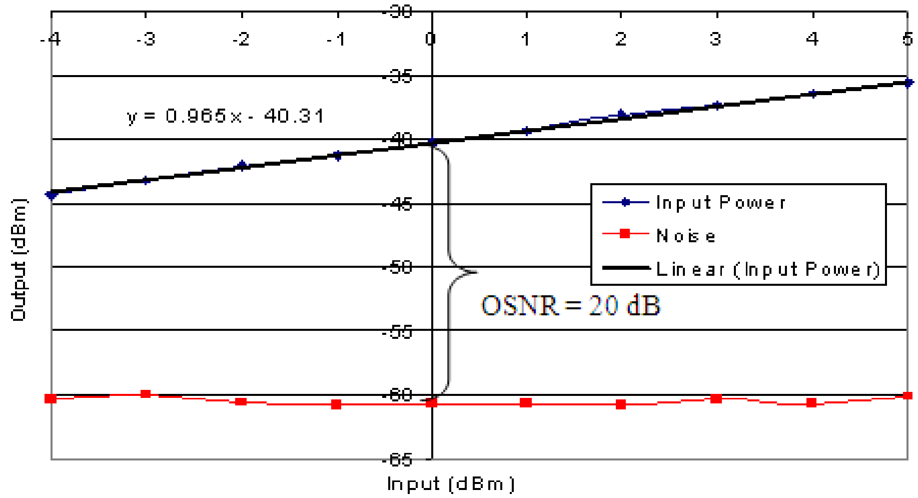

Fig. 11: The measured output power for path exchange operation.

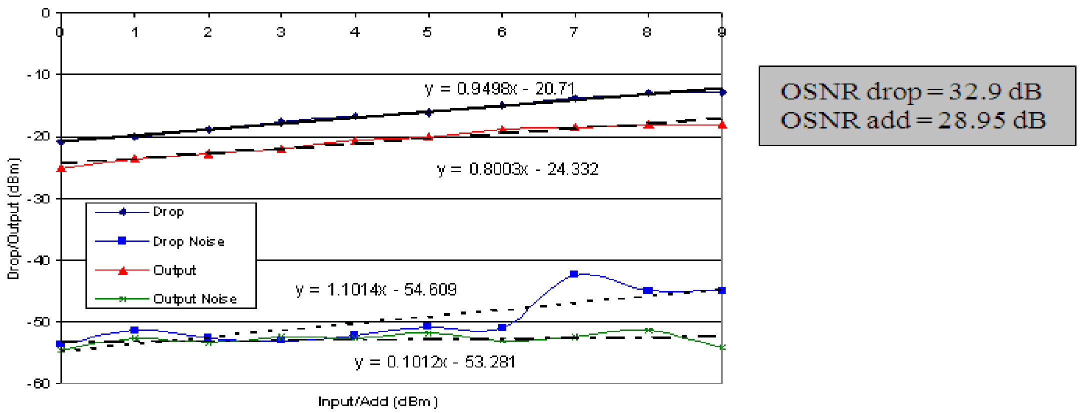

Fig. 12: The output power measured for add and drop operation.

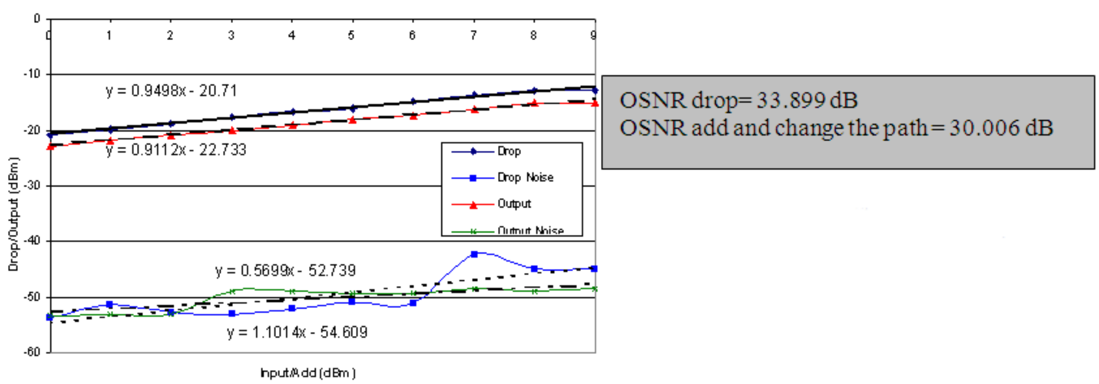

Fig. 13: The output power measured for add and drop and path exchange operation.

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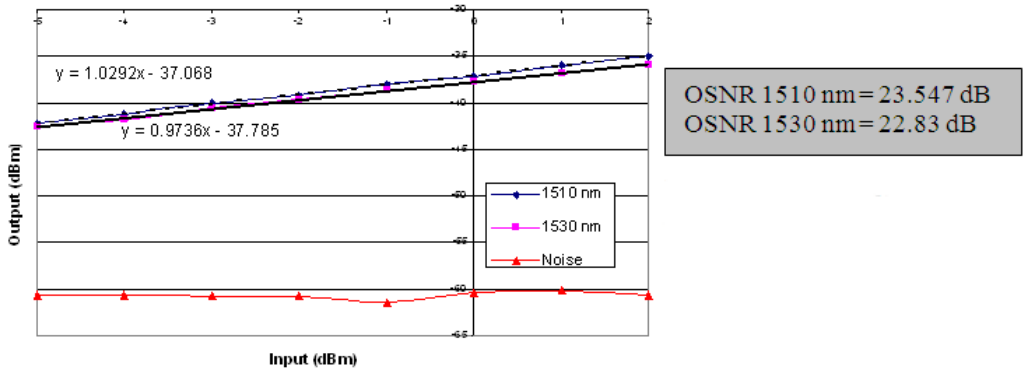


Fig. 14: The measured output power at two operating wavelength for bypass operation.

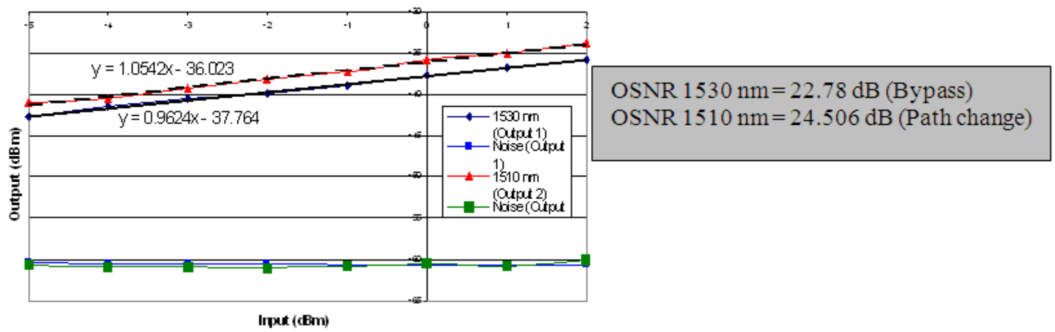


Fig. 15: The measured output power two operating wavelength for path exchange operation.

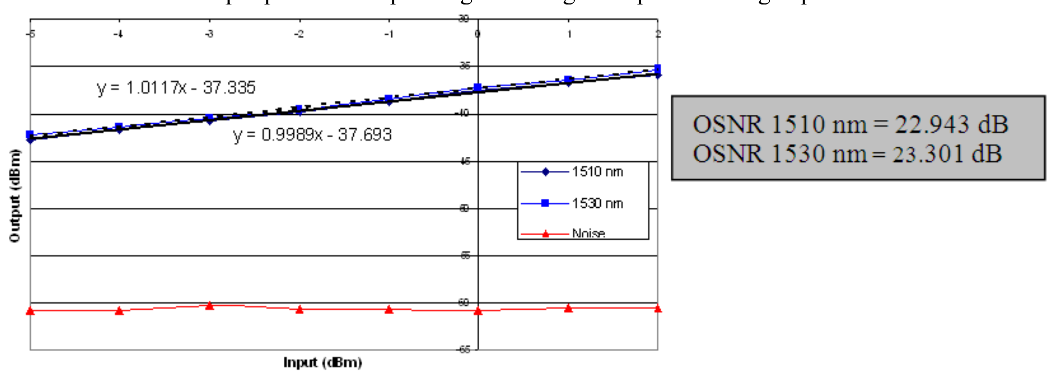
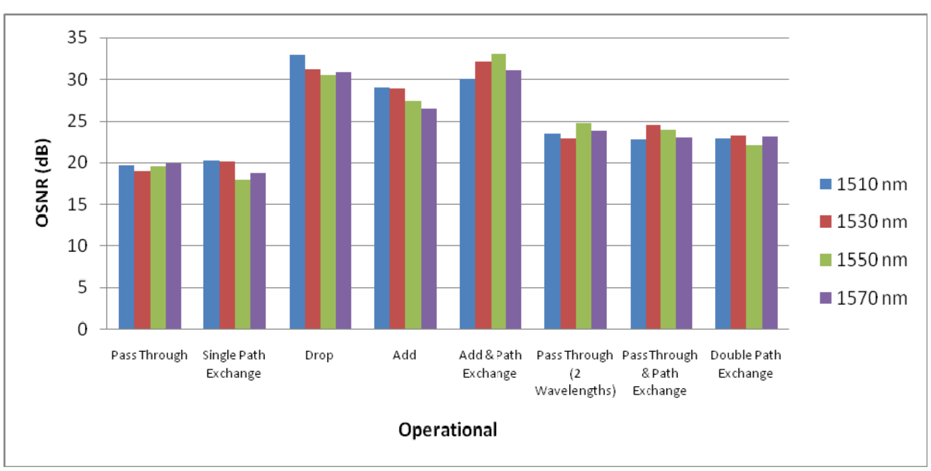


Fig. 16: The measured output power at two operating wavelength for path exchange operation.



Analytical Verification – Simulation versus Analytical”

Figure 6.2 shows a linear relationship OSNR and the distance between two nodes on a network point to 2.5 Gbps OXADM a method of simulation and analytic calculation. Reading the small deviation of 1.4 dB with the same slope (m = -0.5) shows the two characterization methods give the same measurement accuracy of OSNR reduction rate of increase in distance between two nodes is 0.25 dB / km (1510 nm, 1530 nm and 1570 nm) and 0.5 dB / km (1550 nm) by using the DCF fiber. Gain of the amplifier used is 24 dB with noise figure NF = 4 dB. Sensitivity of photodetector was set at -25 dBm. Optical power ratio of each crosstalk contribution to the signal used is, ε = 41 dB (7.9432 x 10-5).

Conclusion:

We have introduced a new switching device which utilizes the combined concepts of optical add and drop multiplexing and optical cross connect operation through the development of an optical cross add and drop multiplexer (OXADM). The experimental results show the value of crosstalk and return loss is bigger than 60 dB and 40 dB respectively. In our previous results have also shown the value of insertion loss was less than 0.06 dB under ideal condition, the maximum length that can be achieved is 94 km. While when considering the loss, 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 (M.S.A. Rahman, *et al*., 2006).

The OXADM switching mechanism has been explained and compare with other existing optical switch; directional coupler optical switch and OXC.

The OXADM optical device is particularly designed for WDM metro application. It can be used as restoration switch in FTTH network (M.S.A. Rahman, *et al*., 2006). OXADM can also work as any single device such as demultiplexer, multiplexer, OADM, OXC, WSC and WRB (M.S.A. Rahman, *et al*., 2006).

In other application, the OXADM can also provide survivability through restoration against failure by means of dedicated and shared protection that can be applied in WDM ring metropolitan network (M. S. A.Rahman, S. Shaari, 2006; M. S. A. Rahman, *et al*., 2006).

The ideal of OXADM will be realized through the Optiwave simulators (OptiSystem and BPM_Cad) and after that the designed layout is being used to produce the photomask for actual fabrication for waveguide-based OXADM (M. S. A. Rahman, S. Shaari, 2004).

References

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 and K. Ishida, 1993. Lossless and low-crosstalk characteristics in an InP-based 2x2 Optical switch, *IEEE Photonics Technology Letter*. pp: 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. New Jersey: Prentice Hall

Rahman, M.S.A., A.A. Ehsan, S. Shaari, 2006. Mesh upgraded ring in metropolitan network using OXADM, *Proceeding of the 5th International Conference on Optical Communications and Networks & the 2nd International Symposium on Advances and Trends in Fiber*.

Rahman, M.S.A., H. Husin, A.A. Ehsan, S. Shaari, 2006. Analytical modeling of optical cross add and drop multiplexing switch”, *Proceeding 2006 IEEE International Conference on Semiconductor* Electronics, pub. IEEE Malaysia Section., pp: 290-293.

Rahman, M.S.A., S. Shaari, 2004. Modeling of planar lightwave circuit OADM for CWDM”, *Proceeding 2004 Postgraduate Conferenc*. pp: 116-120.

Rahman, M.S.A., S. Shaari, 2006. OXADM restoration scheme: Approach to optical ring network protection”, *IEEE International Conference on Networks*. pp: 371-376.

Tzanakaki, A., I. Zacharopoulus, I. Tomkos, 2003. Optical add/drop multiplexers and optical cross-connects for wavelength routed network, *ICTON*. pp: 41-46.