Strictly Non-Blocking Optical Path Cross – Connect System for DWDM Wavelength Path Networks.

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Abstract: We describe the design and performances of a strictly non-blocking optical cross-connect node for WDM wavelength path networks, tested with 2 x 2 x 2.488 Gb/s, externally modulated and 200 GHz spaced WDM signals.

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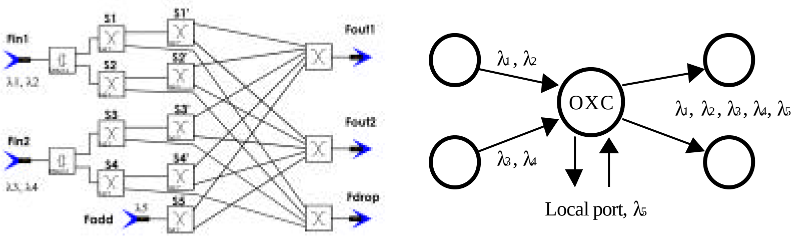
1. Introduction

The wavelength division multiplexing (WDM) technique is widely recognized as the preferred transport mechanism for the next generation of high capacity systems. WDM has a high potential to upgrade further the capacity of the existing transmission links in a cost effective way and also opens the door to new and very efficient all-optical routing schemes, replacing what is today performed using complex electronics [1,2]. All optical WDM functionality could provide an effective answer, in terms of performance and cost, to the requirements of the transport network at the transmission path layers level and may also pave the way to less hierarchical network structure [3]. In optical networks using WDM technology, an optical cross-connect (OXC) is an essential equipment, transparent to signal format the OXC allows the optical network to be re-configurable on a wavelength-to-wavelength basis, to interchange and optimize traffic patterns providing the routing function, facilitating network growth and enhancing network survivability. In its most general architecture form, a strictly non-blocking, (meaning that any set of demands can be routed through the cross-connect but any additional demands, that need to be routed, will never require the re-routing of the previously routed channels), optical cross connects with *k* input fibers and *N* wavelengths channels per fiber consist of 5 stages [4]: demultiplexing, wavelength conversion, space switching, multiplexing, and amplification. Several OXC based on these stages have been proposed, using non-blocking architectures for the space-switching matrix like: *Crossbar*, *Benes*, *Spanke-Benes* and *Spank* [5].

In this paper, we propose an architecture using 1 x 2 optical switches and based on the half *Spanke*, where the multiplexing stage of the OXC was substitute by a power coupling stage. In these way, a completely non-blocking, re-configurable and modular OXC was achieved. Figure 1a) shows the OXC scheme, with 2 input ports, each one with capacity for a WDM signal with 2 carriers separated by 200 GHz and figure 1b) presents the OXC implementation topology. The input signals can be routed to any of the 2 output ports. The OXC has also a tributary port, which allows a local add-drop functionality, for simplicity the EDFA´s placed at the output ports to compensate the OXC attenuation are not shown.



a) b)

Fig. 1. a) OXC scheme, b) network implementation topology.

The necessary time to reconfigure the OXC is related with the electrical characteristics of the mechanical-optical switch matrix, in our case, the reconfiguration time is less than 25 ms, which is acceptable for the operations of network configuration

In all-optical network, the wavelength channels are considered as a transport resource allocated to a given data stream. An end–to–end connection can be either supported by one wavelength (Wavelength Path - WP) or can physically be transported over different wavelengths through the transmission links (Virtual Wavelength Path - VWP). In the later case, the wavelength allocations are performed on a link-by-link basis and wavelength conversion must be, in principle, possible at all OXC nodes [3]. The WP technique suffers from a limitation of the network extension, flexibility, scalability and performance, imposed by the total number of wavelengths available. To cope with this limitation, the same set of available wavelengths must be reused but only on fully disjointed parts of the network. The proposed OXC architecture can provide cross-connect for both WP and VWP networks. The introduction of a wavelength conversion stage will allow the use of this OXC on a VWP network. The implemented OXC was specified for a WP network, therefore no wavelength conversion is used and it is assumed that all wavelengths present at the OXC inputs are different [6].

2. Experimental Results

To investigate the operation and system performance of this OXC, two point-to-point links with 50 (25+25) km and 45 (20+25) km of standard single mode fiber (G.652) were connected by the OXC routing node, figure 1 b). Each link transports 2 WDM signals based at the ITU grid of 200 GHz (≈ 1.6 nm) spacing with wavelengths of 1547.72 nm + 1549.32 nm and 1550.92 nm + 1552.52 nm. The signals from four distributed feedback lasers (DFB) were externally modulated, through a Ti:$LiNbO_3$ Mach-Zehnder intensity modulator, at 2.488 Gb/s (STM-16) with a non-return to zero (NRZ) 2^7-1 pseudo random bit sequence (PRBS).

Figure 2 displays the optical spectra, from back to front: signal at input port 1, input port 2, locally dropped port, output port 1 and output port 2. The high rejection to the adjacent channels (> 45 dB) of the MUX's an the high isolation (> 55 dB) of the optical switch's allow us to reduce the induced homodyne and heterodyne crosstalk.

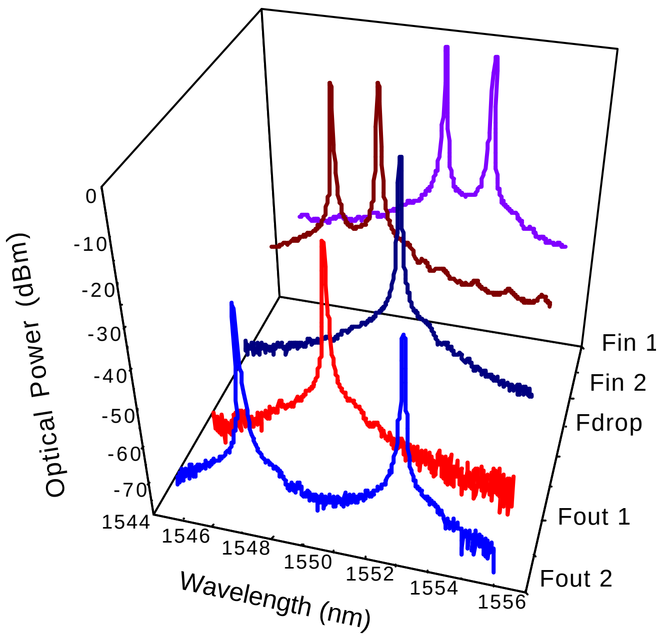
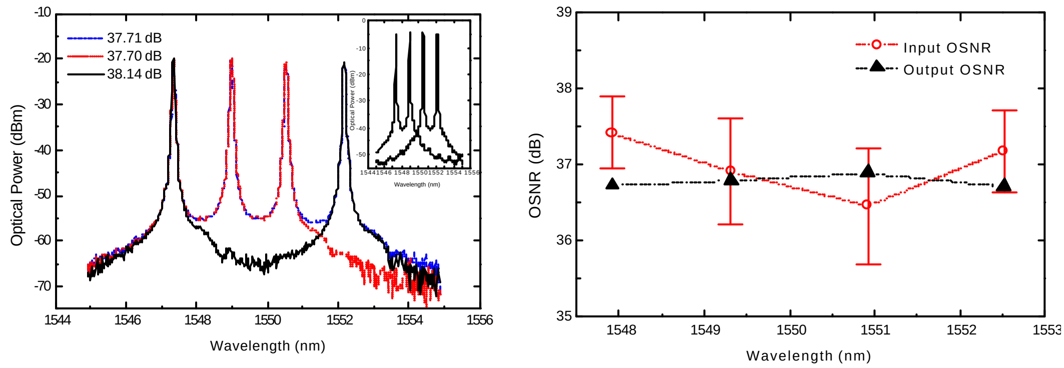


Fig. 2. Optical spectra from back to front: Input 1, input 2, output of local drop, output 1, output 2.

The number of optical components that a given WDM signal passes through determines the attenuation. Two important parameters exist here: the worst case or total attenuation and the differential attenuation between the highest loss and the lowest loss path. A high differential attenuation is more disadvantageous than a high worst-case attenuation. A high constant attenuation can be compensated with the addition of EDFA's. A high differential attenuation adversely affects the optical receiver and can reduce the SNR. The average attenuation for the port 1 is

14.96 dB with a differential attenuation value of 1.42 dB for the port 2 the attenuation is 13.13 dB, with 1.04 dB of differential attenuation. The differences between the attenuation of the two ports are due to the characteristics of the optical couplers used. The attenuation of the dropped channel is 3.51 dB with 2.29 dB of differential attenuation. The insertion losses of the locally added channel are 4.40 dB and 4.01 dB for the output port 1 and port 2, respectively.

Figure 3 a) shows the optical spectra of the output port 1, for three configurations of the OXC. The optical signal to noise ratio (OSNR) of the lowest wavelength channel is shown for the 3 configurations, the spectra at the input ports are also present. The OSNR of the commuted output channels for whole the OXC configurations was measured at a noise equivalent bandwidth of ± 100 GHz, with a 0.1 nm optical resolution. Figure 3 b) displays the average OSNR for the 4 channels and the respective standard deviation. The OSNR of the input channels is also shown.

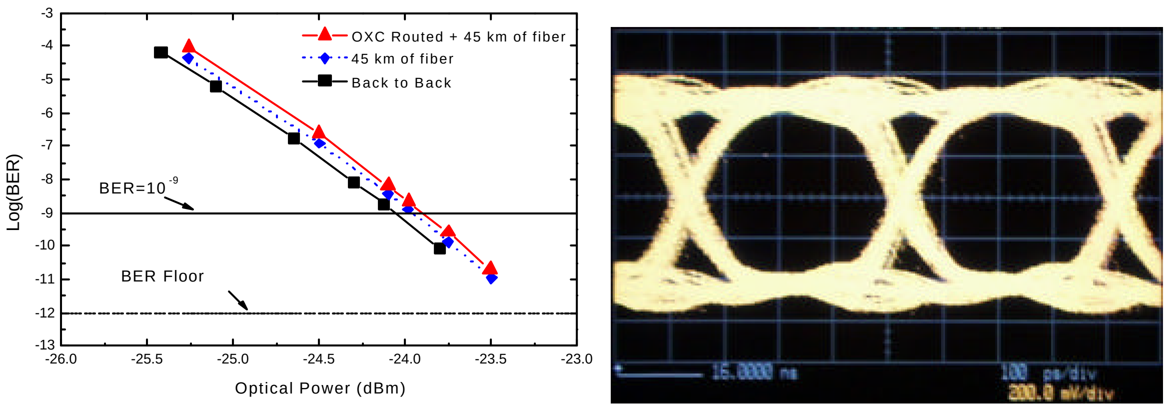


a) b)

Fig. 3. a) Output optical spectra for 3 different OXC configurations; b) OSNR for all the commuted channels.

The increased of the OSNR for the extremity channels could be explained by the MUX's spectral characteristics, and could be clearly seen in figure 3 a), all the OXC configurations for which a channel does not have a nearest neighbors will contribute for a increased of the channel OSNR.

Figure 4 a9 shows the BER of a test channel after propagation on 45 km of fiber and routed at the OXC node, the back to back and solely propagation on point to point system with the same fiber length are also display. The observed BER degradation is comparable with the experimental uncertainty. The eye diagram for the test channel for a 10^{-9} BER is show on figure 4 b).



a) b)

Fig. 4. a) BER for the test channel; b) Eye diagram for the detected test channel.

3. Conclusions

Experimental results from the relevant OXC characteristics include system attenuation, crosstalk, signal to noise ratio (SNR) degradation, optical signal to noise ratio (OSNR) degradation, bit error rate (BER degradation and configuration characteristics of the OXC will be present. The proposed architecture has a worst-case attenuation of 14.96 dB with 1.42 dB differential attenuation, and have no BER degradation due the channel routing. The experimental results are also complemented with simulation results obtain with a photonic transmission simulation package, PTDS from Virtual Photonics©.

4. References

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