Optical cross – connect routing node demonstrator 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 demonstrator for WDM wavelength path networks. The optical cross-connect (OXC) prototype was experimentally tested as an 2 x 2 WDM system with two input / output ports and two wavelengths per port. The OXC was inserted in a 95 km network with a STM-16 bit stream per channel. The performance of a single and a cascade of OXC's were simulated and the results verified against the experimental ones.

I Introduction

The increase in traffic demand associate with new applications is triggering a dramatic growth in capacity requirements for medium and long haul transport networks. Most network providers are tuning to dense wavelength division multiplexing (DWDM) to solve the capacity problem. DWDM offers the potential of an enormous increase in transmission throughput by using the very large bandwidth of optical fibres [1]. Therefore, DWDM is one of the election techniques for further upgrading the capacity of the existing transmission links in a cost effective way, opening the door to new and potentially efficient all-optical routing schemes, replacing what is nowadays performed by complex [2].

To avoid an explosion in the cost of routing function, it is essential to introduce a new all-optical layer that can handle large bit rate signals to provide provision, restoration and wavelength switches that allow routing at the wavelength level. All optical WDM functionality could provide the requirements of the transport network at the transmission path layers level and may also pave the way to less hierarchical network structure.

Archiving the goal of a multichannel path, reconfigurable all-optical network requires the employment of several enabling technologies, such as all-optical cross-connects (OXC) and optical add-drop multiplexer (OADM). Current OXC are based on electronic switch fabrics that cross-connect the incoming data on the electrical domain. However, with the emergence of WDM networks that carry large number of wavelength channels, a new level of cross-connect in the optical domain are highly desirable [3].

II Implemented OXC Architecture

Various OXC schemes have been proposed, based in two elementary switching schemes: space switching and wavelength switching. For each of these switching schemes several architectures can be used [4, 5]. It is not viable to determine the best solution for every case because this depends on the applications in case. However, it is possible to conclude that an OXC based on space switching provides better transmission performance at the expense of complete modularity [4].

The goal of this work is to investigate, implement and test a OXC architecture, based on discrete commercial available optical components and ready for immediate field integration. This node has two main functions, routing of optical paths and optical path termination. Advanced components such as all-optical wavelength converter, space switch based on clapped gain SOA integrated with DEMUX have been implemented in laboratory. However few components suitable for the practical and immediate implementation of transparent optical routing nodes are commercially available.

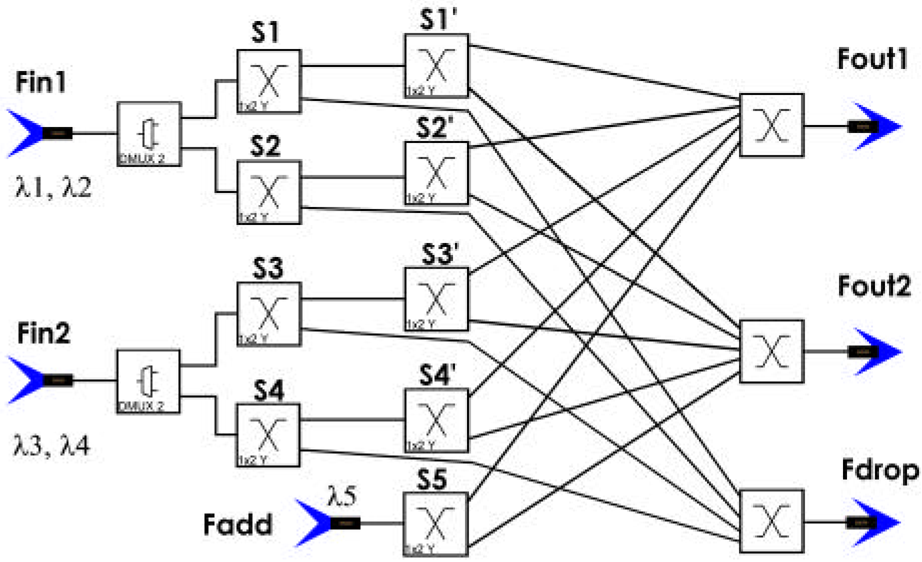


Figure 1 - Implemented OXC architecture.

The demonstrator, figure 1, have two input ports each one handling two 200 GHz DWDM channels. The input signals can be routed to any of the 2 output ports. The OXC also has a tributary port, which allows a local add-drop functionality. By definition, this node demonstrator architecture is strictly non-blocking and transparent to bit rate and data format, due to its all-optical implementation. This OXC is also link modular but isn't wavelength modular.

The reconfiguration time of 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 sufficient for operations of network configuration and restoration [6].

In all-optical networks, 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 latter case, the wavelength allocations are performed on a link-by-link basis and wavelength conversion must be, in principle, possible at all OXC nodes. The WP technique suffers from a limitation of the network extension, flexibility, scalability and performance, imposed by the total number of wavelengths available. The proposed OXC architecture can provide cross-connect for both WP and VWP networks, since the introduction of a wavelength conversion stage will allow it's use on a VWP network. The implemented OXC was specified for a WP network, therefore no wavelength conversion is used and is assumed that all the existing wavelengths were different.

The performance of the prototype was accessed by the measurements of relevant characteristics such as: configuration capacity, insertion loss and differential insertion losses, optical signal to noise ratio degradation and by the measurement of the channels bit error rate (BER) degradation when the OXC was inserted in an optical network test-bed.

III OXC Test

In our prototype, the average insertion losses, measured before the output EDFA's, of all the input channels to the output 1 and 2 are 14.9 dB and 13.1 dB, respectively (these differences are due to the use of deferent's types of passive optical couplers), with a differential insertion losses of 1.0 dB and 1.2 dB for output 1 and 2, respectively. The insertion loss for the local tributary port is 4.5 dB.

The optical signal-to-noise ratio (OSNR) could be used as a WDM channel quality monitoring [7], since the OSNR is simple to measure and has been suggested as adequate for BER specification [8, 9]. The OSNR degradation due to the OXC commutations was measured using a 12.5 GHz resolution of the optical spectrum analysed. The input OSNR of channels 1 to 4 (1552.52 nm, 1550.92 nm, 1549.32 nm and 1547.72 nm) was 36.7 dB, 36.9 dB, 36.8 dB and 36.8 dB, respectively. The average output OSNR (before the EDFA's) for all the possible routing configurations of the four channels was 37.2 dB, 36.5 dB, 36.9 dB and 37.4 dB with standard deviations of 1.1 dB, 1.5 dB, 1.4 dB and 1.0 dB, respectively, indicate a small OSNR degradation, within in the experimental uncertainty, these results are displayed in figure 2.

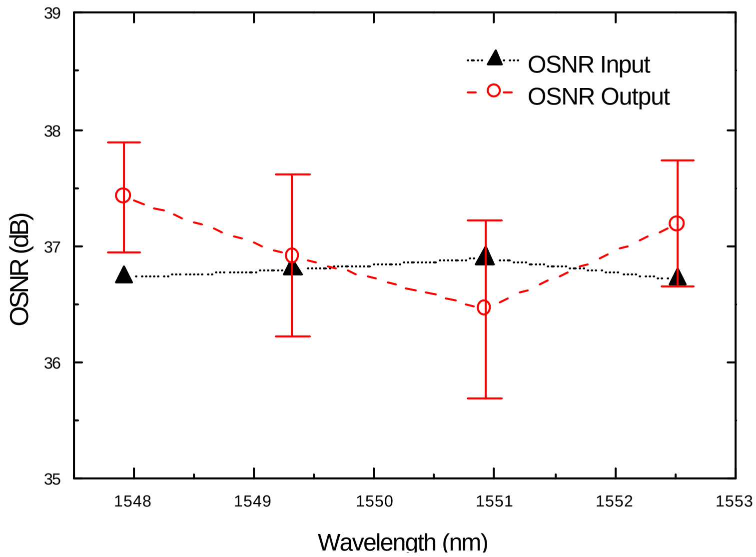


Figure 2 - OSNR Degradation due to OXC commutation.

To investigate the operation and system performance of this OXC, two point-to-point links with 25 km + 25 km and 20 km + 25 km of standard single mode fibre (G.652), were connected by the OXC routing node, figure 3.

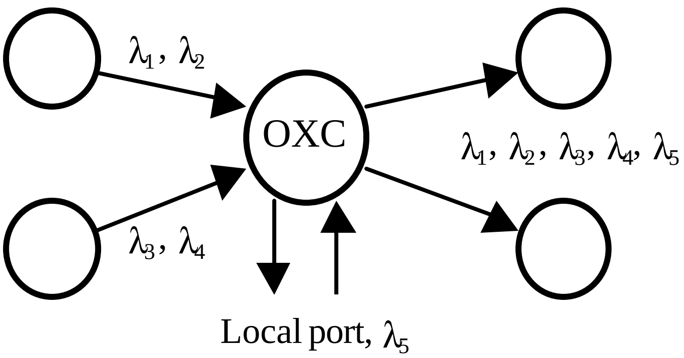


Figure 3 - Network scheme.

Each link transports 2 DWDM signal from four distributed feedback lasers (DFB), with a 50 MHz linewidth, externally modulated, through a Mach-Zehnder intensity modulator, at 2.48832 Gb/s (STM-16) with a non-return to zero (NRZ) 2^{15}–1 pseudo random bit sequence, resulting in a 13 dB extinction ratio optical pulse stream. The OXC local add channel could have any wavelength in the ITU frequency grid. After propagation on 25 km of the G.652 fibre the channels from input 2 were routed at the OXC to output 1 and propagated over 20 km. The performance of our network is assessed by the measurements of the bit error rate (BER) on channel 1 against the receiver power. Figure 4 show the optical spectrum at the receiver of the commuted test channel and figure 5 shows the BER performance, for the back-to-back operation (0 km), for the mid span routed channel on the OXC and for the same channel after just propagation on 45 km of fibre (without being routed on the OXC).

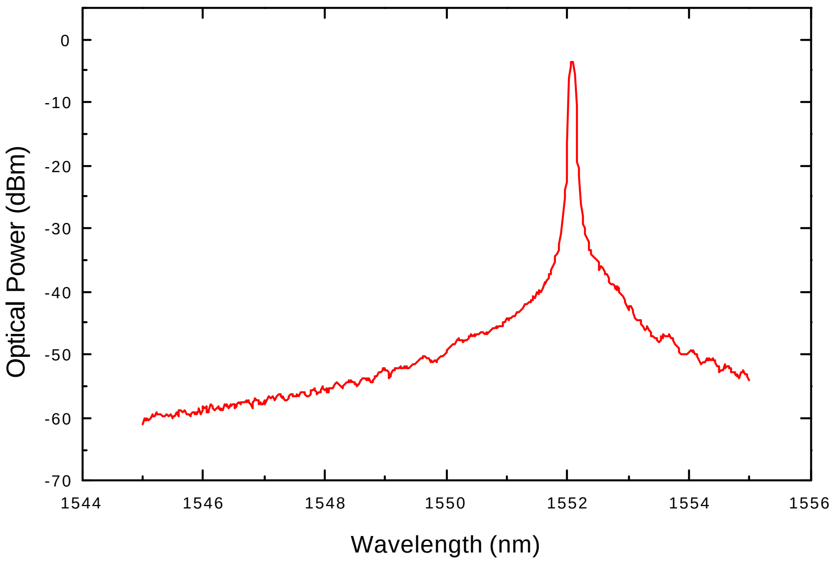


Figure 4 - Optical spectrum at the receiver.

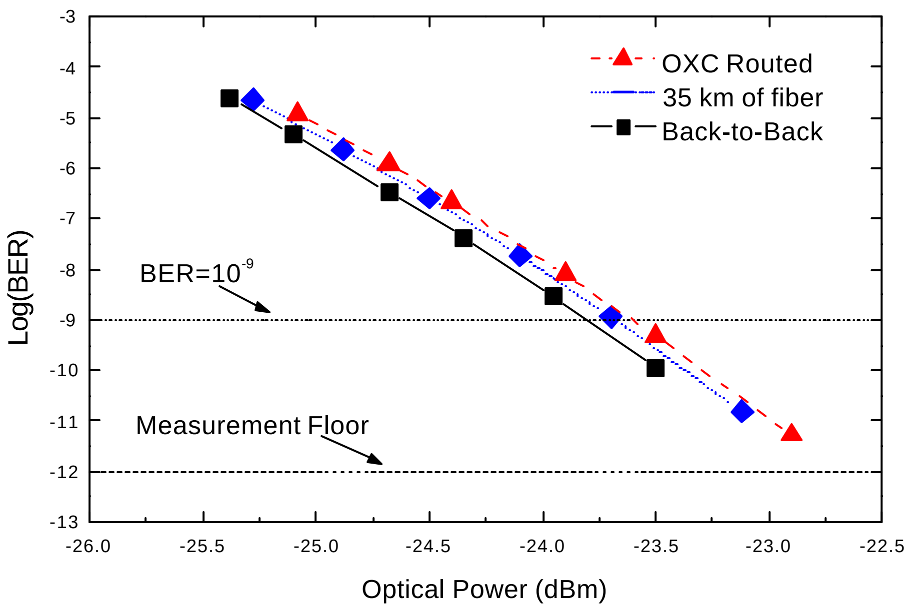


Figure 5 - BER performance for the channel 1 routed at the OXC.

The power penalty measured at a 10^{-9} BER is less than 0.1 dB, which indicate no performance degradation due to OXC routing (within the measurement uncertainty). The measurement floor (experimental measurement limit) and the 10^{-9} BER are also indicated.

IV Simulation

The experimental implemented network was simulated in a commercial photonic transmission simulation tool, *VPI Transmission Maker*Ó [10].

The objectives of the simulation were the assessment the experimental network performance by comparison with the simulation results and to verify the cascadability of the OXC. Figure 3 presents the eye diagram optical power for the channel 1 after the cascading of 30 OXC nodes. To assure that the network performance degradation was only originated by the crosstalk and by the amplified spontaneous emission (ASE) noise, the fibre segments between the cascade OXC were replaced by passive attenuators with a loss equivalent to 50 km of fibre (10 dB).

The channel 1power penalty for a 10^{-12} BER was 1.4 dB when a total of 30 nodes were cascade, figure 6. This penalty due to crosstalk and ASE noise accumulation is small, when compared with other architectures [5], due to the high isolation and low crosstalk of the used optical components and to the low noise figure of the EDFA's (4.0 dB).

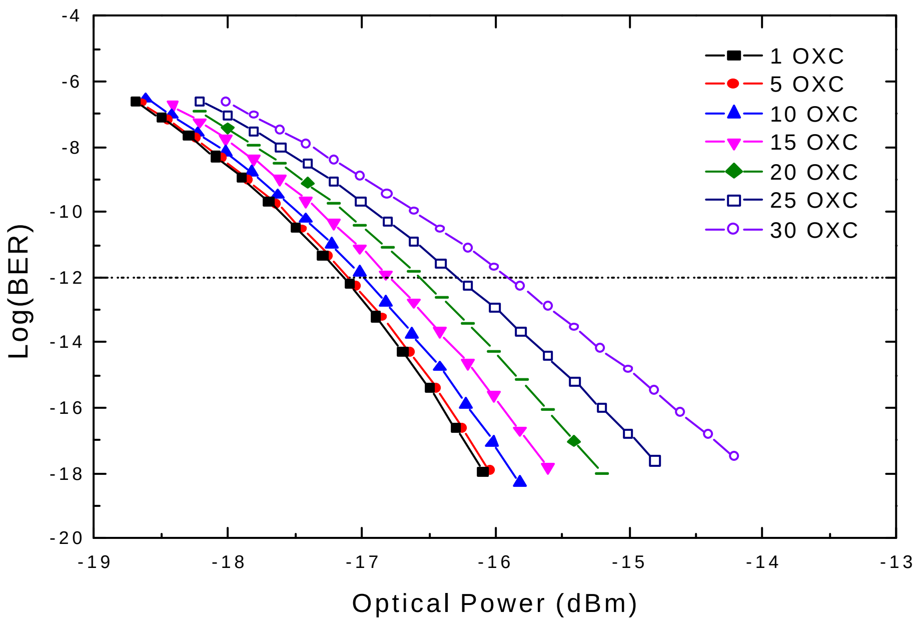
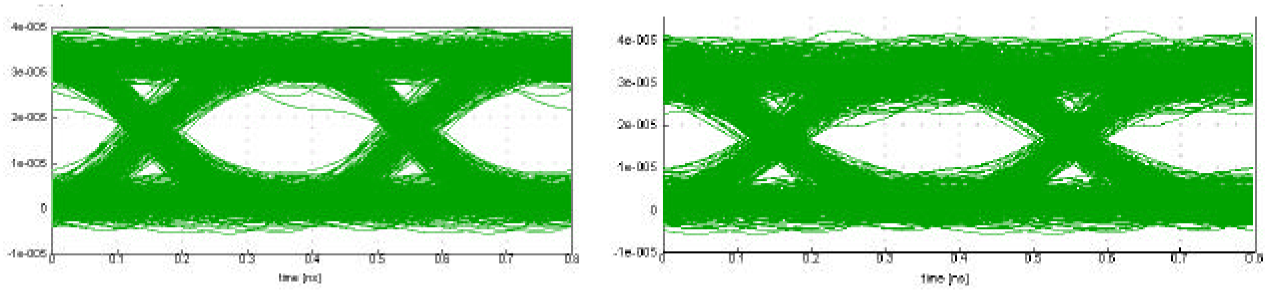


Figure 6 - BER performance of one channel after cascading on several OXC.

Figure 7 a) and b) show the channel 1 detected eye diagram of the test channel after 1 and 30 OXC, respectively.



a) b)

Figure 7 - Eye diagram of: a) 1 OXC, b) 30 OXC.

The simulate eye confirm the small signal degradation due to the routing on the OXC.

V Conclusions

These work describes the design, implementation and performances of a strictly non-blocking optical cross-connect demonstrator node, based on a half *Spanke* switching matrix and passive optical coupler for DWDM wavelength path networks. The OXC prototype was experimentally tested at an 2 x 2 WDM. The proposed node was inserted in a network with a transmission length of 95 km and a STM-16 bit stream per channel. The performance of a single and a cascade of OXC's were simulated and the results verified against the experimental ones.

These results point to the feasibility, cascadability and compatibility with significant transmission distances of the proposed OXC architecture. All-optical layer could be implemented, and can provide management and restoration capability beyond the electrical layer, using commercial available optical components at a low implementation cost and for immediate field implementation.

Acknowledgements

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