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A Novel Dynamic Wavelength Cross-connect Based on Mach-Zehnder Interferometer Optical add/drop Multiplexer and Optical Space Switch

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I. Introduction:

Wavelength Cross-connect (WXC) is one of the key components in future all-optical wavelength division multiplexing (WDM) networks [1]. WXC reduces congestion in cross-connect nodes, enhances the survivability of WDM networks, makes WDM networks be reconfigured and expanded easily. Recently, a dynamic WXC based on fiber grating and optical space switch is proposed [2][3]. However, in this structure, the differential insert loss (DIL) for different paths in the WXC limits it to be used in WDM networks.

In this paper, a novel dynamic WXC structure employing optical space switch (OSW) and Bragg grating based Mach-Zehnder interferometer (MZI) optical add/drop Multiplexer (OADM) is proposed. In this structure, the DIL of different paths will not limit the scalability and cascading of the WXC in WDM networks with large number of wavelengths. Furthermore, the exchanging units used in the dynamic WXC are reduced by one half, compared to Ref. [3]. Since no circulator is needed in this structure, the WXC can be integrated. In experiment, the path with maximum number of OADMs in a dynamic 2x2 WXC capable of exchanging five wavelengths is tested and shows high performance.

II. Structure of the WXC:

Using a cascaded MZI-OADM with different central wavelength (meeting the ITU WDM standardisation), a static 2x2 WXC is realized, as shown in Fig. 1. In the static 2x2 WXC, each input wavelength will be exchanged by the OADM with the same central wavelength, and pass all other OADMs. Since each wavelength is exchanged once at most, the maximum DIL of all wavelengths into the 2x2 static WXC is the DIL between the dropped and the passed wavelengths in one OADM, no matter how many OADMs are cascaded. This remarkable feature makes the structure can be expanded to large dimensions. For presently used OADMs, the DIL between intra-band and out-band wavelength is less than 0.2dB.

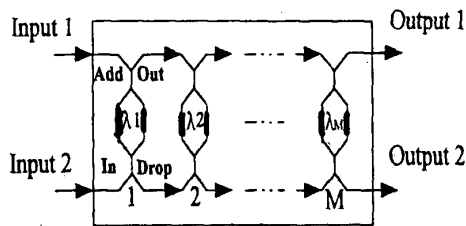


Fig. 1 Static 2x2 WXC.

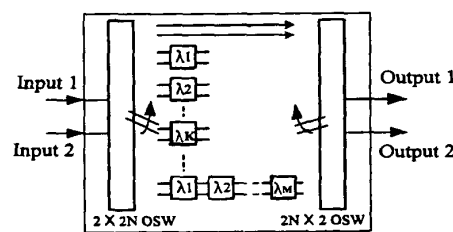


Fig. 2 Dynamic 2x2 WXC.

Using N pieces of 2x2 static WXC with different stages and two 2x2N OSW, a 2x2 dynamic WXC is realized, as shown in Fig. 2. Switching the OSW to proper position, any of wavelengths in the two input fibers can be exchanged. Assuming K wavelengths in each fiber, if all the K wavelengths need to be exchanged, it can be realized by switching the two fibres. The two direct paths in Fig.2 are designed for this situation. If $K-1$ wavelengths need to be exchanged, and assuming λ_1 need not to be exchanged, the left OSW will switch the two input fiber to the input port of the 2x2 static WXC unit which exchanges λ_1 . At the output of the 2x2 static WXC unit, the right OSW will switch the output signal to finish the requirement. So, only one OADM is needed for exchanging $K-1$ wavelengths, two OADMs are needed for exchanging $K-2$ wavelengths. In the 2x2 WXC dynamic WXC, if K is odd, the maximum number of cascaded OADMs in the largest 2x2 static WXC units is $(K-1)/2$, if K is even, the maximum number is $K/2$. The number of 2x2 static WXC units needed is:

$$N = (C_K^0 + C_K^1 + C_K^2 + \dots + C_K^K) / 2$$

The number of the exchanging units needed in the 2x2 WXC dynamic WXC is reduced by one half compared to Ref. [3]. Using less exchanging units is good for reducing the crosstalk in the WXC. Because no circulator is used, the device can be integrated.

As mentioned above, the DIL of the different wavelengths in each 2×2 static WXC unit is equal, corresponding attenuators can be added after each 2×2 static WXC unit to balance the loss of different paths in the 2×2 dynamic WXC. Based on 2×2 dynamic WXC, a rearrangeably nonblocking $K \times K$ WXC can be formed using classical method [4]. Assuming the DIL between the dropped and the passed wavelengths in an OADM is 0.2dB, for a 128×128 dynamic WXC based on this scheme, the maximum DIL in all paths is only 2.6dB. So, the DIL will not limit the scalability and the cascading of this kind of WXC in WDM networks with large number of wavelengths.

III. Experimental setup and results:

To investigate the feasibility of this kind of dynamic WXC, a path with the maximum number of OADMs in a 2×2 dynamic WXC capable of exchanging five wavelengths is tested, by using two cascaded fiber grating based MZI-OADMs. Because the OSW does not deteriorate the WXC (the crosstalk of the commercial OSW can reach -75 dB), the OSW is replaced by a fixed connection. Fig.3 shows the experiment setup. Three DFB lasers with wavelengths 1552.4nm (λ_1), 1555.6nm (λ_2) and 1558.8nm (λ_3) are used. After multiplexed and then amplified by EDFA1, the three channels are modulated together by a LN modulator with a $2^{11}-1$ NRZ pseudorandom bit sequence at 10Gb/s. Then, it is amplified again by EDFA2, and divided into two paths by the coupler. One of them is delayed by 1km dispersion-shifted fibre. The two paths of WDM signal are injected into the WXC. In the WXC, λ_3 is exchanged by the OADM with central wavelength 1558.8nm and passes through the OADM with central wavelength 1555.6nm. λ_2 is exchanged by the OADM with central wavelength 1555.6nm and pass through the OADM with central wavelength 1558.8 nm. λ_1 passes through the two OADMs. After demultiplexed, the bit error rate (BER) of the three channels is detected. Fig.4 shows the BER of the three channels. λ_1 and λ_3 show the negligible power penalty 0.2dB, λ_2 shows 0.3 dB power penalty at BER of 10^{-9} . The system operation and performance confirm the feasibility of the novel structure WXC.

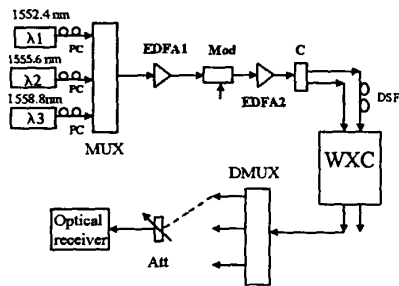


Fig. 3 Experimental setup.

C: Coupler, Att: Attenuator, PC: Polarisation Controller, DSF: Dispersion Shifted Fiber.

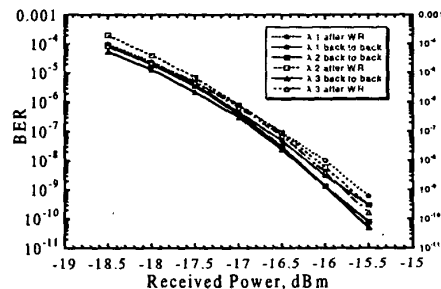


Fig. 4 BER performance of the three channels for back-to-back and after the WXC at 10Gb/s.

Besides scalability of the WXC and using less switch units, there are other important features for the WXC with potentially low crosstalk and the ability to be integrated.

IV. Conclusion:

We have proposed a novel dynamic WXC based on MZI-OADM. The advantages of this dynamic WXC are very low DIL, using less exchanging units than reported structure, and the ability to be integrated. In experiment, the three channels from the path with maximum OADMs in a 2×2 dynamic WXC capable of exchanging five wavelengths show negligible power penalty at BER of 10^{-9} . The above advantages make this kind of dynamic WXC very promising for the future WDM networks.

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