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Novel Bidirectional Optical Cross Connect by Using Reversible Optical Switches Together with Optical Circulators in WDM Networks

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Abstract: A novel bidirectional optical cross connect by using reversible optical switches together with optical circulators in WDM network is proposed in this study. This study reduced the complexity of the optical cross connects.

Key words: Bidirectional optical cross connect, reversible optical switches, optical circulators

INTRODUCTION

Bidirectional Wavelength Division Multiplexing (WDM) ring networks have attracted much attention and have been widely studied in that they offer a cost-effective network topology with self-healing capability for Metropolitan Area Networks (MANs) (Kim *et al*., 2001). As the wavelength-count and fiber-count increase rapidly in WDM networks, high port count optical switch matrix in needed. Generally a large switch matrix can be built by smaller available constituent switches as exemplified by the well known Bense and Clos architectures. WDM networks are wavelength routed and generally show bidirectional symmetry in end to end wavelength connections (Simmons and Saleh, 1998). By exploiting this symmetry, the complexity of the switch Matrix and OXC can be reduced (Simmons and Saleh, 1998; Kim, 2000; Yuan and Hu, 2004). In this study, such a bidirectional OXC is denoted as BOXC while a conventional unidirectional OXC is referred to as UOXC.

A class of BOXCs based on tunable fiber Bragg gratings, AWGs and 3 or multi-port Optical Circulators (OCs) were reported in Kim (2000) and Yuan and Hu (2004). However, the number of wavelengths that can be supported by them is rather limited, e.g., much less than 160. Simons and Saleh (1998) reported another BOXC which achieved N×N cross connects by using N/2×N/2 switches. However, the optical switches have to be bidirectional cross connected, in which each mirror is designed to reflect two light beams, as opposed to a single light beam. As a result, the mirrors would be enlarged in area and collimators be double in number.

In this study, we propose and demonstrate a novel BOXC by using Reversible Optical Switches (ROSs) together with Ocs. This study reduces the complexity and implementation cost as compared to other existing approaches, since it uses some conventional optical switches as reversible optical switches. The feasibility and performance are investigated experimentally as well.

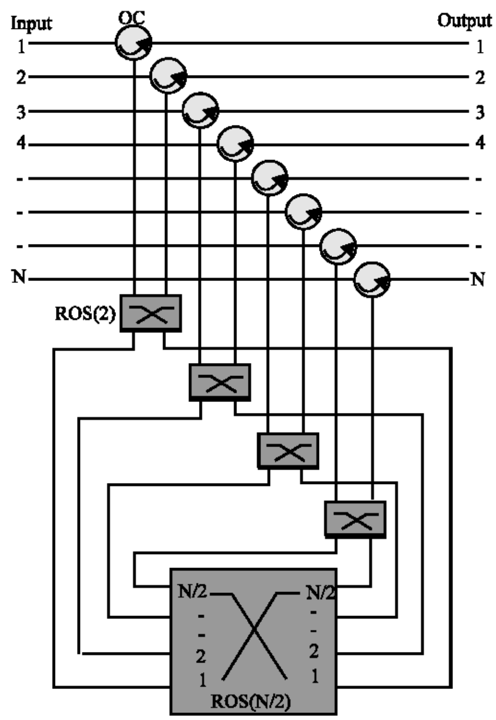

Fig. 1: Proposed N*N BOXC architecture

Proposed approach: The reversibility in optical domain allows a ray be reflected and traverse back exactly through the incoming path (Ditteon, 1998). The opto-mechanical switches and MEMS optical switches work on the basis of light ray principle and are reversible in optical path. As a result, they would work bidirectionally, i.e., a pairs of reverse lights goes in the same path. Therefore, they can be used as a BOXC.

Figure 1 shows the proposed generic BOXC architecture. One N/2×N/2 and N/2 2×2 ROSs are used, which are labeled as ROS(N/2) and ROS(2) respectively, for simplicity in the following part. Totally N three-port OCs are equipped to pass N input and N output light paths separately. According to the principle discussed in (Kim *et al.*, 2001) the proposed approach in Fig.1 has the property of N×N cross connects in re-arrange ably non blocking manner. Taking input x_i to output y_i for example, the cross connect operation is described as follows. Input signal comes into the x_i OC and is subsequently fed into the pROS(2), where p = integer [(x_i+1)/2]. Then one of the following two cases is encountered:

The p ROS(2) in bar state passes the signal to the left port p of ORC(N/2), which switches the signal to its right port q, where q= integer [(y_i+1)/2]. Next, the signal is sent back to q ROS(2), then to y_i OC and finally to output y_i, where the q ROS(2) is in cross state if y_i is odd and in bar state if y_i is even.

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Conversely and symmetrically input y_i is simultaneously switched to output x_i since both ROS(2) and ROS(N/2) transmit lights bidirectionally. Our proposed BOXC achieved the same functionality as the one reported (Kim *et al.*, 2001). However, our approach reduces the complexity and cost. More important, our approach can be implemented using currently available optical switches without redesigning.

ARCHETYPE AND EXPERIMENT

A archetype is set up to validate the feasibility, functionality and performance of the proposed BOXC. The experimental set up is shown in Fig. 2, which is comprise of four three-port OCs and three ROSs, which are conventional optical switches of mechanical technique (Ditteon, 1998). Four wavelength channels from 1549 to 1552 nm with channel spacing of 100 GHz are combined by an optical coupler. The combined signals are modulated by a 10 Gb/s NRZ signal with PRBS word length of 2^{23}-1. The modulated signals are de-multiplexed by an AWG into four individual signals before they are launched into the BOXC.

Two cases are comparatively studied in the experiment. One is that the four wavelength channels are

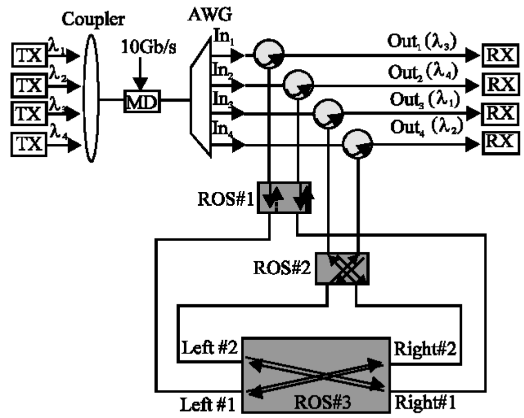

Fig. 2: Experimental set up of the proposed BOXC

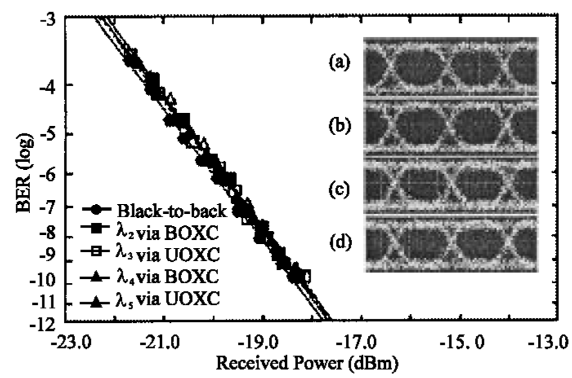

Fig. 3: Measured BER and eye diagram

switched in bidirectional pairs. For example, two pairs are set up in ROS #3 between the left #1 and right #2 and between left #2 and right #1, respectively, as shown in Fig. 2 the other is in normal UOXC and four unidirectional cross connections are set up.

RESULTS

The measured BER and eye diagram of the four channels are shown in Fig. 3. It is clearly seen that all the wavelength channels exhibit clear eye openings. The average receiver sensitivities of the optical paths in both BOXC and UOXC at BER of 10^{-9} are about -18 dBm. No error flow is observed. The experimental results have verified the feasibility of the proposed BOXC architecture and shown no power penalty.

CONCLUSION

We have proposed a novel BOXC approach with reduced complexity by using ROSs and OCs. Both analytic and experimental results have shown that conventional optical switches of mechanical and MEMS technique can be employed as ROSs due to the reversibility of optical paths. In comparison with the normal UOXC, the proposed BOXC achieves the same BER level and eye diagrams without power penalty.

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