Fiber Bragg Gratings Based Multiwavelength Cross-Connect with High Dynamic Range

Shien-Kuei Liaw, Keang-Po Ho*, Lian-Kuan Chen*, Frank Tong*, and Sien Chi

Institute of Electro-Optical Engineering, National Chiao-Tung University, Hsin-Chu 300, Taiwan.
*Dept. of Information Engineering, The Chinese Univ. of Hong Kong, Shatin, N.T., Hong Kong.

Multiwavelength cross-connect (MXC) is an essential component for wavelength-division-multiplexing (WDM) networks [1]. The primary function of MXC is to reconfigure the channel routing of the optical network for different traffic pattern, to reduce congestion, to facilitate network growth, to enhance network survivability, etc. Fig. 1(a) shows the schematic of conventional reconfigurable 2x2 MXC device. Space division switches are used between WDM multiplexer/demultiplexer pair to select, interchange, and rearrange WDM channels [2-3]. The architecture is expensive and complicated due to the requirement of many space division switches. Recently, a dynamic wavelength-selective MXC device comprising the reflective fiber Bragg Gratings (FBGs) and optical switches (OSW) was proposed [4]. In this paper, extending previous results, the MXC device is integrated with optical limiting amplifiers (OLAs) to provide high dynamic range. The MXC device is also demonstrated for a 2.5 Gb/s x 2 100-km system.

Fig. 1(b) shows the schematic diagram of the proposed 2x2 MXC device. Big MXC can use the device in Fig. 1(b) as building block. There are two input ports of I1 and I2 as well as two output ports of O1 and O2 in the MXC device. These two input ports can operate in the same direction or opposite direction (i.e., bi-directional) only by rearranging the lower 3-port (number 1, 2 and 3) optical circulator (OC) in clockwise or count-clockwise direction. The MXC device also consists of N numbers of cross-connect (XC) units and two sets of bidirectional EDFAs (Bi-EDFAs). Each XC unit has one OSW and one FBG_i (i =1, 2... N). The FBG_i is designed to match to the WDM-channel signal of λ_i (or λ_i') transmitted in the upper or lower fiber link. Without wavelength interchange, all OSWs are in the bar-state and the FBGs reflect all wavelength channels back to the port 3 of the corresponding OC. All wavelength channels are passing-through channel. If wavelength interchange is required, for example, the exchange of λ_1, λ_1' and λ_N, λ_N', the OSWs corresponding to FBG_1 and FBG_N can be switched to cross-state. All wavelengths of λ_1, λ_1', λ_N, λ_N' will pass through the chain of XC units and exchange to another port (I1 to O2, I2 to O1). The WDM channels other than λ_1, λ_1', λ_N, λ_N' are still reflected by FBGs and passing through from I1 to O1, I2 to O2, respectively. Even if λ_1 and λ_1', for example, appear simultaneously, because the interaction distance is very short, as long as other reflections are eliminated, Rayleigh backscattering does not provide any degradation. All WDM channels pass through Bi-EDFA twice. The passing-through channels are amplified by the same Bi-EDFA twice in different direction and the cross-connect channels are amplified at both Bi-EDFAs once. In both cases, the Bi-EDFAs function as optical power limiting amplifiers (OLAs) to improve the input power dynamic range and increase the link budget. Pumped laser can be shared by the Bi-EDFAs for cost saving. In the above implementation of the MXC device, all passing-through channels are reflected by the corresponding FBGs. In another implementation, the label of O1 and O2 can be interchanged and all passing-through channels do not interacted with the corresponding FBG.

The functionality of the MXC device is demonstrated using the experimental setup in Fig. 2. The MXC of Fig. 2 includes two XC units for feasibility study. Two tunable laser sources (TLS1 and TLS2) with the central wavelengths of 1552.8 and 1557.1 nm are connected to a 50/50 directional coupler and then external modulated by a modulator with 2.5-Gb/s $2^{23}-1$ PRBS sequence. The FBG1 and FBG2 have reflective central wavelengths matched to those of TLS1 and TLS2, a 3-dB bandwidth of 0.25 nm, and a reflectivity of 99.9%. Fig. 3 shows that the input dynamic range for the OLAs in the MXC device is over 20 dB for both dual-pass Bi-EDFA and two-cascading Bi-EDFAs amplifying schemes. The characteristic of a conventional EDFA, as used in Fig. 1 (a), was also measured for comparison. Fig. 4 shows the bit error rate (BER) performance as a function of received optical power for the baseline (0-km), cross-connect (100-km) at 1557.1 nm and passing-through (100-km) at 1552.8 nm with power penalty of 0.6 and 1.0 dB, respectively. The power penalty of cross-connect signal may be due to the accumulation of amplified stimulated emission (ASE) and the power-penalty of passing-through signal may be due to the reflections of ASE and amplified signals at those FC/PC connection ports between each Bi-EDFAs and FBGs. The study for further reducing the power penalty is undergoing.

In summary, a MXC device based on FBGs with integrated OLAs is investigated. High input dynamic range and small power penalty for 2.5-Gb/s x 2 100-km fiber transmission are demonstrated for the feasibility study. The MXC device has low insertion loss, no spectral depending, high dynamic range, simple structure and low cost and expandable to larger size with little modification. The MXC device can also provide more reconfiguration flexibility and enhance network survivability.

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References

1. A. F. Elrefaie *et. al., IEEE Photon. Technol. Lett.,* vol. 5, no. 9, pp. 1026–1028, 1993.
2. O. Ishida *et. al., IEEE Photon. Technol. Lett.,* vol. 6, pp. 1219-1221. 1994.
3. K. W. Cheng *et. al., IEEE J. Select. Areas Commun.,* vol. 8, pp. 1015-1025, 1990.
4. S-.K. Liaw *et. al., CLEO'98* paper CWT4, San Francisco, CA, 1998.

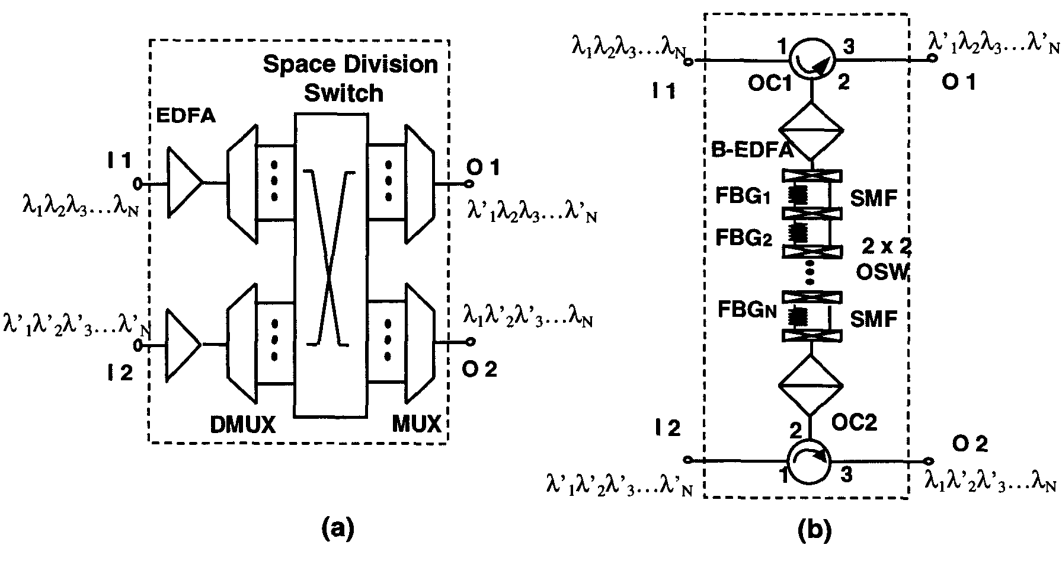


Figure 1. Schematic diagrams of (a) the conventional 2x2 MXC device, (b) the proposed FBG based MXC device. OC: optical circulator. FBG$_i$: fiber Bragg grating i. SMF: single-mode fiber. B-EDFA: bidirectional EDFA. OSW: optical switch.

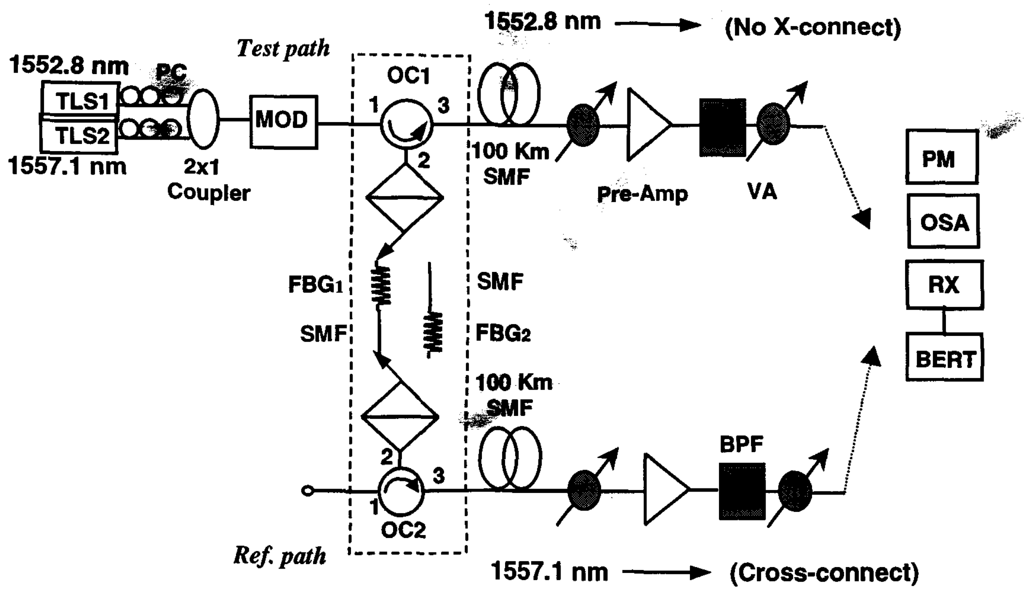
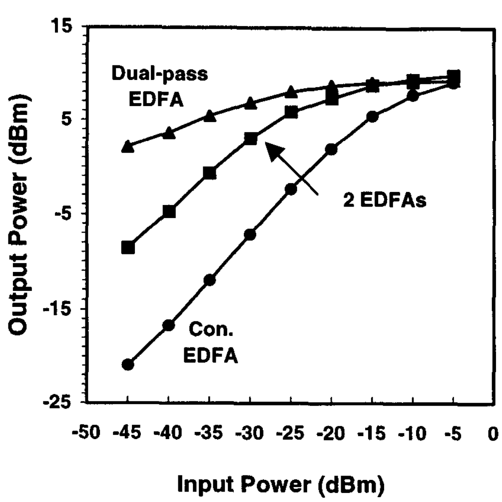


Figure 2. Experimental setup: TLS: tunable laser source. MOD: 2.5-G/s external modulator. VA: variable optical attenuator. BPF: optical bandpass filter. BERT: bit-error-rate test set.



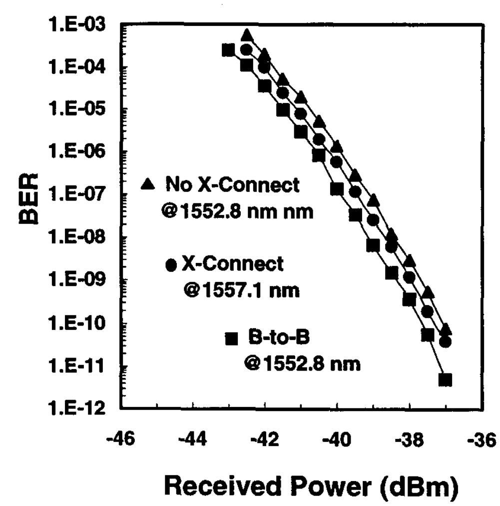


Figure 3. Output power versus input power for the dual-pass Bi-EDFA, two cascading EDFAs and the conventional EDFA amplification schemes, respectively.

Figure 4. Measured BER performance of the back to back, cross-connect (100km) and passing-through (100 km) signals for the MXC device.