Multichannel add/drop and cross-connect using fibre Bragg gratings and optical switches

Shien-Kuei Liaw, Keang-Po Ho and Sien Chi

A dynamically selective wavelength add/drop multiplexer (WADM) and a multiwavelength cross-connect (M-XC) configuration for dense wavelength division multiplexed networks are proposed. Multiple channels add/drop and/or cross-connect can be realised according to the control of the optical switches and fibre Bragg gratings arrangement. The selective WADM and M-XC devices could provide more reconfigurable flexibility and survivability in WDM networks.

Introduction: Recently, significant research efforts have been devoted to the design of high-capacity, flexible, reliable and transparent multiwavelength optical networks [1, 2]. Wavelength add/drop multiplexer (WADM) and multiwavelength cross-connect (M-XC) switches will play key roles in future optical dense wavelength division multiplexing (WDM) networks. The WADM is used for selectively dropping and inserting optical signals into the WDM network. It can reduce the processing load and latency in intermediate nodes by handling through-traffic. The closed related M-XC is configurable on a link-by-link basis to allow optimisation of capacity allocation, management, and scalability of network size, especially in a reconfigurable ring topology.

Conventional optical WADMs usually consist of a $1 \times N$ demultiplexer (DMUX) followed by an $N \times 1$ multiplexer (MUX). A certain channel is dropped and/or added at each WADM unit according to a specific add-drop plan [3]. A wavelength selective (i.e. rearrangable) M-XC can be implemented by adding a space division switch in between a WDM MUX/DMUX pair to select wavelengths and rearrange them in the spatial domain. This approach seems not to be very practical because the cost and noise associated with the optoelectronic repeater stages will make it difficult to construct a suitable electronic switch [4]. Recently, two system experiments for one-channel selective add-drop [5] and two-channel cross-connect [6] from trunk lines carrying several signals, by integrating some reflective fibre Bragg gratings (FBGs) with optical switches (OSWs), were demonstrated. Though another WADM configuration based on FBGs and OSWs for simultaneous multiple wavelength add/drop via an FBG chain was also proposed [7], it seems less practical since the inclusion of multiple gratings would require an extra DMUX in the drop port and an extra MUX in the add port. In this Letter, we propose a WADM and M-XC configuration for simultaneous multiple wavelengths add-drop and cross-connect, respectively, by using FBGs, optical circulators (OCs) and OSWs.

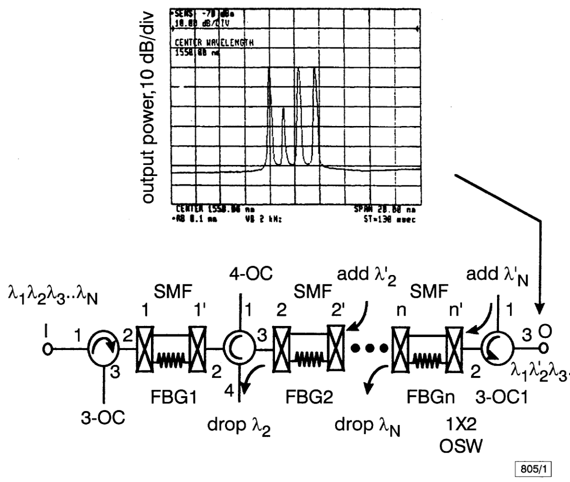

Fig. 1 *Schematic diagram of proposed WADM configuration using optical circulators, optical switches and fibre Bragg gratings*

Inset: pass-through (one-wavelength dropped) spectrum for WADM at output port O
OC: optical circulator, OSW: optical switch, FBG: fibre Bragg grating

Proposed configurations for WADM and M-XC: Fig. 1 shows a schematic diagram of the proposed wavelength-selective WADM device. One pair of a three-port OC and a 1×2 OSW are located at both the input and the output ports with n ADM units cascading in sequence between them. Each ADM unit consists of one piece of FBG_i with the central reflective wavelength matching the WDM signal λ_i (i = 1, 2, 3, ..., N), one piece of singlemode fibre (SMF), an 1×2 OSW and a three/four-port OC. The optical signals are launched into the first three-port OC at the left-hand side. Some of these OSW-pairs are switched to the FBG port(s) rather than the SMF port(s) for dropping and re-adding optical signal(s) with corresponding wavelength(s). For example, signal i drops or passes through the cascading FBG chains depending on whether the corresponding 1×2 OSW pair is switched to FBG_i or SMF. When λ_i drops from port three/four of the three/four-port OC, a new signal wavelength λ'_i with the same central wavelength as λ_i will add from port one of the four/three-port OC to the fibre link after it is reflected by FBG_i. Other optical signals not dropped by the FBG chains will pass through all the ADM units and then continue their forward propagation.

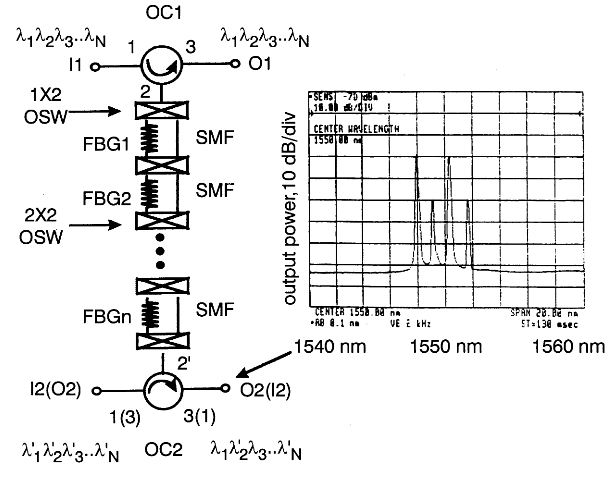

Fig. 2 *Proposed dynamically selective multiwavelength cross-connect configuration*

Inset: two-wavelength cross-connect spectrum for M-XC at output port O2

Fig. 2 shows the proposed configuration of the selective M-XC. N cross-connect units, each consisting of one piece of FBG_i (i = 1, 2, 3, ..., N) matching the WDM channel signal i, a piece of SMF and a 2×2 OSW, are cascaded one by one and inserted in between the three-port OC and the 1×2 OSW pair. For example, by simultaneously switching some of these switch-pairs to the desired FBG ports such as FBG_2 and FBG_4, λ_2 and λ_4 of the upper fibre link will reflect and leave from port 3 of the OC1, continuing their forward propagation (termed here as passed-through) in the same fibre link. The channel signals other than λ_2 and λ_4 are spatially cross-connected (here, passed through the N cross-connect units) to the lower fibre link. Meanwhile, channel signals other than λ'_2 and λ'_4 of the lower fibre link are cross-connected to the upper fibre link. Thus, multiple channel cross-connection can be realised. There are two input ports (I1 and I2) as well as two output ports (O1 and O2) in the M-XC configurations. These two input ports can operate in the same direction or in opposite directions (i.e. bidirectional) by simply re-arranging the lower three-port (number 1, 2 and 3) OC in the clockwise or anti-clockwise direction, dependent on the network structures in which the M-XC is located. The power loss for both WADM and M-XC configurations due to the cascading of fibre components and devices can be compensated easily by using optical amplifiers.

Experimental results of optical spectra: To investigate the feasibility of these proposed FBG and OSW-based WADM and M-XC, one set of four WDM channel signals (λ_1, λ_2, λ_3 and λ_4) with 1.3nm channel spacing in the 1.55μm band are launched from port I of Fig. 1 and port II of Fig. 2 to demonstrate the one-wavelength drop (without re-add) and two-wavelength cross-connect functions, respectively. The inset of Fig. 1 shows the resulting output spectrum at point O of the pass-through signals for the WADM, and the inset of Fig. 2 shows the resulting output spectrum at point O2 of the cross-connect signals for the M-XC. The interport insertion loss of the OCs is 1.2 dB and the insertion loss is 0.5 dB for each OSW from the common port to any other ports, respectively. The isolation of each OC is > 48 dB. The 3 dB bandwidth and reflectivity of the FBGs used in these two experiments are 0.25 nm and 99 %, respectively. In Fig. 1, one small spectral component contaminating the other three passed-through signals with –20 dB crosstalk level results from the 1% transmittivity of FBG_2. A similar result can also be found in Fig. 2. Further reduction in the crosstalk level for upgrading system performance is possible by improving the FBG reflectivity.

Conclusion: In summary, two configurations are proposed for multiple wavelengths add-drop and cross-connect based on FBGs and OSWs. The WADM and M-XC devices have potentially large add-drop efficiency, low channel crosstalk, uniform channel loss, high scalability and low cost, and hence may provide increased flexibility and survivability in WDM networks.

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References

1 FUJIWARA, M., GOODMAN, M.S., O'MAHONY, M.J., TONGUZ, O.K., and WILLNAR, A.E.: 'Special Issue on multi-wavelength optical technology and networks', *J. Lightwave Technol.*, 1996, **14**, pp. 932–935

2 ELREFAIE, A.F., GOLDSTEIN, E.L., ZAIDI, S., and JACKMAN, N.: 'Fiber amplifier cascades with gain equalization in multi-wavelength unidirectional inter-office ring networks', *IEEE Photonics Technol. Lett.*, 1993, **5**, pp. 1026–1028

3 ANTONIADES, N., ROUDAS, I., WANGER, R.C., and HABIBY, S.F.: 'Simulation of ASE noise accumulation in a wavelength add/drop multiplexer cascade', *IEEE Photonics Technol. Lett.*, 1997, **9**, pp. 1274–1276

4 SHARMA, R., and MACDONALD, R.I.: 'A signal transparent 10 × 10 space-division optoelectronic switch core for virtual-transparent path-based multiwavelength networks', *IEEE Photonics Technol. Lett.*, 1997, **15**, pp. 1522–1529

5 LIAW, S.-K., CHEN, Y.-K., and LEE, C.-C.: 'System demonstration of wavelength tunable multiple-ITU-WDM-channel add/drop multiplexer using an optical-switch pair and fiber Bragg gratings'. OFC'98, San Jose, CA, 1998, Paper WM39

6 CHEN, Y.-K., LIAW, S.-K., and LEE, C.-C.: 'Multiwavelength dynamically selective cross connect based on fiber Bragg gratings and optical switches'. CLEO'98, San Jose, CA, 1998, Paper CWT4

7 OKAYAMA, H., OZEKI, Y., KAMIJOH, T., XU, C.Q., and ASABAYASHI, I.: 'Dynamic wavelength selective add/drop node comprising fibre gratings and optical switches', *Electron. Lett.*, 1997, **33**, pp. 403–404