Two-channel CWDM OADM Based on Large Bandwidth Fibre Bragg Gratings

Paulo T. Neves Jr., Fabiano Kuller, Hypolito J. Kalinowski, José L. Fabris and Alexandre A.P. Pohl
Federal University of Technology - Paraná, Av. Sete de Setembro, 3165, 80.230-901 Curitiba, Brazil
Tel: ++55 (41) 3310 4695, Fax: ++55 (41)3310 4683, e-mail: pohl@cpgei.cefetpr.br

ABSTRACT

We report on the fabrication of large bandwidth (12 nm) FBG and its application in two-channel CWDM optical add/drop multiplexer. The OADM allows complete channel dropping, showing a suppression ratio of over 20 dB between adjacent channels.

Keywords: Fibre Bragg Grating, optical add-drop multiplexer, coarse wavelength multiplexing (CWDM).

1. INTRODUCTION

Fibre Bragg Gratings (FBG) have been widely used as key devices in optical communication components and systems. Among others, applications include single and multichannel add/drop filters, dispersion compensation devices, gain flattening filters for erbium-doped fibre amplifiers, devices for stabilizing semiconductor optical sources and elements of optical switches [1, 2]. Most of applications employ FBG´s with narrow line-width in order to select a specific spectral band in the available spectrum. However, there are applications for which FBG with broad line-width have particular interest. One such application is their use in the gain equalization of Erbium Doped Fiber Amplifiers with a single grating, mid-cavity configuration [3]. Another application foresees their employment as channel selection filters in optical add-drops for coarse wavelength division multiplexing (CWDM) used in metropolitan fiber optics networks. CWDM has a channel spacing of 20 nm and is designed for use with uncooled semiconductor transceivers. FBG´s for use in such application must have a wide and flat bandwidth with low-loss, which imposes a tremendous effort on the fabrication technology. Alternative technologies for such filters employ thin-film filters (TFF) [4] and planar ligthwave components (PLC) [5]. In this paper we report the employment of large bandwidth FBG´s (12 nm FWHM) in optical add-drop multiplexers aimed at CWDM systems. Gratings were fabricated with a phase mask interferometer. Experimental results show that the device performs well, with a minimum insertion loss of 4.5 dB when no channels are dropped.

2. FBG FABRICATION AND SPECTRA

The conventional procedure for obtaining a very broad FBG (with FWHM in the order of several nanometers) is their recording through a chirped phase-mask. The process can be easily accomplished by direct writing the grating under the phase-mask illuminated with a wide UV beam. With lasers of small beam diameters (commonly used in phase-mask interferometers), the recording can be accomplished by translating the writing beam along the phase-mask, such that each section of the grating has a different spatial period. In principle, gratings with any line-width can be obtained in this way, only limited by the phase-mask characteristics (chirp rate, length). However, the strong dependence of the grating period on the longitudinal position also imposes a trong chirp to the grating, which can be undesirable for some applications, particularly in high data rate optical communications. The gratings described in this work are recorded using exposure times from several tens of minutes to several hours. Details of the fabrication process are described elsewhere [6]. The main difference from conventional Bragg grating recording is the use of over-exposure to the UV pattern.

Figure 1 presents the spectra of the gratings used in this work, recorded with the chirped phase-mask interferometer. The FWHM of the grating depicted in Figure 1*a* is 12.24 nm and its Bragg central wavelength is at 1532 nm. The FWHM of the grating depicted in Figure 1*b* is 12.86 nm and its Bragg central wavelength is located at 1551 nm. The separation between the two central wavelengths (19 nm) corresponds almost to the separation between two CDWM channels. The magnitude of the reflected signal presents an almost flat top spectrum, an indication that the strength of the grating is very high. This is caused by the saturated hydrogen loading and by the over-exposure to the UV-beam. Reflectivity fluctuations on top of the flat band reveal the resonance character of the structure, which is mainly due to the stepwise fabrication process. Within the scope of the work no attempt was made to record the dispersion characteristics of these gratings, although our previous work presents data of earlier gratings [6].

The work reported in this paper is part of the GIGA project and received financial support from FUNTTEL/FINEP, CNPq and Fundação Araucária in Brazil.

1-4244-0236-0/06/$20.00

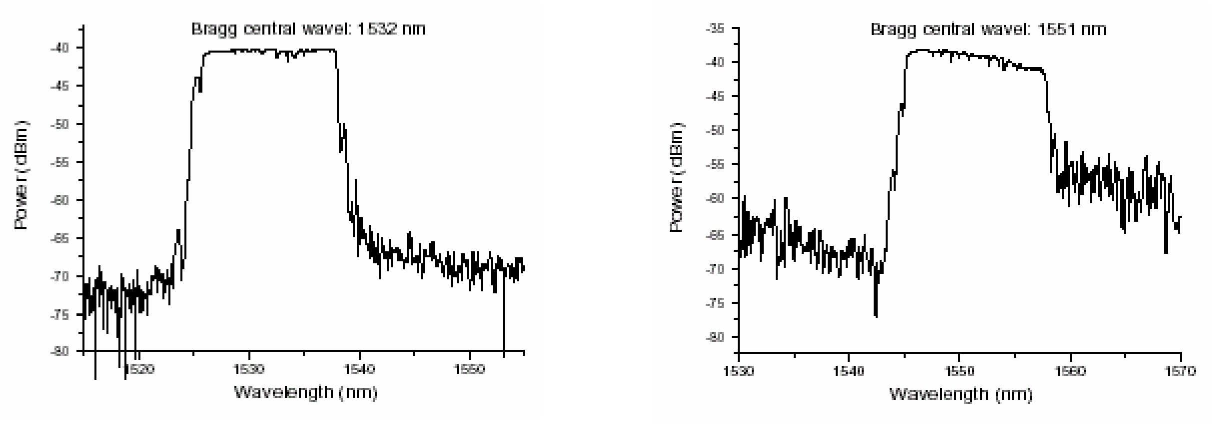

Figure 1. a) Power spectrum of FBG 1: 1532 nm central wavelength and 12.24 nm (FWHM) bandwidth; b) Power spectrum of FBG 2: 1551 nm central wavelength and 12.86 nm (FWHM) bandwidth.

3. OADM CONFIGURATION AND PERFORMANCE

For testing the gratings performance as a filter we used the serial OADM configuration shown in Fig. 2. This configuration was proposed in [7] and originally uses MEMS optical switches. It has the advantage of allowing the selection of one or more channels at a time. We slightly modified the configuration by using fixed, large bandwidth gratings. Channel selection is provided by 2x2 discrete optical switches (OSW) that are driven manually over a simple turn on-off mechanism. The whole configuration uses two optical switches, two FBG´s, two 3-port and one 4-port optical circulators. In this configuration λ_1 corresponds to the 1532 nm and λ_2 corresponds to the 1551 nm grating, respectively. The OADM is assembled with discrete components using SC connectors.

The operation of the OADM may be understood focusing the attention on the second (from left to right) OSW, for instance. When a multi-channel signal exits port 2 of the four-port optical circulator (OC), it goes to the input branch (# 1) of the 2x2 switch. When the switch is in the bar-state, the signal passes through the switch to the output port 3, which is connected to the input port of the rightmost OC (see Fig. 2).
In this state no channel is dropped at this particular cell.

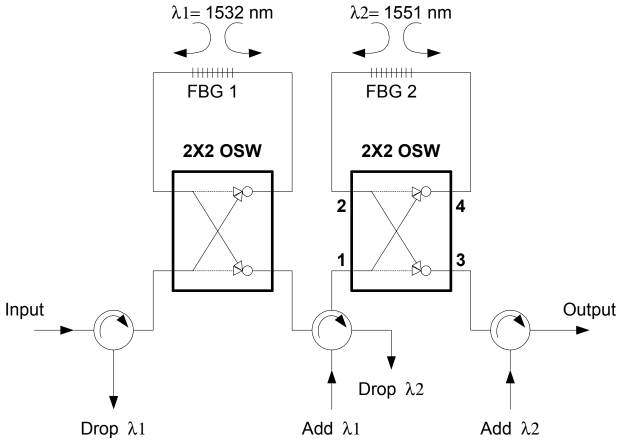

Figure 2. Serial OADM configuration used in the experimental set-up

When the switch is in the cross-state, the incident signal at port 1 is routed to the FBG through branch (# 4) of the switch. The signal feeds the FBG and the corresponding Bragg wavelength band returns to the switch input port (# 1), enters the OC again and emerges at the next OC port as the dropped channel (see "Drop λ_2" in Fig. 2). In the cross-state the transmission band of FBG 2 passes through to the OSW port 2 and exits the switch output port (# 3). In this OADM configuration the addition of a channel occurs always in the next cell. For instance, the channel (λ_1) that is dropped in the first cell is added at the fourth port of the second OC (see "Add λ_1" in Fig. 2).

For testing the configuration a superluminescent LED with center wavelength emission at 1544.2 nm and FWHM = 58.8 nm is used as the light source at the OADM input port. When none channel is selected (switches in the bar state) a 4.5 dB insertion loss is measured at the OADM output port. This loss is mainly due to insertion losses of the OC and of the OSW. Fig. 3 shows the situation when both channels (λ_1 and λ_2) are dropped simultaneously. For this case the insertion loss of the transmission band amounts to 12 dB at the OADM output due to the long path followed by the signal, once the switches operate in the cross-state, and also due to the SC connectors. Insertion loss is expected to be drastically reduced by using splices instead of connectors to link the optical components. Fig. 4 takes a closer look at the dropped channels. The insertion loss of λ_1 at the third port of the first OC amounts to about 3 dB. When the first OSW is in the bar state and the second OSW in the cross state only λ_2 is dropped. One sees that the insertion loss is about the same as for λ_1. Fig. 4 shows also the superimposed spectrum of the λ_2 channel for the situation when both λ_1 and λ_2 are dropped simultaneously and for the situation when λ_2 is dropped exclusively. The corresponding insertion loss difference for the λ_2 channel is about 4 dB between the two cases. This is due to the long path followed by the signal in the configuration when both channels are dropped simultaneously.

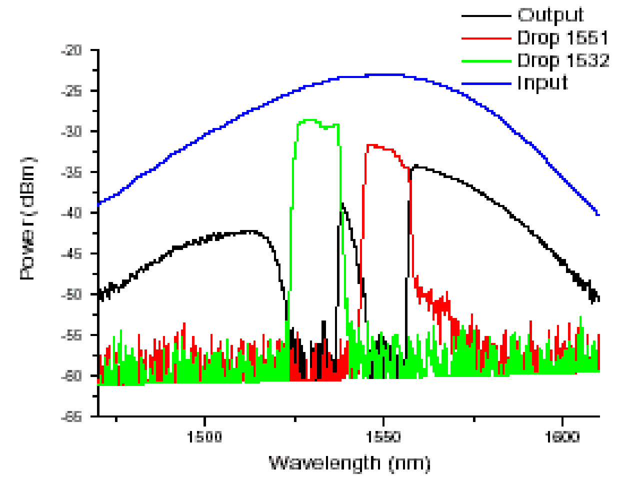

Figure 3. Superimposed spectra of transmitted and dropped channels.

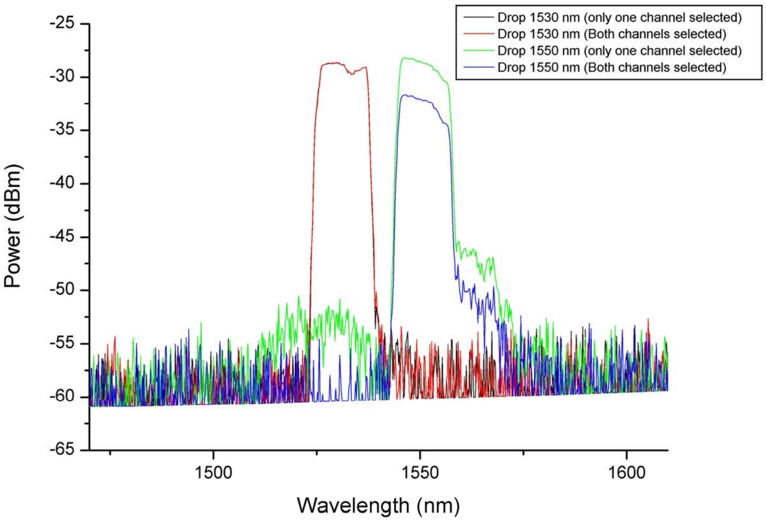

Figure 4. Superimposed spectra of dropped channels.

4. CONCLUSIONS

We have demonstrated the operation of a CWDM OADM using large bandwidth (> 12 nm) fibre Bragg gratings. The spectral band of the dropped channels is preserved after removal by the OADM. The suppression ratio between the dropped and its adjacent channel is over 20 dB, when one (λ_1) or the (λ_2) channel is dropped. The high insertion loss observed at the OADM output and drop ports are only partially due to the intrinsic optical path configuration of the device. An estimative reveals that the nominal insertion loss would amount to 4 to 5 dB at the OADM output for the situation when both channels are simultaneously dropped. However, the high insertion loss measured (12 dB) is mainly due to the SC connectors used to link the components to each other. If connectors are replaced by splices, a reduction of up to 7 dB in insertion loss may be expected.

ACKNOWLEDGEMENTS

P.T. Neves Jr. thanks Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the graduate scholarship.

REFERENCES

[1] R Kashyap, *Fiber Bragg Gratings* (Academic Press, London, 1999).

[2] A Othonos and K Kalli, *Fiber Bragg Gratings* (Artech House, Norwood, 1999).

[3] M.C. Fugihara, H.J. Kalinowski, P.S.B André, "Estudos para equalização de ganho em um ADFE com uma única rede de Bragg" *in Proceedings of X Simpósio Brasileiro de Microondas e Optoeletrônica*, Recife, Brazil, pp. 79-82 (2002).

[4] Yao Li; Lee, L.; Daoyi Wang; Lingzhi Ji; Jing Li; Wu, F.; Wei-shin Tsay, "Performance of an ultra-low loss, ultra compact, free-space packaging platform for CWDM applications", *in Digest of the LEOS Summer Topical Meetings*, pp. 28-30 (2004).

[5] C.R. Doerr, M. Capuzzo, L. Gomes, E. Chen, A Wong-Foy, C. Ho, J. Lam and K. McGreer, "Planar Lightwave Circuit Eight-Channel CWDM Multiplexer with < 3.9 Insertion Loss", *J. of Lightwave Technology*, vol. 23, no. 1, pp. 62-65 (2005).

[6] H.J. Kalinowski, F. Kuller, J.C.C. da Silva, R.N. Nogueira, J.L. Fabris, A.A.P. Pohl and P.S.B. André, Production and characterization of broad fibre Bragg gratings for photonics devices, in: Optical Fibers: Technology (Warsaw, PL) *Proc. SPIE*, vol. 5951, pp. 1-5 (2005).

[7] J. Li, A.Q. Liu, W.D. Zhong, Q.X. Zhang and C. Lu, "MEMS switched based serial reconfigurable OADM", *Optics Communications*, 230, pp. 81-89 (2004).