4-Channel Reconfigurable CWDM OADM Based on FBG Gratings

Paulo de Tarso Neves Jr., Paulo Vinicius Cosmo, Fabiano Kuller, Alexandre de Almeida Prado Pohl , Hypolito José Kalinowski and José Luis Fabris
Universidade Tecnológica Federal do Paraná, Av. Sete de Setembro 3165, 80230-901 Curitiba, Brazil
Phone: +55-41 33104695, Fax: +55-41 33104683, e-mail: pnevesjr@cpgei.cefetpr.br

Abstract — **We have assembled and demonstrated the operation of a 4-channel OADM using large bandwidth fiber Bragg gratings for application in CWDM networks. The FBG present a flat bandwidth and reflectivity in the order of 20 dB to 25 dB. The OADM is reconfigurable through an electronic circuitry that controls the switching of one or more channels simultaneously.**

I. INTRODUCTION

Fiber 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 fiber amplifiers, devices for stabilizing semiconductor optical sources and elements of optical switches [1, 2]. Most applications employ FBG´s with narrow bandwidth in order to select a specific spectral band in the available spectrum. However, there are applications for which FBG with large bandwidth has 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. The CWDM system 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.

II. FABRICATION AND SPECTRA

A. Broad FBG Fabrication

The conventional procedure for obtaining a very broad FBG (with FWHM in the order of several nanometers) is the 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 bandwidth can be obtained, 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 strong 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.

B. Broad FBG Spectra

Fig.1 presents the reflected spectra of the gratings fabricated and used in this work

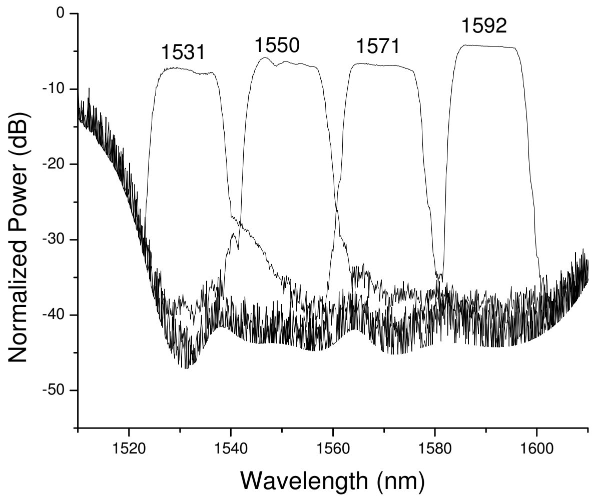

Fig. 1. FBGs reflected spectra

The central wavelength and the FWHM for each FBG are shown in Table I.

This work received financial support from Conselho Nacional de Desenvolvimento Científico e Tecnológico (process CNPq 473.454/2003-3) and from the GIGA project, supported by Funttel/FINEP. P. Neves. Jr. thanks Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the research scholarship.

Table I
Relationship between control signals and dropped channels

	Central Wavelength (nm)	FWHM (nm)
FBG 1	1531	12.6
FBG 2	1550	14.0
FBG 3	1571	13.7
FBG 4	1592	13.1

The average separation between adjacent central wavelengths is 20 nm, according to ITU-T G.694.2, which corresponds 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.

III. OADM CONFIGURATION AND PERFORMANCE

The performance test of two-channel OADM was done with the serial configuration [7] shown in Figure 2. It has the advantage of allowing the selection of one or more channels at a time.

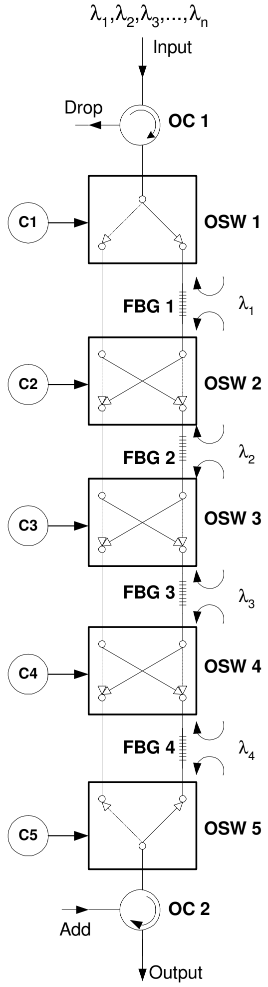

Fig. 2. OADM configuration for 4 channels.

We assembled the OADM for four channels, using non-tunable and large bandwidth gratings. Channel selection is provided by 1x2 and 2x2 discrete optical switches that are driven by a TTL level signal (represented by C1, C2,…, C5) over a simple turn on-off device. The whole configuration uses two 1x2 optical switches (OSW 1 and OSW 5), three 2x2 optical switch (OSW 2, 3, 4), four FBG´s and two 3-port optical circulators (OC 1 and OC 2). For each additional channel one 2x2 optical switch and one FBG are needed. In this configuration λ_1, λ_2, λ_3 and λ_4 corresponds to the 1531, 1550, 1571 and 1592 nm gratings, respectively. The OADM is assembled with discrete and connectorized devices.

The relationship between the control signals (C1, C2 and C3) and the optical switches states can be set arbitrally as shown by Fig. 4. Thus, a Control Table can be implemented to set each optical switch state in order to add and drop desired channels.

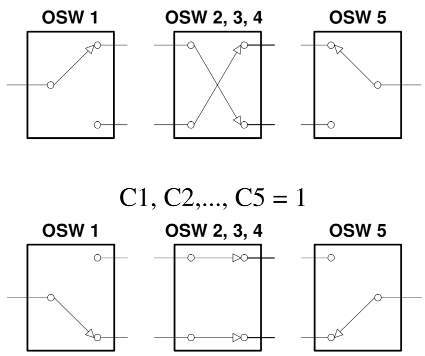

Fig. 3. Relationship between control signals and optical switch states.

We have assembled an electronic circuitry fed by a –48 volts power supply, compatible with standard communication equipments. Optical switches are controlled by an 8 bits microcontroller with a serial interface (RS232) and an Ethernet interface (10Mbit/s). The Control Table is implemented by software in the microcontroller, which will activates correctly the optical switches. In order to inform which channels are selected, the circuitry board has four LEDs indicating the status of each channel. This circuitry is able to receive data from remote Control Center by internet.

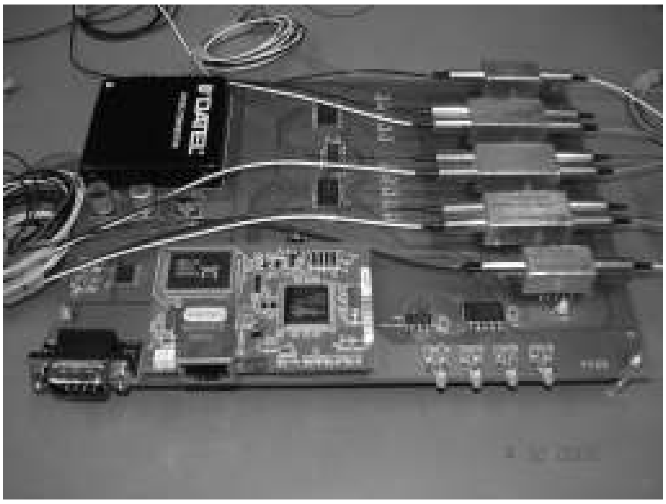

Fig. 3. The 4-Channel OADM circuitry board.

If one wishes to drop only channel λ_2, per example, the OSW 1 must to be setting in order to bypass FBG 1; furthermore, the OSW 2 and OSW 3 must to be at the cross-state in order to drive the cannels to FBG 2 and bypass FBG 3, while OSW 4 must to be at bar-state in order to bypass FBG 4. Thus, all the channels will pass trough the optical circulator OC1, trough the OSW 1 by the bottom branch and through OSW 2, going forward to FBG 2. However, only λ_2 will be reflected at FBG 2; the reflected channel λ_2 will return all the way trough the same path to optical circulator OC1 and will be available at the Drop OC 1 port. On the other hand, remaining channels will go forward trough the bottom branch in OSW 3 and will be available at the output OC 2 port. The Add operation is analogous.

This configuration only allows to add and to drop simultaneously channels of the same wavelength. Furthermore, the FBG's rejection must be greater than 99% in order to avoid crosstallk.

For testing the configuration a C+L Band ASE Broadband source, with 1567.3 nm center wavelength and 10 dB bandwidth = 84.6 nm, is used at the input OC 1 port. When none channel is selected the insertion loss is minimum (measured as 5 dB at the output port).

Fig. 4 shows the situation where none channel is selected (dashed line) and when each channel is selected individually. In this case the insertion loss increases due to additional losses caused by connectors and the FBG selected. Note that the spectra of the dropped channels have almost the same power.

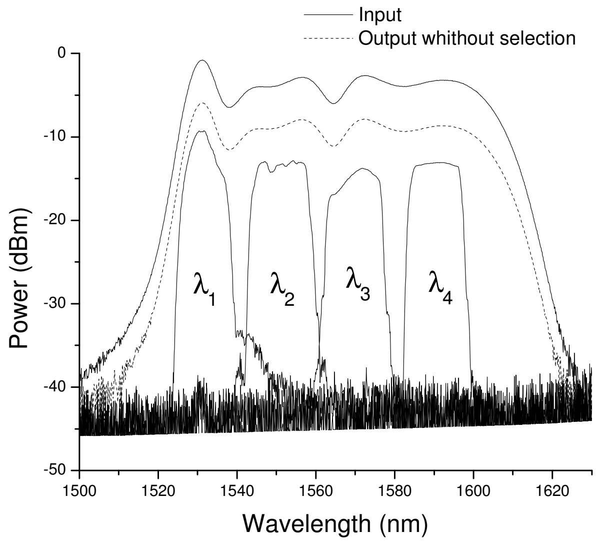

Fig. 4. Spectra of the input, output when none channel is selected (dashed line) and dropped (λ_1, λ_2, λ_3, and λ_4) channels when each channel is selected individually

By dropping two or more channels simultaneously, the dropped channels will not remain power equalized. Since the drop port is unique, the dropped channel concerning the FBG nearest the OC 2 will have the greater attenuation.

The time response of this assembly is limited by the time response of the circuitry and optical switches.

IV. CONCLUSION

We have assembled and demonstrated the operation of a 4-Channel CWDM OADM using large bandwidth fiber Bragg gratings. The performance of the dropped channels shows that their power will not remain equalized when both channels are dropped simultaneously. Besides, the insertion loss may be reduced by an estimated 2.4 dB using splicing between the fiber patches in replacement of connectors used in the present configuration.

REFERENCES

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

[2] A Othonos and K Kalli, *Fiber Bragg Gratings*, Norwood: Artech House, 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, 2002, pp. 79-82.

[4] Y. Li; L. Lee, D.nWang, L. Ji, J. Li, F. Wu, W. Tsay, "Performance of an ultra-low loss, ultra compact, free-space packaging platform for CWDM applications", in

Digest of the LEOS Summer Topical Meetings, 2004, pp. 28-30.

[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", *Journal of Lightwave Technology*, vol. XXIII, no. 1, pp. 62-65, 2005.

[6] H.J. Kalinowski, F. Kuller, J.C. Cardoso da Silva, R. Nogueira, J.L. Fabris, A.A. P. Pohl, and P.S.B. André, "Production and Characterization of Broad Fibre Bragg Gratings for Photonic devices", Optical Fibers: Technology (Warsaw, PL) Proc. SPIE, vol. 5951, pg 1-5, 2005.

[7] S. Liaw, K. Ho and S. Chi, "Multichannel add/drop and cross-connect using fibre Bragg gratings and optical switches", *Electronics Letters*, vol. XXXIV, no. 16, pp. 1601-1603, 1998.