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# Tunable Transparent and Cost Effective Optical Add-drop Multiplexer based on Fiber Bragg Grating for DWDM Networks

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**Summary:**

The enormous grow in the demand of bandwidth is pushing the utilization of fiber infrastructures to their limits. To fulfill this requirement the constant technology evolution is substituting the actual single wavelength systems connected in a point-to-point topology by dense wavelength division multiplexing (DWDM) systems, creating the foundations for the Optical Transport Network (OTN). The objective is the deployment of a optical network layer with the same flexibility as the equivalent SDH, because it is more economical and allows a better performance in the bandwidth utilization. Optical add-drop multiplexers (OADM) are the simplest elements to introduce wavelength management capabilities by enabling the selective add and drop of optical channels. A wavelength tunable OADM, giving access to all the wavelengths of the WDM signals provides more flexibility to satisfy reconfiguration requirements and to enhance network protection. We proposed a tunable OADM based on fiber Bragg gratings (FBG) where the dropped channel is removed by the used of a optical circulator and the added channel is incorporated to the wavelength combo by a passive optical coupler. These OADM is transparent by design and cost effective due to the used of just one optical circulator.

The wavelength tuning capacities of the OADM are related with the FBG capacities to shift their central reflection wavelength. The significant discovery of photosensitivity in optical fibers lead to the development of a new class of in-fiber component, called the fiber Bragg grating. Basically a Bragg grating is a longitudinal periodically modulated refractive index profile in the core of an optical fiber, figure 1. Due to that modulation, it presents a reflection band centered at the Bragg wavelength $\lambda_B$. There are two main methods: to shift the Bragg grating central wavelength peak by modifying the fiber refractive index or by changing the grating period. These variations can be dynamically induced either by temperature or by mechanical stress. We present a hybrid method based on a thermal-stress thermally enhanced actuation on a FBG, to tune its central wavelength. These thermal enhanced tuning, employs a different configuration to amplify the thermal induced wavelength shift by using a positive thermal expansion material as support for the fiber Bragg grating. This hybrid tuning technique allows us to increase the tuning range and keep the thermal tuning advantages. For a typical wavelength on the region of 1550 nm the tuning coefficient is 41.1 pm/°C.

The grating used in this work was manufactured by illuminating an optical fiber exposed to a phase-mask spatially modulated UV (248 nm) writing beam originated from a KrF excimer laser. The optical fiber (standard single mode type) has been previously kept under high-pressure hydrogen atmosphere in order to enhance its photosensitivity due to hydrogen diffusion into the glass matrix. This process is reliable and gives excellent results in the reduction of the writing time of the grating.

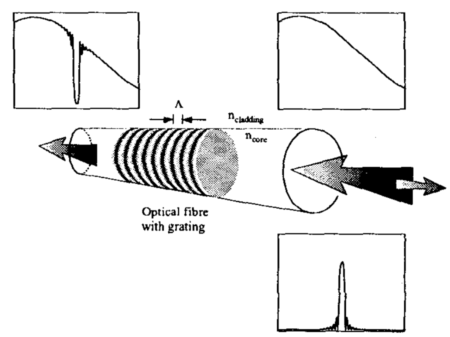


Fig. 1 – Schematic representation of a fiber Bragg grating.

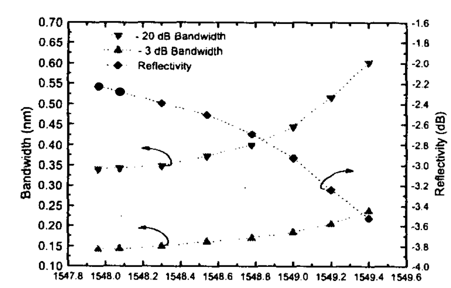


Fig. 2 – Spectral characteristics of the FBG with temperature.

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The increased of temperature and stress applied on the FBG, results on a lowering of the reflectivity and an increase of the bandwidth, however these alteration on the FBG performance does not affect significantly the performance of the OADM. Figure 2 shows the variations of the reflectivity, the -3 dB and -20 dB bandwidth of the FGB with temperature. Figure 3 a) and b) presents the optical spectra of the drop channel when the temperature of the FBG was 30 and 50 C, respectively.

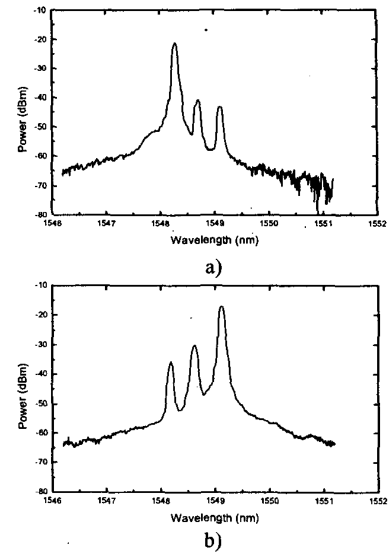

Fig. 3 – Optical spectra of the channel 3 dropped for 30° C and 50° C FBG temperature (top and bottom), respectively.

The tunable OADM performance and functionality was tested on a 3 channels, 50 GHz spaced, DWDM network of figure 4.

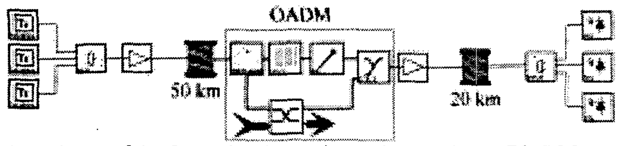

Fig. 4 – Scheme of the OADM and experimental transmission DWDM network.

Three distributed feedback lasers were externally modulated, at 2.48832 Gb/s (STM-16) with a non-return to zero $2^{15}-1$ pseudo random bit sequence. In the experimental transmission WDM link, 70 km of single mode standard fiber are used. Two Erbium doped fiber amplifiers having saturated output powers of 13 and 17 dBm and noise figures smaller than 4 dB are employed to provide the required power to compensate the link and OADM losses.

The performance of our network is assessed by the BER measurements on the central wavelength channel for a 50° C FBG temperature. Figure 5 displays the BER performance against the receiver power, for the back-to-back operation (0 km), for the drop channel on the OADM after propagation on 50 km of fiber and for the same channel just after propagation on 50 km of fiber (without be dropped at the OADM). The BER floor (measurement limit) and the $10^{-9}$ BER are also indicated.

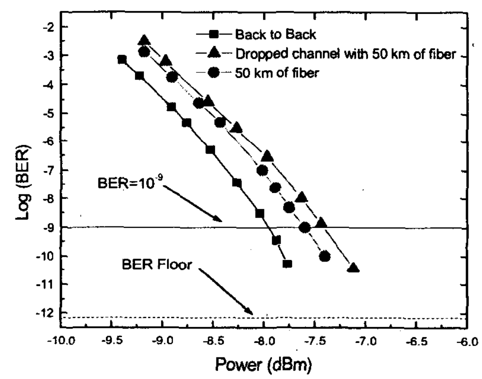

Fig. 5 – BER performance for the dropped channel.

The power penalty measured at a $10^{-9}$ BER is 0.08 dB, for the dropped channel at the OADM compared with the same channel at the OADM input after propagation on 50 km of fiber. This power penalty is due to heterodyne crosstalk induced by the leak of the signal power from the other neighbors signal components. These residual components interfere with the detection process, resulting in noise addition on the detector. The transparency of the OADM to the channel spacing and number of channels was demonstrated and the system performance degradations due to homodyne and heterodyne crosstalk induced by the FBG based OADM have been measured. The results indicate that the investigated OADM configuration is promising, due to its good spectral characteristics which results in low homodyne crosstalk, and consequently potential high cascability.

**Acknowledgments:** This work was supported by the DAWN PRAXIS XXI and O-NODE project.

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