Selective Wavelength Transparent Optical Add - Drop Multiplexer Based on Fibre Bragg Gratings

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Abstract: A configurable optical add-drop multiplexer (OADM) based on fibre Bragg gratings is reported. Dynamically selection of the add-drop or pass-through functionality is realised according to the control of an optical switch. OADM performances measurements in a 70 km, 3 x 2.5 Gb/s channels WDM network are reported.

1. Introduction

The optical add-drop multiplexer is one of the key components for dense wavelength division multiplexing (DWDM) networks. The OADM is used for selectively dropping and inserting optical signals into a transparent DWDM network. Several wavelength OADM’s have been proposed based on arrayed wave-guide gratings (AWG) [1], Fabry-Perot filters [2], combination of dielectric thin film MUX and DEMUX [3] and Bragg gratings written in Mach-Zhender interferometers [4]. In this work, we propose a more simple, cost effective, flexible, easily upgrade and transparent configuration, using a fibre Bragg grating (FBG), an optical circulator, a power combiner and a mechanical – optical switch [5].

Due to wavelength reuse scheme, crosstalk is a major problem. The crosstalk arises from coherent mixing of a received signal with a crosstalk wave on the photodetector, originating an interference beat noise locally at the receiver. In the case of these OADM configuration a heterodyne crosstalk is induced between the drop signal and the leakage of the remaining input signals at different wavelengths. The power penalty can be calculated by the following equation [6], based on the eye closure, where X is the crosstalk value.

$$P_p = -10 \cdot \log(1 - X) \tag{1}$$

Another type of crosstalk is the homodyne crosstalk induced between the add signal and the leakage of the drop signal at the same wavelength. The power penalty due to this crosstalk can be calculated by equation 2, assuming the worst-case situation, where the states of polarization (SOP) from the interference signals are the same and when the decision threshold is set at the optimised value to minimize the bit error rate (BER) [6],

$$P_p = -10 \cdot \log\left(1 - Q^2 \cdot X\right) \tag{2}$$

where Q indicates the signal-to-noise ratio (SNR). In this case we consider a small crosstalk value, and consequently the noise will have a Gaussian probability density function.

Therefore Q will be equal to 6for a 10^{-9} BER. This power penalty will be far larger than the heterodyne power penalty and may limit the ability to cascade many OADM simultaneously. The homodyne crosstalk can be reduced by eliminating reflections from connectors and components and by using a FBG with high reflectivity.

2. Experimental setup

The basic architecture of the OADM node is show on figure 1. It consists of a fibre Bragg gratings, an optical circulator, a power combiner and an optical switch. At first, N multiplexed wavelengths are led to the Bragg grating through the circulator, then the filtered signal is reflected and go back to the circulator where is removed. The remaining channels are coupled with the added channel in a power combiner. The optical switch allow the selection of the add – drop operation with the remotion and addition of a channels or a pass through operation where the removed channels is added again.

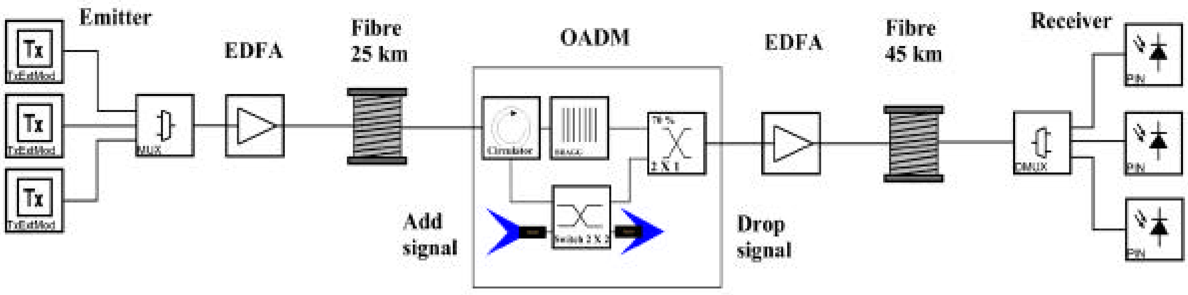


Figure 1 – Schematic of the OADM, and experimental transmission network.

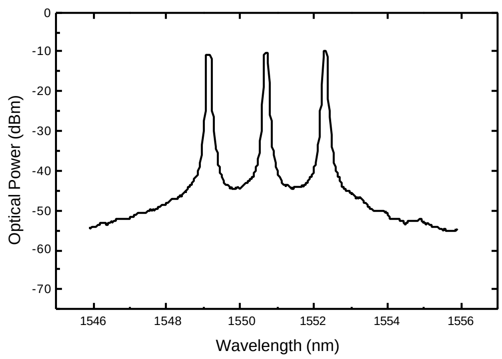
To investigate the operation and system performance of this OADM, three distributed feedback lasers (DFB) based at the ITU grid of 200 GHz (≈ 1.6 nm) spacing with wavelengths of 1549.32 nm, 1550.92 nm (dropped channel) and 1552.52 nm, were externally modulated, through a Ti:$LiNbO_3$ Mach-Zhender intensity modulator, at 2.5 Gb/s with a non-return to zero (NRZ) $2^7–1$ pseudo random bit sequence (PRBS).

The average pass-through, added and drop insertion loss for the dropped channel is 6.5 dB, 5.0 dB, 5.2 dB respectively, the insertion loss for the remaining channels is 6.0 dB. The relatively high insertion losses are due to the power combiner and optical attenuators used to equalise the power of all the channel at the OADM output on add-drop or pass-through operation. The isolation and crosstalk of the optical circulator are greater than 60 dB and the FBG have a central reflective wavelength of 1550.92 nm, with a 0.73 nm bandwidth and a reflectivity of 99.97 %.

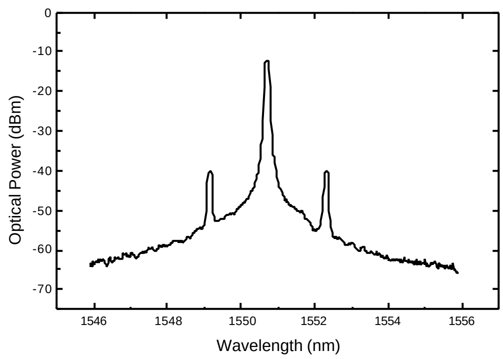
The functionality of the OADM is demonstrated using the experimental setup in figure 1, with 3 channels, 200 GHz spaced, WDM network with 70 km, operating at 2.5 Gb/s. In the experimental transmission link, single mode fibre is used. Two Erbium doped fibre amplifiers (EDFA) having saturated output powers 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.

3. Experimental results

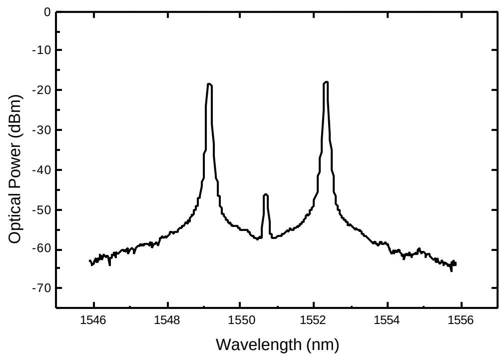
The figure 2 shows the power spectra of the input three WDM signals, the dropped signal at the OADM, the passed trough signal without re-adding and the output signal. The two small components present with the dropped signal (Fig 2 (b)) are due to residual reflections on the circulator and on the FBG. The small spectral component at 1550.92 nm (dropped channel) on the pass-through signal (Fig. 2 (c)) results from the imperfect reflection of the central wavelength by the FBG.



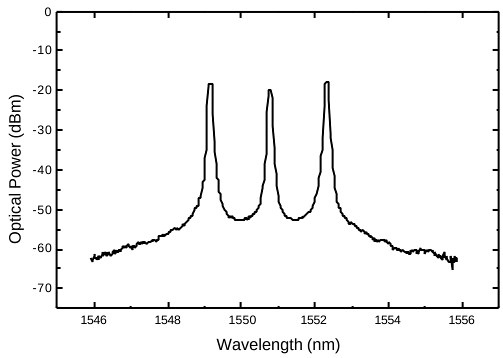
(a)



(b)



(a)



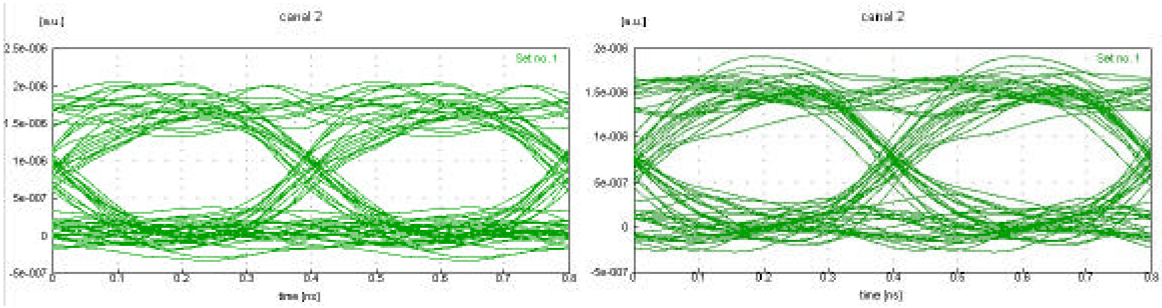
(d)

Figure 2 – Measured power spectra of: (a) The input signal, (b) the dropped signal, (c) the passed through signal without re-adding, (d) the output signal, with an added channel.

The OADM heterodyne and homodyne crosstalk is – 27.5 dB and – 36.0 dB for the drop and pass-trough channels, respectively. Using equations 1 and 2 is possible to calculate the power penalty induced in the drop and add channel, yielding to 0.02 and 0.04 dB, respectively, for a 10^{-9} BER.

4. Simulation results

The 70 Km SMF experimental system with the OADM was simulated in a photonic transmission simulation program, *PTDSÓ*. The input power into the fibre was maintained below 3 dBm to exclude the nonlinear effects in fibre, so that we can obtain transmission performance mainly depending on the crosstalk of the OADM. The power penalty of the simulated network with the OADM is identically with the experimental and analytical values. On figure 4 are show the simulated detected eye diagram for the system without OADM and for the channel 2 added on the OADM. In this simulation 128 bit were used.



(a) (b)

Figure 4 – Simulated eye diagram for the channel 2: (a) with no OADM, (b) added on the OADM.

5. Conclusions

We have demonstrated a selective OADM based on fibre Bragg gratings, which performance was demonstrated in a 3 channel, 2.5 Gb/s WDM network. The power penalty imposed by the interferometric crosstalk was investigated and compared with analytical and simulated results. The simulation results for the experimental network agreed with the experimental results and verify the good performance of this OADM configuration.

References

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