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Characterization of Optical Add Drop Multiplexers in High Bit Rate WDM Networks

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Abstract

Characterization of Optical Add Drop Mutiplexers (OADMs) in High Bit Rate Wavelength Division Multiplexing (WDM) systems is presented using theoretical systems simulations. Firstly the interferometric full-coupler based OADM is modelled in various configurations using coupled mode theory. Implications of the inherent non-optimum overall performance of this device in conjunction with additional system issues like filter misalignments and cascading are analysed. Filters with typical degraded spectral characteristics in the Drop or Add action exhibits at least 0.15 dB higher Eye Opening Penalty (EOP) compared to filter with optimized flat spectral response. For this kind of OADMs we found also that the Intra-Band dispersion EOP performance in a cascaded *Add-and-Drop* operation - in a single-wavelength-processing-node - for a specific OADM is insensitive to the arrangement of the Bragg grating in the coupler waist and consequently to the individual spectral characteristics of the Add or Drop actions.

I. Introduction

Wavelength Division Multiplexing is a very promising technological solution for the successful construction of the next generation of Broadband Optical Networks. A special class of WDM components on great demand are the Optical Add-Drop Multiplexers-Demultiplexers. To date Arrayed Waveguide Gratings (AWG, PHASAR) and Bragg Grating Based devices form the two main classes. In the later class, narrow-band reflective Bragg gratings have been used for the construction of four-port devices with the fundamental functions of Adding or Dropping of a particular WDM channel. This four port device gives an essential optical processing function and can serve as building block for more complicated modules such as switch matrices. Such OADMs have been proposed and implemented in interferometric [1,2] or non-interferometric [3,4,5] waveguide structures. An OADM device which theoretically can give ideal overall performance is based on a perfectly matched Mach-Zendher Interferometer (MZI) [1], but unfortunately is very susceptible to any imbalances of the order of wavelength (~1μm) which can severely degrade its performance. An alternative interferometric configuration based on symmetric full (100%) couplers (SFC-OADM) [2] with a grating placed in the coupler waist is a more fabrication robust and compact solution. However the grating has to be placed precisely in the correct position for optimum operation. The paper analyses the implications of the spectral characterstics of this device in high bit rate systems.

II. Full-Coupler-Based-OADM Principle of Operation

For the optimised Drop or Add action of this OADM the grating should be placed asymmetrically in the coupler waist -taking into account its penetration depth- in order to make the reflecting point of the grating at the central operating wavelength (here 1.55 μm) coincident with the 3-dB point M of the coupler. At Figure 1 the device is configured for optimised Drop action of wavelength λ_1. For this arrangement is clear that the Add action cannot be implemented optimally. By placing the grating at the centre of the coupler waist ($L_1=L_3$) the device exhibits a symmetric operation with equivalent but compromised Add and Drop actions. In the simulated device here, the length of the coupler waist is Lw=10mm, the grating length Lg=5200μm, with refractive index modulation $\Delta n=3.7*10^{-4}$, Sine apodisation profile and reflectivity 35 dB. The penetration depth at the operating wavelength λ_1=1.55 μm is Lp~ 965μm.

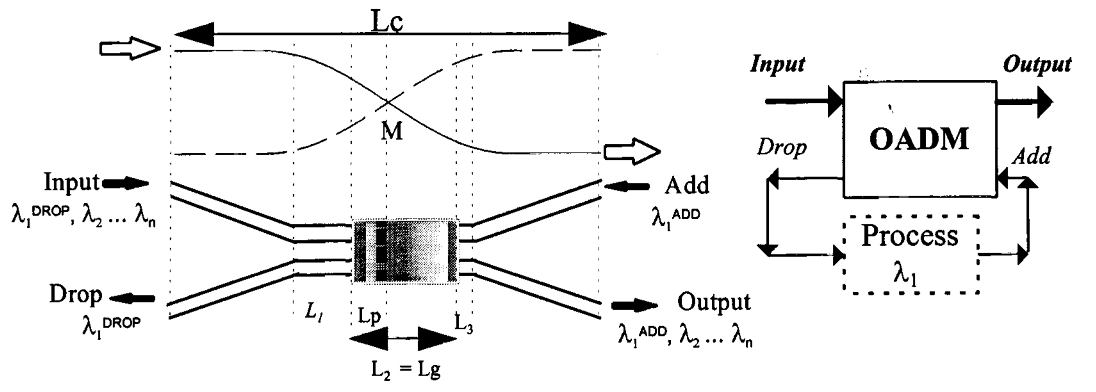

Figure 1. (a)Schematic of the OADM. Power evolution in the full coupler and configuration for Optimised Drop action. (b) Schematic of a node where a channel is dropped, processed and added again into the optical channels stream

Using local normal mode analysis and coupled mode theory we simulate the device response. The reflection spectra for the *optimised [O]* Drop , the *degraded [D]* Add corresponding to the optimised Drop-configuration, and the *compromised [C]* -for symmetrical grating placement- are concluded in Figure 2a.

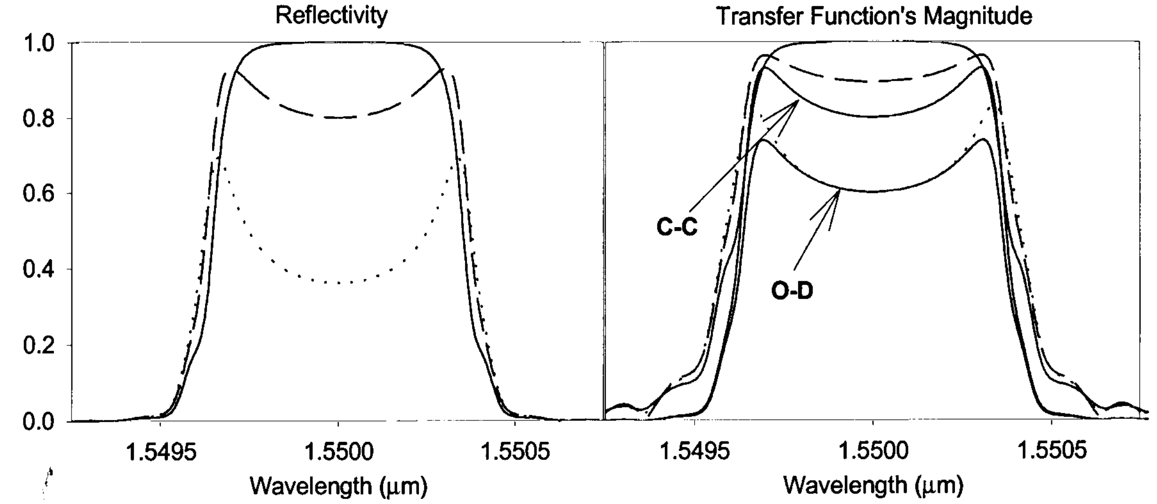

Figure2. (a) Reflectivity of optimised Drop (solid line), degraded Add (dotted line), compromised Add/Drop (broken line). (b) Magnitude of the reflection coefficients

In Figure 2b are shown the magnitude of the reflection coefficients of these three responses. The reflection coefficients form the transfer functions of the OADM and will be used later for the characterization procedure. Figure 1b describes the operation of an *Drop & Add* cascaded operation at the same OADM which forms a processing node for a single channel. For the two configurations that we have already described, the *'optimised Drop & degraded Add' (OD)* and the *'compromised Add and Drop' (CC)* we estimate the total transfer functions by multiplying the individual ones. By arrows these are indicated in Figure 2b. It is clear that the (CC) *Drop & Add* cascading gives lower insertion loss. But regarding the intra-band dispersion effects it will be shown later that they are *identical.*

III. Simulation of the Characterization System

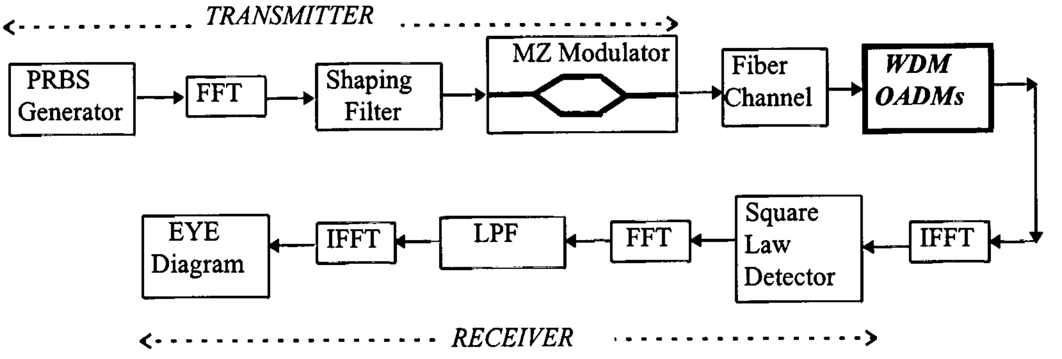

Figure 3. Block diagram for the simulation of a typical IM/DD Communication system

The quality of the spectral characteristics of an OADM is very critical in high speed WDM systems because of strong dispersion effects arising from non-optimum filters. Here we characterize the above simulated OADM responses, by estimating their Eye Opening Penalty (EOP) in a Intensity Modulation/Direct Detection (IM/DD) Communication System. The bandwidth of the OADM reflection spectrums is ~0.7 nm and their dispersion effects are examined for the compatible 40Gbs transmission speed. The simulated system is based on the SONET standards and the employed filters at the transmitter and receiver are 4-order Bessel filters with 3dB bandwidth 0.75*(BitRate). A chirpless input is assumed into the OADMs. Figure 4a gives the EOP for the three different spectral responses as a function of the offset from the centre of the filter. We notice that for the missalignement range [-0.2,0.2] nm the non-optimum OADM responses leads to an EOP higher by at least 0.15dB. Figure 4b shows the EOP for the Drop & Add operation described in Figure 1b. The Optimised Drop (OD) and symmetric compromised (CC) configurations show *exactly the same EOP relation* versus the filter missalignement. For the sake of comparison the graph shows also the *'degraded Drop-degraded Add (DD)'* and *'optimised Drop -optimised Add (O-O)'* EOP curves. We can notice that even a two stage cascading makes the difference between optimum and degraded filters more pronounced especially for missalignements above 0.05 nm. The curve (OO) could be associated with the two circulators based OADM [6] device which generally gives excellent overall performance.

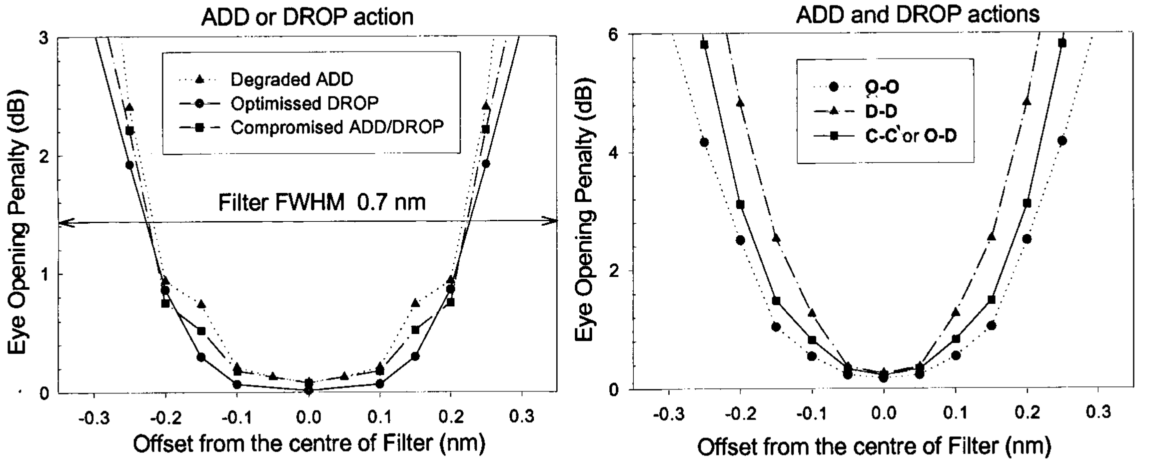

Figure 4. (a) EOP for the three different OADM responses. (b).EOP for the DROP and ADD operations

Conclusions

Using High Bit Rate system simulations we show that a typical non-optimum operation of the full coupler based interferometric OADM leads to an excessive EOP at least 0.15dB compared with that of the optimised filter performance. Depending on the application system these limitations could be critical for the overall system performance and together with the additional insertion losses associated with a non-optimum OADM response, should be taken into account in the design process. We show also that for an *Drop-and-Add* operation the overall dispersion-EOP performance does not depend on the individual Add or Drop transfer functions and thus for a specific OADM is insentitive to the grating arrangement. However the total insertion loss is less in the symmetric compromised configuration.

References

[1] D.C.Johnson et al, Electronics Letters, Vol. 23, pp. 668-669, 1987.
[2] K.Bakhti, Electronics Letters, Vol. 33, No. 9, pp. 803-804, Apr. 1997.
[3] A. S. Kewitsch,et al, Optics Letters, Vol. 23, No. 2, pp. 106-108, Jan. 1998.
[4] L.Dong,et al, IEEE Photonics Tech. Letters, Vol. 8, No. 12, pp.1656-1658, Dec. 1996.
[5] C. Riziotis, M.N. Zervas, Paper TuD1.6, ECOC '99, Nice, France, 1999.
[6] K. P. Jones et al, Electronics Letters, Vol. 31, No. 24, pp. 2117-2118. Nov. 1995.