Analysis of a Proposed Dropping Filter for WDM Systems

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In this paper, the modeling and optimization trade-offs of a three channel dropping filter are discussed by using the transfer matrix approach. The device is intended for use on dense WDM optical networks and may easily incorporate more channels. Its structure is composed of two asynchronous exchange-coupled waveguides, with coupling being achieved by a rectangular Bragg gratings. A systematic study of the effect of the filter parameters on crosstalk, optical bandwidth and optical loss is carried out.

Introduction

Channel dropping filters are of key importance in WDM communication networks due to the need of extracting single wavelengths from the optical bus of multiplexed optical carriers, for routing and/or photodetection. In the literature, filters using ARROW structures were already demonstrated [1], but these devices detect the optical signal in the filter structure itself, degrading the optical response. On the other hand, the structure proposed by Hauss and demonstrated in [2] uses a quarter-wave shifted distributed Bragg reflector on a codirectional coupler, but couples only 50% of incident power and provides limited bandwidth. Another proposition, studied in [3], employs a codirectional filter integrated with a photodetector. However, as the detector is built in-line with the filter, there is a mode overlap of the undesired channel with the detector element, causing a degradation on the filter response, due to excess crosstalk. In contrast, the device proposed here uses an exchange-Bragg coupler to filter the desired wavelength and corner mirrors in order to avoid waveguide bend losses and a non-desirable field interaction with the detector element.

Device structure and operating principle

A longitudinal cross-section view of one block of the structure is presented in Fig. 1 where d_1 and d_2 represent the core diameters of waveguides 1 and 2, respectively, s is the separation between the waveguides, h is the grating depth and Λ is the grating period. The periodic structure may be positioned at any interface, but our simulations have shown that the upper interface of guide 2 is the best location since the overlap integral of the odd and even modes is maximum there.

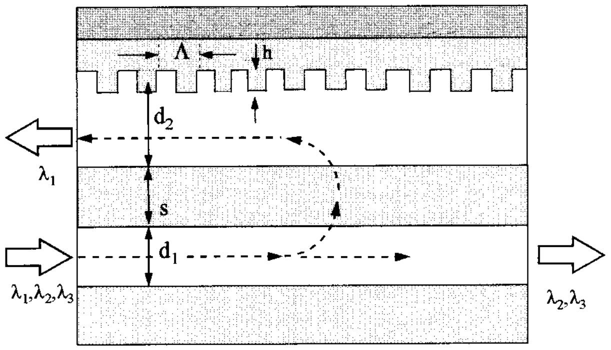

Figure 1. Cross sectional view of one block of complete filter structure.

The principle of operation is as follows: light launched in guide 1 is coupled counter-directionally to guide 2 through exchange-Bragg coupling. The grating period in each section is chosen in such way that the Bragg condition is satisfied only for the selected wavelength. This selected optical carrier is reflected through a 45 degree mirror and guided to a photodetector, which may be of evanescent or the butt-coupled type. It should be stressed that the photodetector is far away from the input waveguide. Thus, an extremely low overlap of the undesired fields on the detector element is expected. A top view of the complete structure is depicted in Figure 2.

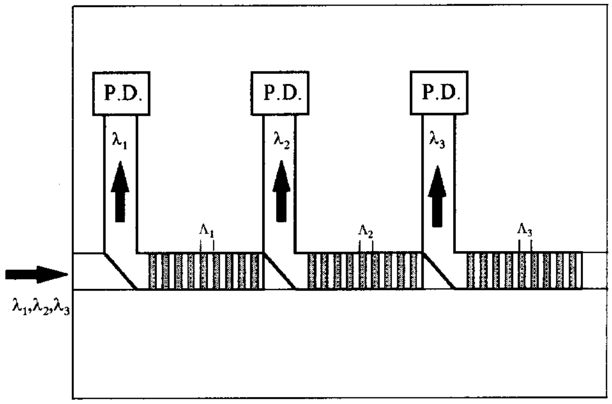

Figure 2. Top view of the structure.

Simulation results

The filter response is presented in Fig. 3. The calculations where made employing the transmission matrix formalism described in [4]. The InGaAsP core and InP cladding refractive indexes and material losses were included according to data reported in the literature [5-6]. Solid lines represent the transmittance of the first filter, while the dashed lines represent the second filter transmittance and the short-dashed one refers to the transmittance in the third output. As light transmitted to the second output has passed through the first filter and light in the third output passed through the first and second filters, the response of the optical channels is affected by the interaction with the Bragg structures. Specifically, the transmittance sidelobes of the first filter will introduce an undesirable crosstalk of channels 2 and 3 into optical carrier 1. On the other hand, the second section sidelobes will affect the third wavelength but not the first one. In summary, this overall interaction may introduce a serious crosstalk and lack of flatness on the channel response.

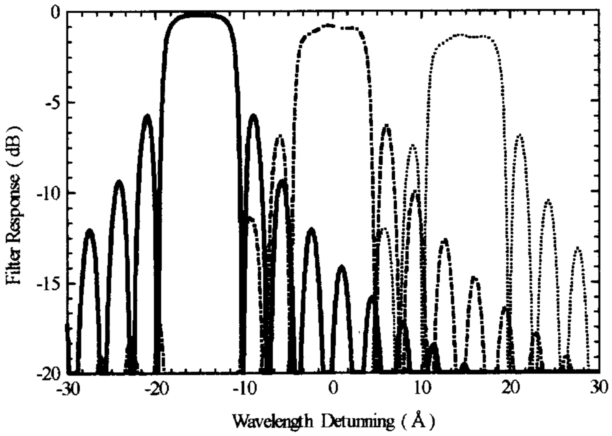

Figure 3. Filter response of each section. Solid lines represent the first section response, the dashed ones show the response of the second section and the dotted lines show the third section response.

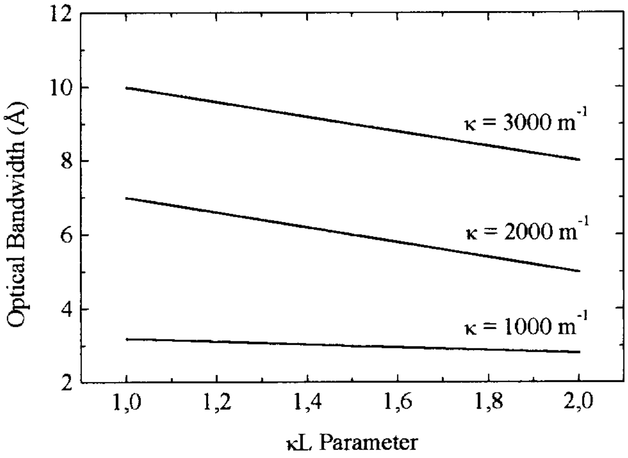

Figure 4. Optical filter bandwidth as a function of the κL parameter Top view of the structure.

A systematic study was carried out to verify how the filter design parameters influence the optical response. Generally, an increase in length will yield lower crosstalk, narrower optical bandwidth but larger loss. On the other hand, by increasing the coupling coefficient (i.e., increasing the grating depth or decreasing the separation between the waveguides) one achieves opposite results. Thus, the product κL, coupling constant-device length, may be used as parameter when analyzing design trade-offs. The above discussion is summarized in Figs. 4 and 5.

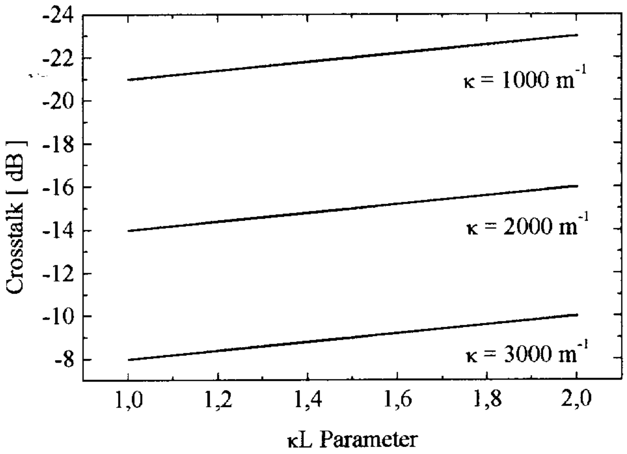

Figure 5. Calculated crosstalk plotted as a function of κL parameter. The indicated crosstalk refers only to the dominant next neighbor.

Conclusions

In conclusion, a three-channel optical dropping filter for use on dense WDM systems was proposed and some of the design trade-off were discussed. For future work, we will investigate the use of chirped gratings, yielding optical equalization while the signal is demultiplexed.

References

1. T. L. Koch, P. J. Corvini, W. T. Tsang, U. Koren, and B. I. Miller, Applied Physics Letters, Vol. **51**, no. 14, 1060 (1987).
2. M. Levy, L. Eldada, R. Scarmozino, R. M. Osgood Jr., P. S. D. Lin, and F. Tong, IEEE Photonics Technology Letters, Vol. **4**, no. 12, 1378 (1992).
3. H. Sakata and H. Kawasaki, Applied Physics Letters, Vol. **64** no. 10, 1201 (1994).
4. G. P. Agrawal and S. Radic, IEEE Photonics Technology Letters, Vol. **6**, no. 8, 995 (1994).
5. C. H. Henry, L. F. Johnson, R. A. Logan, and D. P. Clarke, IEEE Journal of Quantum Electronics, Vol.**21**, no. 12, 1887 (1985).
6. F. Fiedler and A. Schlaetzki, Solid-State Electronics, Vol. **30**, no 1, 73 (1987).