Multichannel Bandpass Optical Filter Integrated in Tandem For High-Speed Wavelength Division Multiplexed Systems

A. O. Calligaris Jr. and M. T. Camargo Silva

Optoelectronics and System Research Laboratory - Department of Electrical Engineering
Engineering School Of São Carlos
University Of São Paulo
São Carlos SP

Abstract: **It is reported a multichannel bandpass optical filter based on multiple-phase-shifted Bragg resonator integrated in tandem. The filter with channel separation of 30Å presents a passband of ~70GHz, ripple smaller than 1dB, and return loss greater than 25dB.**

I. Introduction

The need of broad-band communication systems has been increasing and one essential device is the optical filter which in wavelength division multiplexed (WDM) optical communication networks can be utilized as bandpass filters, amplified spontaneous emission (ASE) rejection filters in optical amplifiers, and for optical channel selection. In addition, high-speed WDM systems also demand high rejection sideband and wide and flat bandpass filters with ripple smaller than 1dB to avoid power-penalty transmission. Consequently, device design to obtain filters with those features are of great concern. Semiconductor optical filters are particularly suitable for monolithic integration with other photonics devices amplifiers, photodetectors, and switches. Among the several schemes proposed, the DBR-based [1-3] and Fabry-Perot [4] filters are attractive because of their compactness and low insertion loss. The perceived shortcoming with these devices is the triangular bandpass feature which restrict the network speed to few Gb/s at most for free power-penalty transmission. Recently, it has been shown [5] that the phase-shifted Bragg grating filter transmission spectrum can be tailored by suitable placement of phase-shift sections for specific applications. It is reported a compact semiconductor multichannel optical transmission filter integrated in tandem based on multiple-phase-shifted Bragg resonator. For 30Å of channel spacing the filter exhibits a bandpass ~70GHz wide, ripple smaller than 1dB, and return loss greater than 25dB. The proposed filter displays superior features as required by high-speed WDM systems.

II. Filter Design

The basic block of the semiconductor transmission filter integrated in tandem is shown schematically in Figure 1. The device is composed of a double heterostructure single-mode optical waveguide based on undoped InGaAsP/InP materials grown on a N^+InP substrate. The U:InGaAsP waveguide core is 0,774μm thick and it is surrounded by U:InP with thickness 1,5μm. A grating with period Λ and depth g=740Å is etched in the upper surface of the waveguide core. Three phase-shift regions of phase magnitude ϕ, length L_s, and depth 0,274μm are also etched in proper locations. The grating sections have lengths L_g and L_b. In this specific structure $L_g=2L_b$ and $\phi=\pi/2$. The multichannel filter is composed of N basic blocks in tandem. In the example presented here only three channels were utilized to demonstrate the feasibility of the approach.

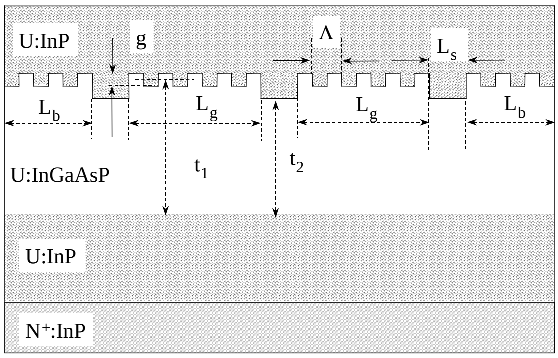

Figure 1. *Fundamental block of the transmission filter.*

III. Threechannel Filter Performance

The transmission spectrum of the multiple-phase-shifted three channel filter was calculated through the scattering-matrix method based on the coupled-mode theory [5] with suitable modifications to include the semiconductor absorption losses [6]. In the simulations the refractive indices [7] of $In_{0.87}Ga_{0.13}As_{0.28}P_{0.72}$ and InP were taken to be 3,2544 and 3,1495, respectively. It was assumed center wavelengths of 1,547, 1,55, and 1,553μm, i.e. a channel separation of 30Å with grating periods of 2413,4, 2418,5, and 2423,5Å. From a grating coupling coefficient K=62,719 cm^{-1} and KL_g=1,45 grating lengths L_g=231,19μm and L_b=115,595μm were obtained. The length of the phase-shift sections is 25,09μm. Each filter is 769,08μm long yielding a total device length of 2,307μm. The transmission spectrum of the three channel filter is shown in Figures 2 and 3.

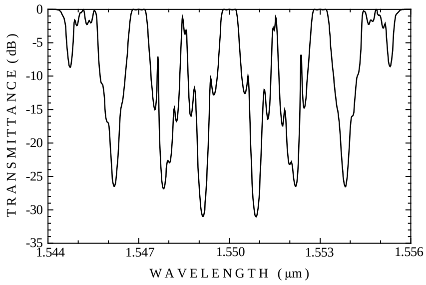

Figure 2. *Transmission spectrum of the filter.*

As can be observed in Figure 2, the device transmission spectrum shows a flat and wide bandpass with steep edges for all channels. Return loss higher than 25dB close to the channels was achieved. However signals midway of the center wavelengths present low return loss. This feature is related to the stopband width of the resonators which due to the large separation between them do not cancel out.

It is shown in Figure 3 that the transmission spectrum has a flat, <0,1dB deviation, region ~50GHz wide and for 1dB of variation the bandpass is ~70GHz.

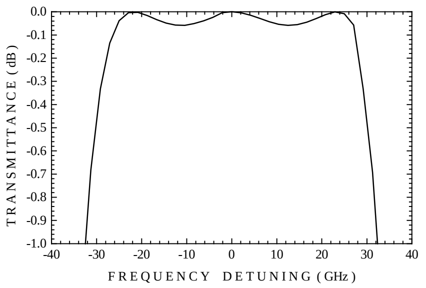

Figure 3. *Close view of transmission spectrum.*

The width of the passband at 1,0dB for all three channels were studied as a function of the product KL_g and grating depth. The results are shown in Figures 4 and 5. In fact the width of the passband is reduced for increasing KL_g. The passband width is nearly constant for KL_g ranging 1,45–1,52 and the deviation increases out of this range, as can be inferred in Figure 4. As shown in Figure 5, the width of the passband increases for deep gratings and it is also nearly constant for grating depth extending from 0,074 to 0,076μm.

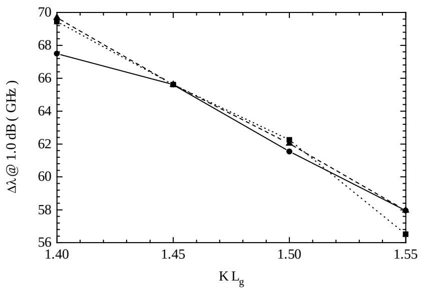

Figure 4. *Width of the passband at 1.0dB as a function of KL_g. The grating depth was kept constant at 740Å. Square: 1,547, Circle: 1,55, and Triangle: 1,553* μm.

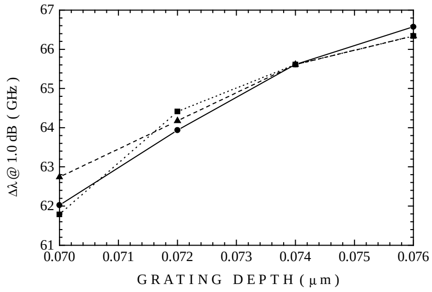

Figure 5. *Width of the passband at 1,0dB as a function of the grating depth. The product KL_g was kept constant at 1,45. Square: 1,547, Circle: 1,55, and Triangle: 1,553* μm.

IV. CONCLUSIONS

We report a compact low-loss multichannel bandpass optical filter based on multiple-phase-shifted Bragg resonator integrated in tandem. The device is based on multiple-phase-shifted Bragg grating in which the number and placement of phase-shift sections are utilized to tailor the width and the ripple of the bandpass. Multichannel filters can be produced with N of such basic structures. The filter with channel separation of 30Å presents a passband of ~70GHz, ripple smaller than 1dB, and return loss greater than 25dB. The filter exhibits excellent features which are required by high-speed WDM systems.

V. REFERENCES

[1] I.A.M. Habbab et all., IEEE Photon. Technol. Lett., 2, 337,1990.

[2] T. Numai, Internat. J. of Optoelectron., 6, 239, 1991.

[3] W.P. Huang and J. Hong, IEEE Photon. Technol. Lett., 4, 884, 1992.

[4] A. Dentai et all., IEEE Photon. Technol. Lett., 6, 629, 1994.

[5] G.P. Agrawal and S. Radic, IEEE Photon. Technol. Lett., 6, 995, 1994.

[6] F. Fiedler and A. Schlachetzki, Solid-State Electron., 30, 73, 1987.

[7] C.H. Henry et all., IEEE J. Quantum Electron., 21, 1887, 1985.

ACKNOWLEDGMENT

The authors wish to thank the financial support of the Ministry of Science and Technology - RHAE Program Grants # 610.346/95-4 and 360.556/96-5.

Alberto Otávio Calligaris Júnior Graduado pelo Instituto Nacional de Telecomunicações – INATEL em 1992 e pós graduação (mestrado) pela Escola de Engenharia de São Carlos, EESC-USP em 1996.
e-mail: albertjc@hotmail.com

Prof. Milson Tadeu Camargo Silva Doutorado pelo Instituto de Física de São Carlos, IFQSC/USP em 1992 e Ph.D. pela Drexel University em 1994.