Wide And Flat Bandpass Tunable Optical Filter For High-Speed Wavelength-Multiplexed Communication Systems

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Abstract **It is reported a tunable bandpass optical filter fabricated with multiple-phase-shifted Bragg resonator based on InGaAs/InP coupled asymmetric quantum wells. The device is very suitable for application in high-speed WDM systems and it is easy to be fabricated.**

I. INTRODUÇÃO

Semiconductor based tunable optical transmission filters presenting high rejection sideband and wide and flat bandpass with ripple smaller than 1dB to avoid power-penalty transmission are critical devices in future high-speed wavelength division multiplexed (WDM) communication systems as bandpass filters and amplified spontaneous emission (ASE) rejection filters. In addition, the filters should be monolithically integrated with other photonics devices such as semiconductor optical amplifiers (SOA) and photodetectors. Consequently filter design to achieve devices with those features are of great concern. Many different devices have been proposed to meet those requirements. Some of these filters are based on distributed Bragg reflector structures [1-4], and some are the Fabry-Perot filter type [5,6].

These devices present a rounded bandpass feature which are not suitable for penalty-free high-speed communication systems. Furthermore, the filters utilize carrier injection as tuning mechanism which increases the insertion loss, produces low speed devices, and generates noise due to the carrier recombination. Recently, it has been shown [7] that the transmission spectrum of phase-shifted Bragg grating filters can be tailored through appropriate placement of several phase-shift regions. It is presented a tunable optical filter fabricated with multiple-phase-shifted Bragg resonator based on InGaAs/InP coupled asymmetric quantum wells. The device exhibits a wide and flat bandpass, high return loss and speed, large tunability at low drive voltage, low insertion loss, and small length.

II. FILTER STRUCTURE

In Figure 1 is shown the longitudinal cross-section of the filter.

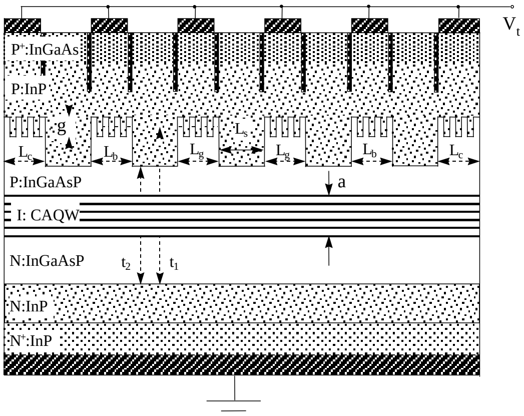

Figure 1. *Longitudinal cross-section of the filter.*

The device, fabricated on a N^+: InP substrate, is comprised of a monomode optical waveguide which core is composed of 36 periods of I: InGaAs/InP coupled asymmetric quantum wells [8] yielding a intrinsic region a = 0,802 μm thick and N($6x10^{17}/cm^3$) and P($10^{17}/cm^3$): InGaAsP layers cladded by N($10^{17}/cm^3$) and P($10^{17}/cm^3$): InP. A P^+: InGaAs layer topped the device. Each quantum well period consists of two asymmetric InGaAs well, 40 and 30Å thick, coupled through a InP barrier of thickness 50Å. The periods are uncoupled by a InP barrier 100Å thick. In the upper layer of the core gratings with lengths L_g, L_b, and L_c and depth g and $\lambda/4$ phase-shifted regions of length L_s and depth (t1+g/2-t2) are etched. In the present design to achieve a flat and wide bandpass feature the grating and phase-shifted sections are L_g=188,56μm, L_b=171,42μm, L_c=94,28μm, L_s=82,24μm, and g=0,15μm, yielding a device length of 1320μm.

Electrical tuning at high-speed is obtained through ohmic contacts on the grating sections which are isolated from each other by ion implantation. A multichannel filter can be fabricated by integrating in-line several of the basic block shown in Fig. 1.

III. FILTER PERFORMANCE

In order to calculate the transmission features of the filter the transfer-matrix approach based on the coupled-mode theory [7] with proper modifications to include materials absorption was used. The refractive index of the core is 3,2540 and that of cladding layers is 3,1495. It was assumed a operating wavelength of 1,55μm. The transmission spectra of the filter with and without applied voltage are shown in Figures 2 and 3 for KL_g=1,6, where K is granting coupling coefficient, K=84,85cm^{-1}.

The device transmission spectrum without applied voltage of the filter shows a wide, 86,7GHz at 1dB, and flat, ripple <1dB, bandpass. The return loss near the bandpass is ~38dB. With the applied voltage, 2,8V, the transmission spectrum is shifted to smaller wavelength but the bandpass features are not altered.

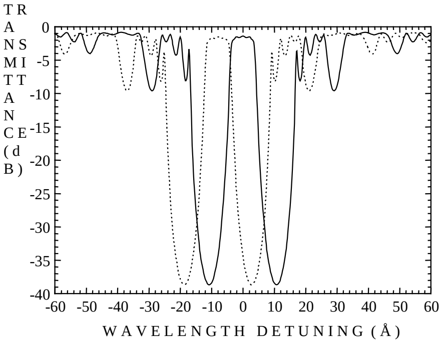

Figure 2. *Transmission spectra of the filter without applied voltage (solid line) and with applied voltage (dotted line).*

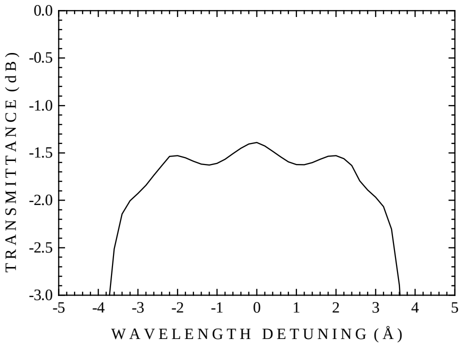

Figure 3. *Close view of transmission spectra.*

The device insertion loss and bandwidth at 1,0dB as a function of KL_g is shown in Figure 4. Both parameters shows a remarkable dependence on KL_g, which produces an increase on the insertion loss and a decreasing on the filter bandwidth.

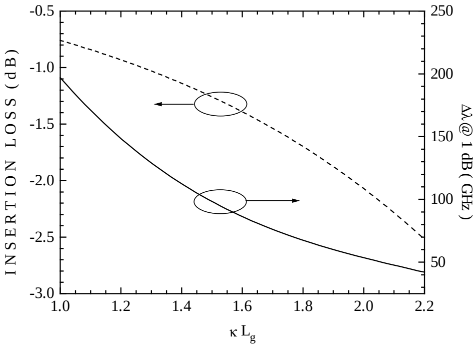

Figure 4. *Insertion loss and bandwidth as a function of KL_g.*

Optical tuning of the device is obtained via the electrorefraction effect in the quantum well layer of the core. The optical tuning as a function of applied voltage of the filter is shown in Figure 5. It can be seen in the figure that the optical tuning is ~8,6Å at 2,8V.

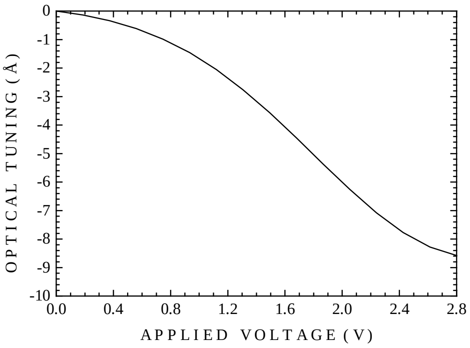

Figure 5. *Optical tuning of device as a function of applied voltage.*

IV. CONCLUSIONS

It was reported a tunable optical transmission bandpass filter. The device is based on multiple-phase-shifted Bragg gratings in which the number and placement of the phase-shift sections are utilized to tailor the width and the ripple of the bandpass. The device presents wide, 87,5GHz, bandpass with ripple <1dB, return loss of ~38dB, optical tuning of 8,6Å, insertion loss of 1,4dB, tuning speed of 10GHz, and a length of 1320μm.

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