Contents

Flat-Top Fourth Order MZI Filter

In telecommunication applications such as high speed links, there are challenges like in-band ripples which can cause unwanted signal distortions and/or power variations induced by wavelength drifts of the light sources (in the absence of thermal control). These challenges can be mitigated by using the optical filters having a flat-top transmission response. This article present a fourth order MZI filter [1] with the use of Multimode Interferometers (MMIs) splitters, designed using the building blocks developed by VLC Photonics, based on the silicon nitride (SiN) technology, establised and running at CNM (Centro Nacional De Microelectronica). Due to their broadband operation and tolerance to fabrication errors, MMI splitters are preferred over the other splitter types. SiN material these days is commonly used in CMOS platform and has an edge over traditional silicon (Si) and III-V material due to its wide index contrast and relatively low thermal oxide coefficient.

Theory

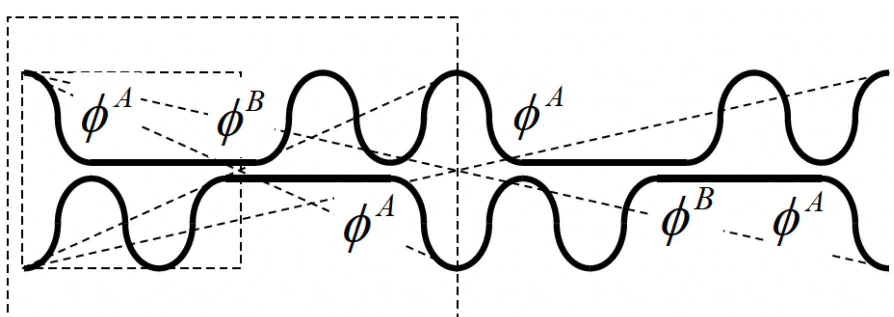

Fig. 1. Schematic of a double point-symmetric configuration, showing the coupling angles ϕ^A and ϕ^B of the couplers [1].

Figure 1 shows a doubly point-symmetric configuration where the building block, composed of a type A coupler and half-type B coupler, is repeated point symmetrically which results in a ABA structure. This structure is repeated point symmetrically to give the desired result. The angular expression of the amplitude coupling ratio [2] of a coupler is defined by:

$$\phi(\lambda) = \kappa(\lambda)[L + \delta L(\lambda)] \tag{1}$$

where,

$\kappa(\lambda)$ is the coupling per unit length in the straight part of the coupler

$\delta L(\lambda)$ accounts for the contribution of the input and output curves

While designing the filter, these two quantities are assumed to be same for all the couplers and also assume any dependence of ϕ on λ to be negligible. Then the fourth order MZIs based filter with the flat-top response can be designed based on analytic equations [3] to determine the coupling angles ϕ^A and ϕ^B as follows:

$$\phi^A = \frac{\pi}{16} + (m+k)\frac{\pi}{8} \tag{2}$$

$$\phi^B = \frac{\pi}{8} + (m-k-t)\frac{\pi}{4} \tag{3}$$

If t=k=0 and m=1, then

$$\phi^A = \frac{3\pi}{16} \tag{4}$$

$$\phi^B = \frac{3\pi}{8} = 2\phi^A \tag{5}$$

which requires a single point-symmetric configuration. ϕ^B exactly matches the coupling angle of an 85/15 MMI [1] whereas, ϕ^A doesn't match any simple MMI design. So, the two ϕ^A at the edges of the filter require a double MMI approach to mimic the functionality of an equivalent directional coupler. Whereas, the two ϕ^A splitters in the middle can be combined in a single splitter of angle $2\phi^A = \frac{3\pi}{8} = \phi^B$. So, the couplers with coupling angle ϕ^B are replaced with the MMI having 85/15 splitting ratio i.e. three 85/15 MMIs at the center. At the input and output edges, a double MMI 50/50 is used to acquire the desired splitting ratio. The proposed flat-top fourth order interleaver filter is shown in figure 2.

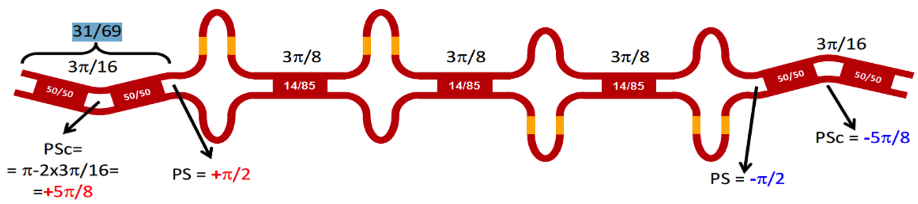

Fig. 2. The proposed flat-top 4^{th}-order MZI based optical filter [1].

A $\frac{\pi}{2}$ phase is added at the end of each double MMI 50/50 to make sure the output phase is correct. In between the double MMI 50/50, an additional $\frac{5\pi}{8}$ phase shift is required to have accurate splitting ratio. This phase shift is slightly different in this particular example since the MMI ratios are not ideal. The orange color in the arms of the asymmetrical MZIs in figure 2 represent the delay length (ΔL).

Design

To design and simulate the flat-top filter shown in figure 2, building blocks from the VLC-CNM PDK and from the OptiSPICE device library are selected. The filter is build and simulated using the simulation tool S-edit from SIEMENS Tanner. The devices used from the VLC-CNM PDK are: cnmMMI2x2BB_TE (MMI 50/50), cnmMMI8515BB_TE (MMI 85/15), cnmWaveguideDE_TE (straight waveguide). All these devices are made of deep etched waveguide and are TE polarized. A complete circuit for the simulation can be seen in figure 3, where a three port laser sends in a signal (freq = 210 THz) at the input of the filter, and the output response, is measured using the optical probes.

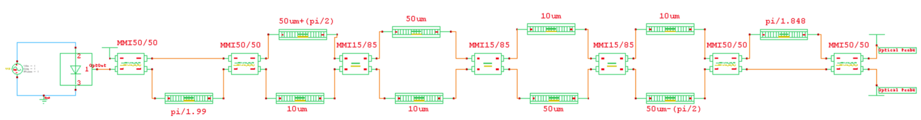

Fig. 3. The simulation circuit designed in S-edit tool showing the lengths of the MZI arms and the MMI splitting ratios.

The phase shift of $\frac{\pi}{1.99}$ and $\frac{\pi}{1.848}$ is added in between the double MMI 50/50 at the input stage and the output stage, respectively. The ΔL for the MZI arms is 40 um. The additional phase shift of $+\frac{\pi}{2}$ and $-\frac{\pi}{2}$ is added to the ΔL as shown in figure 3.

Simulation and Results

An AC analysis is carried out and the laser frequency is swept from 200 THz to 220 THz. The flat-top transmission response of the filter is shown in figure 4. The probe 'OTerminator4' shows the frequency response in the bar state and 'OTerminator3' shows a frequency response in cross state. The measured FSR is 2.35 THz, and the extinction ratio from the plot is measured to be >20dB. The wide bandwidth of the MMIs allow to cover the E-band of the telecom wavelength spectrum.

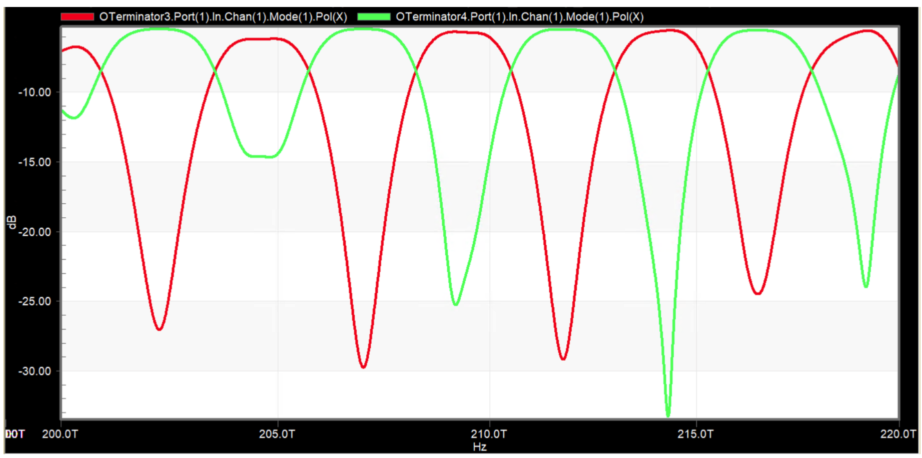

Fig. 4. The simulated transmission response of the filter showing a flat-top behaviour.

Thus, a fourth order interleaver filter based on the point symmetric configuration [1] is presented in this article using the MMI 50/50, MMI 85/15 and waveguide building blocks from the VLC-CNM PDK showing a flat-top filter, which finds it's applications in the telecommunication sector.

References

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Labels

Photonics Integrated Circuits; Flat-top; WDM filters; Mach-Zehnder Interferometer; Multimode Interferometer; Integrated Optics