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C-band Four Channel Optical De-Multiplexer

The rapid traffic growth within the local area networks has tremendously increased the deployment of Wavelength Division Multiplexing (WDM) optical links in short reach applications. With the increasing market size in data centre applications, optical de-multiplexers are being widely used as a key element in WDM transceivers. Optical de-multiplexers can be implemented using various ways but the Mach-Zehnder Interferometer (MZI) hs been the most preferred choice due to the ease of fabrication in the CMOS platform, the size and the insertion loss. Here, we present a four channel optical de-multiplexer filter which is designed using the building blocks developed by VLC Photonics, based on the silicon nitride (SiN) technology, established and running at CNM (Centro Nacional De Microelectronica). SiN is a common material in CMOS fabs which provides moderate index contrast and relatively low thermal oxide (TO) coefficient, thus enables the reduction of process sensitivity and temperature dependence.

Theory

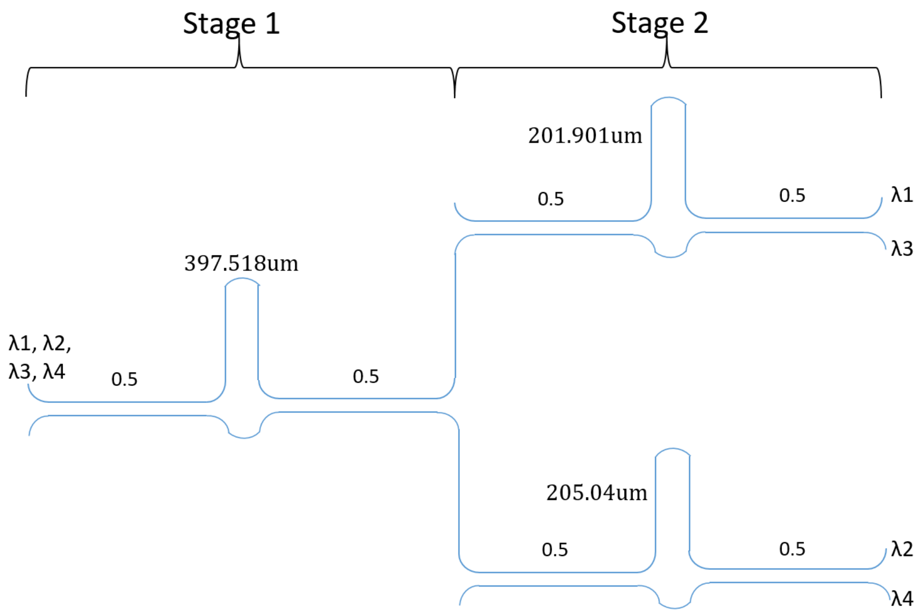

Fig. 1. Schematic of the four channel de-multiplexer. The delay length of each asymmetric MZI is specified.

MZI based optical filters are widely used in the transceivers that separate an incoming spectrum into two complementary set of periodic spectra as even and odd channels. In this article we showcase a 1x4 optical de-multiplexer filter, shown in figure 1, which comprises of two stages. Stage 1 consists of an asymmetric Mach-Zehnder Interferometer (MZI), made of two 50/50 splitters and the waveguides forming the delay length (ΔL). The light is injected into this stage. Similarly, stage 2 has two arms, each consisting of asymmetric MZI. The delay lengths in both the arms of stage 2 is half the delay length (ΔL) in the stage 1. The even and odd frequency channels are separated in stage 1. The odd frequency channels are sent to the upper arm of the stage 2 and the even frequency channels are sent to the lower arm, where they are further separated out. The delay length (ΔL) of the stage 1 MZI is set based on the targeted channel spacing, also known as Free Spectral Range (FSR), of 200 GHz in the C-band, using following relation: -

$$\Delta L = \frac{\lambda^2}{2n_g(\delta\lambda)} \tag{1}$$

where,

λ is the central wavelength of operation

n_g = group index of the waveguide forming the delay length

$\delta\lambda$ = Channel spacing or FSR

Design

The circuit of a 1x4 channel de-multiplexer is build in the simulation tool, known as S-edit from Siemens Tanner. The circuit can be seen in the figure 2, which comprises of the following devices from the VLC-CNM PDK: cnmMMI1x2DEBB_TE (1x2_50/50_MMI), cnmMMI2x2BB_DE (2x2_50/50_MMI) and cnmWaveguideDE (deep etched waveguide). These devices are connected to the other opto-electronic devices from the OptiSPICE library to complete the circuit.

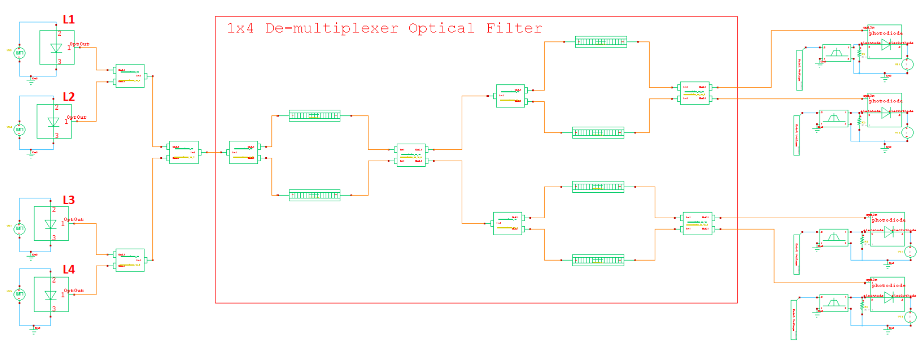

Fig. 2. Complete simulation circuit of the 1x4 de-multiplexer in S-edit using building blocks from VLC-CNM PDK and OptiSPICE library.

Four lasers (L1, L2, L3, L4) from the OptiSPICE library send four different frequency channels (193.451 THz, 193.652 THz, 193.85 THz, 194.052 THz), respectively, into the stage 1 of the 1x4 de-multiplexer optical filter. The MZI of stage 1 is build using the devices: cnmMMI1x2DEBB_TE, cnmMMI2x2BB_DE and cnmWaveguideDE, where the length of the upper waveguide is set to 497.518 um and for the lower waveguide is set to 100 um. This is further connected to the MZIs of the two arms of stage 2, which are also built using the same devices as MZI of stage 1. The length of the upper waveguide, of the MZI of upper arm, is set to 301.901 um and the lower waveguide is set to 100 um. Similarly, the length of the upper waveguide, of the MZI of the lower arm, is set to 305.04 um and the lower waveguide is set to 100 um. The waveguide lengths of the MZIs in the circuit are set to match the delay lengths (ΔL), as shown in the figure 1.

Lasers are connected to the bit voltage source, each sending in random bit pattern which are combined using the device cnmMMI1x2DEBB_TE before entering de-multiplexer filter. Each output of the de-multiplexer filter is connected to the photodiode to detect the signal. This signal passes through a lowpass electrical filter to evict any unwanted noise, which is further measured using the probe. The probe N_5 and N_6 are connected at the output of the upper arm whereas, the probes N_7 and N_8 are connected to the output of the lower arm.

Simulation and Results

A time domain transient analysis is carried out for this circuit with the stop time of 1 ns and the time-step of 0.1 ps. The rise and fall time of the bit source is 10 ps with the pulse width of 100 ps. The vbit_1 (bit pattern = 0101010101) is connected to laser1, vbit_2 (bit pattern = 00011011100) is connected to laser2, vbit_3 (bit pattern = 1110000010) is connected to laser3 and vbit_4 (bit pattern = 0110001111) is connected to laser4. The waveform viewer showing four different frequency channels, measured at the output using the photodetectors, can be seen in figure 3.

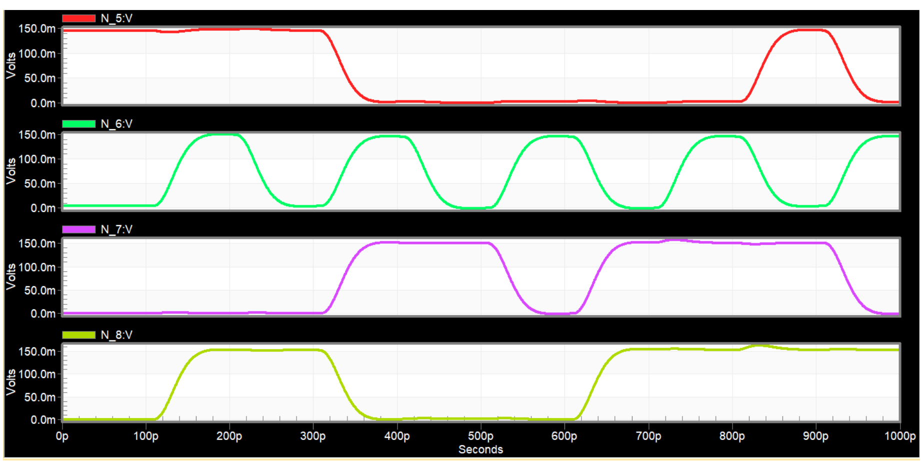

Fig. 3. Waveform viewer showing four different frequency channels (bit patterns) measured at the photodetectors.

The transmission plot above shows the odd frequency channels coming from laser1 and laser3 are measured using the probes N_5 and N_6, respectively, at the output of the upper arm. Similarly, the even frequency channels coming from the laser2 and laser4 are measured using the probes N_7 and N_8, respectively, at the output of the lower arm.

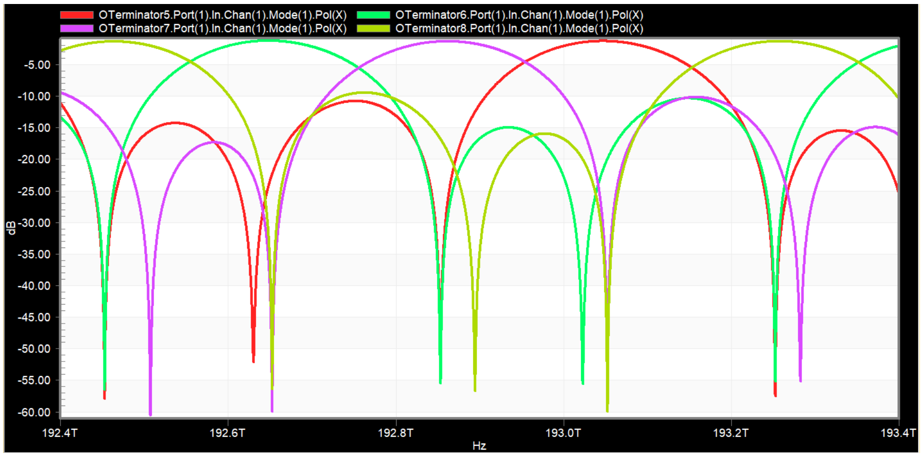

Fig. 4. Transmission spectrum showing the frequency response of the filter at the output.

The AC analysis was also carried out for the filter where the frequency was swept from 192.4 THz to 193.4 THz and the output transmission response is shown in figure 4. The measured FSR of the filter is 200 GHz (1.6 nm) in the C-band (near 1550 nm). The crosstalk with the neighboring channel is measured to be around ~ 20dB and the 3-dB bandwidth is approximately 178.71 GHz (1.432 nm). Thus, optical de-multiplexer filter with the desired FSR is designed and simulated. Which obtains the split odd frequency channels in the upper arm of the stage2 and even frequency channels in the lower arm of stage2.

Labels

Photonic Integrated Circuits; De-multiplexer; Transient; DWDM; Optical filter; 1x4 Channel