

# Mach-Zehnder based interleaver

**File name:** Interleaver.apc

**Reference:** T. Mizuno et al., “12.5-GHz Spacing Compact and Low-Loss Interleave Filter Using 1.5%  $\Delta$  Silica-Based Waveguide”, IEEE Photon. Technol. Letters, Vol. 16, pp. 2484-2486, November 2004

This circuit is a nice example of interleaver realized by cascading several Mach\_Zehnder interferometers. The device, proposed in the Reference, where a folded version is also considered, has a FSR=25 GHz and shows symmetrical Cross and Bar characteristics. The interleaver filter consists of two filter elements, front and rear, cascaded in series to form a tandem configuration to suppress both crosstalk and chromatic dispersion.

Each filter element is a cascaded Mach-Zehnder interferometer composed of four optical couplers and three optical delay lines. The coupling splitting ratios of the couplers are  $r_1, r_2, r_3$  and  $r_4$ , the path length difference of the delay line are  $\Delta L_1 = \Delta L$ ,  $\Delta L_2 = 2\Delta L$  and  $\Delta L_3 = 2\Delta L + \lambda_c/2$ . The value of  $\Delta L$  determines the FSR of the filter,  $\lambda_c$  is the central wavelength of the filter.

In order to cancel chromatic dispersion, the response of the rear filter is shifted by FSR/2. This is achieved by increasing by  $\lambda_c/2$  the value of  $\Delta L$  in the rear filter.

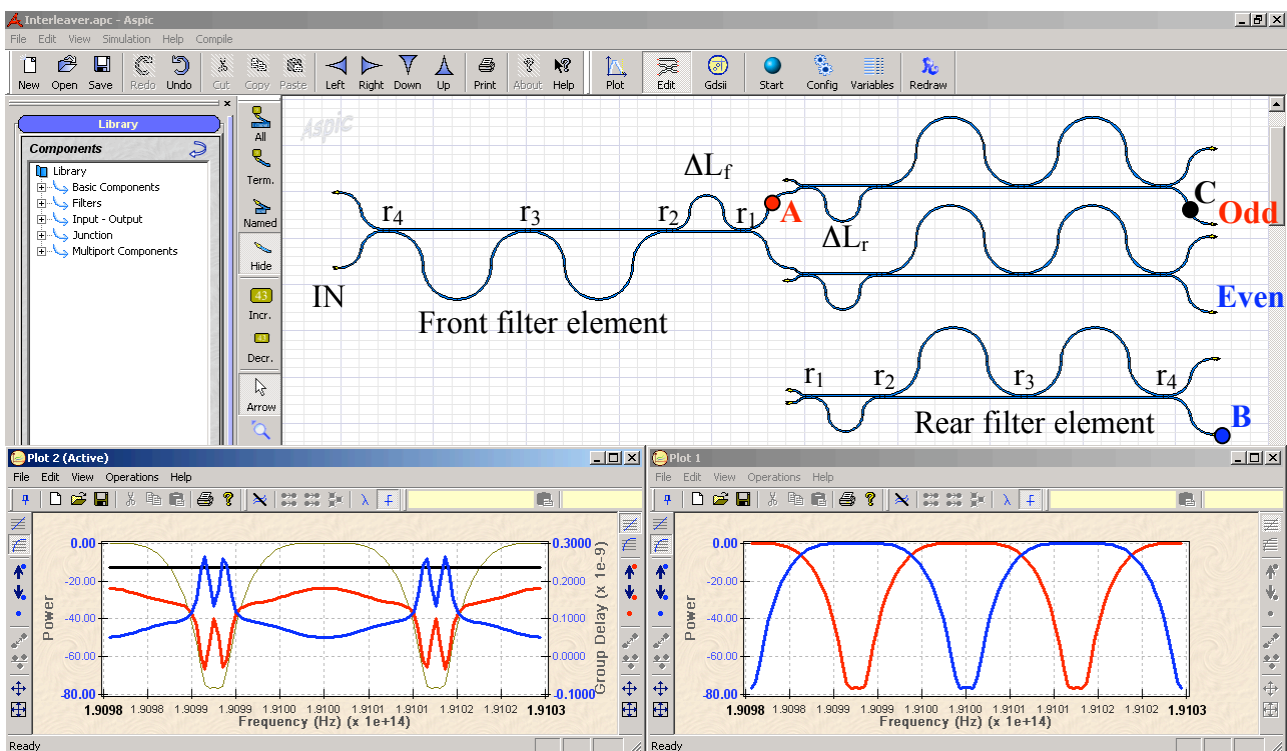


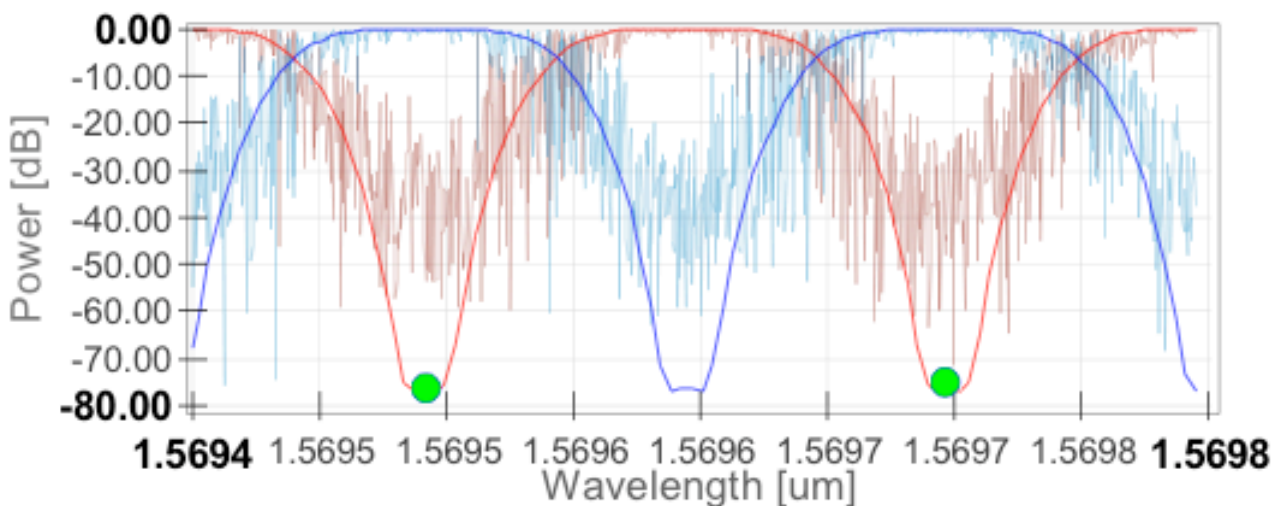
Fig. 1 – Interleaver example –In band group delay and magnitude spectral response

According to the design criterion discussed in the reference, in this example the values of the couplers splitting ratios have been set to  $r_1=1-0.5$ ,  $r_2=1-0.85$ ,  $r_3=0.23$  and  $r_4=0.01$ . The central wavelength  $\lambda_c$  has been set to  $\lambda_1=1569.594$  nm (191 THz). In order to achieve a FSR=25 GHz, the path length difference  $\Delta L_{1f}=\Delta L_f$  and  $\Delta L_{1r}=\Delta L_r$  in the front and rear filter element respectively have been set to  $\Delta L_f=L_1=11999.54613$   $\mu\text{m}$  and  $\Delta L_r=L_{1r}=L_1 + (\lambda_1/2)$ , as can be observed in the variables table.

The filter obtained shows symmetrical Cross and Bar characteristics, as shown in the plot on the right hand side of Fig. 1, where the magnitude spectral responses at the Odd port (red line) and Even port (blue line) are reported.

In the example the rear filter element has been duplicated to analyze the group delay characteristics of the interleaver. The plot on the left hand side of Fig. 1 shows the group delay (GD) in different points of the circuit. The red line is the GD computed in point A of the entire circuit, that is the GD due to the front filter element only, the blue line is the GD computed in point B of the rear filter element and the black line is the GD computed in point C of the entire circuit. It can be noticed how the front and the rear elements have opposite GD trends which give an overall flat in band GD to the entire circuit, hence the chromatic dispersion is cancelled.

To have an idea of the impact of the effective refractive index tolerances on the filter transfer function, the Mach-Zehnder unbalances can be altered by a random amount around their nominal values. As an example, the simulation reported in figure 2 is obtained by changing the unbalances at every wavelength by a normally distributed random value with standard deviation of  $0.1 \mu\text{m}$ . The nominal response is reported too. This technique allow to evaluate the deterioration of the performances in presence of disorder or technological tolerances is much faster than performing the analysis with random but constant parameters values.



*Fig. 2 – Nominal and tolerance affected magnitude spectral response. The green dots are two markers used to measure the extinction ratio and the FSR.*