Task 3 Photonic Devices Course: Hitless Filter

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Design of a ring resonator filter:

To dimension the ring resonator we started from some specifications of the project, i.e.:

$$\Delta f_{WDM} = 100\ GHz \qquad B = 40\ GHz$$

From these data we impose the minimum Free Spectral Range (FSR), the Finesse (F) and the Coupling Coefficient (K_R) . Assuming 8 channels in the WDM system we find:

$$FSR > N_{ch} \cdot \Delta f_{WDM} = 800\ GHz$$

$$F > \frac{FSR}{B} = 20$$

Assuming also an ideal lossless behaviour we find K_R as:

$$K_R = \frac{F}{\pi} = 0.157$$

We can retreive another specification, that is the minimum bending radius of the ring to avoid non-negligible dispersions. Knowing that the technology is Silicon on Silica:

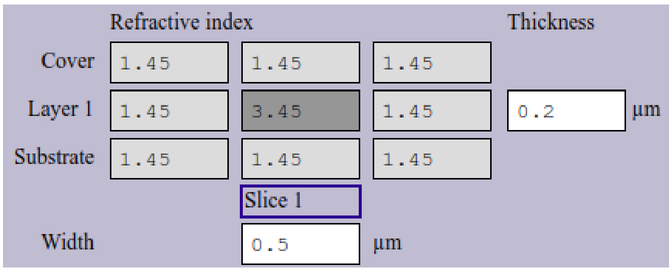
$$R_{min} = 5 \cdot \Delta n^{-1.5} = 3.085\ \mu m$$

Fixed this we choose the proper radius and circumference of the ring in order to achieve the resonance of a certain wavelength to be filtered. For the waveguide in the picture and a radius of 10 microns we find these parameters:

$$N = \left\lceil \frac{2\pi \cdot n_{eff} \cdot R}{\lambda_0} \right\rceil = 93$$

$$FSR = \frac{c}{n_g \cdot 2\pi \cdot R} = 1.818\ THz$$

$$F = \frac{\pi \cdot \sqrt{K_r}}{K_r} = 33.11$$



$TE_{0,0}$: $N_{eff} = 2.273254554$, $\beta = 9.215019107\ \mu m^{-1}$

Now to evaluate the cross-talk between channels and the perfomance of the designed device, we studied the transfer functions:

$$H_t = \frac{r\left(1 - e^{-j\beta\, L_r}\right)}{1 - r^2 e^{-j\beta L_r}} \qquad H_d = \frac{-t^2 \cdot e^{-j\beta \frac{L_r}{2}}}{1 - r^2 e^{-j\beta L_r}}$$

The cross-talk, defined as the portion of power of the considered channel that leaks into another channel, is calculated for the two closest channels and for a value of K_R equal to 0.009. On the right are plotted the same parameters in function of K_R to emphatize the role of the coupling coefficient on the selectivity of the filter.

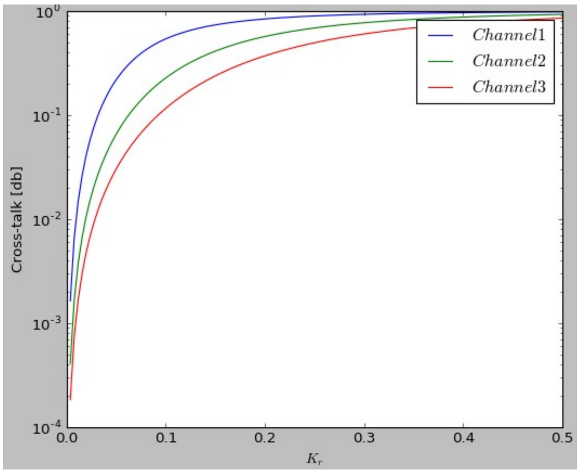
$$X_n = 10 \cdot log_{10}\left(\frac{\left|H_{d_0}\right|^2}{\left|H_{d_n}\right|^2}\right)$$

$$X_0 = R_L(Return\ Loss) = -1.15 \cdot 10^{-14} dB$$

$$X_1 = X_a = -18.63\ dB$$

$$X_2 = -25.12\ dB$$

$$X_3 = -29.53\ dB$$



Hitless filter:

An “Hitless Filter” is a particular IIR filter that can be tuned from a channel to another without disturbing (hitting) any other channels contained in the optical signal. It is realized substituting the directional coupler of a ring add-drop resonator with a pair of reconfigurable Mach-Zehnder Interferometers (MZI). In this way the coupling coefficients K_R between the waveguides and the ring can be modulated, changing the unbalance of the MZI. Moreover a further thermo-optic shifter is added above the ring, so that the resonance frequency can be controlled as well.The transmission coefficient of the Mach Zehnder is:

$$T(\phi) = \frac{\nu}{2}(1 + cos(\phi))$$

Where is the fringe visibility of the MZI, i.e. the maximum power ratio that can be transferred from the input port to the cross port of the MZI. In order to obtain a reconfigurable coupling coefficient between 0 and K_R we need:

$$\upsilon = 4K_c\left(1 - K_c\right) = K_R$$

$$K_c = \frac{1}{2} + \frac{\sqrt{1 - K_R}}{2} \simeq 0.998$$

Every time the filter has to be tuned, the following procedure is performed: the coupling coefficient of the add-drop MZI for the starting channel is turned to 0, in order to obtain a minimum shift filter between the input-through port. Then using the heater associated with the ring, the resonance frequency is shifted towards the desired channel while the add-drop MZI is modulated in order to maintain the filter in a minimum shift state for the resonance frequency. As soon as, the resonance frequency is tuned, the coupling coefficient of the add-drop port is turned back to K_R.