8 channel filter design
With improvements to lower interbank

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Abstract: Step by step design of an eight channel filter using ring resonators and waveguide crossings. We also talk about solutions to minimize interbank crosstalk between channels.

Index Terms: Ring resonator, filter, inerband crosstalk, resonant splitting.

1. Theory

Here we studying the design and crosstalk in an n channel filter using ring resonators and waveguide crossings. There is two types of disruption happening in this circuits;

1) **Resonant splitting**
   This effect happens because of poor filter design where the resonant peak and the FWHM of the individual channels interfere with each other, see Fig. 1. As shown in the Fig. 1 channels 2, 5 and 6 are overlapping. To overcome resonant splitting, we need to properly design the structural parameters of the circuit based on the desired specification; bandwidth, channel's drop wavelength and . . .

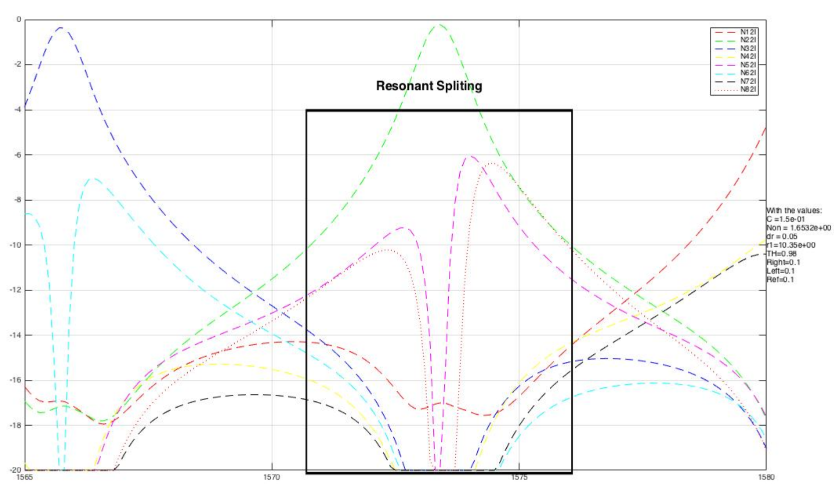

Fig. 1. Resonant splitting in the filter

2) **Interband crosstalk** Interband crosstalk happens between channels with different wavelength, where the power from unwanted adjacent channels interferes, shown in the Fig. 2. Interband crosstalk occurs out of spectral band of a channel and that is why it won't effect resonant much. To overcome this issue we need to design High-Q filters with narrower bandwidth [1].

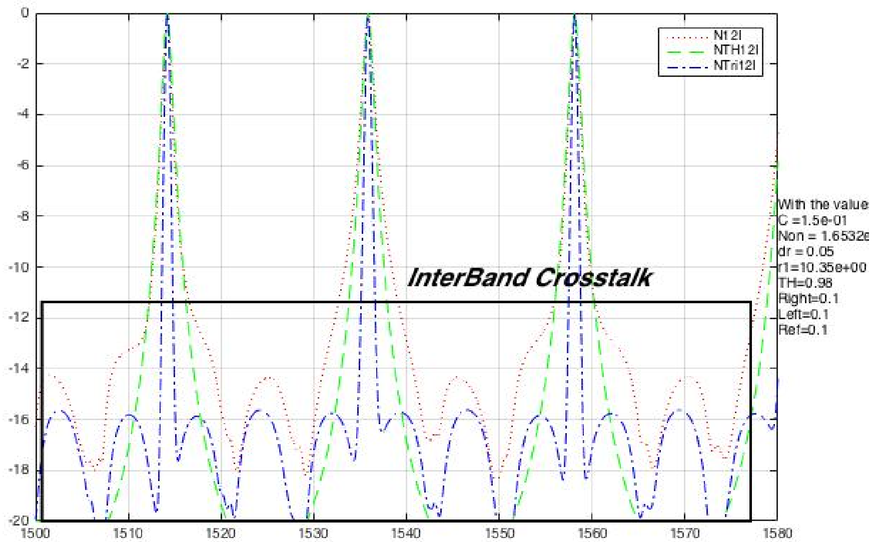

Fig. 2. Interbank crosstalk between channels

2. Design details

The purpose of this paper is to design an equally spaced n-channel filter with minimum interband disruption.

$$m\lambda = n_{eff}L \qquad where\ m\ is\ an\ integer \quad and \quad L = 2\pi R. \tag{1}$$

$$FSR\ =\ \frac{\lambda^2}{n_{eff}L} \tag{2}$$

$$\lambda_1^{(k)} = \lambda_1\ +\ (k-1).FSR \quad where\ k\ is\ an\ integer. \tag{3}$$

Equation 2 is only valid if we can ignore the dependency of index of reflection to wavelength. If this is not the case then we need to use n_g which is the group index of reflection [2].

$$FSR\ =\ \frac{\lambda^2}{n_gL} \tag{4}$$

where

$$n_g\ =\ n_{eff} - \lambda_0\frac{\delta n_{eff}}{\delta\lambda} \tag{5}$$

Channels are equally spaced by the value

$$\Delta\lambda = \frac{FSR}{n} \quad where\ n\ is\ the\ number\ of\ channels \tag{6}$$

$$\lambda_n = \lambda_1 + (n-1)\Delta\lambda \quad where\ \lambda_n\ is\ the\ wavelength\ for\ the\ n_{th}\ channel. \tag{7}$$

To overcome the resonant splitting, channel's linewidths must be designed in a way that channels don't overlap.

$$FWHM = \frac{(1-r^2a)\lambda^2}{\pi L n_g r\sqrt{a}}\ \text{[3]} \tag{8}$$

$$r^2\ +\ \kappa^2\ =\ 1 \tag{9}$$

where

r	is the self coupling factor
κ	is the cross coupling factor

On the other hand if cross-coupling coefficient is too low, the bandwidth will be too narrow, so we need to optimize the cross-coupling coefficient.

Bandwidth spec will define the minimum value of the cross-coupling coefficient. The cross-coupling coefficient has a close relation to the gap between the waveguide and the ring. To have a high κ, the gap must be very small, meaning the ring and waveguide must very close to each other and that has some fabrication difficulties.

2.1. examples

Design of an eight channel , equally spaced filter with the wavelength window of $1529 - 1551\ nm$. The minimum required bandwidth is $2\,THz$. For the simplicity assume $a = 1$ Then for ring 1 (ch1) we have $R_1 = 10.30\,\mu m$. ($n_{eff} = 1.6532$ [4].) Using 1

$$\frac{\lambda_n}{\lambda_1^{(2)}} = \frac{R_n}{R_1} \tag{10}$$

Note that in 10 we chose $\lambda_1^{(2)}$ because of the window size and the direction we are moving in wavelength, see Table I for the channel's wavelength values and the associated ring sizes.

$$\Delta\lambda_{ch} \;=\; \frac{FSR}{n} \;=\; 22nm$$
$$\lambda_n \;=\; \lambda_1 \;+\; (n-1)\Delta\lambda_{ch}$$
$$R_n \;=\; R_1\frac{\lambda_n}{\lambda_1^{(2)}}$$

TABLE I
CHANNEL WAVELENGTH AND RING SIZES

Ch. No.	Wavelength nm	Ring size μm
Ch1	1529	10.303
Ch1	1531.75	10.172
Ch1	1534.5	10.190
Ch1	1537.25	10.208
Ch1	1540	10.226
Ch1	1542.75	10.244
Ch1	1545.5	10.262
Ch1	1548.25	10.28

To avoid resonant splitting for all channels (overlapping channels) and to meet the bandwidth spec, we must fulfil the following constraints.

$$\lambda_k + \frac{1}{2}FWHM_k < \lambda_{k+1} - \frac{1}{2}FWHM_{k+1} \qquad k\; = 1,\; 2\; \ldots \tag{11}$$
$$\Delta\lambda_k \;\equiv\; FWHM_k$$

Equation 12 will define the maximum value for κ (cross-coupling coefficient).

$$BW = c\frac{\Delta\lambda_{tat}}{\lambda^2} \qquad where\; c\; is\; the\; speed\; of\; light. \tag{12}$$
$$\Delta\lambda_{tat} \;=\; \Sigma_1^n\Delta\lambda_i \tag{13}$$

Equation 13 will define the minimum value for κ (cross-coupling coefficient).

Fig. 3 show the outputs of our filter. We see that resonant splitting is fixed and the crosstalk is lower. To improve the crosstalk more, we have used third order filters by replacing each ring with 3 cascaded rings. Doing so, the size of the circuit is larger but crosstalk is much lower and the output is clean, see Fig. 4

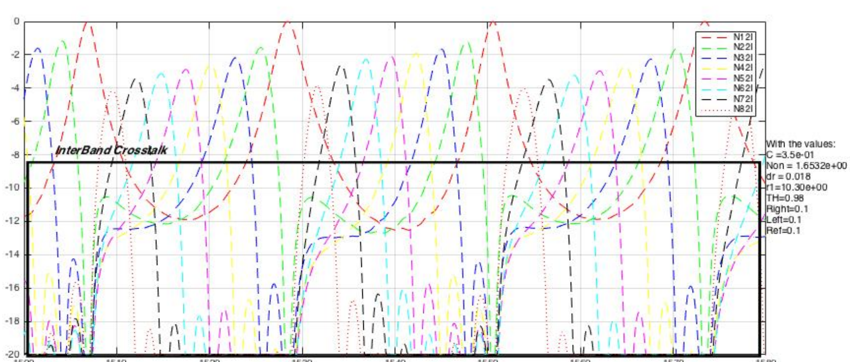

Fig. 3. Fixed resonant splitting

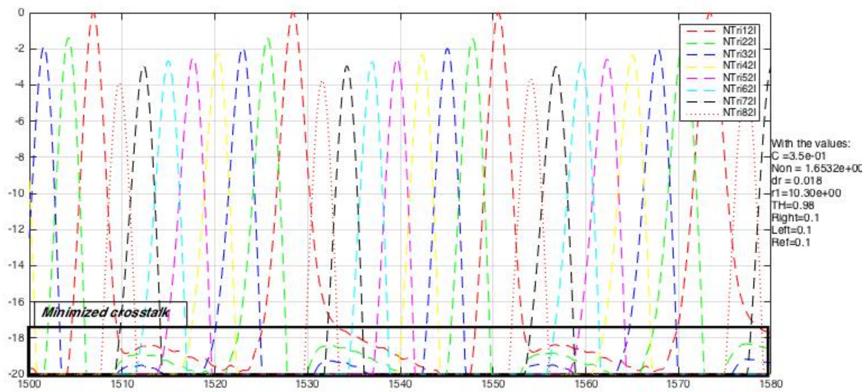

Fig. 4. Improved crosstalk (interband

[5]

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