# The effect of inner ring radius on frequency and insertion loss of optical filters with ring resonator structure

Yagoob Hasanzadeh[1], Abdollah Alizadeh[2]
1. Department of Electrical Engineering. Ahar Branch, Islamic Azad University, Ahar, Iran
Email: yhsnzd@yahoo.com
2. Department of Electrical Engineering, University of Bonab, Bonab 5551761167, Iran
Email: a_alizadeh@tabrizu.ac.ir

## Abstract

*In this paper an optical filter having ring resonator structure with micro rings inside it, has been investigated. By variation the radius of main and inner rings, the variation of central frequency and insertion loss of filter in communication spectrum (1.5 µm to 1.6 µm) have been studied. By increasing the radius of main ring, the central frequency of filter move toward the lower frequencies, then central frequency of filter can be adjusted by the radius of main ring. Radius variation of main ring has not considerable effect in filter loss. Also, variation of inner ring's radius, affects the filter insertion loss, and have a little displacement on the central frequency of filter. The maintained filter will have the minimum loss, when the inner rings radius have been selected equally 0.2 micrometer. By proper selection of radius sizes one can tune the filter precisely for desired resonance frequency and loss.*

**Keywords:** inner ring, optical filter, ring resonator,

## 1. Introduction

All optical telecommunication is a solution to meet the limitation of electro-optic and electronic communication in terms of speed and bandwidth and can allow the capability of system as high speed information processing. Optical equipment's have the integration capabilities comparable to the wavelength of the light which will be suitable for optical networks and rerouting. Optical filters, also, are the necessary parts of the components of optical integrated circuits which are used in order to pass the desired components and to remove the undesired frequency components; thus, have many applications in the telecommunication. The construction of optical filters is possible in different methods, the ring resonator or filter with two inner ring is studied in this paper, which the man characteristics of this kind of optical filters are low losses and small dimensions.

## 2- Theory and Structure Flter

In the ring resonator – based filters, resonance condition is achieved from the following equation, which results from the equality of effective loop length, by the integral multiples of wavelength.

$$n_{eff}\,\pi D = m\gamma_m \qquad (1)$$

In the abovementioned equation, $\gamma_m$ is the resonance wavelength $n_{eff}$ is the effective refractive index of curved waveguide, D is the diameter of main ring and m is an integer's, free spectral range, is the key feature of ring resonators which is a spacing in the optical frequency are wavelength between two successive reflected or transmitted optical intensity maxima or minima of inter ferometer and is defined as follow:

$$FSR = \frac{\gamma_m^2}{n_{eff(\pi D + L_C)}} \quad (2)$$

1. Where Lc the coupler length. Since FSR is inversely proportional to the length of ring resonator, for obtaining a greater resonator, the size of the ring should be as small as possible. According to the above equation, increasing the above equation, increasing the ring diameter results in FSR reduction and poses a problem to separate the frequency mode, so we should decrease D, as possible. Another feature of the filters is the quality or Q factor, which is the ratio of center frequency to FWHM (full width at half maximum) spectrum.

$$Q = \frac{f_0}{FWHM} \quad (3)$$

$$FWHM = \frac{C(1-y_1 y_2)}{4\pi^2 D} \quad (4)$$

In the above equation (4), $y_1$, $y_2$ are the attenuation coefficient in the coupling of waveguide to the ring and from ring to wavequide in the coupler site.

The increase of Q is resulted in the FWHM reduction and approaching to transmission function by a narrow beam, which requires the increasing of D. so by increasing the value of D, Q value increase, too, but FSR is reduced, and by D decreasing, Q is decreased and the value of FSR is increased. The ratio of FSR to FWHM is given by a parameter called filter accuracy. F is denoted to filter accuracy and given by formula (5):

$$F = \frac{FSA}{FWHM} = \frac{2\pi}{1-y_1 y_2} \quad (5)$$

The magnitude of F means the FSR largeness and FWHM smallness, which is our optimal in the filter structure. In addition, the value of F is independent of ring diameter. Figure 1 indicates the general structure of filter, which waveguides with the refractive index of 3.45 constructed on the Si O2 structure with refractive index of 1.45. The input is applied as a wide spread spectrum signal from the waveguide which showed by input and out is indicated by another waveguide which shown by output 2 in the figure 1. Waveguide bandwidth, coupling area and middle radius of inner loops is considered as. 0.2, 0.1, 1.6 and 0.2 µm; respectively.

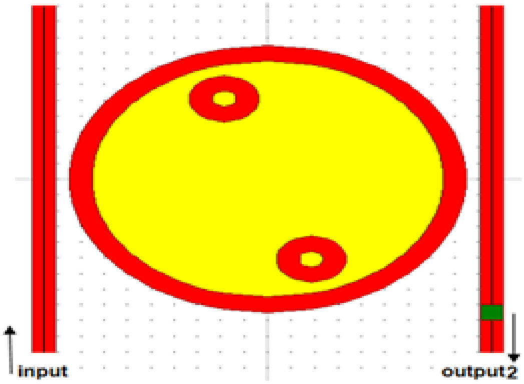


**Fig. 1.** Structure filter

## 3 – Simulation Results

The results of simulations carried out in the filter shown in Fig.1 by changing the dimensions of different parts are presented in the next section.

3-1 UNIFORMLY CHANGING OF THE INNER RINGS RADIUS

In the considered structure, the size of inner ring radiuses changed from 0.1 µm – 0.4 µm equally. The results indicate that, in the range of 0.2 – 0.4 µm for inner ring radius, the center frequency, by increasing the ring radius from 0.2 to 0.4 µm, tends toward the slow frequency and the losses are increased. Also, by the reduction of ring radius from 0.2 to 0.1 µm, the central frequency changes towards higher frequencies but the difference ranges are small and the loos of filters increase. The 0.2 µm radius of inner ring results in the minimum losses. These results are shown in Fig.2 and 3. Frequency in the horizontal axial of frequency response has been normalized dividing by the light speed and multiply of micrometer. The green diagram indicates the input spectrum and other diagrams show the filter out put in terms of different values of inner ring radius. Fig.3 is a magnified from of figure 2.

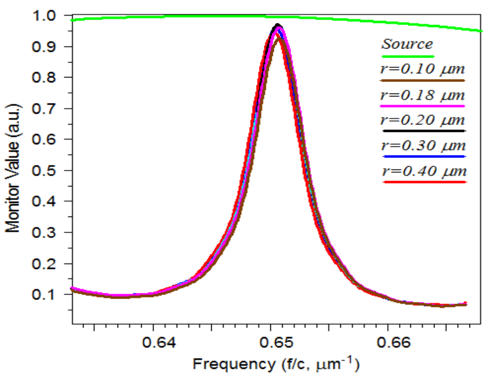


**Fig.2.** The diagram of output spectrum uniformly changing of the inner rings radius

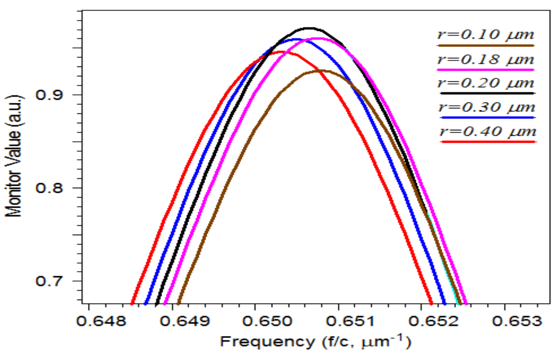


**Fig 3**. This diagram of filter resonance wavelength is a magnified from of Fig. 2

3-2 CHANGE OF INNER RING RADIUS IN THE UNEQUAL MODE

Since in the previous section the optimal value for inner radius is found to be 0.2 µm, in this section the radius of inner rings is varied non – identically.

The process of non – uniform change is such a way that we change one of the radiuses from 0.2 µm to higher values and the other to lower values. The results of the changing of radius none uniformly are shown differences between in the Fig.4, 55. By increasing the radius of the inner rings, filter losses will be increased in the center frequency. The findings show that the central frequency doesn't change. In Fig. 4, the value of radius shown as a title for curves, for example r = 0.20 – 0.18, which shows the output spectrum when one of the radius of inner rings is 0.22 µm and another is 0.18. Fig.5 is a magnified from of Fig.4

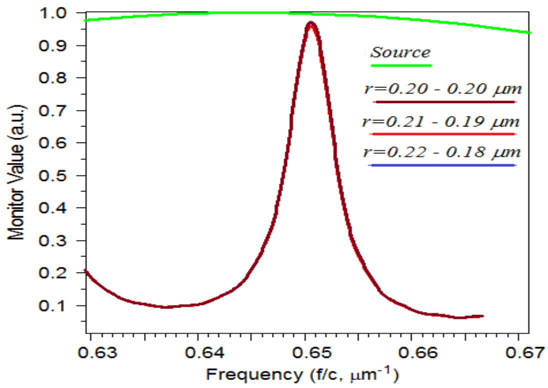


**Fig.4.**The diagram of output spectrum Change of inner ring radius in the unequal mode

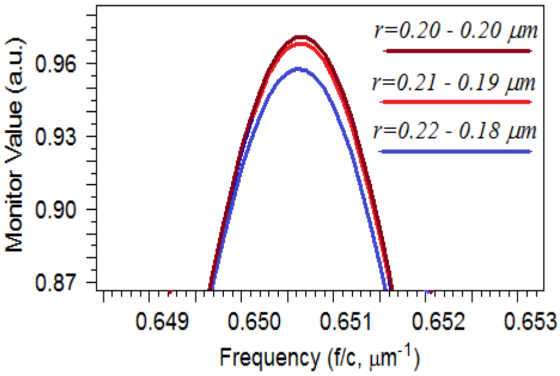


**Fig. 5.** This diagram of filter resonance wavelength is a magnified from of Fig.4

3-3 CHANGING THE RADIUS OF MAIN RING

According to equation (1) by changing the main ring radius the length or distance of path is varied and accordingly the values of λm, center frequency and the FSR of filter will be changed, too. Increasing the radius of main ring causes to the transmission of center frequency towards lower values. The change of the main ring radius causes to miner change in the filter losses. In Fig.6, this transmission of central frequency by changing the radius of main ring (which denoted with R) is shown.

2.

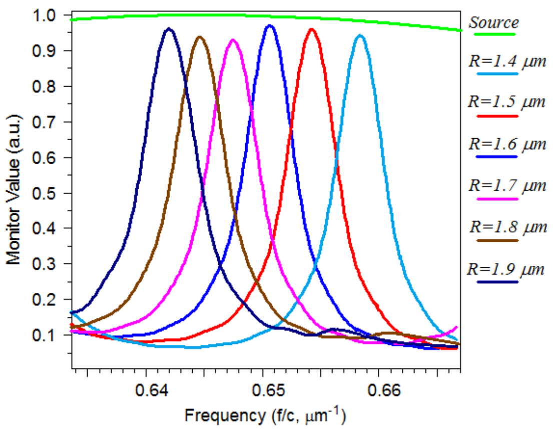


**Fig. 6**. The diagram of resonance filter by variations in main ring radius

## Conclusion

The results of simulations indicate that in the presented transmission function or frequency response of optical filter by changing the radius of main ring (loop) about 1.6 µm, the capability of setting out the central frequency of filter is achieved in the communication spectrum. Also, by changing the radius of inner rings in the range of 0.1 – 0.4 µm, there was no important effect on the shift of central frequency, but, changing of internal radius can control the level of filter losses. In addition, it was shown that the value of inner rings radius, if chosen identically and equal to 0.2 µm, produces the least amount of losses for this this optical filter structure.

## References

[1] Peng, B., Lei, F., Ozdemir, S. K., Long, G. L. & Yang, L. “Engineering the spectral properties of photonic molecules”. Proceedings of CLEO 2013.

[2] Stamatios. V .Kartalopoulos. “DWDM Networks, Devices and Technology”. Wiley-IEEE Press. 2012

[3] ز. الوسکی، ا. عبدالحکیم، مترجم: ک. عباسیان، س. اشرفی جو، ادوات نانو فوتونیک مجتمع.تهران، انتشارات فدک ایساتیس، چاپ اول، 1393.