Temperature Effects on Parallel Cascaded Silica Based paper

by Mark Finne

Temperature Effects on Parallel Cascaded Silica Based Microring Resonator

Fakhrurrozi[1)], Subekti Ari Santoso[1)], Octarina Nur S[1)]

[1)]Department of Electrical Engineering, Faculty of Science and Technology, University of Al Azhar Indonesia

Jakarta, Indonesia

e-mail ; rozi.amran05@gmail.com

Ary Syahriar[1)2)]

[2)]KIN (Komite Inovasi Nasional), The Agency for The Assessment and Application of Technology

Jakarta, Indonesia

e-mail ; ary@uai.ac.id

***Abstract*-Optical device is a telecommunications device that uses glass or plastic media made from silica and SiO_2 to transmit data using light or LED (Light Emitter Diode) as the data is transmitted. Silica is one of the materials / media that serves as the transmission of data on the component microring resonator. This paper, investigate about the characteristic of microring resonator and specifically about the temperature effect on the cascaded parallel microring resonator. In this paper, also explains the resistance of the microring resonator for the various temperatures are given. How big is the change in the wavelength shift is happening and how the resulting output of wavelength. A cascaded parallel microring resonator is simulated using MatLab to analyze the temperature effect on the ring resonator components. This simulation also uses the couple mode theory to get the value of coupling coefficient. The wavelength used in this simulation was C-Band between 1530-1565 µm. The simulations result shows the resistance of the components cascade-parallel microring resonator for a certain temperature. The simulated temperature are varied between 28° Celcius to 500° Celsius. Based on the simulation result it can be concluded that the change in temperature will change the resonance wavelength. As the temperature is increased, the resonance wavelength shifts (The increased temperature will affect to the shifting of resonance wavelength). The results of this study, a temperature parameters are given to the resilience of the microring resonator.**

Keywords ; *microring resonator, cascaded parallel microring resonator, temperature effect.*

Abbreviation

MR Microring Resonator

I. INTRODUCTION

The devices used in communication system is a combination of electronic and optical technologies. In distance communication, optical fiber has been largely used and powerful tool which has been developed with very high performance respect to the transmission speed, the number of wavelengths and transmission distance. advantages of optical technology can be used with the bulk of technical performance is very good but the disadvantage is a very high cost. Today, metropolitan networks are using optical communication networks. Even in Indonesia has been implemented, the system uses fiber optics and many telecommunications companies that use them.

The basic configuration of MR consists of a straight waveguide and a ring resonator. MR as optical filter has attracted much attention because of their high wavelength selectivity in combination with the small size. In general, a device with a full configuration that serves as a MR optical filter consists of two ports with a straight waveguide MR. MR devices can be assembled by a single ring or multiple rings in a serial or parallel configuration[1].

The background of this research, based on paper [2] that simulates the resistance temperature on MR. This paper is an outgrowth of the paper [2] on temperature resistance. The different of this paper with the previous paper [2] lies in the MR component. In the current study uses the concept of parallel MR series which will be described in chapter II (theory). In the previous paper [2], described the effect of temperature on single MR. This paper using a variety parameter of temperature as a function to determine how much of the effect of temperature on the result of transmission on MR.

II. THEORY

Frequency band used in this study were C-band ranging from 1.530 µm up to 1.565 µm. C-Band is the frequency band commonly in use in optical communications. Various frequency bands were shown in Table 1.

Historically, the O band frequency, called the first, at 0.8-0.9 µm, however, the losses were high at this frequency so that the window is used primarily for short-range communications. Lower frequency (O band and E band) around 1.300 µm has much lower loss. Intermediate frequency (S band and C band) around 1.500 µm are most widely used. This frequency has the lowest attenuation loss[3].

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TABLE 1: BAND FREQUENCY OF OPTICAL DEVICES (μm)[3]

Band	**Descriptor**	**Range** (μm)
O band	Original	1.260 to 1.360
E band	Extended	1.360 to 1.460
S band	Short wavelength	1.460 to 1.530
C band	Conventional	1.530 to 1.565
L band	Long wavelength	1.565 to 1.625
U band	Ultralong wavelength	1.625 to 1.675

A. *Microring Resonator (MR)*

MR is a technique that uses the technique of coupling to transmit data to multiple destinations, such as for example is the WDM (Wavelength Division Multiplexing) communication system. employment system MR as well as WDM, ie several wavelengths (lambda) is transmitted in a single channel (mux). As an illustrative example is shown in Figure 1. For example, there are multiple wavelengths to be transmitted in a single channel (λ1, λ2, λ3, λ4). If the wavelength used is λ3, then the other wavelengths (λ1, λ2, λ4) will return and will serve as input to the transmission of data to transmit again.

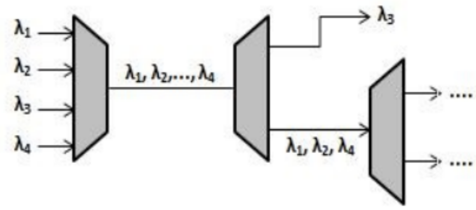

Figure 1. Illustration of MR

Figure 2 illustrates the basic configuration of MR, which consists of unidirectional coupling between a ring resonator with radius R and E_{i2} waveguide. R is radius of of ring and $E_{i2} = \exp(-\frac{\alpha}{2} - j\beta L)$.

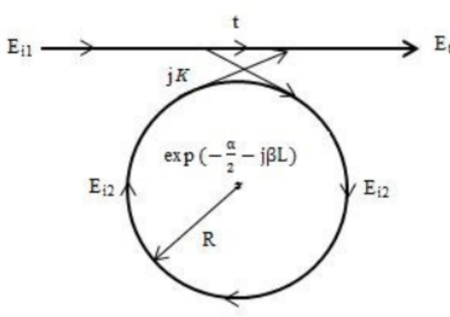

Figure 2. Model of a single ring resonator with one coupling coefficient[5]

Defining that a single unidirectional mode of the resonator is excited, the coupling is lossless, single polarization is considered, none of the waveguide segments and coupler elements couple waves of different polarization. The various kinds of losses occurring along the propagation of light in the MR filter are incorporated in the attenuation constant, the interaction can be described by the matrix relation[4]:

$$\begin{bmatrix} E_{t1} \\ E_{t2} \end{bmatrix} = \begin{bmatrix} t & j\kappa \\ j\kappa * & t * \end{bmatrix} \begin{bmatrix} E_{i1} \\ E_{i2} \end{bmatrix} \quad (1)$$

$$E_{t1} = E_{i1}\, t + jE_{i2} K \quad (2a)$$

$$E_{t2} = jE_{i1} Kt + E_{i2}\, t \quad (2b)$$

The complex mode amplitudes E are normalized, so that their squared magnitude corresponds to the modal power. The coupler parameters t and κ depend on the specific coupling mechanism used. The $*$ denotes the conjugated complex value of t and κ, respectively. The matrix is symmetric because the networks under consideration are reciprocal. Therefore[4]:

$$|t^2| + |K^2| = 1 \quad (3)$$

$$E_{i2} = \alpha \,.\, e^{j\theta} E_{t2} \quad (4)$$

From (1) and (4) we obtain:

$$E_{i2} = \frac{j\kappa *}{1 - \alpha t * e^{j\theta}} \quad (5)$$

This leads to the transmission power P_{t1} in the output waveguide, which is:

$$P_{t1} = |E_{t1}|^2 = \frac{\alpha^2 + |t|^2 - 2\alpha|t|\cos(\theta + \varphi_t)}{1 + \alpha^2|t|^2 - 2\alpha|t|\cos(\theta + \varphi_t)} \quad (6)$$

Where $t = |t| \exp(j\, \phi_t)$, $|t|$ representing the coupling losses and ϕ_t the phase of the coupler. The circulating power P_{i2} in the ring is given by:

$$P_{i2} = |E_{t1}|^2 = \frac{\alpha^2(1 - |t|^2)}{1 + \alpha^2|t|^2 - 2\alpha|t|\cos(\theta + \varphi_t)} \quad (7)$$

On resonance, $(\theta + \phi_t) = 2\pi m$, where m is an integer, the following is obtained[4]:

$$P_{t1} = |E_{t1}|^2 = \frac{(\alpha - |t|)^2}{(1 - \alpha|t|)^2} \quad (8)$$

B. *Cascaded-Parallel MR*

The parallel configuration in Figure 3, MR arranged in such a way that there is no direct interaction between the rings. MR parallel configuration offers more flexibility to the manufacturing process compared with other configurations.

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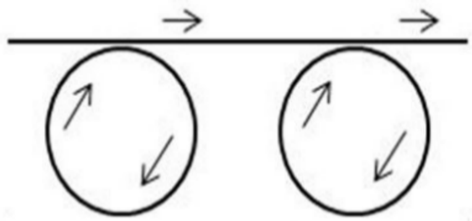

Figure 3. Model parallel coupled MR

Each MR refractive index or n_{eff} there. In the parallel configuration, the distance from one ring to another ring is very close. Value of L also determines the response filter and L being the circumference of the ring. Therefore, this distance should be chosen carefully to obtain the desired interference in the range of a specific wavelength.

When optimizing the response filter design for a desired wavelength, L should vary like one other parameter. In addition to allowing precise phase relationship, the distance should be set to be large enough to avoid direct interaction between the ring with other rings[1].

$$E_{i2} = E_{t2}\,exp\,(-\frac{\alpha}{2}L - j\beta L) \tag{9}$$

Where L = 2πR, and R is radius of ring. By substituting equation (2) to (9), we obtain the transmission amplitude of an optical MR for cascaded parallel as follows :

$$\frac{E_{i1}}{E_{t1}} = \frac{t - t\,exp(-\frac{\alpha}{2}L - j\beta L)}{1 - t^2 exp(-\frac{\alpha}{2}L - j\beta L)} \tag{10}$$

Where γ = exp (- $\alpha\pi$R) and Θ = β L. So, from equation (10), the power for the transmission of cascaded parallel MR is obtained[5]:

$$P_t(\theta) = |\frac{E_{i1}}{E_{t1}}|^2 = \frac{t^2 + t^2\gamma^2 - 2t^2\gamma\cos(\theta)}{1 - 2t^2\gamma\cos(\theta) + t^4\gamma^2} \tag{11}$$

III. METODOLOGY

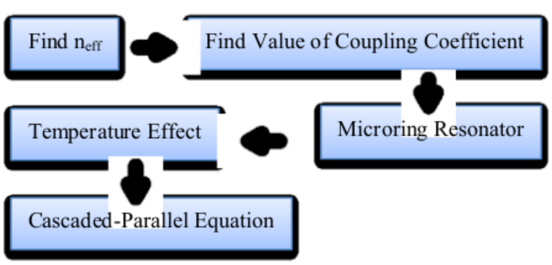

Figure 4. Flow chart process of research

From Figure 4, shows the stages of the research work. For the first, we find n_{eff} values obtained from MatLab function and bisection method. After n_{eff} values obtained, and then find value of coupling coefficient from couple mode equation. Coupling coefficient value is inserted into the formula of MR. After that, conversion MR equation to cascaded parallel equation. And the last, the value of temperature effect on MR can be obtained from $nT = n_{eff} + (T - T_0) * C$.

IV. DISCUSSION

Figure 5 is the transmission power of MR as formulated in equation (10), with the parameters used are as follows : refractive index n_1 (core) = 1.468 µm cladding refractive index n_0 (cladding) = 1463 µm, h = 5 µm wide. By Figure 5, shows the normal power of MR as a function of wavelength and it's a single MR.

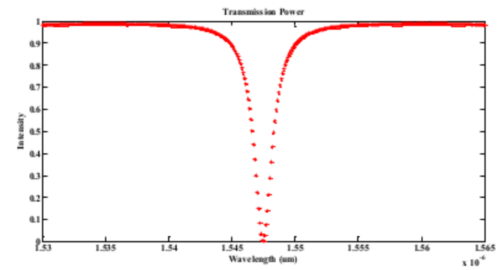

Figure 5. Transmission power of MR

Figure 6, shows the transmission power as a function of wavelength in MR with radius of core R (Cascade Parallel), where the distance between the rings was maintained in order to avoid interference.

In thermo optic base on cascaded parallel MR, structure and assume that only two ring cavity is warming, the parameters that determine the resonance wavelengthis teta (Θ), whereby $\Theta = \beta \cdot L = k_o \cdot n_{eff} \cdot L$.

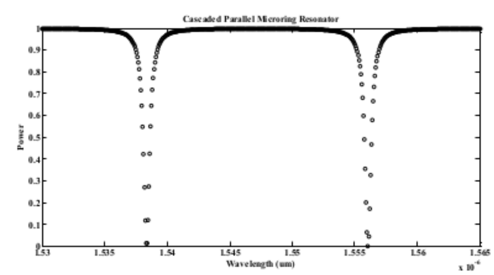

Figure 6. Transmission power as a function of wavelength in cascaded parallel MR

Figure 7 shows the simulation of temperature effect of cascaded-parallel MR with comparison of three temperatures used in the parallel coupled MR, from 28° Celcius up to 500° Celcius with details, 28° Celcius (room temperature/T_0), 150° Celcius (T_1), 325° Celcius (T_2) and 500° Celcius (T_3) wavelength which are affected by the temperature used for first ring is $\Delta\lambda_1$= 1.539-1.540 µm, $\Delta\lambda_2$= 1.540-1.542 µm, $\Delta\lambda_3$= 1.542-1.544 µm, and the second ring is $\Delta\lambda_4$= 1.556-1.558 µm, $\Delta\lambda_5$= 1.558-1.559 µm, $\Delta\lambda_6$= 1.559-1.561 µm.

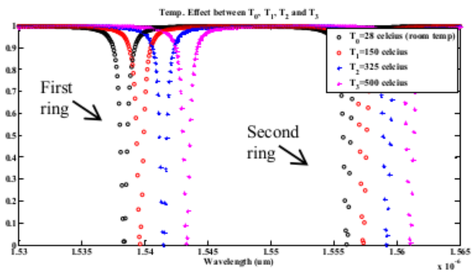

Figure 7. Transmission power of MRR with a comparison between room temperature and 3 simulated temperatures

The refractive index of the optical materials is not a constant parameter over temperature region in which the materials, such as crystals, semiconductors and glasses are used in different optical devices or system. The variation of the refractive index with the temperature at constant pressure is called the thermo optic coefficient. The analysis of thermo optic coefficient are essential to characteristic the temperature dependent nonlinear optical devices, the optical fiber communications system, semiconductor technology and the ultrafast femstone technology.

The sellmeier coefficient at any temperature T are computed from the room temperature sellmeier equation and the smoothed dn/dt or C values by calculating refractive index from the relations[5]:

$$nT = n_{eff} + (T - T_0) * C \qquad (12)$$

Sellmeier equation is the relationship between refractive index and wavelength for a particular media. This equation is used to determine the dispersion of light in the medium[6].

Figure 8, shows that the temperature affects the value of refractive index. The higher the value of refractive index with the increase in temperature occurs. By equation (11), we can get a way to give a temperature which will be used on MR that will make a difference in the stimulation of MR.

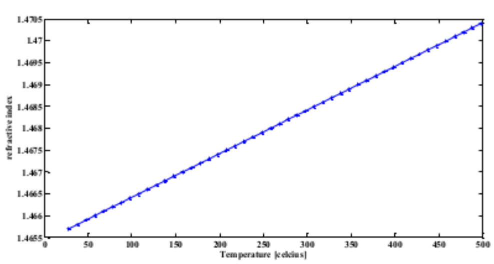

Figure 8. Comparison between refractive index with increased temperature

Figure 9, Explain the comparison between room temperature (T_0=28° Celcius) and high temperature (T_{max}=500° Celcius). Another parameters used is n_1= 1.468, n_0= 1.463 with width of core (h) = 5 µm, R = 14.7 µm. When the temperature is increased, the value of wavelength will go up as well (shifted).

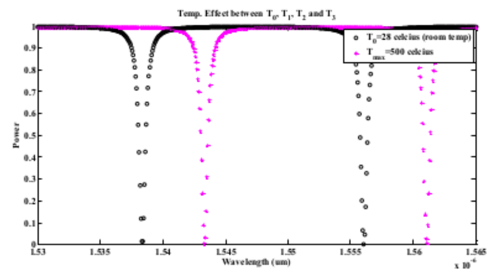

Figure 9. Transmission power of MRR with a comparison between room temperature (T_0=28° Celcius) and high temperature (T_{max}=500° Celcius)

Figure 10 is the simulation result using difference $\Delta\lambda$ between T_1= 150° Celcius, T_2= 325° Celcius and T_3= 500° Celcius. We can see the difference between the temperature of 150° Celcius to 500° Celcius, when the temperature reaches 150° Celcius then obtained a wavelength shift from 1539 µm to 1540 µm. When the temperature shifts to 325°, the wavelength shift up from 1.542 µm to 1.540 µm. And final temperature 500° Celcius with wavelength 1.542 µm shift up to 1.544 µm.

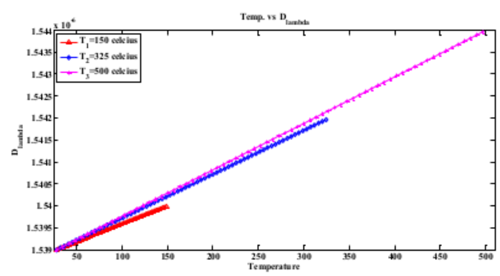

Figure 10. Comparison of $\Delta\lambda$ with each temperature

V. CONCLUSION

Distance between the first ring with the next to be maintained, because if it does not cause interference or coupling process may occur in the transmission process and will result in failure in the transmission that allows the entire wavelength will be sent back as desired.

Wavelength shift caused by temperature used in parallel cascaded MR is not too significant. The shift that occurs in only a few wavelengths. Although the optical communication system using light as the transmission, which use temperature is not too high, because the high temperatures may result in damage to optical devices.

Temperature effect on the ring that has been heated MR has been demonstrated in the simulation study. When it rings in the heating, the propagation constant in the ring will change as well. This condition causes the difference in the resonance wavelength than like before, when using room temperature (T_0). Because of rising temperatures, the $\Delta\lambda$ caused a shift in the resonance wavelength. In this study indicate that increased temperature 500^o given in two rings (parallel cascaded) together $\Delta\lambda$ yield 0.005 µm.

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