Simulation of an Optical Buffer using Microring Resonator Array with 1.5μm Radius

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Abstract

We present the design and FDTD simulations of microring resonator array optical buffer. The proposed buffer consists of six microring array coupled via upper MZI arm, and one microring is coupled via the lower MZI arm, where all coupling gap used is with 105nm. Results obtained have shown that the delay times of the output signals can be used to form the optical buffer (memory), which can be available for high capacity channel multiplexing and filtering applications.

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1. Introduction

Optical buffer or integrated optical delay lines are key elements for a more complex system of optical signal processing. Different schemes have been proposed, among them, micro resonator-based devices seem to provide a potential photonic circuit platform for this purpose [1]-[3]. The simplest and generic structure consists of a single lossless resonator used as an all-pass filter (APF) [4]. In this configuration, the resonator introduces only a phase shift \(\phi\) in the incident field. Near its resonance angular frequency \(\omega_0\), the APF is a very dispersive structure and \(\phi(\omega)\) strongly depends on the angular frequency \(\omega\).

In this paper, we present design and simulation of array of coupled microring resonator to MZI used as optical buffer. We would like to highlight the interest of arrays of microring resonators and the main limitation in practical use.
2. Theory

The proposed structure consists of an array of identical single-mode microring resonator of radius 1.5μm and effective index, \( n_{\text{eff}} = 3.34 \), waveguide width 300nm, and gap coupling 105nm as shown in Fig. 1. The gap coupling between microring resonators is defined by \( g \). The amplitude transfer function of the single-mode microring is given as

\[
t_f = \frac{\rho_s - t_{ss} a \exp(j\varphi)}{1 - t_{ss} a \exp(j\varphi)}
\]

Here \( a = \exp(-\alpha R) \) and \( \varphi = 2\pi n_{\text{eff}} R / \lambda \) are the round-trip amplitude attenuation and the phase shift. For single microring [1], the third-order dispersion (\( \beta_3 \)) at resonance is very strong and negative. This is the first limitation for pulse propagation since \( \beta_3(0) = 0 \), it is possible to cancel \( \beta_3(0) \) by using more microring resonators array [5]-[6].

![Fig. 1. A schematic of optical buffer generation on microring resonator 1.5μm radius array coupled to MZI, waveguide width 300nm](image)

We used numerical optimization to calculate the values of the gap couplings \( G = (g_1, g_2, …, g_6) \) of circuit. The objective function \( \varepsilon \) is defined by

\[
\varepsilon(G) = \sum_{\delta \in I} \left[ \tau_0 - \tau_g(\delta, G) \right]^2
\]

Here \( \tau_0 \) is the targeted delay over a bandwidth \( B \), then \( I = [-B/2, B/2] \). By minimizing the parameter (\( \varepsilon \)), we obtain a flat group delay for a bandwidth \( B \) which also leads to the cancellation of \( \beta_3(0) \)[1].

3. Results and Discussion

All numerical simulation in this paper is used the OptiWave FDTD [7] with Gaussian modulated continuous wave input pulse as;

\[
E(x) = A \exp \left[ -\frac{(x-x_0)^2}{2T^2} \right]
\]

In Fig. 2, the output power of optical buffer detected at output of upper and lower MZI arm have phase shift equal to \( \pi \) [8]. The resonances peak as sketch in Fig. 2, we found that the resonance peak of upper arm (out_1) given high output power more than the lower arm (out_2) which depend on the design device of Fig. 1.
Fig. 2. Output power of optical buffer generation on microring resonator 1.5μm radius array coupled to MZI

Fig. 3. Dynamic optical buffer or memory generation within waveguide device in x direction (in μm)

Fig. 4. Dynamic optical buffer or memory generation within waveguide device in z direction (in μm)
The dynamic optical buffer or optical memory through the design device is strong at the center of device as shown in Fig. 3 for propagate in x-direction and in Fig. 4 for propagate in z-direction. We found that the optical memory or group delay is strongly at $x = 20\mu m$ (see Fig. 3) and $z = 2.97\mu m$ (see Fig. 4).

4. Conclusion

We have performed FDTD simulation of microring resonator array coupled to MZI arm as optical buffer. The dynamic signals are seen by using the Opti-wave program, which can be available for application in the complex optical system design, in which the channel capacity and delay time (memory) are the major requirements.

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