Implementation of OCDMA Using Nested Ring Resonators

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Abstract: We present an implementation of an optical code-division multiple-access (OCDMA) encoder using compact nested two-ring-resonators filter. The encoder is based on silicon on insulator (SOI) technology to filter three wavelengths. The proposed implantation footprint has a 30% reduction of those using cascaded-ring-resonators filters.

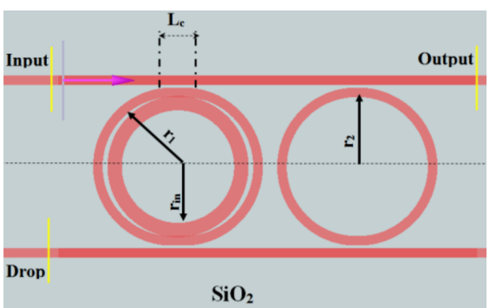
1. Introduction

Optical code-division multiple-access (OCDMA) is a code scheme that differs channels by assigning different codes. Data signals from different users are encoded with different codes at transmitters. One of these data signals is accepted if matched with the code at the receiver. Silicon ring-resonator filters are one of most widely used for implementation of OCDMA codes as they are known for their small footprint, which is important for integrated devices on chip. One or multiple ring resonators can be used to enhance the spectral bandwidth of a certain resonance wavelength. This consumes a large amount of crystalline silicon and increases footprint [1,2].

In this paper, we propose the use of two different sizes ring resonators. One of them has inner rings to construct a notch filter that can drop three wavelength bands, representing an OCDMA code. The design is more compact than that in [1,2]. This device is suitable for reducing the footprint on-chip compared to two cascaded or parallel ring resonators.

2. Device Design and Materials

Fig. 1(a) shows the top view of proposed design. The design consists of two ring resonators of radii r_1 and r_2. One of the two rings has a nested ring of radius r_{in}, which is responsible for dropping the third wavelength. A single mode silicon slab waveguide of 0.22 µm thickness and 0.4 µm width is used, which provides good confinement of light in the waveguide. The proposed design is constructed on SiO_2 substrate of 4 µm thick. The gap length between ring and bus waveguide equals 0.1 µm for circular ring shape.



(a)

C_1	0	0	0	1	1	1	1
C_2	0	1	1	1	1	0	0
C_3	1	0	1	1	0	1	0
C_4	1	0	1	1	0	1	0
C_5	1	1	0	0	1	1	0
C_6	1	1	0	1	0	0	1

(b)

Fig .1 (a) Two rings design on Lumerical FDTD, the gap length = 0.1µm. (b) Implemented OCDMA codes.

Fig. 1(b) shows the desired OCDMA code to be implemented. It is consisted of 6 channels, each channel has 7 bits. Zeros are represented by dropping three wavelengths, while the ones are represented by the rest of wavelengths.

The proposed design has been numerically simulated using 3D finite difference time domain (FDTD). A computational window of size 20 µm ×10 µm× 5 µm (X×Y×Z) has been discretized with non-uniform mesh, where the minimum grid spacing is chosen to be 0.006 nm and the meshing accuracy is 4. The sides of the computational window have been surrounded by perfect matched layer (PML) absorbing boundary conditions.

3. Results and Discussion

Ring resonator cavity is resonating when the waves in the loop complete round trip phase shifts that are equal to multiple integer of 2π:

$$m\lambda_{res} = n_{eff}(2\pi \mathrm{r} + 2L_c) \qquad (1)$$

where λ_{res} is the resonance wavelength, L_c is the coupling section length between the ring and the bus waveguide, r is the ring radius, m is the mode number, and n_{eff} is the effective index of refraction of the waveguide

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material. The proposed design can filter out three wavelengths to represent the zeros as OCDMA codes in Fig 1(b). The code length of each channel is extended from 1.542 μm to 1.556 μm of code length of 14 nm and pulse width of 2 nm.

Fig 2 shows the code length of each channel with the field distribution, which confirms the resonance of each ring at different wavelengths. It also shows the resonance of nested loop at third wavelength as in Fig 2(c). The reason for changing wavelength is changing the radius and coupling length, which in turn changes n_{eff} . The depth of notch filters is exceeding -20 dB.

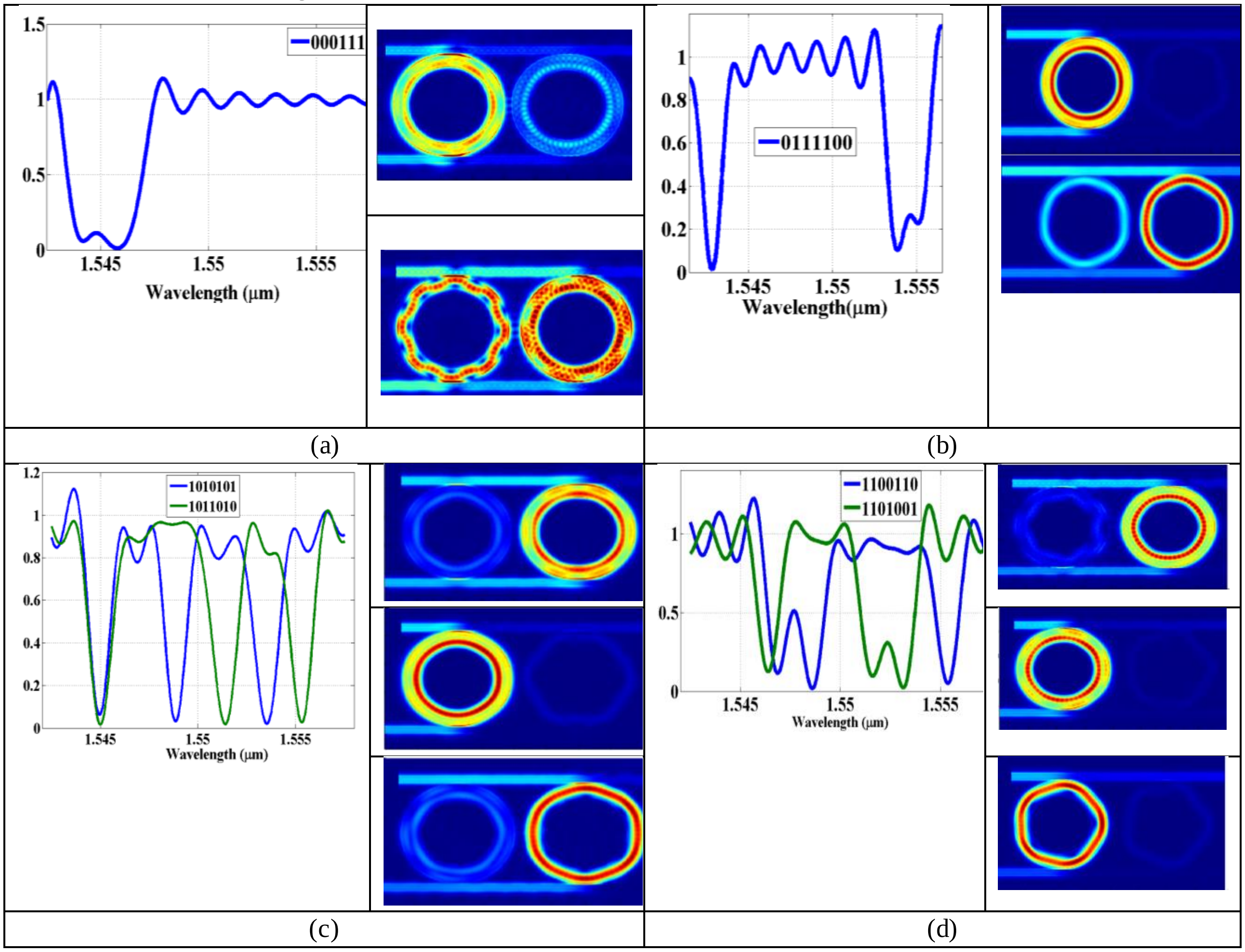

Fig. 2. (a) Output and field distribution of C_1. (b) Output and field distribution of C_2. (c) Outputs and field distributions of C_3 and C_4. (d) Outputs and field distributions of C_5 and C_6.

4. Conclusion

We have presented compact nested-ring resonators that work at two different resonance wavelengths. The device has small footprint for implementing OCDMA code. The proposed design has an advantage that it can filter out same number of wavelengths as that of cascaded-ring resonators, while using 2/3 of its footprint.

5. References

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