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Box-like filter response of quadruple series coupled microring resonator by coupling efficiency control

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Abstract

To realize box-like spectrum response, we designed and fabricated a hitless wavelength selective switch using Thermo-Optic (TO) tuning of quadruple series coupled microring resonator. Both Butterworth and Chebyshev filters were successfully demonstrated by the control of coupling efficiency.

1 Introduction

We proposed and demonstrated a hitless wavelength selective switch using TO-tuning of double series coupled microring resonator [1]. This switch can serve as the building block of the wavelength selective switch matrix. However, to apply this switch element to large scale switch matrix, more box-like spectrum than that of double series coupled microring was required [1], [2]. This is because the bandwidth is reduced by cascading filter elements and only the box-like can be free from the spectrum narrowing due to cascading.

Therefore in this study, we proposed and demonstrated a box-like filter response (Butterworth and Chebyshev filters) of quadruple series coupled microring resonator by the control of coupling efficiency [3]-[5].

2 Principle and design

The Butterworth filter has no ripple in the pass band and gradual roll-off, while the Chebyshev filter has equi-ripples and sharp roll-off. The Chebyshev filter is more suitable for the box-like filter than the Butterworth filter, if the ripple is allowably small.

In the quadruple series coupled ring resonator, the Butterworth condition is given by $\kappa_1=\kappa_0^2/(2-\kappa_0)^2$, and $\kappa_2=\kappa_1/$ [6]. In our device, we designed as $\kappa_0=0.5$ to reduce the loss in the pass band. In this case, the theoretical spectrum response was calculated as shown in Fig. 1. The shape factor (the ratio of -1dB bandwidth to -10dB bandwidth) can be improved to 0.59, which is greater than that of double series coupling (0.41).

On the other hand, the Chebyshev condition depends on the allowable ripple. In our device, the allowable ripple was assumed to be 0.3dB and we designed as $\kappa_0=0.5$, $\kappa_1=0.100$, and $\kappa_2=0.0678$. In this case, the theoretical spectrum was calculated as shown in Fig. 2. The theoretical shape factor was calculated to be 0.74.

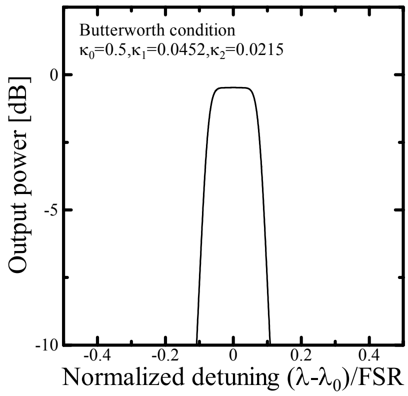

Fig. 1: Theoretical spectrum of Butterworth filter.

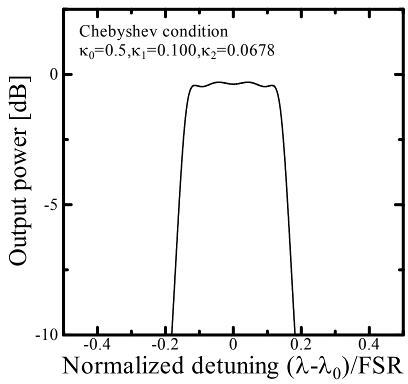

Fig. 2: Theoretical spectrum of Chebyshev filter.

3 Device fabrication

The structure of hitless wavelength selective switch is shown in Fig. 3. The core and the upper cladding materials were sputter deposited 17mol%Ta_2O_5-SiO_2 (n=1.660 @λ=1550nm) and SiO_2 (n=1.445 @λ=1550nm), respectively. The busline waveguide and microring resonator were laterally coupled. The resonator was shaped like a racetrack, and the coupling efficiency was controlled by the overlap length of straight waveguide portion and the distance between cores. The core height and width were 1.3μm and 1.3μm, respectively. The round trip length of racetrack resonator was 611μm, which corresponds to the FSR of 2.22 nm.

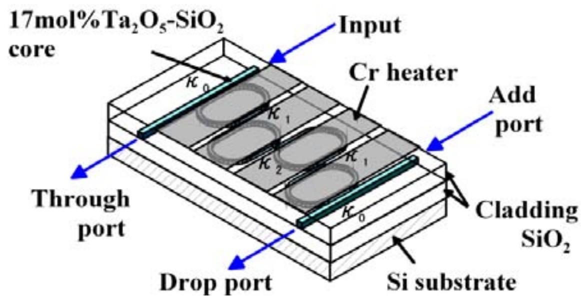

Fig. 3: Perspective view of wavelength selective switch.

4 Experiment

In the initial stage, the resonant wavelengths of individual microrings were slightly different due to the fabrication error. By controlling the electric current to each Cr thin film heater above individual ring resonators separately, we realized the Butterworth and Chebyshev filter responses as shown in Figs. 4 and 5, respectively.

In the device with coupling efficiencies κ_0=0.5, κ_1=0.0452, and κ_2=0.0215, the Butterworth spectrum reponse was successfully obtained as shown in Fig. 4. Other two peaks around λ=1549.44nm are slightly mixed orthogonal polarizations. The shape factor was 0.699, the FWHM bandwidth was 0.092nm, and the ripple depth was -0.44dB. The discrepancy between theoretical and experimented values is attributed to the error of coupling efficiency resulting from the fabrication error.

On the other hand, in the device in which the coupling efficiencies were designed as κ_0=0.5, κ_1=0.100, and κ_2=0.0678, the Chebyshev filter response was obtained as shown in Fig. 5. Other three peaks around λ=1551.1nm are the slightly mixed orthogonal polarizations. The shape factor was 0.852, the FWHM bandwidth was 0.201nm, and the ripple depth was -2.13dB.

The shape factor in the double series coupled microring resonator was 0.41, and we successfully improved the shape factor using the quadruple series coupled microrings.

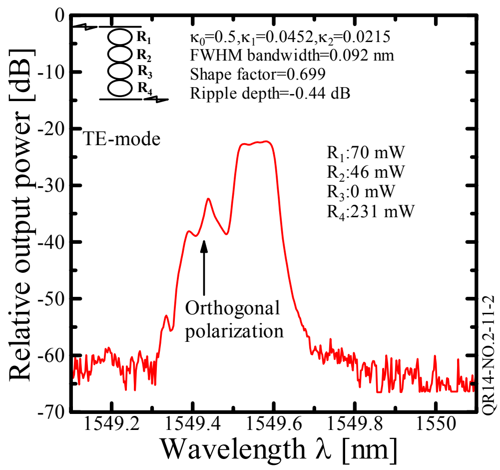

Fig. 4: Measured drop port spectrum response of Butterworth filter.

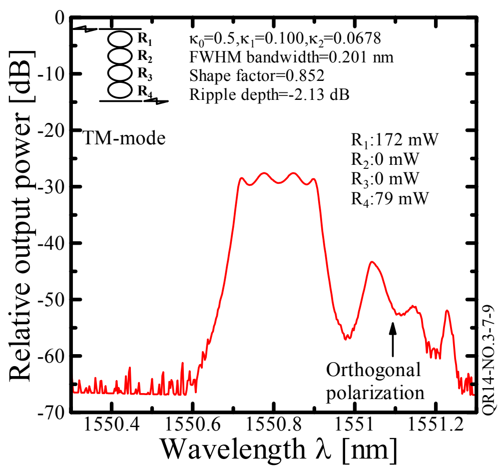

Fig. 5: Measured drop port spectrum response of Chebyshev filter.

5 References

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