ULTRALOW LOSS ADIABATIC MICRORING RESONATOR WITH THERMAL TUNING

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ABSTRACT

We report a micro-ring resonator with adiabatic bends, non contact waveguide heaters and small bend radius. The ring has the lowest reported off resonance loss and can support 8 wavelength division multiplexed channels at 200 GHz spacing. We measure 0.49 nm/mW tuning efficiency and 0.085 dB off resonance loss.

Keywords Microring Resonators · Photonic Integrated Circuits · Optical Switching Devices · Silicon Photonics

1 Introduction

Microring resonators (MRR) for the backbone of all silicon phootnics photoninc integrated circuits (PIC). High index contrast enables tight bend radius and high free spectral range (FSR) resonators. MRR off resonant loss or pass through loss at off resonant wavelengths is a major contributor to optical path loss when there are many MRRs along the path of light. We encounter this situation in switches [1, 2, 3, 4, 5, 6, 7, 8], add-drop multiplexers [9] and modulator arrays [10].

For a $N \times N$ switch, with L MRR at each crosspoint reported in [1] the worst case path loss of a switch scales linearly with L (number of MRR per crosspoint), the radix N and off-resonance loss of the MRR. Off-resonance loss of the MRR is the most important metric for the switch. Authors are a

MRR reported in literature do not have both low off-resonant loss and > 20 nm FSR required for wavelength division multiplexing (WDM) applications [11]. Second order filters are sensitive to fabrication variation. MRR where heater is in contact with the optical waveguide have higher optical loss and a higher tuning efficiency [11]. MRR filter with the lowest loss reported has a heater in the center and waveguide spokes connected to a microdisk. Optical loss of 0.05 dB is reported for this MRR in [12]. In this paper, we report our adiabatic microring resonator with adiabatic bends and coupling bus waveguide based on Bezier bends [13]. We report device design, experimental results and compare our MRR with other MRRs from literature.

2 Methods

(c) (i)

Fig 1 (a) shows layout of the MRR. There inner edge of the MRR is an ellipse and outer edge a circle. The waveguide is wider at the point farthest from the bus waveguides similar to [11]. The outer radius is $4 \ \mu m$ and semi-minor axis of the ellipse on the inner edge is $3.2 \ \mu m$. The smallest gap between outer edge and the bus waveguide is $0.18 \ \mu m$. Minimum width of the MRR is $0.4 \ \mu m$.

Heater dimentions are as follows, outer minor and major axis 3.8 μm and 5.8 μm . Inner minor and major axis 3 μm and 5 μm . The smallest gap between heater and MRR inner edge is 0.3 μm . Heater is p doped silicon waveguide. Fig. 2 (d) shows IV of heater.



Figure 1: (a) Layout of the MRR (b) bezier coupler

Optical off resonance loss can be either due to scattering at the coupling region of MRR due to mode mismatch, optical loss in the path of light in the MRR due integrated heater or mode overlap of propagating mode with p doped heater.

We use Lumerical 3D FDTD to design bus waveguide to MRR coupling. The bus waveguide near the MRR is a bezier curve and reduces scattering loss. Fig 1 (b) shows the bezier coupler. The bezier section from input waveguide to minimum width point is 6 μm and height of the top of the bezier curve from the straight input routing waveguide is $1.4 \mu m$. We used parameter sweeps using for loops to minimize the extinction at the through port of the MRR.

3 Experimental Results annd Discussions

In this section, we present experimental results of the MRR. Fig 2 (a) shows the drop and through spectrum of the MRR. Extinction of the MRR at through port is <-15 dB. Fig 2 (b) shows tuning of the MRR by 16 nm out of 25.6 nm FSR. Fig 2 (c) shows tuning efficiency of the MRR = 0.49 nm/mW. We measure off resonance loss of 0.085 dB . This off resonance loss is half the off resonance loss of the MRR ring designs from [14] and measured in [4].We measured this loss by taking an average loss measured with test structures with 0, 10, 20 and 40 MRRs in series. We use functions from Lumos a python library for our measurements [15]. In the following table, we summarize work from several papers. We consider MRRs with > 20 nm FSR. The tuning efficiency reported in this work is much higher than tuning efficiency reported in other papers because of non contact heaters.

Device	Tuning Efficiency	FSR	Switching Speed	Loss (dB)
MRR with adiabatic bends [11]	$4.4~\mu W/GHz$	32.85 nm	$1 \mu s$	-
Micro-disk resonator with integrated heater [12]	$5.5 \ \mu W/GHz$	35 nm	-	0.05 (drop)
Second order MRR [14]	_ **	19 nm	-	-
This work	15.75 $\mu W/GHz$ (0.49 nm/mW)	25.6 nm	-	0.09 dB (off loss)

** The authors report tuning efficiency of 0.69 nm/mW (per ring). We do not report this value in the table. They calculate this value based on 36 mW per FSR tuning. The paper does not report full FSR tuning and IV curves of MRR are non linear as shown in Fig. 2 (d). The authors do not mention how they extrapolate the tuning power. We calculate 0.49 nm/mW tuning efficiency based on 16 nm tuning range instead of the whole FSR.



Figure 2: Measurements on custom first order ring resonator (a) Drop and through transfer spectra of a single first-order ring resonator, (b) Tuning curve of custom ring,(c) Tuning is demonstrated. The ring tunes by 16 nm (FSR = 25.6 nm) with power efficiency of 0.49 nm/mW. (d) IV and RV curves for the cascaded ring resonators. Nonlinear dependence of R vs. V is measured.

4 Conclusion

We report a MRR with adiabatic bends and coupler optimized for low scattering loss. Our MRR is suitable for use in WDM systems with 4 channels at 400 GHz spacing or 8 channels at 200 GHz spacing based on 16 nm/25.6 nm tuning range. This MRR has the lowest reported measured off resonance loss among all the MRR papers in literature and is the most suitable for WDM applications.

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