Direct measurement of the on-chip insertion loss of high finesse microring resonators in Si_3N_4-SiO_2 technology

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Abstract

Microring resonators show the possibility for designing Very Large Scale Integrated (VLSI) photonic circuits by cascading them. In order to realize the devices, the on-chip insertion loss becomes an important parameter. The direct measurement of the on-chip insertion loss of a high finesse microring resonator will be presented. Its value (0.1 ± 0.1) dB is low, in agreement with calculations.

Introduction

Microring resonators (MRs) are potentially important optical components because of their functionality and compactness [1]. They have been proposed as all-optical switch [2], micro-laser [3], and add-drop filter [4,5]. For MRs in a Si_3N_4-SiO_2 technology [10], we observed finesses (*F*) up to 182 [6]-[9]. In this paper we present preliminary results of direct measurements of the on-chip insertion loss in a waveguide-coupled microring resonator based on Si_3N_4-SiO_2 technology.

Microring resonator

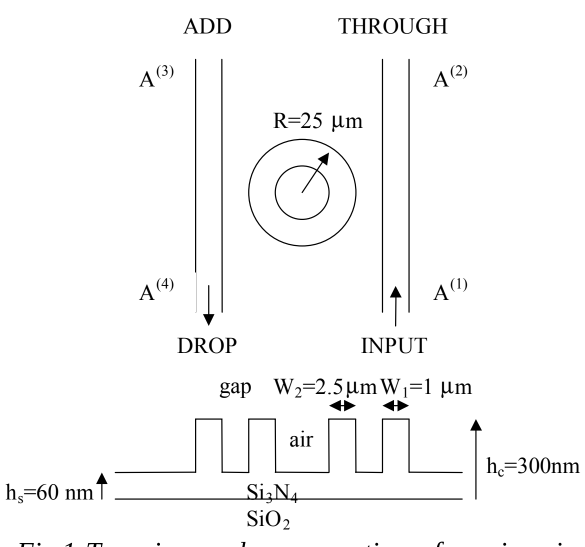

Fig.1:Top view and cross section of a microring resonator with laterally coupled waveguides

A schematic layout of a MR with laterally coupled waveguides is given by Fig. 1. Light from a single-mode input channel is coupled partly to the whispering gallery mode q (depending on the coupling constant, κ_q) in the ring resonator which can support several radial modes. The remaining light will propagate to the through port. The light in the ring, with an effective index $n_{eff,q}$ and absorption α_q, propagates half a roundtrip and is coupled partly (with the same κ_q) to the drop port. The remaining light completes one roundtrip, couples partly back to the through port - once again coupling constant

κ_q - and has now a fraction X_q of the original modal amplitude. A second adjacent waveguide serves as an add and drop channels.

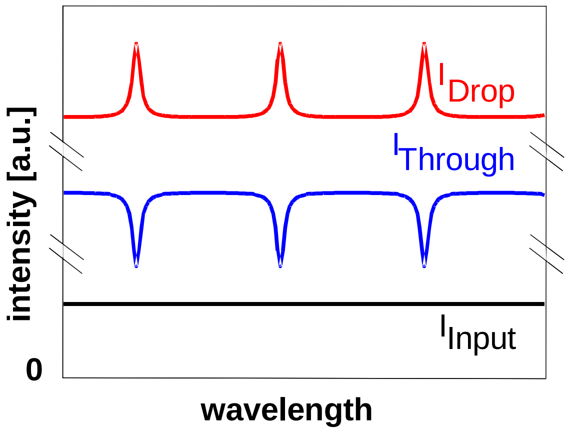

Fig.2: Spectral response of a microring resonator as a function of wavelength

For efficient coupling between the ring resonator and the input waveguide, the waveguide mode is phase-matched to the lowest order resonator mode. By varying the gaps, the coupling between the resonator and the waveguides can be controlled. Fig. 2 shows the input signal, I_{input} and the typical spectral response of the microring resonator. At certain wavelengths the field inside the cavity adds up coherently and resonance dips or peaks can be observed in the through port and drop port respectively.

Design and experimental result

For the application as a WDM add/ drop filter the input and output waveguides should be mono-modal in the communication window around 1550 nm. A second constraint is that the phase-mismatch between these waveguides and the fundamental radial mode of the MR should be as small as possible [7]-[9]. As we used a single-mask approach the height of the waveguide and the MR core are equal, see Fig. 1. The relatively narrow width of the waveguide core (1 µm core with $n_{eff} \sim 1.505$) results in waveguides that fulfills these demands. The bending loss of the ring resonator with diameter 50 µm is, according to a 2-D bend solver [11], $\alpha_{bend} \sim 3.5$ dB/ cm, i.e. 0.014 dB/90^o. From our experiment, however we deduce that the main losses are due to materials and scattering losses [8,9].

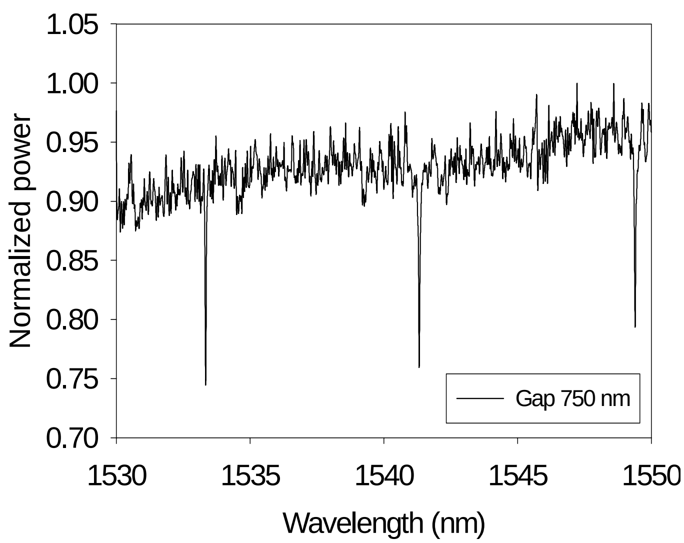

Fig. 3: Throughput measurement by means of the indirect method

The devices were fabricated by LPCVD deposition of silicon nitride (n = 1.98) on a thermally oxidized silicon wafer [10]. Structuring was done by standard optical lithography and RIE etching.

In order to characterize the device basically two experimental methods can be employed, an indirect measurement by measuring the output from the through- and drop port and a direct measurement by imaging from the top the scattered light and perform image processing. Fig. 3 shows the spectral response of the through port by means of the indirect measurement as a function of wavelength.

The direct measurement method has been used for the characterization of a MR with diameter 50 μm and 750 nm gap by launching the TE polarized light of a tunable laser diode into the input port of the waveguide. The scattered power from the device has been projected by a lens system to the IR camera to produce the image. Fig. 4 shows the images for the MR being on- (Fig. 4a) and off-resonance (Fig. 4b). For a MR on resonance, a strong enhancement of the intensity inside the MR can be observed. On the other hand for the off-resonance state, most of the power remains in the straight waveguide and is transferred to the through port. Fig. 5 shows the through port power (log scale) as a function of wavelength obtained from substraction the scattered power just after and

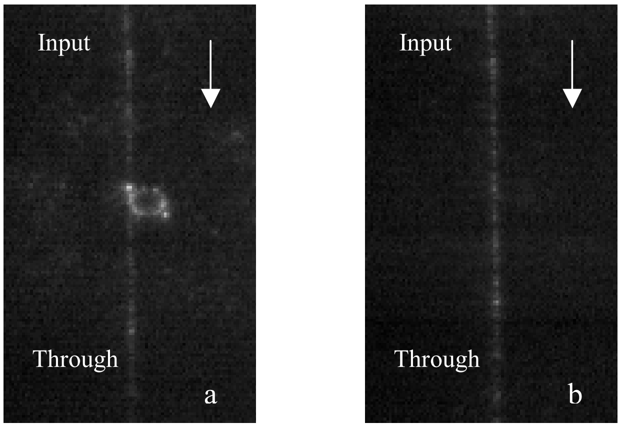

Fig.4 Images obtained by an IR camera of a MR around a wavelength of 1549 nm; a: on-resonance, b: off-resonance

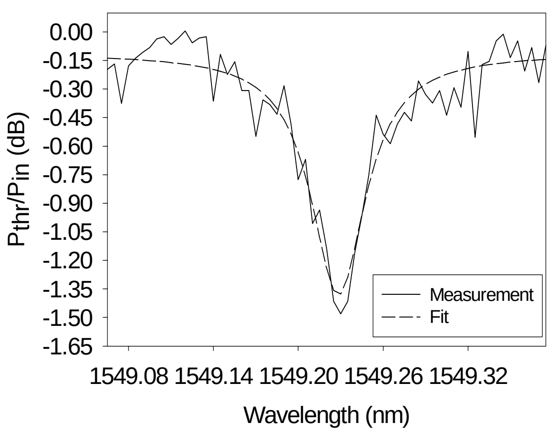

Fig.5:The through port power of a MR obtained by direct measurements after correction for the straight waveguide loss

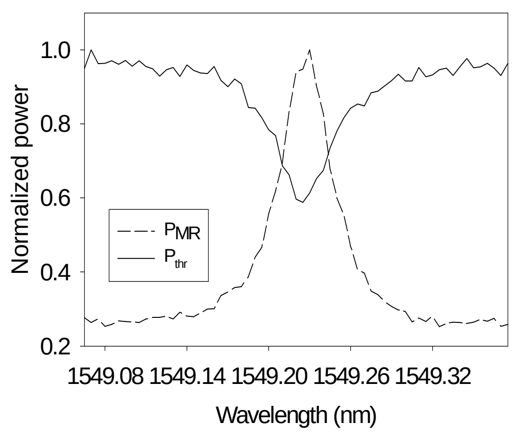

Fig. 6: Cavity power, P_{MR} (peak) from direct measurement and through port power, P_{thr} (dip) from indirect measurement

just before the MR. Hereby we have corrected for the scatter losses in the straight waveguide. From Fig. 5, we obtain a direct value for the off-resonance on- chip insertion loss $\alpha_{ins} \sim 0.1 \pm 0.1$ dB. On the other hand, the estimated value based on our model is $\alpha_{ins} \sim 2.46 \cdot 10^{-4}$ dB. This small discrepancy is probably caused by the excess loss in the coupling between waveguide and MR which was not included in our model.

Fig. 6 shows the integrated power inside the MR (P_{MR}) as a function of wavelength. The position of the maximum in P_{MR} is in good agreement with the minimum in P_{thr}. The experimental full width at half maximum ($\Delta\lambda \sim 42$ pm) of the P_{MR} agrees well with the value obtained from fitting P_{thr} to our analytical model [6] that gives ($\Delta\lambda \sim 56$ pm).

Conclusion

A direct measurement method has been used to determine the on-chip insertion loss. The low value, 0.1 dB is in agreement with simulations. This demonstrates the feasibility of cascading ring resonators to form eventually VLSI photonic devices [12].

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