Apodized coupled resonator optical waveguides using the longitudinal offset technique

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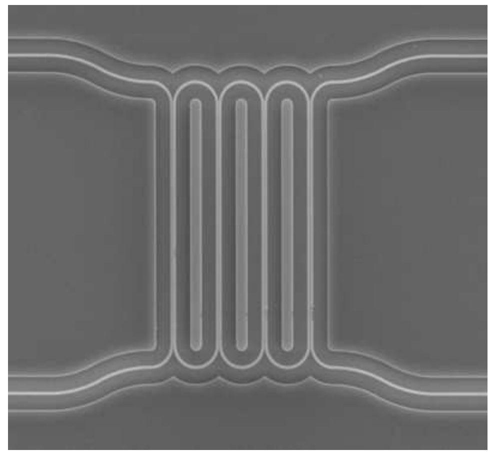
***Abstract*—In this paper, an experimental demonstration of the apodization of coupled resonator optical waveguide (CROW) devices through the longitudinal offset technique is presented for a 3 racetracks CROW device and compared against the uniform case.**

I. Introduction

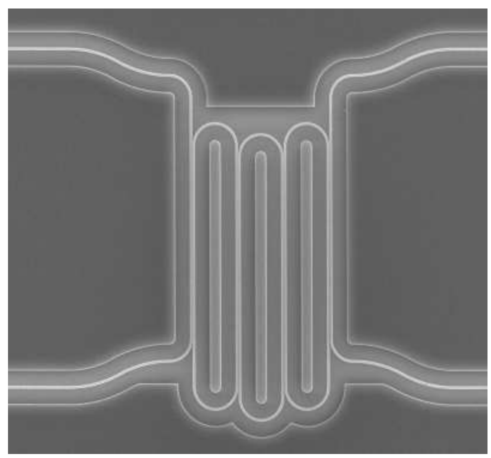
Coupled Resonator Optical Waveguide Devices (CROW) [1] are promising building blocks for the future photonic integrated devices, and their main application amongst others is for filtering purposes. The device consists on a series of directly coupled ring resonators. When the coupling constants between the pairs of resonators are equal, the spectral response of these device exhibits pass band ripples. They can be reduced by means of windowing or apodization of the inter-ring coupling coefficients as already demonstrated theoretically in [2]. Typically the apodization of the coupling coefficients has been done by increasing or decreasing the lateral coupling distance between the cavities [3], in steps that can be of the order of tens of nanometers, in order to increase/decrease the coupling coefficients. For some fabrication processes, as photolithography, these steps are below the achievable resolution. Recently we proposed the longitudinal offset technique [4], in which the change of the coupling coefficients is done by applying a longitudinal offset to the cavities and keeping constant the transversal distance between the resonators. This changes the effective length along which the resonators are coupled, and therefore the coupling constant. However, the steps required for the apodization are found to be of two orders of magnitude above those employed in the conventional technique [3], allowing a more precise control of the coupling.

II. Experimental results

The CROW devices presented in Fig. 1 are fabricate on a Silicon-On-Insulator platform. The devices are based on 3 racetracks shaped resonators with a bending radius of 5 microns and a straight coupling section of 53.3 μm. The devices were designed and fabricated with waveguides of a 500 nm x 220 nm cross-section, providing single mode operation at 1550 nm with a layerstack of 220 nm thick Silicon on top of $2 \mu m$ Silicon Oxide BOX. With the aforementioned ring dimensions, the predicted Free Spectral Range is 4 nm for the wavelengths close to 1550 nm, where the group index of these waveguides is 4.25. The devices were fabricated in the ePIXfab SOI platform [5] using deep UV lithography. All the couplers were designed to have a gap of 150 nm. Two CROW devices were fabricated: the first device with a uniform distribution of the coupling coefficients shown in Fig. 1-(a), that is, the same coupling constant for all the couplers (no offset); the second one with the coupling constants following a Gaussian distribution by applying a longitudinal offset to each cavity in the CROW device depicted in Fig. 1-(b).



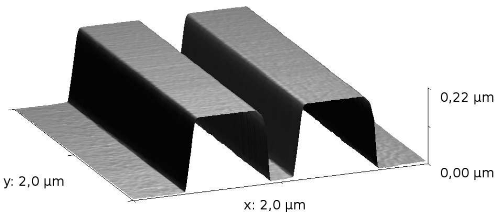
(a)



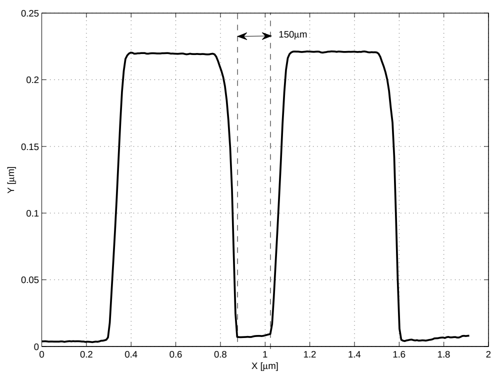
(b)

Fig. 1. SEM images of a 3 racetracks CROW uniform (a) and apodized with the longitudinal offset technique (b).

The gap amongst the coupler parallel waveguides was measured using an Atomic Force Microscope (AFM), since

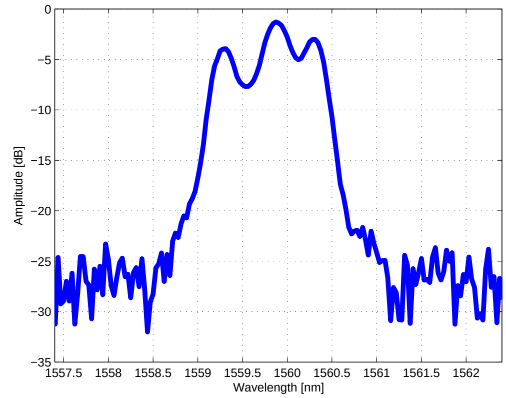


(a)

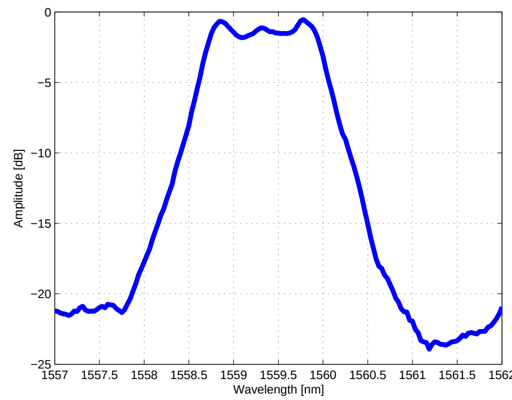


(b)

Fig. 2. AFM measurements on-chip coupler surface (a) 3D profile and (b) cross-section.



(a)



(b)

Fig. 3. Transmission spectra for 3 racetracks uniform (a) and offset apodized (b) CROWs.

it is a very relevant parameter for the control of the coupling constant. The results are shown in Fig. 2-(a) and (b), where a three dimensional reconstruction of the waveguide profile, and a cross-section with the obtained gap are shown respectively.

Light was coupled in to/out from the devices by means of grating couplers [6] optimized for TE transmission around 1550 nm, and optical fibers properly positioned and aligned. A reference transmission spectrum through a straight waveguide was acquired for normalization purpouses. The spectral response of the uniform device in Fig. 1-(a), is shown in Fig. 3-(a). The spectrum exhibits the well known pass-band ripples for this kind of devices. For the apodized device using the longitudinal offset technique, shown in Fig. 1-(a), the spectrum in provided in Fig. 3-(b). A reduction of nearly 5 dB in the pass band ripple is obtained.

III. Conclusions

In this paper, the longitudinal offset technique for the apodization of CROW devices has been experimentally demonstrated. The technique is able to perform pass-band ripple reduction in the spectral response of a CROW device. The technique allows apodization of the response using fabrication technologies with coarse resolution steps, as photolithography, at a cost of increased device footprint in the lateral dimension.

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