Fast Silicon-Photonics Wavelength-Selective Phase Shifter

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Abstract: *A fast wavelength-selective phase shifter in silicon-on-insulator technology based on carrier-depletion effect in a microring resonator is designed and experimentally verified. Phase variation of 250°, bandwidth of 10GHz and insertion loss of 3.5dB have been demostrated*

INTRODUCTION

Microring resonators (MRRs) in all-pass configuration have long been proposed and demonstrated as an effective mean for controlling the phase of radio-frequency (RF) signals [1].

Strong thermo optic effect of silicon by heating the ring waveguide has been widely used [2], [3] to design devices with high efficiency and phase tuning range ☺ but with response time limited to few us ☹

To overcome bandwidth limitation ☺ the use of fast plasma dispersion effect using carrier injection in a doped MRR has also been reported [4] but with limited phase shift range <180° ☹

For the first time an optimized design of a MRR embedding pn-doped waveguides to exploit carrier-depletion mechanism to obtain a fast phase shifter (10Ghz bandwidth ☺) with a wide phase range: >250° ☺ has been proposed

MRR DESIGN AND OPTIMIZATION

An analytical model describing the pn-doped waveguide behavior as a function of the applied reverse voltage has been employed to take in account relatively weak index change associated with modulation of depletion region and the optical losses due to free-carriers in the doped waveguide.

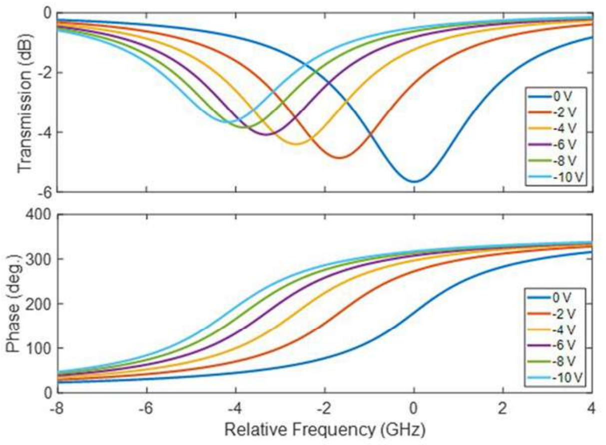
Available doping concentrations for the selected foundry in a multi-project wafer (MPW) run has been estimated based on the provided values for the sheet resistance of the implanted waveguide with p- an n-type dopant

The doped waveguide length, Lpn and the cross-coupling power coefficient κ of the directional coupler (DC) between the ring and input-output access bus waveguide have been optimized to:

- Maximize the phase shift for a maximum applied voltage below the inverse breakdown threshold
- to keep low as low as possible the Q-factor of the resonator for minimizing the residual amplitude modulation

Transmission and phase response for different reverse voltage bias are shown for Lpn=200 μm, and κ=0.2

Model results



Experimental setup and results

The fast selective PS has been fabricated using a SiP MPW run [6].

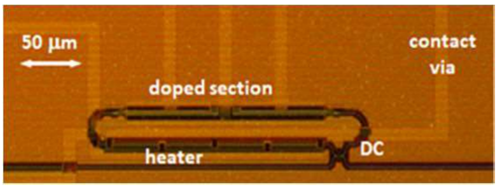
A resistive heater is placed in proximity to a portion of the MRR undoped waveguide to provide an additional broad tuning mechanism, as required for precise resonance alignment when multiple MRRs are cascaded to achieve full 360° phase shift control.

The group-delay characteristics of the MRR for different levels of Vbias have then been measured using a standard phase shift method [7].

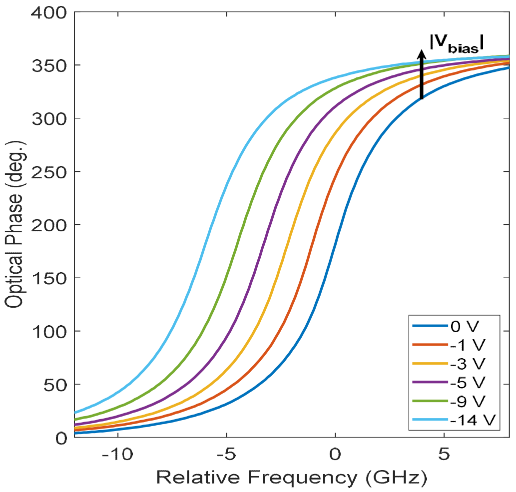
The optical phase variation and insertion loss over the full considered voltage swing at a detuning of 3 GHz in respect to the unbiased resonant frequency are plotted

the high-speed operation of the selective PS has been assessed by measuring the electro-optical bandwidth of the device under small-signal regime using a Network Analyser

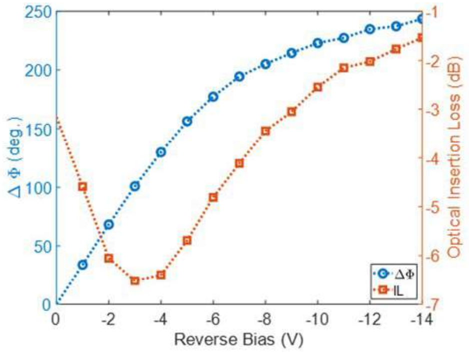
Device micrograph



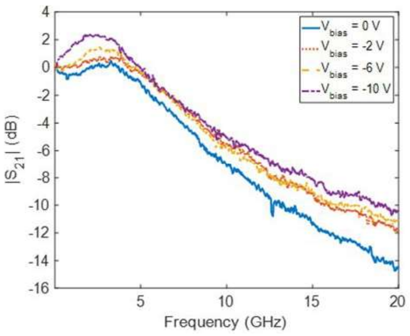
Measured



Phase and loss measure



Bandwidth measure



Final remarks

- A silicon-photonics microring resonator embedding a pn-doped waveguide designed for implementing a novel fast wavelength-selective phase shifter through carrier-depletion mechanism has been presented
- The MRR has been dimensioned for optimizing its performances in terms of optical phase variation, amplitude modulation and insertion loss
- Experimental characterization confirms phase shift range >200° , residual amplitude modulation <3dB and response time <1ns

References
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