Fast Silicon-Photonics Wavelength-Selective Phase Shifter

C. Porzi¹, F. Falconi², L. Ansalone³, P. Ghelfi², A. Bogoni¹,²
1: Scuola Superiore Sant'Anna, TeCIP Institute, 56124 Pisa, Italy
2: CNIT – National Inter-University Consortium for Telecommunications, 56124 Pisa, Italy
3: ASI-Italian Space Agency, Via del Politecnico, snc 00133 Roma

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 demonstrated.

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 μs.

To overcome bandwidth limitations 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 achieve 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-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=200μm, and κ=0.2.

Experimental setup and results
The fast selective PS has been fabricated using a SI-P 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 3GHz 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 Analyzer.

Final remarks