# Reconfigurable Silicon Photonic Signal Processor Based on the SCOW Resonant Structure

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**Abstract:** We propose a reconfigurable silicon photonic signal processor composed of three stages of self-coupled optical waveguide (SCOW) resonators. The processor can be configured to ring resonator and MZI-based optical filters.

**OCIS codes:** (130.3120) Integrated optics devices; (130.7408) Wavelength filtering devices; (060.5625) Radio frequency photonics

## 1. Introduction

Universal photonic signal processors, which can be reconfigured to perform multiple tasks by using the same hardware platform, are drawing much attention for their wide applications in microwave photonics, quantum optics, optical communications, and so on [1]. They are inspired by the concept of Field Programmable Gate Arrays (FPGAs) in optical domain, which are more flexible and cost effective compared with application specific PICs (ASPICs). Several programmable photonic processors have been proposed and demonstrated by placing tunable couplers in square [2], hexagonal [3], or triangular [4] meshes.

In this paper, we propose a new type of silicon reconfigurable processors based on a self-coupled optical waveguide (SCOW). The SCOW is formed by a single meandering waveguide self-coupled to form directional couplers at the input and the output ports [5]. Both clockwise and counter-clockwise resonance modes are excited in the SCOW resonator. The proposed reconfigurable processor is composed of three-stages of SCOW resonators and can be conveniently constructed as single- and coupled-ring resonators, Mach-Zehnder interferometers (MZIs), etc.

## 2. Device structure

Figure 1(a) shows the schematic of the reconfigurable processor. The directional couplers are replaced by MZIs to work as tunable couplers (TCs). As each two contiguous SCOW resonators share two TCs, there are totally six TCs, which are named as TC*i* (*i*=1, 2, ... ,6). We also insert a phase shifter (PS) and a variable optical attenuator (VOA) between two adjacent TCs. By reconfiguring the light routing paths through TCs, PSs, and VOAs, the structure is programed to exhibit different optical properties, allowing for versatile applications. The PSs are based on the thermo-optic effect by the TiN microheaters, while the VOAs are based on the free carrier absorption after turning on PIN diodes. The PS and the VOA can be integrated in the same waveguide, as illustrated in Fig. 1(b).

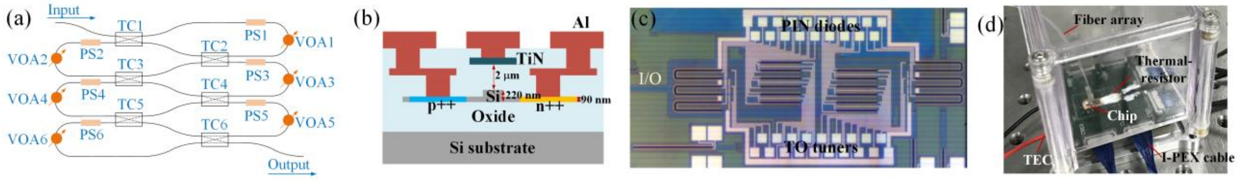

Fig. 1 (a) Schematic of the reconfigurable processor. (b) Cross-sectional view of the active waveguide. (c) Microscope image of the fabricated chip. (d) Photo of the chip after home-packaged.

The chip was fabricated on a SOI wafer with a top silicon layer thickness of 220 nm. Figure 1(c) shows the microscope image of the fabricated chip. The footprint of the chip is 3×1.6 mm$^2$. Figure 1(d) shows the picture of the home-packaged reconfigurable processor. Grating couplers are used to couple light in and out of the chip through a fiber array. A thermal-resistor and a thermo-electric cooler (TEC) are used to monitor and stabilize the chip temperature during the measurement.

## 3. Experimental results

We first calibrate the initial states of all the TCs. Although the chip is a one-input and one-output device, it is very convenient to tune the TCs to exact bar or cross state with the assistance of VOAs. With certain VOAs turned on, there can be only one light pass route without any feedback. In this way, we can reach the cross or bar state of each TC by monitoring the output power.

Figure 2 shows the experimental results of the reconfigurable processor. In Fig. 2(a), the structure is configured to an all-pass ring resonator, where the ring is formed by an internal single loop as illustrated by the gray dashed line.

By tuning the coupling coefficient of TC1, the ring can be tuned from under-coupling to over-coupling. The FSR of the ring is ~12.5 GHz and the 3-dB optical bandwidth of the critical-coupling ring is ~3.5 GHz. When VOA1 and VOA4 are turned on and TC4 acts as a coupler, the structure is configured to an add-drop ring resonator as shown in Fig. 2(b). The drop passband can be varied by changing the coupling coefficient. The processor can also be configured to double-ring structures in Figs. 2(c) and 2(d). The output of the coupled ring resonators can be tuned by TC1, TC4, and TC6. Beside the ring resonators, the processor can also work as MZI-based finite impulse response (FIR) filters. As shown in Fig. 2(e), when TC1 and TC4 are configured to even splitters, the interference of the two paths in the MZI (illustrated by the blue and orange lines) generates high extinction ratio notches. VOA2 is turned on to attenuate the light coupled back to TC1. The filter central wavelength is tuned by the PS in Path 1. Figure 2(f) shows a more complex structure of a ring resonator-coupled MZI. The output spectra show an asymmetrical Fano-resonance like transmission.

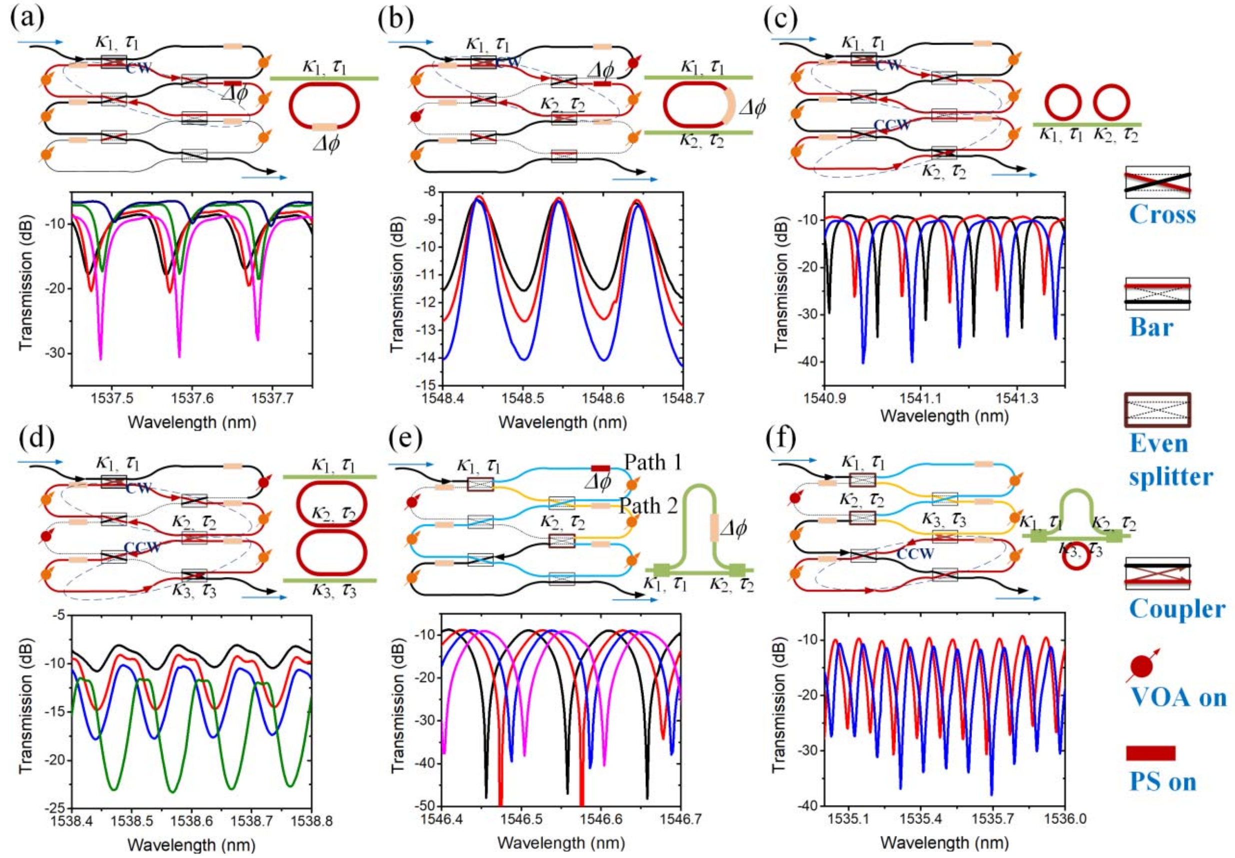

Fig. 2 Configurations and experimental results of the processor as (a) an all-pass ring resonator, (b) an add-drop ring resonator, (c) two cascaded all-pass resonators, (d) two directly-coupled ring resonators, (e) an asymmetric MZI, and (f) a ring-coupled MZI.

## 4. Conclusions

We have proposed and experimentally demonstrated a silicon reconfigurable processor based on a three-stage SCOW structure. By tuning TCs, PSs and VOAs, the processor can be configured to various ring resonator and MZI filters. These results open the way for a new class of programmable silicon photonic processors that utilize self-coupled waveguide to increase the flexibility and extend the functionality.

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