Optical Tunable Delay Lines Based on Self-Coupled Optical Waveguide (SCOW) Resonators

Linjie Zhou, Jianping Chen, Xiaomeng Sun, Jingya Xie, Zhi Zou, and Liangjun Lu

State Key Laboratory of Advanced Optical Communication Systems and Networks
Department of Electronic Engineering, Shanghai Jiao Tong University, Shanghai 200240, China

ljzhou@sjtu.edu.cn

Abstract: We experimentally demonstrate optical tunable delay lines based on novel self-coupled optical waveguide (SCOW) resonators. Due to the co-excitation of the contra-propagating modes in the SCOW resonator, it features a high delay-bandwidth product suitable for broadband optical signal buffering.

OCIS codes: (230.3120) Integrated optics devices; (230.5750) Resonators; (200.4490) Optical buffers.

Optical tunable delay lines are essential components in all-optical switching and optical signal processing to synchronize and buffer optical packets [1, 2]. Silicon microresonator is a promising candidate to implement compact on-chip tunable delay lines with low power consumption, as well as its potential in monolithic integration with silicon microelectronic devices [3]. In order to obtain ns-scale continuous optical delay for broadband optical signals, we design a novel delay line based on self-coupled optical waveguide (SCOW) resonators to fully utilize the contra-propagating modes to enhance the delay-bandwidth product [4, 5].

The SCOW resonator is composed of a folded waveguide with two coupling points. By controlling the coupling strength, clockwise and counter-clockwise resonance modes can be co-excited, resulting in a large group delay. The coupling strength is made tunable by using push-pull Mach-Zender interferometer (MZI) couplers with p-i-n diodes embedded in the two arms. Upon a forward bias of the p-i-n diodes, free carriers are injected in the MZI arms, inducing a change in phase and therefore the coupling coefficients. The devices are fabricated using standard complementary metal-oxide-semiconductor (CMOS) processes. Preliminarily experimental results show the transmission spectrum of the SCOW resonator exhibits second-order resonance characteristics with a group delay of ~80 ps and a 3-dB bandwidth of 10 GHz. The group delay is gradually reduced to zero when the coupling coefficients of the MZI couplers are electrically tuned. Because of the push-pull configuration of the MZI coupler, the resonance wavelength is kept fixed during tuning. It helps with the signal delay application, since the second-order group delay dispersion (GDD) is always zero at resonance wavelengths.

To further enhance the group delay, we also investigate the cascaded SCOW resonators. An electromagnetically induced transparency (EIT)-like effect is present when two SCOW resonators are connected in series. The group delay is greatly enhanced (~300 ps) near the sharp EIT peak. The EIT-induced group delay is quite sensitive to the phase of the inter-resonator connection waveguide. With a 1-V voltage change, the group delay can be tuned by 200 ps, which indicates that it has low tuning power consumption.

References

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