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# Silicon Waveguide Michelson Interferometer For Multi-Wavelength Modulator

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***Abstract*:** A waveguide multi-wavelength modulator is investigated. The modulator is based on Michelson interferometer, which is composed of phase shifter and microring resonator wavelength filters, leading to respective wavelength arms. Multi-channel operation of Michelson interferometer switch is demonstrated using a thermo-optic phase shifter.

## 1. Introduction

Due to the accelerated growth in performance of micro-processors and the recent emergence of chip multiple-processors, a critical performance bottleneck of high performance computing has shifted to the communication infrastructure. Optically-connected systems can enable continued performance scaling through high-bandwidth capacity, energy-efficient bit-rate transparency, and latency. Silicon photonics is a promising technology for realizing low-cost and compact optical transceivers [1]. However, a light emission in Si is a problem because of the indirect bandgap. A hybrid integration with an off-chip laser diode composed of III-V compound semiconductor is a reasonable solution [2].

By exploiting the capacity of wavelength division multiplexing (WDM), optical interconnects offer a high-bandwidth and low-latency solution in on-chip and inter-chip applications. To realize an optical WDM network, a multi-wavelength modulator is one of important components. It is a modulator which operates independently for each wavelength signal provided by an off-chip WDM light source. Although a microring resonator (MRR) is the compact wavelength filter, the characteristics of the modulator is sensitive to the wavelength mismatch between input and output ring resonators [3, 4].

We have proposed a structure of multi-wavelength modulator with phase shifters in Michelson interferometer arms. It includes MRR wavelength filters inside the Michelson interferometer. By placing MRRs closely, the wavelength mismatch can be mitigated. It enables hitless operation for multi-wavelength channels. In this article, we demonstrate the multi-channel operation of this Michelson interferometer based modulator.

## 2. Structure and operation

The proposed multi-wavelength modulator is composed of a directional coupler, MRRs, loop mirror in each arm and phase shifter. Input light from a WDM source or a broadband source will split half at the directional coupler. After splitting, each carrier wave will shift to their own ring resonator. Let us consider a carrier wave with a particular resonant coupling wavelength of the MRR.

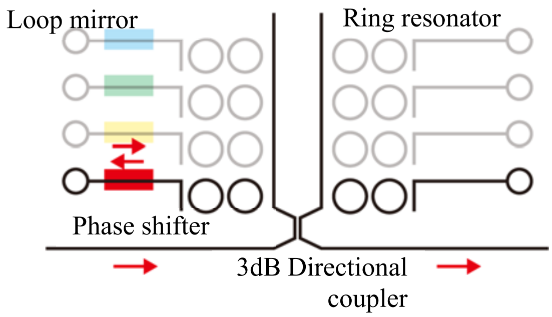


Fig. 1. Structure of Michelson interferometer based multi-wavelength modulator.

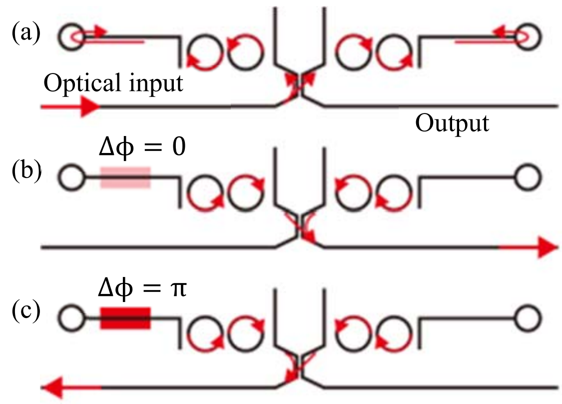


Fig. 2. Operation of Michelson interferometer considering a resonant carrier wavelength

As shown in Fig. 2, the resonant carrier wave will pass the interferometer arms, reflect at the loop mirror, again pass the ring resonator and coupled at the directional coupler. The phase difference will be added between the two Michelson interferometer arms. When there is no phase difference, the carrier wave goes out from the output port, and when phase difference of $\Delta\phi = \pi$ has been added at the phase shifter, the carrier wave will go out from the input port instead of output port. Here, we assume that an optical isolator is installed in front of the light source. Consequently, applied electrical signals to each phase shifter modulate the carrier wave. The modulation is done independently for each wavelength signal, and then the output signals are multiplexed, if necessary.

The advantages of this configuration are as follows; (1) Because wavelength filter for MUX/DEMUX is identical, the wavelength mismatch is ignored. Two MRR filters in the interferometer arms are placed closely, the mismatch between them is mitigated. (2) By applying loop mirror, the phase shifter length will be half. The only directional coupler works as a splitter and coupler. The overall footprint is small. (3) Low crosstalk is expected because the only resonant wavelength light is output. Non-resonant or imperfect wavelength filtering light is eliminated from the ends of upper ports of the Michelson interferometer.

## 3. Switching performance

A multi-wavelength switch for two wavelength signals was fabricated on an SOI wafer. Two pairs of MRR were designed to have the resonance with a free-spectrum range of 10 nm and a channel spacing of 5 nm. As a thermo-optic (TO) phase shifter, a Cr heater and an Au electrode were formed on the Si waveguides.

First of all, the wavelength characteristics was characterized for the TE-mode input from an ASE light source. For the specific wavelength signal, we conducted an amplitude modulation measurement by modulating a TO phase shifter where a tunable laser diode was used as a light source. The phase shifter was heated by flowing a current from a variable voltage source.

Figure 3 shows the measured transmittance where two resonant spectra of MRR with the FSR of 10 nm were overlapped by the spacing of 5 nm. A wavelength channel at around 1567 nm was selectively modulated when the corresponding heater CH1 was modulated. Figure 4 shows the amplitude modulation for 1567 nm and 1571 nm. Extinction ratios were 20.8 dB and 18.3 dB at 1567 nm and 1571 nm, respectively. The switching characteristics can be improved by reducing the MRR mismatch and improving the wavelength characteristic of the directional coupler such as a 2x2 MMI coupler.

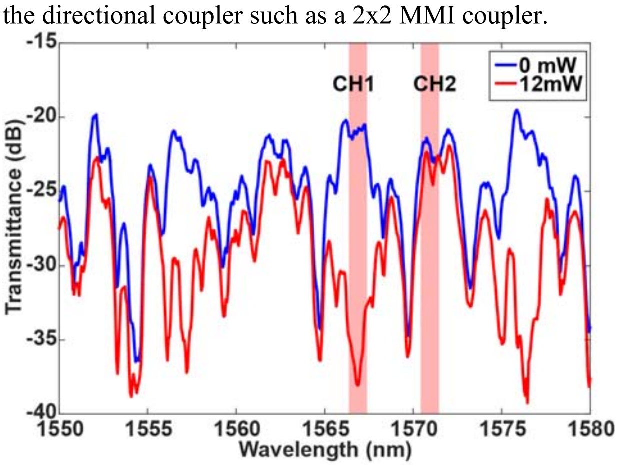


Fig. 3. Wavelength characteristic of Michelson interferometer when modulating CH1

## 4. Conclusion

We fabricated and demonstrated a multi-channel Michelson interferometer switch with MRRs and TO phase shifters for a multi-wavelength modulator. The MRR works as a filter to lead specified wavelength to each Michelson interferometer arm where the selected wavelength channel is modulated. The wavelength-dependent optical switching was demonstrated by modulating TO phase shifters corresponding to respective channels.

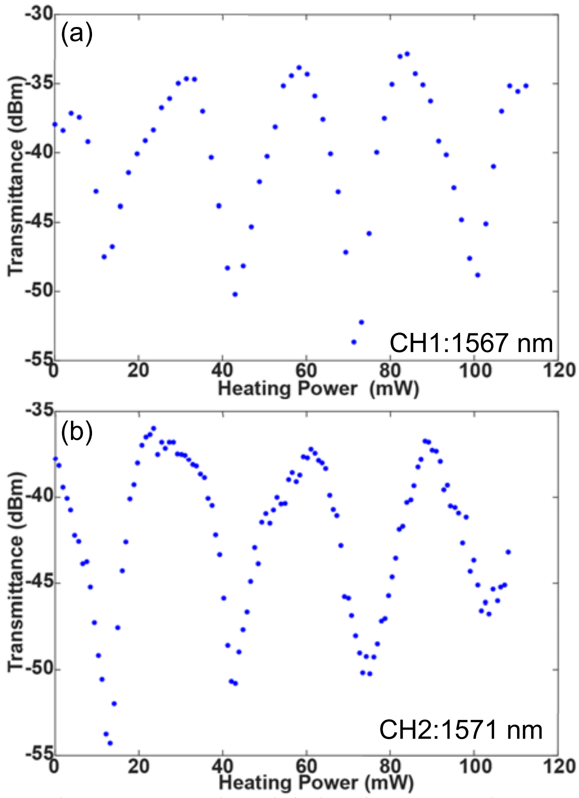


Fig. 4. Measured modulation for 1567 and 1571 nm wavelength channels.


## Acknowledgments

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