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Add-drop multiplexing in WDM signal transmission link using silicon photonic crystal R-OADM devices

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Abstract: We present add-drop multiplexing of WDM optical signal using silicon photonic crystal R-OADM modules in the fiber transmission setup. Wavelength tunable add-drop multiplexing of 4-channel WDM signal with each channel bit rate of 10 Gb/s has been achieved with very compact, integrated R-OADM devices.

1. Introduction

For developing ultra-small photonic devices and integrating them, Si photonic device technology attracts considerable attention [1-3]. Taking advantage of sophisticated Si electronic device manufacturing technology, Si photonic devices utilizing various micro-/nano-structure can be realized cost-effectively. Such devices are highly expected for photonic network nodes. Currently, the concept of photonic networks is being realized by installing reconfigurable optical add-drop multiplexers (R-OADMs) consisting of discrete optical components. For extending photonic networks in terms of functions and areas [4], newly developed, compact and integrated photonic devices are required. We previously demonstrated an R-OADM device in which a tunable filter and a 2 x 2 switch were integrated on a Si-on-insulator (SOI) substrate using photonic crystal (PhC) structure and Si wire waveguides [3,5-12]. In this report, we present the add-drop multiplexing of wavelength-division-multiplexing (WDM) optical signal using moduled R-OADM devices in a fiber transmission setup. Wavelength tunable add-drop multiplexing of 4-channel WDM signal with each channel bit rate of 10 Gb/s has been achieved with very compact, integrated R-OADM devices.

2. Si Phonic crystal R-OADM device and module

Our R-OADM device consisting of a tunable filter and a switch is shown in Fig. 1. Waveguides defined by line defects in 2-dimensional photonic crystal (2D-PhC) slab were used as Bragg reflectors placed in a Mach-Zehnder interferometer (MZI) composing the tunable filter and also phase shifters placed in another MZI composing the switch [5-8]. The 2D-PhC structure was formed by making holes arranged in a hexagonal lattice through a 250-nm thick Si layer and then being buried with SiO_2. The hole diameter was about 250 nm and the lattice constant was about 420 nm. The Bragg reflector was designed to reflect one wavelength channel among input WDM channels. A refractive index change based on a thermo-optical effect on Si was used for tuning the reflection wavelength in the filter and for inducing a phase shift in the switch. These PhC waveguides were connected with Si wire waveguides through low-loss trapezoidal interfaces [9-10]. Sharp bending and very short directional couplers [11] provided by Si wire waveguides also contributed to device miniaturization. The net device footprint of the R-OADM device was about 500 μm x 140 μm [12].

To make a fiber-pigtailed module, optical coupling of two beams between the Si wire waveguides and the arrayed fibers on each device facet was done using two lenses. The photograph and the schematic of the module are shown in Fig. 2.

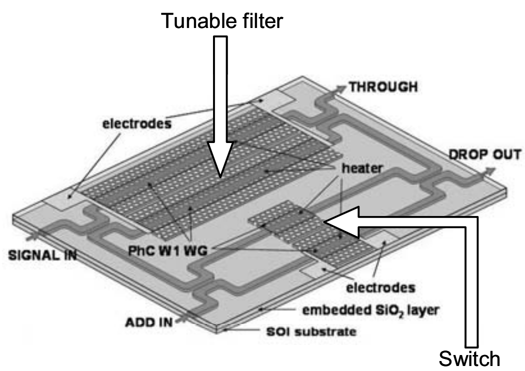

Fig. 1: Si photonic crystal R-OADM device

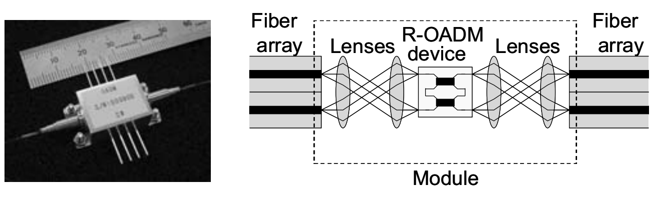

Fig. 2: R-OADM module

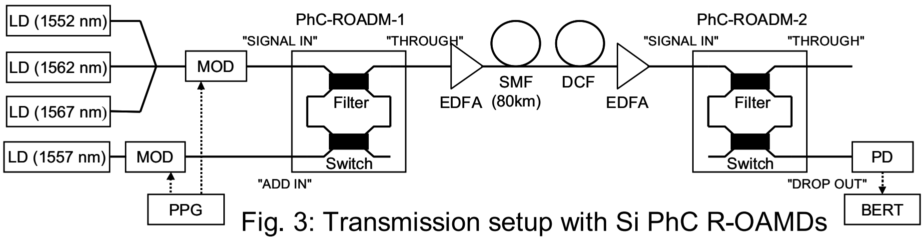

Fig. 3: Transmission setup with Si PhC R-OAMDs

3. Add-drop multiplexing in transmission setup

We did the experiment on the transmission and the add-drop multiplexing of WDM optical signal using R-OADM modules. The setup is shown in Fig. 3. The WDM optical signal consists of four-channel 10 Gb/s optical signals with a wavelength spacing of 5 nm. The first R-OADM module on the transmitter side was used to add the channel at 1557 nm to the other three channels at 1552, 1562, and 1567 nm. In this R-OADM device, the 1557-nm signal was propagated through the switch and then reflected with the Bragg reflector of the filter. The optical spectrum of the four wavelength channels output from the THROUGH port is shown in Fig. 4(c). The four-channel WDM optical signal was transmitted through 80-km single mode fiber with dispersion compensation fiber inserted on the receiver side. The second R-OADM module on the receiver side dropped the channel at 1557 nm from the four wavelength channels. The optical spectrum shown in Fig. 4(d) was obtained from the DROP OUT port. Optical signal from the DROP OUT port shows clear eye opening, as shown in Fig. 4(b). Measured BERs of this channel at 1557 nm shown in Fig. 4(g) indicate error-free operation with low power penalty.

The tunability of the wavelength to be added or dropped enables add-drop multiplexing of a different wavelength channel. Fig. 4(e) and (f) show optical spectra when the channel at 1562 nm was added and then dropped. In the R-OADM devices, 5-nm shift in the Bragg reflection wavelength was induced with an electric power of about 500 mW applied to the heater of the R-OADM device. As shown in Fig. 4(g), good performance was also confirmed at this wavelength.

4. Conclusions

In conclusion, we have demonstrated add-drop multiplexing of WDM optical signal using silicon photonic crystal R-OADM modules in the fiber transmission setup. Wavelength tunable add-drop multiplexing of 4-channel WDM signal with each channel bit rate of 10 Gb/s has been achieved with very compact, integrated R-OADM devices..

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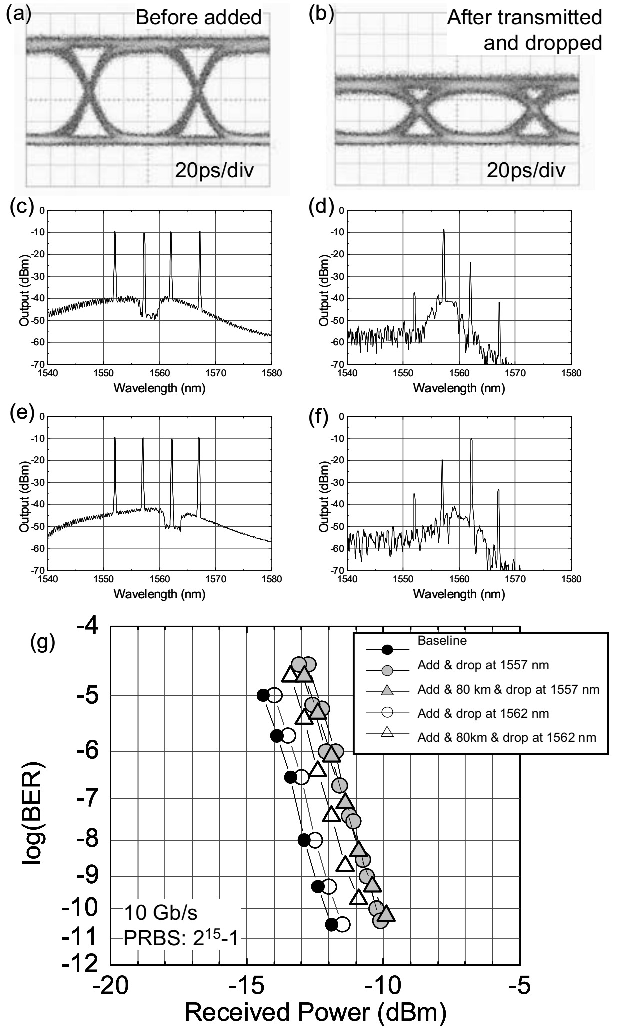

Fig. 4: Experimental results
(a)-(b) Eye diagrams before add and after drop
(c)-(d) Optical spectra after add and after drop at 1557 nm
(e)-(f) Optical spectra after add and after drop at 1562 nm
(g) Measured BERs