P15

4 Channel Optical mode Switch by Using Selective Mode Switch and 3dB MMI Coupler

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Abstract
We propose a novel optical mode switch, which is a new concept of the optical switch. It can overcome the matrix size limitation issue, which has been a general issue for the waveguide optical space switch, because of its simple fiber-coupling configuration. In addition, it contributes to the lossless mux/demux function such as wavelength multiplexing with powerless mode conversion unlike wavelength conversion. In this paper, we propose the principle of the optical mode switch. The simulation results showed less than %30 dB mode crosstalk, with less than only 0.1 dB excess loss for a two-mode optical switch. Moreover, the scalable configuration up to four modes is also proposed in this paper.

1. Introduction

The optical modes can be exploited as an independent channel or signals. Thus, it makes mode-division-multiplexing (MDM) as a promising technology to expand the transmission capacities in order to keep up the rapid Internet traffic growing demands [1, 2]. For this, a mode converter is needed in order to convert the fundamental mode to the higher order mode. However, optical mode switch is needed in order to realize more reconfigurable MDM network. This optical mode switch is working just the same with optical switching technology that will decrease the power consumption of the router by eliminating the optical-electrical-optical (OEO) signal exchange in electrical switches [3-6]. The difference between optical mode switch and another optical switch, especially optical spatial switch, is the number of input and output ports. Differently with the optical spatial switch, optical mode switch is only need one input and output port by employing the few-mode fiber (FMF) or multicore fiber (MCF).

In this paper, we propose optical mode switch configuration for four modes [4]. It switches one mode to another among 0th to 3rd modes, while keeping compact size of 0.033 mm^2 including input/output access waveguides.

2. Device Concept

2.1. Selective mode switch

Figure 1 shows a schematic of the optical mode switch for four modes by using selective mode switch. This device switches one mode to another mode each other like space cross-bar switch in between 0th, 1st, 2nd, and 3rd modes. In case "space port information" is replaced to "mode information", this switch configuration corresponds to 4x4 matrix space switch. As it requires to connect with so called "few mode fiber" instead of array fiber, the size of it is limited within 0.033mm^2, that is approximately 10 times less than conventional 4x4 matrix switch due no need of S-bend fiber connecting region. Selective mode switch means that we provide 2 kind of phase shifter region. Region D,E, and F in the Fig. 1 shows the fundamental mode phase shifter

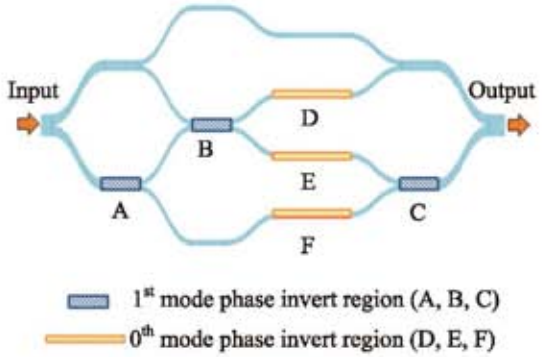

Figure 1. 4 Channels optical mode switch by using selective mode switch.

while region A, B, and C is showing the 1st order mode phase shifter. In the Region 3, only fundamental mode that will shift as π rad, on the other hand in region 1, 2, and 3 the 1st order mode will shift as π rad while fundamental mode will remain the same in this region.

2.2. 3dB MMI Coupler

One of the problem in selective mode switch is the first order mode phase shifter needs the current injection 10 times higher than the fundamental mode. It means that higher power is needed to realize this optical mode switch. To overcome this problem, we exchange the first order mode phase shifter with a 3dB MMI coupler as it is shown in Fig. 2. The principle is just the same, to shift the first order mode, but in here we exchange the port of the modes. At first each of the modes will be divided into fundamental modes because of the Y-junction. When a current is injected into one of the arms in 3dB MMI coupler, it will switch the propagation of the lights as shown in Fig, 3(b).

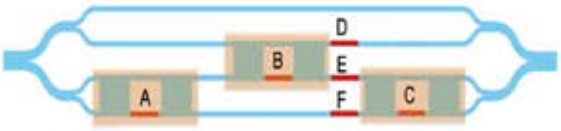

Figure 2. 4 Channels optical mode switch by using 3dB MMI coupler.

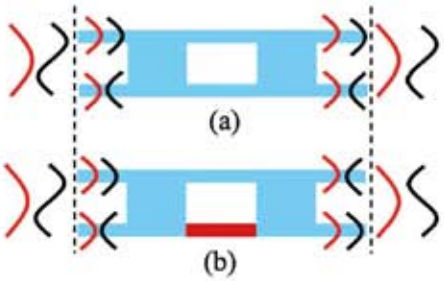

Figure 3. 3dB MMI coupler principle, (a) when there is no current injection, and (b) when the current is injected into one of the arms

3. Result

Figure 4 shows the simulation results of the case that injected 0th mode is switched to the other modes. In the optical mode switch, the information of the modes is used instead of that of the ports. Therefore, it is necessary to discuss about the crosstalk between modes instead of the crosstalk between ports.

The worst cross-talk was estimated to be less than -19.0dB when 3rd mode was switched to 1st mode. Much more improvement is expected when the structural optimization is completed. However, it shows the potential higher scalability of the optical mode switch.

Theoretically selective mode switch and 3dB MMI coupler principle can realize the 4 channel optical mode switch, however, experimentally it has not been done yet. Currently we are trying to fabricate these devices.

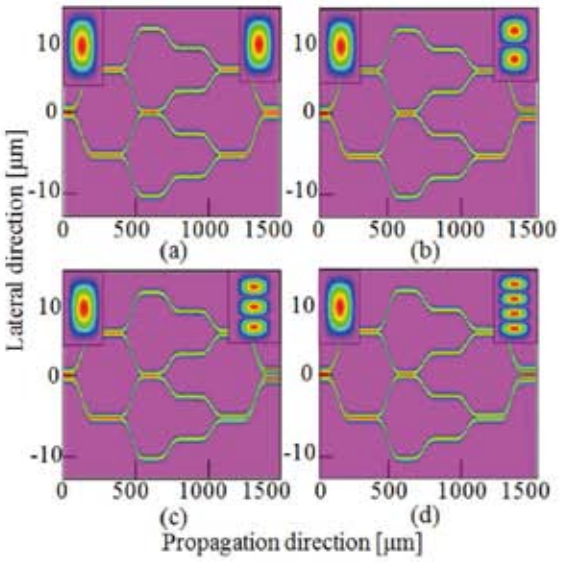

Figure 4. BPM results of switching 0th mode to other mode (a) 0th to 0th (b) 0th to 1st (c) 0th to 2nd (d) 0th to 3rd.

4. Conclusion

The study to realize the 4 channel optical mode switch has been done. The first principle is by using selective mode switch, however, this principle needs a high current injection or long dimension. To overcome this problem 3dB MMI coupler is proposed to exchange the selective mode switch.

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