(Invited) **Optical Mode Switch for Future Optical Router**

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Abstract: We have proposed novel optical mode switch, which overcomes matrix size limitation issue that has been a general issue for waveguide optical space switch, because of its simple fiber coupling configuration. In addition, it contributes to loss-less mux/demux function like wavelength-multiplexing with power-less mode-conversion unlike wavelength-conversion.

Introduction: Due to the recent data traffic increase with high power consumption, optical router has been researched intensively [1] as it avoids energy-exchanges between optical signal and electric one that is one of the main cause of the high power consumption. Optical switch is one of the key devices to realize such that optical router. Among them, waveguide optical switch is attractive because of the potential of high-speed operation and low power consumption [2-3], however, there has been a limitation in the switch matrix size. One of the reason that limits the matrix size of the optical space switch is that it is required to connect to fiber-array, that arises the necessity of S-bending region integration to open up the input and output ports to a certain (typically 125mm) adjacent spacing of the fiber-array even if the main switch matrix configuration itself can be shrunk by using latest advanced waveguide technologies including Si-photonics and others. To overcome this issue, we have proposed novel optical mode switch [4-5]. It overcomes matrix size limitation issue because it requires only single fiber (in this case, few mode fiber or multi-core fiber) connection at the both input and output port. In addition, it contributes to loss-less mux/demux function like wavelength-multiplexing with power-less mode-conversion unlike wavelength-conversion. In this paper, we explain the concept, the principle, and the scalability will be discussed.

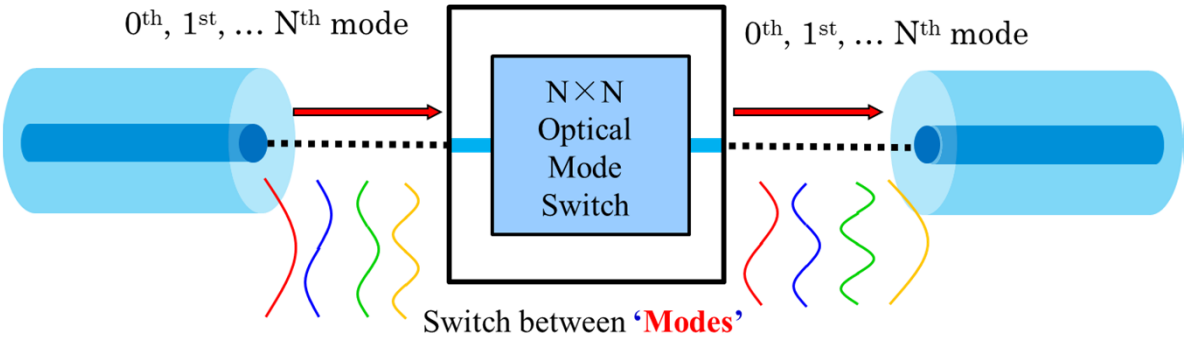

Fig.1: Schematic configuration of optical mode switch module.

Concept: The waveguide-based optical space switch has always a matrix size limitation issue mainly due to S-bend region, needed for fiber array connection, that prevents large scale integration. The optical mode switch solves this issue. Instead of switching port information, it switches "optical mode". As each optical mode is orthogonal in principle, the input and the output ports can be summarized into single space ports, respectively, as is shown in Fig. 1. S-bend region is no more required that results in downsizing or higher integration. Moreover, the optical mode switch also offers a merit of low power consumption. The optical mode exchange itself does not need energy unlike wavelength, while the optical mode also realizes loss-less mux/demux like wavelength. The remaining issue was to prove the principle of the optical mode switch.

Device principle: Typical optical mode switch for two modes has two symmetric Y-junction waveguides as 3dB splitter and coupler. It also has a phase shifter region. At the phase shifter region, the refractive index is variable and can be controlled by injecting current. The width of the input and the output ports are set to be twice compared to branch waveguides. When 0th mode is injected in the input port, it is going to split into two 0th modes with same phase at the 3dB splitter. While when 1st mode is injected, it is split into two 0th modes with phase π difference each other.

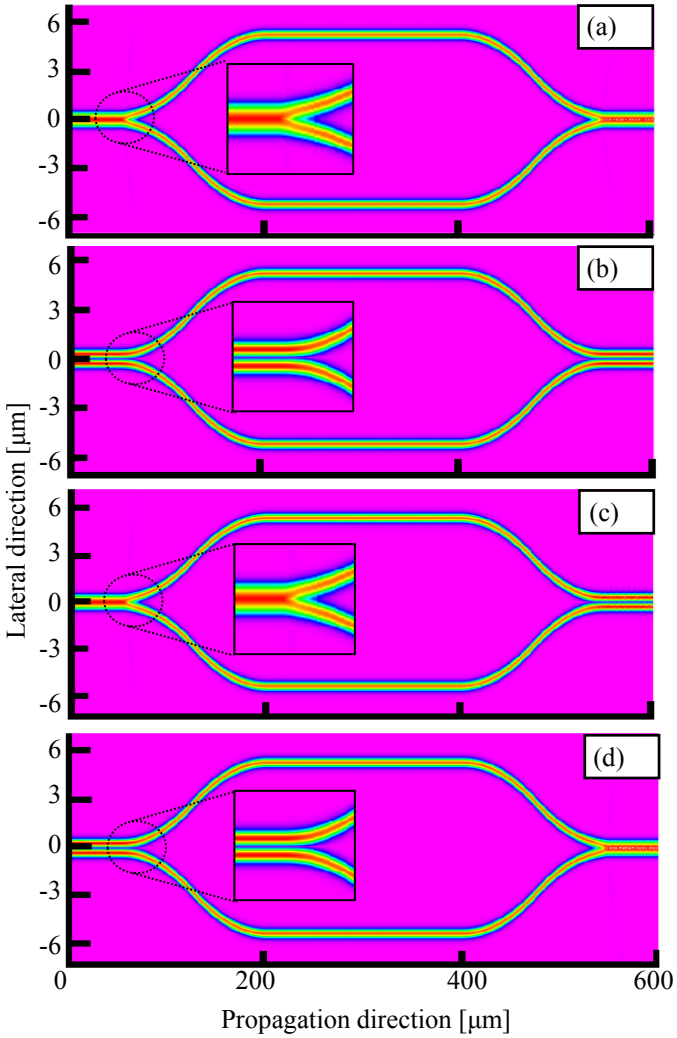

Fig.2: Simulated results of optical mode switch.

To realize such that four modes switching, it is consisted from the following five regions as is shown in Fig. 3; Region 1: 3dB divider up to 3rd order. The divided light propagates as up to 1st order mode in each arm. One arm is consisted of π phase shifter (section A) for 1st mode. Region 2: 3dB divider up to 1st order mode. The divided light propagates as fundamental mode. The center arm is shared with two 3dB couplers. Region 3: π phase shifter (section D, E and F). Region 4: 3dB coupler up to 1st order mode. One arm of one coupler is consisted of π phase shifter (section C) for 1st mode. Region 5: 3dB coupler up to 3rd order. As is shown here, only 6 phase shifters are needed in this configuration.

Figure 2 shows the beam propagation method (BPM) simulation results of the optical mode switch between 0th and 1st modes. When the phase shifter is OFF state (Fig. 2 (a), (b)), the modes propagate and then couple at the mode coupler into the same modes as the injected modes. When a certain current is injected into the phase shift region and the phase shifter is ON state (Fig. 2 (c), (d)), the phase of the one split 0th mode is shifted with π. Thus, these are coupled as 1st mode at the end. While the injected 1st mode is converted into the two 0th modes in the same phase, and then couple as the 0th mode. Thus, this structure realizes the switching between 0th mode and 1st mode.

Scalability: Figure 3 shows a schematic of the optical mode switch for four modes. The device switches one mode to another mode each other like space cross-bar switch among 0th, 1st, 2nd, and 3rd modes. In case "space port information" is replaced to "mode information", this switch configuration corresponds to 4 × 4 matrix space switch. As it requires to be connected with single fiber (few mode fibers or multi-core fibers instead of array fiber) at the input and the output ports, the size of it can be shrunk down within 0.033mm^2 that corresponds to approximately 10 times less than conventional 4 × 4 matrix switch due no need of S-bend fiber connecting region.

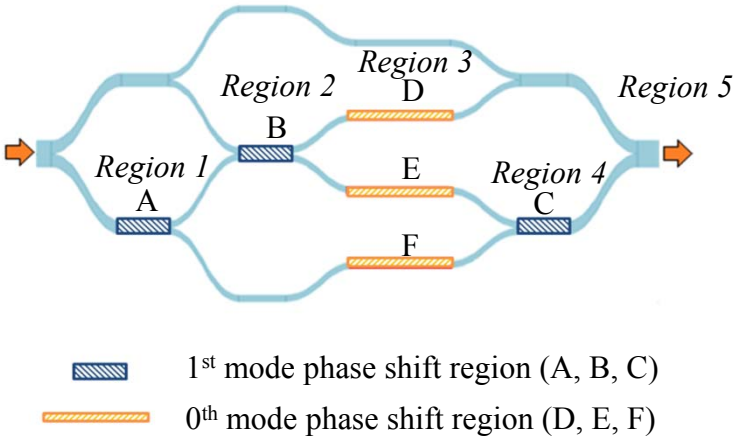

Fig.3: Schematic configuration of four mode optical mode switch.

Summary: We have proposed optical mode switch to overcome matrix size issue in addition to low power consumption. This work has been supported by NICT, Japan.

References

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