# Proposal and numerical analysis of MMI waveguide type optical switch with tunable air core

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## 1. Introduction

In recent years, with the explosive increase in broadband internet traffics, we meet the demand of high-speed and large scale photonic networks. Wavelength division multiplex (WDM) systems have been developed. In addition, the rapid growth of short reach links, metro networks, FTTH, etc. is going on. The development of ring networks is also considered. In order to build reliable and flexible photonic networks, compact and large-scale optical devices are becoming important. An optical switch is one of key optical devices. We proposed hollow waveguides for use in photonic integrated circuits, enabling a large change in propagation constants of light with a variable core[1]. We suggested a possibility of large tuning in propagation constant by using 2 dimensional models in which the mode field distribution changes in a vertical direction[2]. The relative change in propagation constant is as large as a few % in a small air core. Also, a hollow waveguide MMI coupler was recently demonstrated[3]. In this paper, we propose a novel hollow waveguide optical switch composed of the MMI coupler with a variable air core. Switching operation can obtained by the combination of hollow waveguide and MEMS.

## 2 Design of hollow waveguide optical switch

Figure 1 shows the schematic structure of MMI coupler type hollow waveguide optical switch. A MMI coupler type optical switch shown in Fig. 1 is based on the interference between the hollow waveguide modes with a self-imaging effect. The length of self-imaging can be also changed by a variable air core thickness. The mechanical displacement can be obtained by using electrostatic force with applying a voltage in the gap attained. Figures 2 (a) and (b) show the sectional view of an input waveguide and MMI waveguide, respectively. The parameters of the modeling include a step difference in an air core of 3.4 μm, an input waveguide width of 6 μm and an MMI waveguide width of 12 μm, which is twice that of the input waveguide. The hollow waveguide consists of GaAs/AlAs multilayer mirrors. The pair numbers of the upper and the bottom multilayer mirror are 5 and 10, respectively.

## 3 Results

We carried out the numerical simulation of the proposed hollow waveguide optical switch with an MMI coupler using the simulator of FIMMWAVE/FIMMPROP (Pohoton Design Co.). At first, a core thickness $D_{core}$ of an input waveguide was changed and we found a fundamental guided mode confined in the air core. A guided mode excises in the range whose $D_{core}$ is between 5.5 and 8 μm. We assumed the input light is a TE mode with an electric filed parallel to a substrate. The top view and cross-sectional view of the field distribution of light in the hollow waveguide is shown in

Figs.3 (a) and (b). The thickness of the air core is 5.5 μm and 8 μm, respectively. When the core thickness changes from 5.5 μm to 8 μm, the lateral intensity peak switches from the left hand side to the right hand side at a distance of 500 μm. Figure 4 shows an optical intensity distribution at a distance of 500 μm from the input port. Figures 4 (a) and (b) shows the cases where the thickness of a core is 5.5 and 8 μm, respectively. The results show a possibility of optical switching with a small displacement of air core $\Delta D_{core}$=2.5 μm, when we connect an output waveguide with the MMI coupler.

## 4. Conclusion

We proposed two types of hollow waveguide optical switches composed of a directional coupler and MMI coupler. We presented the full-vectorial numerical simulation in an MMI hollow waveguide switch. The results shows a possibility of switching operation with a switching length of 500μm. A large change in propagation constant in hollow waveguide may enable us to reduce the switch size with further optimization of device structures.

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**References**

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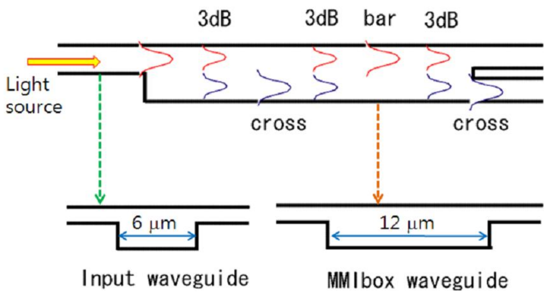


Fig. 1 Schematic cross-sectional view of the designed MMI coupler type optical switch

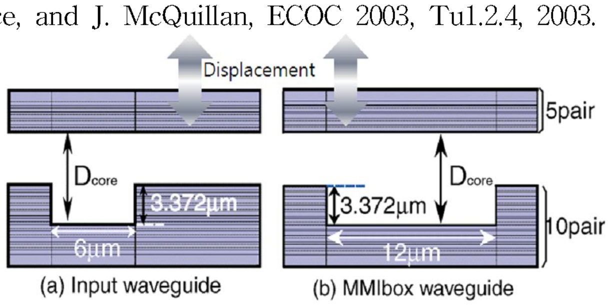


Fig. 2 Schematic cross-sectional view of the designed hollow waveguide
(a)Input waveguide, (b)MMIbox waveguide

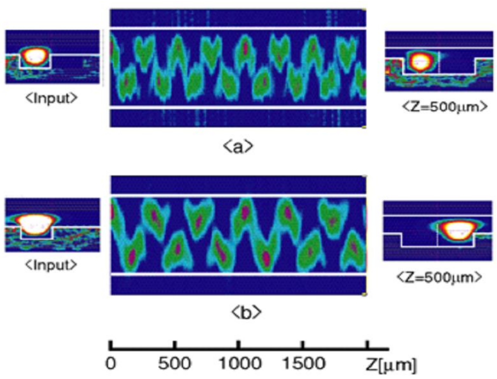


Fig. 3 Calculated field distribution of MMI coupler (a) $D_{core}$=5.5 μm, (b) $D_{core}$=8 μm

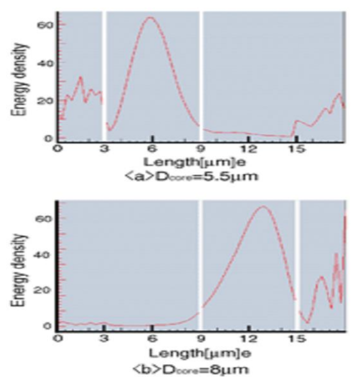


Fig. 4 Show an optical intensity distribution in 500 μm of switching distance.