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An Effective Way of Reducing Waveguide Crossovers using 3D Silica Waveguide

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Abstract: *Large number of waveguide crossovers have a significant effect on the optical switching circuit since it accelerated insertion loss and crosstalk. In this paper, a three dimensional (3D) bending silica waveguide is proposed to reduce the number of crossings. The structure consists of four bending waveguides to facilitate four input-output path. Doped silica is chosen as the core material, and 1% refractive index difference is provided between core and cladding. Values for bending radiuses and spacing between cores were selected based on simulation results. In-detail analysis of the presented device was done by a 3D beam propagation method (BPM) to investigate the light propagation and to estimate the crosstalk. Here, the concept of the designed device is discussed thoroughly as well as the simulation result is presented. As a result, nearly 100% of inserting light at the output of each waveguide and approximately -80dB of crosstalk were achieved successfully.*

Keywords: Optical switch, 3D waveguide, silica waveguide, crosstalk

1. INTRODUCTION

Continuous increase of network traffic is expected in the future due to the spread of high definition video format and high data traffic. To handle this huge traffic, optical switching is regarded as a promising technology over electronic switching. Optical switches can meet the bandwidth and energy requirements of optical networks that are limited by electronic switches. However, these network comprise different losses, and the losses are mainly depends on the number of crossovers or crossing points, number of waveguide bends and bend radius. Among them losses due to waveguide crossover is crucial. Waveguide crossings can reduce system performance in two significant ways. Firstly, the optical signal is attenuated at each crossing due to scattering from the intersection. This leads to increase in the insertion loss. Secondly, since optical signal scatters from the intersection, power is coupled into the unwanted waveguide at the crossing points. This is known as crosstalk. This factor has severe impact on the device scalability.

Though waveguide crossings are fundamental building blocks in an optical switching circuit; however, its reduction is necessary. Several authors have made steps in optimizing in-plane waveguide crossing performance through modification of the waveguide dimensions. Approaches included the use of photonic crystals [1] and sub wavelength diffraction gratings [2]. Multimode interference (MMI) structures are utilized to moderate the loss at the crossing [3]. Recently, mach-zehnder interferometers based design was proposed to reduce the waveguide crossing [4]. A generic foundry approach has been proposed to lower the barriers of photonic integrated circuits design [5]. Many of the highest performance waveguide crossings reported by others are required strict fabrication tolerances because these circuits are developed in planar direction. Alternatively, the introduction of three dimensional (3D) optical interconnection is beneficial for telecom and datacom industry [6]. 3D polymer based vertical MMI coupler [7] is proposed to expand switching scalability.

In this work, we simulate and analyze three dimensional silica waveguide where four bending doped silica cores are surrounded with a silica cladding on a single chip. This paper also describes the concept regarding the design of 3D structure as well as the simulation results followed by a conclusion in the following sections.

2. DEVICE DESIGN

A schematic structure of half of the proposed device is shown in Fig.1. The other half is the mirror image of that figure. Two halves will be connected to each other at output multicore fiber (MCF) position via MCFs and a 90^0 core rotation inside of MCFs is provided for better connection between two parts. In this design, four cores are oriented in rectangular fashion at the output MCF facet which helps this structure to the conventional shuffle converter application. Rotational alignment mechanism eases to adjust the absolute core positions of the MCFs with pluggable connection. This is to be done by rotating one of the fiber connection arrangement between two output MCF positions. For this, there is no need to rearrange the 3D waveguide configuration. Another important advantage is the utilization of MCFs which can be used for inter-board connection in the data centers. As a result, a reduction in the number of single core fibers can be possible. This helps to reduce the space of equipment as well as the cost due to less set-up time by the operators.

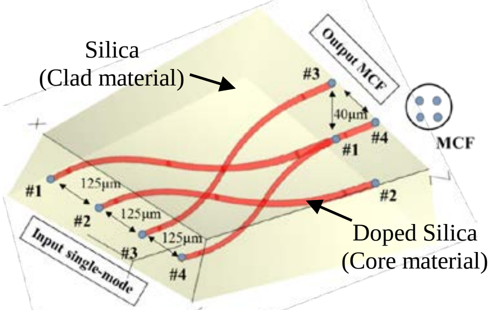

Fig. 1. Structure of the proposed device

Since there is no crossing between the cores as shown in Fig.1, it is expected to have lower losses of this device. The core material is doped silica, and the cladding material is silica. The refractive indexes of silica is 1.444 at 1550nm wavelength range, and the index difference between core and cladding is maintained by 1% in that wavelength range. The core diameter is set to 5μm for all the waveguides. A spacing of 125μm between cores is chosen at single-mode input end. On the other hand, at the output MCF position, 40μm separation is allocated because the cores in the supplied MCFs are separated by 40μm from each other. The device has four inputs (at input single-mode) and four output ports (at output MCF). Here, silica materials were chosen since high performance silica waveguide with low propagation loss can be fabricated on silicon substrates. Moreover, silica is transparent at 1.55μm wavelength which allows to use direct laser writing technology [8], and this technique is to be used for the device fabrication.

3. SIMULATION RESULTS AND DISCUSSION

Two dimensional view of the proposed structure is shown in Fig.2. Design and analysis is done by a three dimensional beam propagation method (BPM). 1.55μm wavelength of light is injected into all the waveguides represented by WG1, WG2, WG3, and WG4 simultaneously to investigate the light propagation. In simulation, we considered the total structure length is 8mm. On the other hand, values for bending radius r_1 of WG1 and WG4, r_2 of WG2 and WG3, core spacing d between waveguides at single-mode position are selected based on the simulation results with a light inserted into WG1. Nearly 100% light propagation was observed through all the waveguides. After extraction of simulation data and manipulation in excel sheet, the relation between bending radiuses and crosstalk are generated as shown in Fig.3 (a) and (b). Moreover, core spacing and crosstalk relation is done in the same way which is given in Fig.4. It is clearly seen that both Fig.3 (a) and (b) shows almost the same trends. Crosstalk values initially increases, decreases, then and becomes saturated with the increase in radius r_1 and r_2 though some fluctuations was occurred at different points for WG2, WG3, and WG4. In Fig.4, crosstalk values fluctuated between -50 and -100dB with change in d between 50μm to 150μm. Lower crosstalk value is highly expected since it has a direct impact on device scalability and performance. From Fig.3 and Fig.4, crosstalk values less than -80dB can be achieved by setting r_1, r_2, and d to 6cm, 12cm, and 125μm respectively. WG4 exhibits slightly higher crosstalk value than expected value at r_1=6cm. Almost the same kind of crosstalk scenario was observed when the light injection position is changed from WG1 to WG2, WG3, and WG4 respectively.

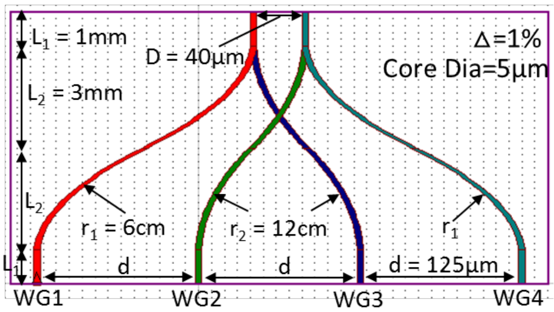

Fig. 2. Two dimensional view of 3D waveguide structure with all dimensions

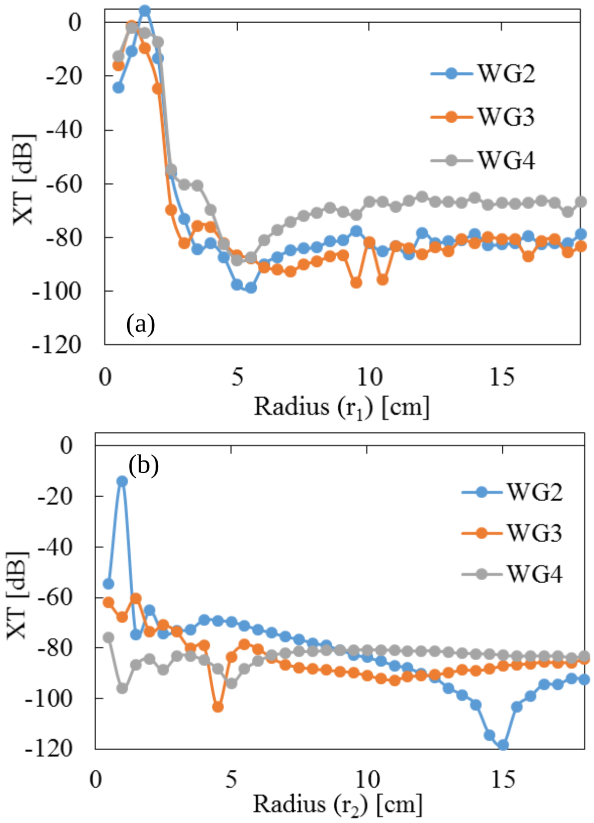

Fig. 3. Relation between crosstalk and (a) radius r_1, (b) radius r_2 with light input to WG1

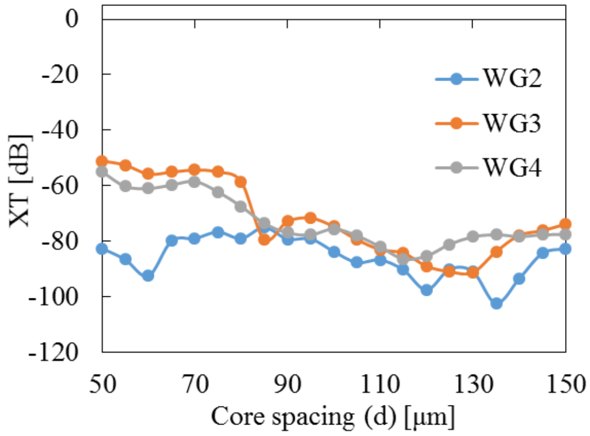

Fig. 4. Crosstalk and core spacing (d) relation

4. CONCLUSION

Using 3D silica waveguide lower than -80dB crosstalk value is attained for all the waveguide with no crossovers. This design concept may play important role in the development of optical network since it has low loss and low crosstalk. Thus, it can be possible to extend this idea for higher port numbers.

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