Compact Mode-Division De(multiplexer) with Anti-Reflection Grating for Optical Interconnects

Omnia M. Nawwar[1]**, Hossam M. H. Shalaby**[1]**, and Ramesh K. Pokharel**[2]

[1]*Egypt-Japan University of Science and Technology (E-JUST), Alexandria, Egypt*
[2]*Graduate School of Information Science and Electrical Engineering, Kyushu University, Fukuoka, Japan*
omnia.nawwar@ejust.edu.eg, shalaby@ieee.org, pokharel@ed.kyushu-u.ac.jp

Abstract: A bidirectional mode-division de(multiplexer) with anti-reflection grating is proposed. The proposed device can de(multiplex) 3 modes in a simple and compact way. Good insertion losses and crosstalks are achieved for the device.

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1. INTRODUCTION

On-chip optical interconnect is emerging as a promising solution for high data rates to allow for the exponentially increasing bandwidth for future parallel chip multiprocessors [1]. Space-Division Multiplexing (SDM) is a promising multiplexing technique which is suitable for applications that do not have restrictions on space occupied by the system [2]. However, it is not suitable for the case of on-chip systems, as every signal must have its own path, which increases the footprint. Wavelength-Division Multiplexing (WDM) technique provides a solution for large footprint at the price of complexity of the system [3]. Each wavelength requires an independent light source, which increases the cost of the whole system. To come across the aforementioned problems, Mode-Division Multiplexing (MDM) seems to be a promising technique that can increase capacity while reducing the footprint at the same time [4]. In this technique, each mode of a multimode waveguide is considered as an independent channel to carry data. A mode multiplexer/demultiplexer is an essential component in MDM systems in order to combine/retrieve the data from each mode.

Many techniques have been proposed to work as multiplexers/demultiplexers [5, 6]. One technique, based on Y-splitter and multimode interference, is presented in [5]. Although it can achieve broadband operations, it requires a large footprint and precise waveguide fabrication. In addition, it cannot be used to demultiplex more than two channels. Another approach, based on asymmetrical directional coupler to demultiplex four or more channels, has been proposed in [6]. It depends on multimode interference coupler (MMI), which is very sensitive to design and fabrication errors.

In this paper, a simple strip-based mode-division de(multiplexer) using two waveguides, a Bragg grating, and anti-reflection gratings, is proposed. The device can work as a multiplexer or demultiplexer if we invert the input and output ports. It can de(multiplex) 3 modes in compact and simple way. The length of the proposed de(multiplexer) is about 17.5 µm. Our device is based on the concept proposed by Shalaby for a slab-waveguides coupler [7]. In this paper, we extend this concept to the strip waveguides case to have a practical implementation of the idea. In addition, anti-reflection gratings are added to reduce back reflection as has been proposed in [8] for WDM devices. Furthermore, a taper is added at the end of the multimode waveguide to ensure single-mode reception at its output.

2. PROPOSED SYSTEM MODEL

Figure 1 shows the structure of proposed device. The basic concept is to couple the second mode co-directionally to the output waveguide and couple the third mode contra-directionally to the output waveguide via a Bragg grating. The first mode remains in the input waveguide. Thus, the third mode must satisfy the following phase-matching condition:

$$\beta_2^{\text{multi}} + \beta_0^{\text{single}} = \frac{2\pi}{\Lambda}, \tag{1}$$

where β_2^{multi} is the propagation constant of the third mode in the multimode waveguide, β_0^{single} is the propagation constant in the single mode waveguide, and Λ is the grating period. Figure 2 shows the mode chart for a strip waveguide of 220 nm height at 1550 nm. The width of the input waveguide is chosen to support 3 TE-like modes and that of the output waveguide is chosen to support single-mode operation. The width of the input waveguide is 930 nm and that of the output waveguide is 450 nm.

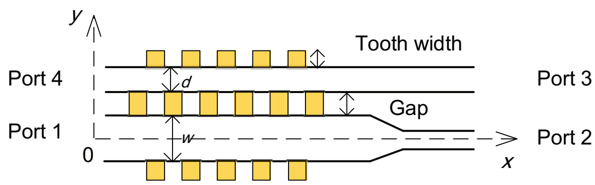


Fig. 1. Schematic diagram of proposed structure

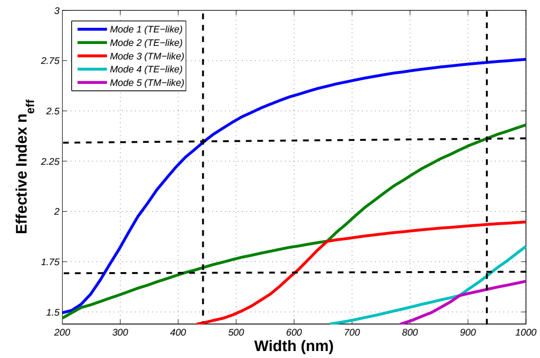


Fig. 2. Mode chart of strip waveguide at thickness of 220 nm

3. FDTD SIMULATTIONS AND RESULTS

In this section, the FDTD simulation of the proposed device is presented. Our design parameters are chosen based on sweeping every parameter to get the best performance. The period of the grating is 345 nm and the number of grating periods is 40. The outer grating tooth width is 70% of the gap. The gap between the two waveguides is 140 nm. Sweeping results for the middle grating tooth width and duty cycle are shown in Fig. 3 for both modes 2 and 3. The

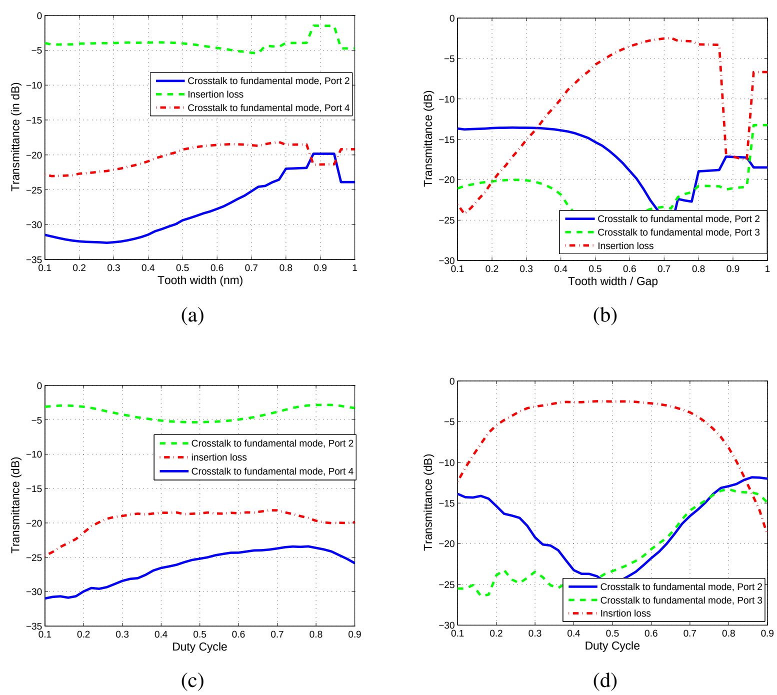
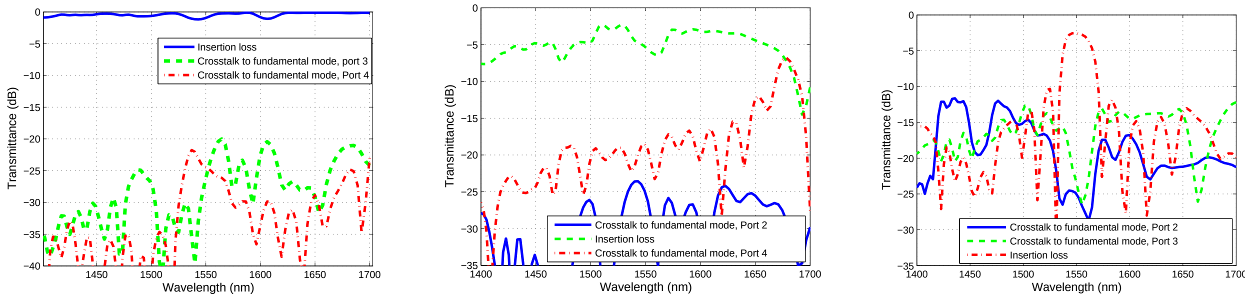


Fig. 3. FDTD simulation of middle grating tooth width sweep and duty cycle sweep when (a),(c) mode 2 and (b),(d) mode 3 are injected.

figure shows that the tooth width has no much effect on the second mode while it affects the third mode a lot. The choice of tooth width as 70% of the gap yields a good insertion loss for both modes 2 and 3 at the same time. This value gives an insertion loss of -5 and -2.5 dB for the second and third modes, respectively. The best duty cycle for both modes is 30%.



(a) (b) (c)

Fig. 4. FDTD simulation of crosstalk and insertion loss versus wavelength of proposed structure when injecting: (a) mode 1, (b) mode 2, and (c) mode 3.

The output from all ports when the first, second, and third modes are injected is shown in Fig. 4. The results show an insertion loss of -1 dB, -5 dB, and -2.5 dB for the first, second, and third modes, respectively. The simulated crosstalks at 1550 nm are -20 dB, -17.5 dB, and -22.5 dB when injected first, second, and third modes, respectively. The bandwidth of operation is limited by the third mode to be 30 nm around the desired wavelength. This bandwidth can be controlled by changing the tooth width at the price of insertion loss.

4. CONCLUSION

Three-mode division de(multiplexer) has been proposed. The structure has the advantage of being compact; its length is 17.5 μm with the taper and output waveguide inserted. The device uses only two waveguides, a Bragg grating, and anti-reflection gratings. Low insertion losses of about -2.8 dB, -3.5 dB, and -2.9 dB for the three modes have been achieved. In addition, crosstalks less than -17.5 dB have been achieved. The device has the potential for being extended and used to de(multiplex) many modes with the choice of the correct parameters.

5. REFERENCES

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