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Propagation loss on a Si-Slab Waveguide: Simulation revisited

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ABSTRACT

The slab waveguide is one of the simplest types of optical waveguide, the confinement factor is only determined by the thickness of one side so that the propagation of light passing through it will be confined in the material. The slab waveguide is built from Si as the core material and SiO_2 as the substrate. The use of various optical waveguides is very dependent on the objectives to be achieved in its application, for it is very important to know the characteristics of each optical waveguide. In this paper we want to know the characteristics of a slab waveguide, specifically with regard to propagation loss. The simulation results show that the propagation loss in the slab waveguide design that the authors propose is around 0.1dB/mm in TE mode conditions. The occurrence of propagation loss in the simulation is likely due to imperfections in determining the effective material index in the design of the slab waveguide.

1. Introduction

Current and future technological developments will be greatly influenced by the progress of integrated circuits, both in the electronic, optical or a combination of both. One thing that is very supportive in the development of integrated circuits is the optical waveguide, this is because the optical waveguide has brought increased efficiency, energy consumption and size of the device [1].

Currently the development of optical waveguide can be enjoyed in a variety of applications and purposes, ranging from displays, storage to the field of security. The two most prominent things about the types of optical waveguide that are widely used are channel waveguide and slab or planar waveguide [2]. The quality of an optical waveguide is usually determined by propagation loss and scattering loss. But because the optical waveguide will be connected to an emitter device such as a laser or LED, there is usually loss due to connectivity, usually called coupling loss. As we all know that the waveguide channel has an advantage in confinement factor but the slab waveguide has other characteristics such as interference and scattering when two propagation lights do not intersect [3].

Optical slab based silicon waveguide has been intensively studied at the wavelength of light 1550 nm. The slab waveguide designed in our laboratory is constructed by the Si as a core and SiO_2 as the substrate. The Si has 3.44 in refractive index (n_f), while SiO_2 has 1.47 in refractive index (n_s) at 1550 nm wavelength of light. In this case, the incident light will be confined and guided in the silicon core region. Finally, the purpose of this research is to measure and analyze in detail about optical waveguides in terms of propagation loss.

2. The design Issue

The slab waveguide is constructed from Si material as a core, SiO_2 as a substrate and Air as the top layer as shown in Figure 1.

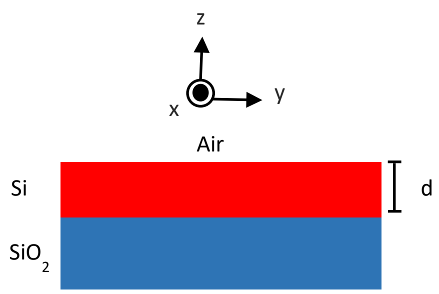

Fig. 1: Cross sectional view of the slab waveguide.

In this research, the slab waveguide has 0.21 μm in thickness (d), as shown in Fig. 1. These dimensions are designed to carry the single mode condition.

In this research, the function and characteristics of a slab waveguide can be seen from the design.In its application it is very difficult to guide the light that comes directly inside the slab waveguide, considering the confinement factor in the slab waveguide is only limited to 1 dimension. For this reason, many researchers propose using a grating coupler or spot size converter, meanwhile from the design side to be propagated use taper design [4-7]. Taper is a slab design with a certain length but has a different size from each end, it is shown in Figure 2. The taper design can control the divergence angle of the input light of slab waveguide. Using taper structure, the divergence angle of the input light of slab waveguide can be kept small.

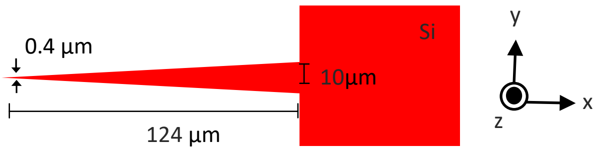

Fig. 2: Design of the taper on top view, which connected to the channel waveguide at the input port and connected to the slab waveguide at the output port.

The design of the taper with a size of 0.4 µm at the left end, 10 µm at the right end and has a length of 124 µm is the most optimal size to be able to keep the propagation light running parallel (not spread) in the slab waveguide. In addition, the thickness of the proposed slab waveguide design is 0.21 µm (z-direction) which is the minimum value to be able to propagate the single mode conditions.

3. Simulation

Referring to Figure 3, the design of the taper will keep the propagation of light confined and propagating parallel.

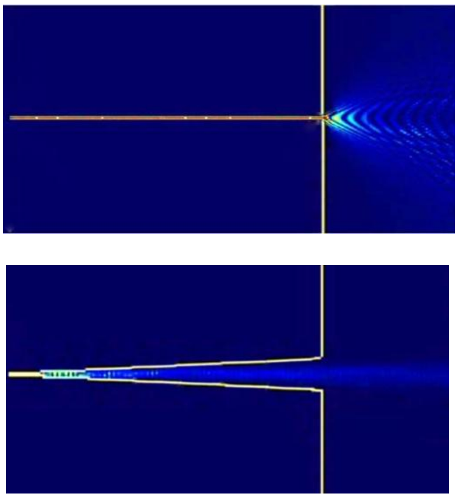

Fig. 3: The upper and below picture is the slab waveguide simulation results without and with the taper design.

From Figure 3 (upper) it can be seen that the use of a 0.4 µm wide waveguide channel directly and connected to the slab waveguide will make the propagation light experience scattering so that it is very possible that the propagation loss will be very large if measuring with this method. Meanwhile, from Figure 3 (below) it can be seen that the use of design taper can make propagation light propagate perfectly in the slab waveguide [8-10].

After it can be ascertained that the light does not spread inside the slab waveguide, then the propagation loss measurement can then be performed. Because propagation loss is a loss caused by differences in measurement distances, in the simulation conducted with FDTD simulation software the measurement of propagation loss is seen from the power at several points through which the propagation of light in the slab waveguide as shown in Figure 4.

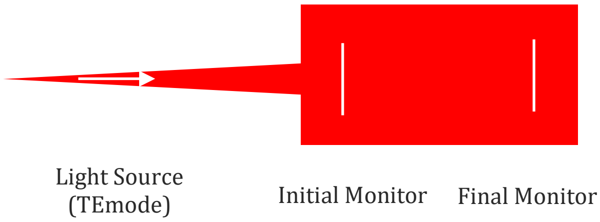

Fig. 4: The propagation loss method by the simulation on the slab waveguide.

Simulations have been carried out using the FDTD method to test the effect of the tapered design on the propagation form when light comes propagating through the slab waveguide as shown in Figure 3. Based on the simulation results, the tapered design is 0.4 m wide by the width of the port input, 10 µm wide from the output port and 124 µm long are the best designs to maintain the parallel propagation of the input light and prevent the spread of input light.

4. Results and Discussion

Based on our design, losses can be calculated by comparing power output and power input as shown in Equation 1.

$$Propagation\ loss = 10 \log \frac{P_{out}}{P_{in}} \qquad (1)$$

P_{out} and $P_{in}$are the optical power output and input from the slab waveguide. Based on Figure 4 the Pout condition is obtained from the monitor power in the final position, while the Pin is obtained from the monitor power in the initial position. This comparison value is greatly influenced by the distance between the two monitor positions. As for the conditions at the time of simulation is to use a wavelength of 1550 nm with TE mode propagation mode. Assuming that the wavelength is higher than the Si bandgap as the core region so that there is no absorption due to refractive material index.

P_{out} and P_{in} are the optical power output and input from the slab waveguide. Based on Figure 4 the P_{out} condition is obtained from the monitor power in the final position, while the P_{in} is obtained from the monitor power in the initial position. This comparison value is greatly influenced by the distance between the two monitor positions. As for the conditions at the time of simulation is to use a wavelength of 1550 nm with TE mode propagation mode. Assuming that the wavelength is higher than the Si bandgap as the core region so that there is no absorption due to refractive material index.

5. Conclusion

We designed the taper on the slab waveguide to control the divergence angle of the light propagation. Morover, we investigate the propagation loss in the slab waveguide. In this analysis, we describe the loss of propagation as a comparison between P_{out} and P_{in}. The coupling loss at the input and output portson the slab waveguide is the dominant factor in the propagation loss, but coupling loss can be reduced by using a lens fiber at the input port. In this design we propose there has been a propagation loss of 0.1 dB/mm.

References

[1] R. N. Noyce, Large-Scale Integration: What Is Yet to Come?, Science Vol. 195, pp. 1102-1106, (1977).

[2] X. Zheng and A. V. Krishnamoorthy, Si Photonics Technology for Future Optical Interconnection, Asia Communications and Photonics Conference and Exhibition (ACP), 2011, pp. 1-11.

[3] P. J. Bock, P. Cheben, J. H. Schmid, J. Lapointe, A. Delâge, X. Dan-Xia, S. Janz, A. Densmore, and T. J. Hall, Subwavelength Grating Crossing for Silicon Wiro Waveguides, Opt. Express. Vol. 17, pp. 16146-16155, (2009).

[4] A. M. Scheggi, R. Falciai and M. Brenci, Radiation Characteristics of Tapered Slab Waveguide, J. Opt. Soc. Am. Vol. 73, pp. 119-121, (1983).

[5] S. Dwari, A. Chakraborty and S. Sanyal, Analysis of Linear Tapered Waveguide by Two Approaches, Prog. Electromagn. Res. Vol. 64, pp. 219-238, (2006).

[6] P. Bienstman, S. Aseffa, S. G. Johnson, J. D. Joannopoulos, G. S. Petrich and L. A. Kolodziejski, Taper Structure for Coupling into Photonic Crystal Slab Waveguide, J. Opt. Soc. Am. Vol. 20, pp. 1817-1821, (2003).

[7] J. H. Karp, E. J. Tremblay and J. E. Ford, Planar Micro-optic Solar Concentrator, Opt. Express. Vol. 18, pp. 1122-1133, (2010).

[8] M. Kawachi, Silica Waveguides on Silicon and their Application to Integrated-Optic Component, Opt. Quant. Electron.Vol. 22, pp. 391-416, (1990).

[9] J. F. Bauterst, M. J. R. Heck, D. D. John, J. S. Barton, C. M. Bruinink, A. Leinse, R. G. Heideman, D. J. Blumenthal and J. E. Bowers, Planar Waveguides with less than 0.1 dB/m Propagation Loss Fabricated with Wafer Bonding, Opt. Express. Vol. 19, pp. 24090-240101, (2011).

[10] J. J. Ackert, K. J. Murray, P. E. Jessop and A. P. Knights, Photodetector for 1550 nm Formed in Silicon-On-Insulator Slab Waveguide, Electron. Lett. Vol. 48, pp. 1148–1150 (2012).