ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)
Vol 1, Issue 8, December 2016

Performance Analysis of Curved Directional Coupler

[1]Sonal Patil, [2] Santosh Jagtap, [3] Pravin Patil
[1] Student, [2] Assistant Professor, [3] Assistant Professor

Abstract:**-- Optical transport networks are designed for high data rate transmission. To implement such a network it requires various passive components. The optical coupler is one of the important components of such a high capacity optical transport network. The coupling efficiency of coupler is wavelength sensitive and this degrades the performance of optical system that uses directional couplers for WDM transmission. A curved directional coupler has been proposed using silicon waveguides realizing the wavelength insensitive operation. The simulations are carried out using BeamPROP software and the effect on transmittance with respect to wavelength is analyzed. This curved coupler reduces the wavelength dependence.**

Index Terms:**-- BeamPROP, directional couplers, Wavelength independence**

I. INTRODUCTION

Optical transport networks (OTNs) are Wavelength Division Multiplexing (WDM) networks providing transport services via light path. Modern optical networks include components like couplers, lasers, optical amplifiers, optical switches, filters and multiplexers. The optical coupler is one of the important optical link elements of optical transport network used for splitting or combining optical signals. Directional couplers have an application in power combiner/dividers, add-drop multiplexers and switches. The fabrication of directional couplers is done using optical fiber, semiconductor based, silica based, or lithum-niobate based optical waveguides. The coupling lengths of their coupled waveguides are long, so the couplers are more than several millimeters long [3]. Silicon wire waveguides are appealing structures to be used for optical interconnections on Si chips [3]. Their bending radius becomes small of the order a few micrometers due to large difference between the refractive indexes of the Si core (n = 3.5) and silica (n = 1.5) cladding which strongly confines the optical field to the waveguide core [3]. It's another feature is Si waveguides have high power density due to the robust confinement. Therefore, Si wires have become a platform for nonlinear optical devices [4].

The coupler can be designed in order to work as wavelength selective or wavelength independent over a usefully wide range. In a wavelength-independent device, coupling ratio is independent of the wavelength; in a wavelength selective device, coupling ratio relies upon the wavelength [5].

Optical directional couplers are widely used in WDM systems to select a particular wavelength and couple it to the output. Since DWDM is a multichannel system, channel spacing is 0.8 nm which is very small. So, a coupler desired for a particular wavelength may select its adjacent wavelengths and this may give crosstalk effect. So, they have wavelength sensitivity and this degrades the characteristics of devices that use directional coupler for WDM transmissions.

There are three main techniques to decrease the Wavelength, Polarization and Fabrication (WPF) sensitivity of couplers: to couple extra modes, to make the coupler asymmetric and to use multiple sections[2]. In this paper, performance characteristics of conventional coupler, curved coupler are simulated and studied.

II. STRUCTURE OF DEVICE

The structures of conventional directional coupler and curved coupler in the Rsoft Cad Layout are shown in Fig.1. (a) and Fig.1. (b) respectively.

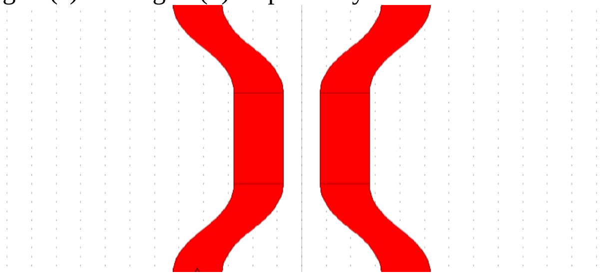

Fig.1. (a) Structure of conventional coupler in Rsoft CAD Layout

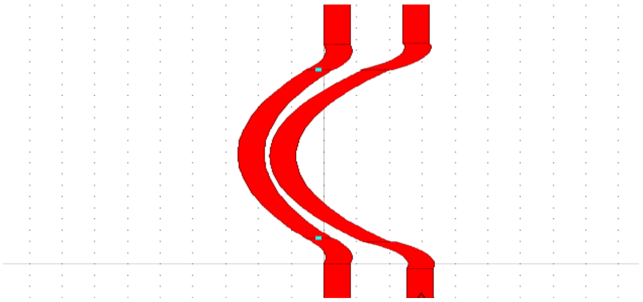

Fig.1. (b) Structure of curved coupler in Rsoft CAD Layout

The light launched into the input port gets split into cross port (coupled power) and bar port (transmitted power) [1]. As per the coupled mode theory, the output power of directional coupler is given by,

$$P_1 = P_0\left\{\left(\frac{k_c}{K}\right)^2 \cos^2(K.L)\right\} \qquad (1)$$

$$P_2 = P_0\left\{\left(\frac{k_c}{K}\right)^2 \sin^2(K.L)\right\} \qquad (2)$$

Where P_0 is the input power, P_1 and P_2 is the output power of bar port (transmitted port) and cross port (coupled power), L is the length of the coupled waveguide and kc is the coupling coefficient.

III. SIMULATION RESULTS

Simulations are carried out for a conventional coupler and the curved coupler using BeamPROP which is a design tool for the simulation of fiber-optic waveguide devices and circuits. For conventional coupler: coupling length (Ls) = 10 mm, Waveguide width (W) = 4 µm, Waveguide separation (G) = 3 µm, Core is locally defined material with refractive index n = 3.378 and cladding is of air with n = 1. For curved coupler: Bending radius(R) = 21.2 µm, Waveguide width (W) = 0.4 µm, Core is silicon material with refractive index n = 3.5 and cladding is silicon dioxide with n = 1.5. The power give to input port is 1 Watt. TE polarization is used since the TM mode has considerably higher propagation loss, particularly inside the waveguide bends.

A. Wavelength Dependence

The transmittance of the conventional directional coupler and the curved coupler versus wavelength in the range of λ = 1.5-1.6 µm are shown in Fig.2. (a) and Fig.2. (b) respectively. These curves are obtained for transverse-electric (TE) polarization. The transmittance of 0.5 dB is obtained at wavelength (λ) = 1.56 µm for conventional directional coupler with the coupling length Ls= 10 mm. It shows wavelength dependent operation since with the increase in wavelength the transmitted power decreases and the coupled power increases. The curved coupler with bending radius R = 21.2 µm provides a wavelength independent operation in the range λ=1.52- 1.56 µm as shown in Fig.2. (b).

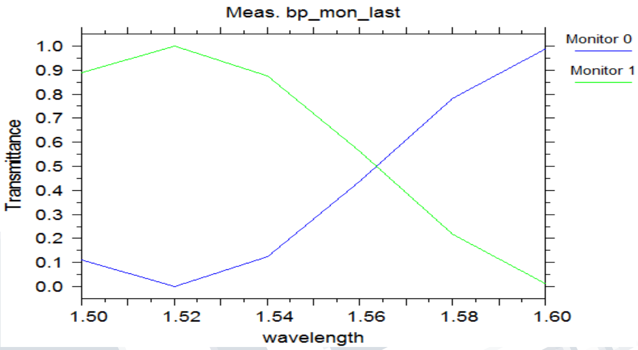

Fig.2. (a)Wavelength dependence of transmittance of conventional coupler using Most Scanner (transmitted power and coupled power)

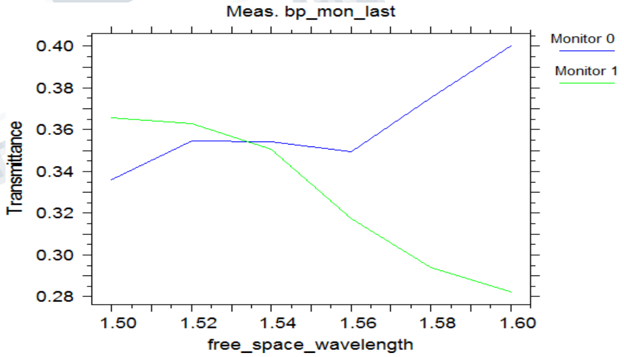

Fig.2. (b) Wavelength dependence of transmittance of curved coupler using Most Scanner (transmitted power and coupled power)

Bending Radius Dependence

The figures shown below indicate the bending radius dependence of the curved coupler. It shows that as the bending radius is varied from 20.8 to 21.4 µm, there is shift in the transmittance plot at bar and cross port. From these results, a curved coupler with *R* = 21.2 µm shown in Fig.3. (c) gives the broadband operation in the wavelength range of 1.52 – 1.56 µm.

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)
Vol 1, Issue 8, December 2016

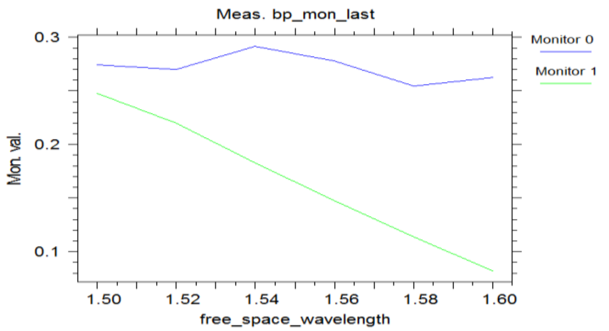

Fig.3. (a)Bending radius (R) = 20.8 µm dependence of transmittance (transmitted power and coupled power) for curved coupler

Fig.3. (a) gives the plot of transmittance versus wavelength for *R* = 20.8 µm. It shows the decrease in the transmitted power from 0.245 W at 1.5 µm to 0.082 W at 1.6 µm. The coupled power varies from 0.275 W at 1.5 µm then rising to a peak of 0.29 W at 1.54 µm. At 1.6 µm, the transmittance at cross port is 0.262 W.

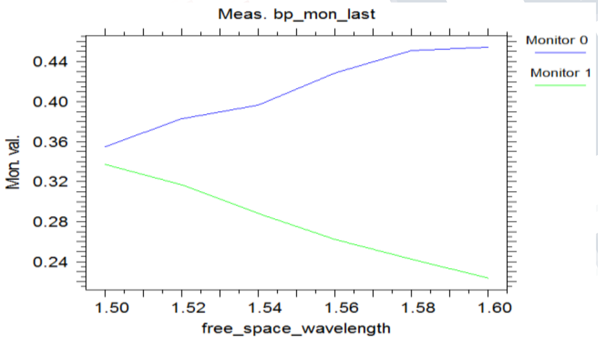

Fig.3. (b)Bending radius (R) = 21 µm dependence of transmittance (Transmitted power and coupled power) for curved coupler

Fig.3. (b) shown above describes the plot of transmittance versus wavelength for *R* = 21 µm. At 1.5 µm, the transmitted power is noted as 0.34 W and then it goes on decreasing to 0.25 W at 1.6 µm. The coupled power increases from 0.355 W at 1.5 µm to 0.455 W at 1.6 µm.

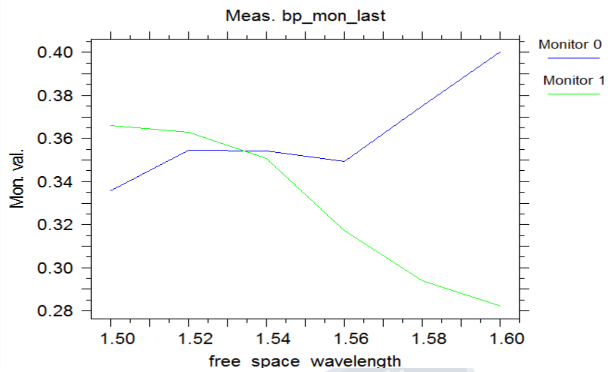

Fig.3. (c)Bending radius (R) = 21.2 µm dependence of transmittance (transmitted power and coupled power) for curved coupler

Fig. 3. (c) gives the plot of transmittance versus wavelength for *R* = 21.2 µm.It shows that the transmittance at cross port remains of about 0.35 W for the wavelength range 1.52 to 1.56 µm provides bandwidth enhancement of 0.4 µm. Fig.3. (d) gives the plot of transmittance versus wavelength for *R* = 21.4 µm. It shows that the transmitted power decreases from 0.39 W at 1.5 µm to 0.352 at 1.6 µm. The coupled power varies from 0.315 W at 1.5 µm to 0.369 W at 1.52 µm and then decreases to 0.314 W at 1.6 µm.

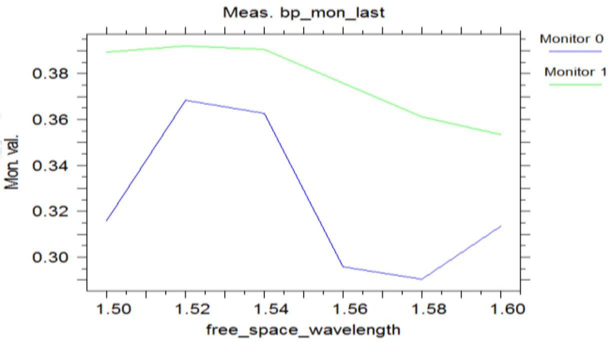

Fig.3. (d)Bending radius (R) = 21.4 µm dependence of transmittance (Transmitted power and coupled power) for curved coupler

IV. CONCLUSION

The design of a curved coupler using silicon wire waveguide with bending radius of 21.2 µm is proposed using the BeamProp software in 2-D. The conventional coupler provides a wavelength dependent operation which is its drawback. So, by introducing a curvature into the coupling region of a conventional coupler, bandwidth enhancement by a factor of 0.4 µm is achieved. These results imply that silicon curved coupler is promising to the wavelength independent operation and can be widely used in the Wavelength Division Multiplexing (WDM) technology.

REFERENCES

[1] Hisayasu Morino, Takeo Maruyama, Member, IEEE, and Koichi Iiyama, Member, IEEE, “Reduction of Wavelength Dependence of Coupling Characteristics Using Si Optical Waveguide Curved Directional Coupler,” JOURNAL OF LIGHTWAVE TECHNOLOGY, VOL. 32, NO. 12, JUNE 15, 2014.

[2] C. R. Doerr, M. Cappuzzo, E. Chen, A. Wong-Foy, L. Gomez, A. Griffin, and L. Buhl, “Bending of a planar lightwave circuit 2 x 2 coupler to desensitize it to wavelength, polarization, and fabrication changes,” IEEE Photon. Technol. Lett., vol. 17, no. 6, pp. 1211–1213, Jun. 2005.

[3] H. Yamada, T. Chu, S. Ishida, and Y. Arakawa, “Optical directional coupler based on Si-wire waveguides,” IEEE Photon. Technol. Lett., vol. 17, no. 3, pp. 585–587, Feb. 2005.

[4] T. Tsuchizawa, K. Yamada, H. Fukuda, T. Watanabe, J. Takahashi, M.Talahashi, T. Shoji, E. Tamechika, S. Itabashi, and H. Morita, “Microphotonics devices based on silicon micro fabrication technology,” IEEE J. Sel.Topics Quantum Electron., vol. 11, no. 1, pp. 232–240, Feb.2005.

[5] Rajiv Ramaswami, “Optical Networks”, Third Edition.