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Design and analyses of Silicon S-shape Optical interconnects based Rectangular Bend Waveguide

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Abstract

photonics Chip technology has great potential of improving the performance on optical board and Photonics chip, through the optical devices and interconnects. The devices and chip are needed for performing various optical signal processing at high data rate. The straight forward solution is to couple the various devices through optical waveguide interconnects. In optical waveguide interconnects confine the light to propagate along a defined path to connect, optical component and devices oriented in different location on chip. They required specific S-shaped bend waveguide optical interconnect.

Obtained the performance of S- and U-shaped bend waveguide optical interconnect for improved the performance of the optical devices and optical chips. Optimum bending radius for minimum bending loss and Coupling losses are optimized, and also support high data rate signal processing for tite bending of S-shaped sub-wavelength range for PICs.

Keywords: Optical waveguide, S and U-shaped Bend Interconnect, photonics Integrated Circuits (PICs), Optical Interconnects, coupling Loss.

I. Introduction

In **photonics integrated Chip v**arious kind of optical devices are developed to increase the preference of optoelectronic devices [1,2]. However, researcher encountered major problem in maintaining the data transmission rate during conversion from optical domain to electrical domain and vice versa [3-4]. Present research is going on to develop the optical interconnect compatible with optical devices such as laser and photodetector that reduces the transmission loss as compared to electrical interconnects [5, 6]. These limitations can be overcome by using optical interconnects. Moreover, optical waveguides fabricated on silicon chip are being envisaged as interconnects between different parts of a complex communication or sensor systems [7,8]. Silicon based optical interconnects have the potential to satisfy the performance requirements of current and future version of data processors [4,9]

Various optical component and devices are fabricated in different position on SOI chip. All those devices are connected through optical interconnect for propagate the light signal in same mode [10,11]. Input output terminal of devices, they required various shape and size of optical waveguide interconnect [12]. Now we consider different structure of optical interconnect. Such as straight waveguide, L-shape, S-shape and U shape rectangular waveguide optical interconnect

In this paper focused to geometrical design and performance analysis of S- shaped bend waveguide optical interconnect for improved the performance of the optical devices and optical chips. parametric variations are correlated to losses due to bending and coupling of bend and straight waveguides is calculated

II. Methodology

S- BEND OPTICAL INTERCONNECT

Initially S-bend optical interconnect is designed by the combination of two similar connected arcs with opposite curvatures. Their path line starts and ends parallel to each other along the z-axis. There are several geometries to design the S−bend waveguide such as back-to-back curvature and sinusoidal S – bend [12]. The basic geometrical structure of 2−dimensional S − bend silicon waveguide in a x–z plane of silicon-based PICs is shown in Fig.1. It is used to connect optical waveguide and optical devices with same Input/output dimension. Here, initially the sub-wavelength waveguide width range is 250 nm to 500 nm and height is 220 nm.

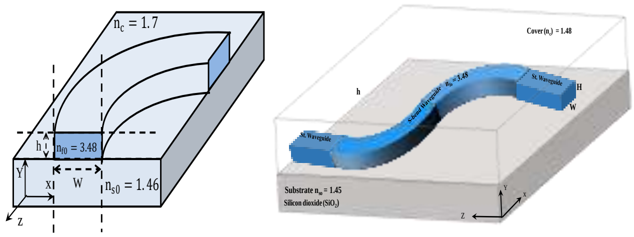

Fig. 1 (a) 90^0 bend rectangular waveguide and (b) S-shape bend rectangular waveguide geometry.

However, the material parameters are high indexed profile of S–bend optical silicon waveguides (refractive index nf = 3.48), cover layer is a low index material (nc=1.48) and substrate is silicon dioxide (ns=1.45) [13]

II. FORMULATION

Simple bends configuration is applied to design S – shaped waveguide using two different bend waveguides. Two back-to-back circular arc section of constant radius of curvatures are used as shown in Fig.2. In sinusoidal S−shaped bend, the bending is depicted by a 'shaped function' y = f(x), where f(x) is continuous in its first derivative [12]. In shows a schematic diagram of back-to-back S − bend structure

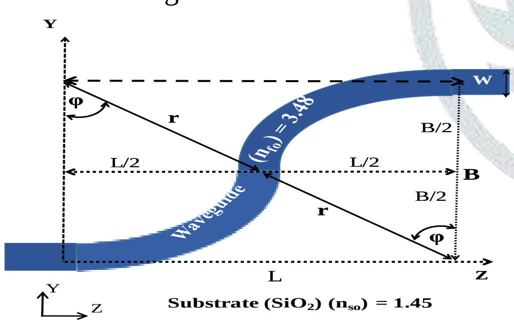

Fig. 1. Schematic diagram of S − bend back-to-back.

For the formulation of the end to end for the 2-D S-bend waveguide structural expression is[14]:

$$r\ \sin(\varphi) = \frac{L}{2} \qquad (1)$$

$$r\ (1-\cos(\varphi)) = \frac{B}{2} \qquad (2)$$

Where φ is the angle denoted at the half of S − bend waveguide, L is the transition length, and B is the lateral offset. Further the analytical relations for radius of curvature (r) at arc of S − bend waveguide are obtained using Eqs. (1) and (2)[15]

$$r = \frac{L^2}{4h}\left(1+\frac{B^2}{L^2}\right) \qquad (3)$$

That can be expressed as reciprocal 1/r as:

$$\frac{1}{r} = \pm\left[\frac{L^2}{4h}\left(1+\frac{B^2}{L^2}\right)\right]^{-1} \qquad (4)$$

The efficient performance of S–bend as an interconnect depends on: Optimum bending radius for minimum bending loss; and Optimum splicing between coupling interface of S– bend waveguides for minimum transition loss.

Total internal loss is split into bending and coupling loss. Bending loss can be calculating by the logarithmic ratio of input/output power of S−bend waveguides. Bending loss can be written as[16]

$$\text{Total Input/output power}(P) = \left[(P_x)^2 + (P_y)^2 + (P_z)^2\right]^{1/2} \qquad (5)$$

$$\text{Bending Losses} = 10 * \log\left(P_{in}/P_{out}\right) \qquad (6)$$

IV. Results

S − BEND OPTICAL INTERCONNECT

The feasibility of proposed S−bend waveguide interconnect should be judged by its tolerance to axial shift, bending and coupling losses.

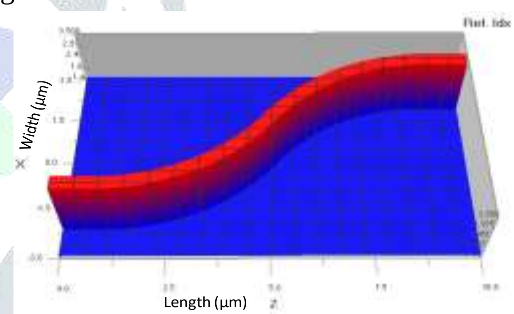

Fig.3.Refractive index prifile for S-bend optical interconnects.

The bending and coupling losses as a function of Bending Radius of the S − bend interconnect are shown in Figs.1 The results show proper optimization of geometrical parameters of the S − bend waveguide.

Fig.3 shows the material refractive index of the S−bend optical interconnect. Here the refractive index difference between waveguide and substrate is clearly visualized with the red colour indicating pure silicon high index waveguide material (nf = 3.48) and blue colour representing substrate (ns0 = 1.45) of PICs.

The modal profile intensity for various dimension of S − bend waveguide width of 300 nm, 350 nm and 400 nm is shown in Figs.4 (a), (b) and (c) respectively. The width of S − bend waveguide is optimized to 400 nm and height of 220 nm through effective mode field analysis along the x-y plane to avoid distortion in modal field. Fig(c)

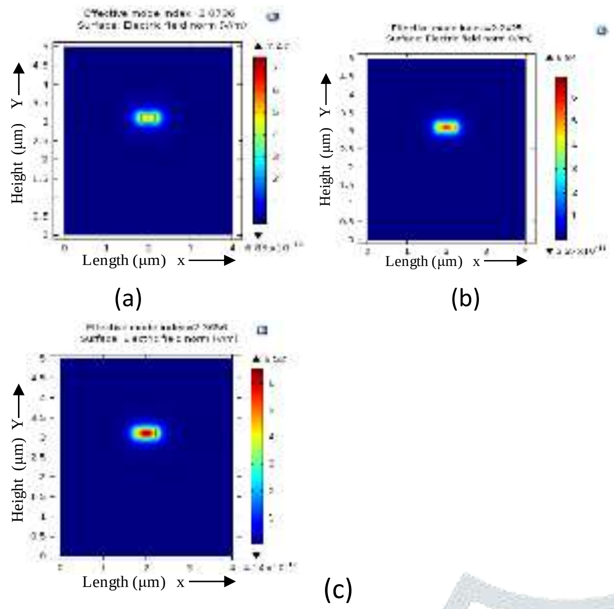

Fig. 4. Electrical modal field across the waveguide.

The light wave propagates in higher index region along the *x-z* plane in single layer PICs. In fig. 5(a) and 5(b) the 2-D and 3-D modal field of S − bend waveguide are depicted. The modal field is observed to radiate power towards the outer edge of the S − bend optical interconnect. Fig 3.6(a) shows that radiation in two sections for end-to-end S − bend. At first half of S − bend waveguide, modal field radiation is along the radius of curvature, and reverses direction in the second half as the direction of radius of curvature also changes.

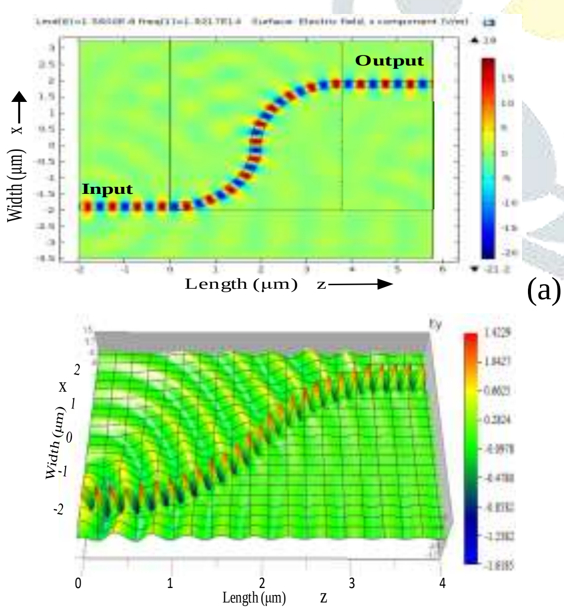

Fig.5. 2-D and 3-D views of modal electric field propagation

In Fig 6 the modal power distributions along the S − bend interconnecting waveguide between two waveguides or optical devices placed on the surface of PIC along the horizontally *x-z* plan. The geometrical dimension of waveguide is optimized width is 400 nm and height is 220 nm. to enhance the performance of optical interconnects

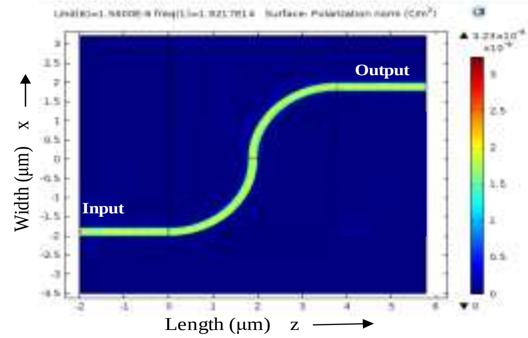

Fig. 6. Total power propagation in the S-bend

In an optical S − bend interconnect, the light wave signal is guided. These propagated light wave signals are radiated to the outer boundary. Such types of losses depend on the bending of the S − bend waveguide. It directly affects the performance of the interconnect, so to reduce this type of losses maximum bending arc is required. Fig.7 illustrates the curvature of S − bend waveguide on basis of length (L) and width (B) of the end-to-end S − bend waveguide shown in Fig. 2. The optimized radius of curvature is calculated using expression (3).

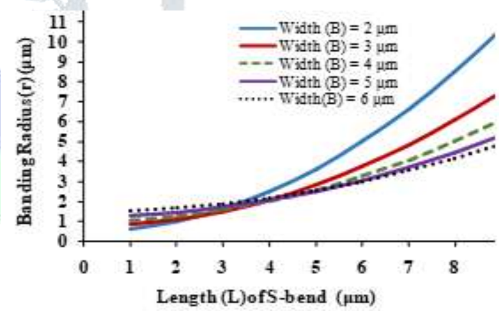

Fig. 7. Bending radius verses length (L) of S-bend waveguide for different heights (B).

The significant characteristics of the bending loss is calculated for using expression (5) and (6). Fig. 8 shows that the bending loss rapidly decays for 1 to 4 μm radius, then it becomes linear for 6 to 10 μm arc radius and the minimum bending losses at waveguide width is 400 nm.

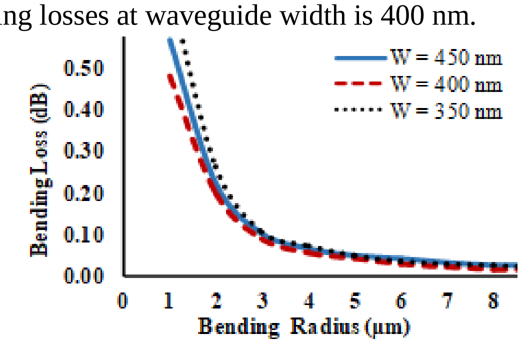

Fig.8. Bending loss versus various tight bending radii

Axial shift (Δx) directly depends on geometry dimension of guided wave S−bend interconnect. Figure 3.12 shows that the axial shift is rapidly increases for tight bending of S − bend interconnect.

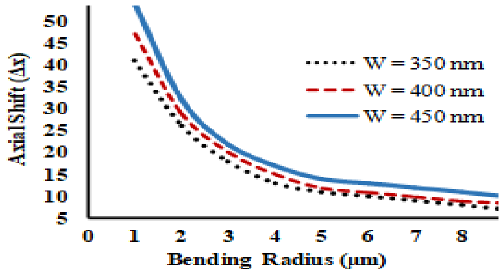

Fig. 9. Axial shift in the S − bend waveguide for different bending radius.

The coupling loss is generated on transition point of the optical devices, due to the mismatch behind the mode field of interconnect and optical devices. It is rapidly decays for 1 to 4 μm bend radius and after 4 μm the coupling loss is lesser then 0.02 dB, which is obtained for widths of 350, 400 and 450 nm as shown in Fig.10

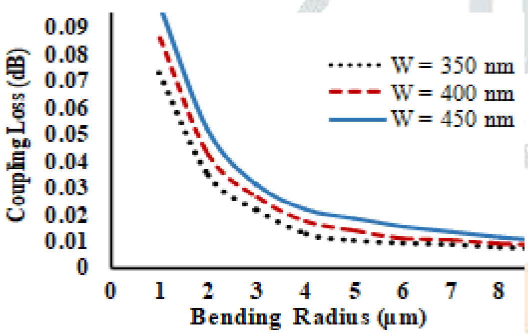

Fig.10. Coupling loss with respect to bending radius.

Figure 11. illustrate the bending loss in optical interconnect for wavelength range (1460 nm to 1620 nm), it depends on propagation of mode field and propagation constant (β). The total loss of S − bend depend on wideband spectral variation as well as bending of interconnect. Total internal losses linearly increase with increase in wavelength. For the sharp bends varying within 0.025 dB sum of bending may be ascertained for various bending of curvature in S − bend interconnect

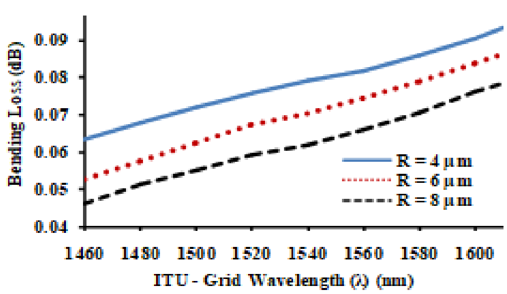

Fig. 11. Total loss in S − bend silicon waveguide in terms of different bending radius.

VII. Conclusion

The S − bend single layer optical interconnects are based on silicon-on-Insulator (SOI) fabrication technology. The bending of curvature for S−bend waveguide depends on length (L) and width (B) of the end-to-end S−bend waveguide to connect two devices. The quasi- TE mode for S−bend interconnect for various waveguide widths from 250 nm to 500 nm maintaining 220 nm height. The, width and height of interconnect is optimized to 400 nm and 220 nm respectively based on minimum losses.

The optimal value of the bending radius of r ≥ 4 μm for bend interconnects is obtained. It is observed that the peak values of modal electric field shift (Δx) toward outer boundary for tight bending interconnect. For the axial shift, coupling loss is generated in coupling point between bend interconnect and devices.

Lastly, total loss versus wavelength in ITU grid band (1460 nm to 1600 nm) for different radius of S − bend waveguide is obtained. These results provide the simple solution to design a high performing and low loss S − shaped optical rectangular interconnect on SOI base single layer PIC.

References

[1] Gabrielli L. H., Liu D., Steven, Johnson G. And Lipson M.: On-chip transformation optics for multimode waveguide bends. Nature Communications, (2012), DOI:10.1038/Ncomms2232

[2] Pollock C.R., and Lipson M.: Integrated photonics. Library of congress cataloging-in-publication, ISBN: 1-4020-7635-5. (2003)

[3] Lipson, M., 2005. Guiding, modulating, and emitting light on Silicon-challenges and opportunities. J. Light. Technol. 23, 4222–4238. doi:10.1109/JLT.2005.858225

[4] Ghatak A. K., Thyagarajan K.: Optical Electronics. Cambridge University Press India Pvt. Ltd, (2011).

[5] Grillot F., Vivien L.,.: Propagation loss in single-mode ultrasmall square silicon-on-insulator optical waveguides. J. Lightw. Technol, **24**, 891-896, (2006).

[6] Hiremath K . R ., Hammer M., Stoffer R., Prkna L. and Yroky J . C.: Analytic approach to dielectric optical bent slab waveguides. Optical and Quantum Electronics. **37**, 37–61 (2005).

[7] Huang S., Li Ming-Jun and K. P. Chen.: Board-level optical interconnect using glass. CLEO: Science and Innovations, San Jose, California, USA, (2015)

[8] Khan I. and Rahman M.: Bending loss analysis of optical waveguide for SOI & SOS material system towards photonic

integration. Global Engineering, Science and Technology Conference 27-28. (2013).

[9] Jedidi R. and Pierre R.: High-order finite-element methods for the computation of bending loss in optical waveguides. J. Light w. Technol. **25**, 2618-2630, (2007).

[10] Kumar A. and Gallawa R. L.: Bending-induced loss in dual-mode rectangular waveguides. optics letters, **19**, 707-709, (1994).

[11] Kwan C. H and Chiang K. S.: Study of polarization-dependent coupling in optical waveguide directional coupler by the effective-index method with built- in perturbation correction. J. Lightw. Technol. **20**, 1018-1025, (2002).

[12] Devayani, I.J., Syahriar, Characteristics of S-bend optical waveguides based on back-to-back and sinusoidal structures, in: 2014 ICEECS. IEEE, pp. 65–68. doi:10.1109/ICEECS.2014.7045221

[13] Brimont, A., Hu, X., , R., 2016. Low-Loss and Compact Silicon Rib Waveguide Bends. IEEE Photonics Technol. Lett. 28, 299–302. doi:10.1109/LPT.2015.2495230

[14] Navalakhe R. K., Dasgupta N. and Das B. K.: Design of low-loss compact 90° bend optical waveguide for photonic circuit applications in SOI platform. IEEE Region 10 Colloquium, the Third ICIIS,1-5 (2008).

[15] Popovic M., Wada K. and Akiyama S.: Air trenches for sharp silica waveguide bends. J. Lightw. Technol.**10**, 1762-1772, (2002).

[16] Priye V. and Sarkar S. N.: Calculation of sfhift and 3-db width of fundamental mode of a bent monomode fiber having arbitrary refractive index profile. J. Opt. commun. 140-143, (1988).

[17] Miller, D.A.B., 2009. Device requirements for optical interconnects to silicon chips. Proc. IEEE 97, 1166–1185. doi:10.1109/JPROC.2009.2014298