ISSN: 2278 – 909X
International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 5, Issue 6, June 2016

Three Dimensional High Contrast Grating Based Hollow Core Waveguide for Chip Scale Integrated Optical Interconnects

Sandeep, Anil Arora
ECE Department, Thapar University, Patiala, Punjab-147004, India

***Abstract*: Three Dimensional high contrast grating based hollow waveguide is purposed which provides very low loss and efficient confinement of light in it. This HCG based hollow waveguide can be implemented in chip scale integrated platform of optical inter connects. We simulated and analyzed the propagation loss in waveguide is 0.031 db/cm with 5 um as core height of HCG based HW.**

***Index terms*— Distributed Bragg Reflector, high contrast gratings, Optical interconnects, sub wavelength, waveguide.**

I INTRODUCTION

In recent years, the hollow-core waveguide (HCW) has attracted researchers because of their unique properties of wavelengths. These property make HCG based HWs unique while the conventional solid waveguide surfaces problems such as high loss due to abortion in material and challengeable non-linear effects[1]. Conventional designs like DBRs and Photonic crystals are not capable to efficiently confine the light into a hollow core waveguide . The basic fundamental of these hollow core waveguides is the interactions with grooves of gratings of sub wavelength range while that of DBRs is many layers, which is difficult to fabricate and bulky in size which make it near to impossible to work as chip scale integrated components. Moreover these waveguides have material which interact with light causes loss and high material dispersion and hollow waveguide provide flexible design and cost effective fabrication which make HCG-HW ideal candidate for realization of chip scale integration of optical interconnects.
interconnects.

HCG based Hollow-core waveguide which guides the light into air core, that is a promising candidate for achieving low propagation loss, small material dispersion because of the elimination of the core material.[3] These features are very significant for chip scale integrated platform. Papers publish recently on high contrast grating based hollow waveguide have shown that high contrast gratings (HCGs) provides ultrahigh reflectivity which is a crucial part in designing of low loss waveguide and can obtain ultra low dispersion and very low nonlinearity in waveguides [4] . Secondly, the HCG-HWs are easy to fabricate due to less process steps as compare to other waveguides. The fundamental principle is to guide the light inside the hollow core waveguide is via reflections using high contrast gratings whose one layer gives reflection that of 40 layers of DBR.

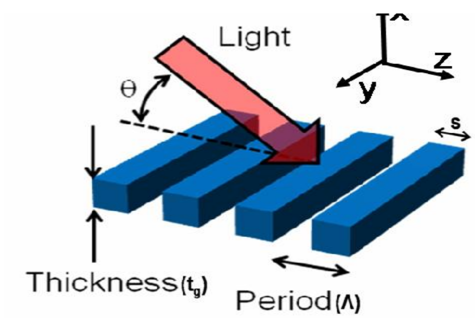
Here we purpose a 3-D HCG based HW which is designed by the two HCGs. Because of ultra high reflectivity in waveguide the two HCGs are able to confine efficiently light in the waveguide. Here, we propose and high contrast gratings to achieve low propagation loss in HWs. We represent that when HCG are placed parallel to propagation of wave it confine light efficiently in the waveguide. As a result, reduction in loss achieved. High contrast gratings give high reflectivity, greater than 99.5% when grating period is of sub wavelength range [5]. When grating period of sub wavelength range (1170 nm) is used then only zero order mode exists and higher modes becomes evanescent and high reflectivity achieved. [7]

High reflectivity is prime reason for ultra low loss in waveguide. We show that propagation loss of 0.031 dB/cm is achieved using Rigorous coupled wave analysis. The loss in waveguide can vary with the width and core height of waveguide. With increase in width loss decreases but on the other hand size increases and these days devices are becoming small so these factors need to be optimized according to present technology and fabrication limits. In hollow core waveguide the core material is air due to which the chromatic dispersion has reduced to large extent as chromatic dispersion is caused by material dispersion and waveguide dispersion. Due to air core material dispersion is almost negligible and non linearity is very low which are desired for chip scale integrated platform as distortion in optical signal is prevented. [12]. All these properties make this high contrast grating based hollow waveguide suitable for chip scale integrated chips based on applications that include optical interconnects like connection between micro-processor and memory, multi core micro processors and other integrated chips.[13]

II WAVEGUIDE STRUCTURE

The schematic of a 3-D HCG-HW is shown in Fig. 1(b) given above , The light travels along the grooves of gratings and interacts with them. Two silicon on insulator are the substrate wafers which are parallel to each other. Each one has 340 nm Si layer, and a 2 u m SiO_2layer on the Si substrate. The height of core is 5 um. Fig 1.a) Shows HCGs with low index core of the air. The basic parameters that define design of grating have major impact on the grating reflectivity, its period Λ, the air gap a_g, and grating thickness tg. Incident angle θ is between plane of gratings and incident light. Here θ is very small (θ<<1) as wave is made parallel to gratings. High contrast gratings are at distance d apart (d is core height). At wavelength of 1.55 um refractive index of silicon and core material air is obtained according to the At 1550 nm, they are 3.478 and 1, respectively [4].

a)



b)

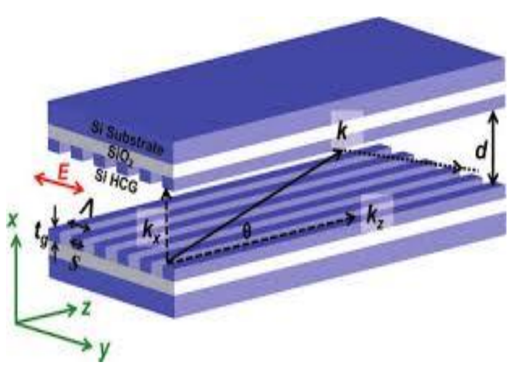


Fig1. a) HCG grating shows grating parameters.
b) Schematic consisting of two reflecting 3-D HCG-HW in the y-direction. High index gratings are on top which made of Silicon and a 2 m SiO_2 layer and Silicon substrate. The light propagates in waveguide in the z-direction.

Ray optic model can be implement to find the properties of propagation of HCGs based HW due to their ultra high reflectivity. The HW through which light travels has height d and incident at a angle θ travels the distance d / tanθ per bounce of light in waveguide. According to ray optics there is a loss of δ=1-R at each bounce, where R is the reflectivity of the HCGs . Assuming that there is no material loss in the HW's core, the optical propagation loss per unit length over distance L is

$$\alpha\ (dB/m) = \frac{10}{L} log\left(\frac{Pt}{Pi}\right) = -\frac{10}{L} log\left(R^N\right) \quad (1)$$

$$-\frac{10}{L} N\ log\ (R) = -10 \frac{tan\theta}{d} log(R \quad (2)$$

where the number of bounces in distance L is represented by N and N = L tanθ / d.

Given that,

$$\delta << 1,\ log\ (R) = \frac{ln\ (1-\delta)}{ln\ 10} = -4.3\ \delta \quad (3)$$

Θ<< 1,
therefore tan θ becomes nearly equal to θ
therefore the waveguide loss can be estimated as

$$\alpha\ (dB/m) = 4.3\ \alpha \frac{\theta}{d} \delta \quad [5]$$

HCG's various design parameters like reflectivity are calculated that is the result of calculations using rigorous coupled wave analysis (RCWA) , is used to calculate the gratings on the two wafers can provide light confinement in the z-direction. We choose grating parameter of 1170 nm, air gap is maintained 450nm. The grating thickness in all simulations is 340 nm.

III RESULTS

At 1550 nm wavelength reflectivity (> 99.5 %) is maximum is shown in fig 2 therefore at this wavelength HCG-HW structure provide minimum loss. Here the property of HCGs based HW's property with the wavelength is represented through graph in which the unique results at 1.55 um wavelength have obtained and it is providing maximum reflectivity and minimum loss at this wavelength.

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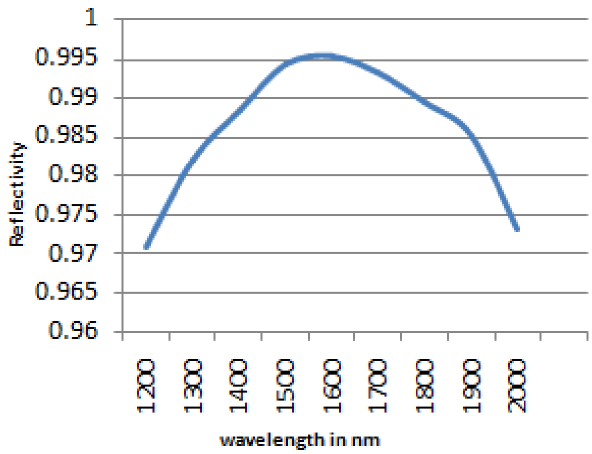

fig 2 Simulated for HCGs based HW with grating period (Λ) = 1170 nm, thickness (t_g) = 340 nm, duty cycle (η) = 0.65. Incident angle θ <<1

The variation of reflectivity with incident angle is shown in fig 3 which represents that incident angle has major impact on reflectivity of light in waveguide. From the RCWA calculations it is found that reflectivity of light in waveguide decreases with increase in incident angle. So with minimum angle of incidence maximum reflectivity can be obtained that is only when propagation of the light is parallel with grooves of HCGs gratings and maximum reflectivity is obtained at minimum incident angle .

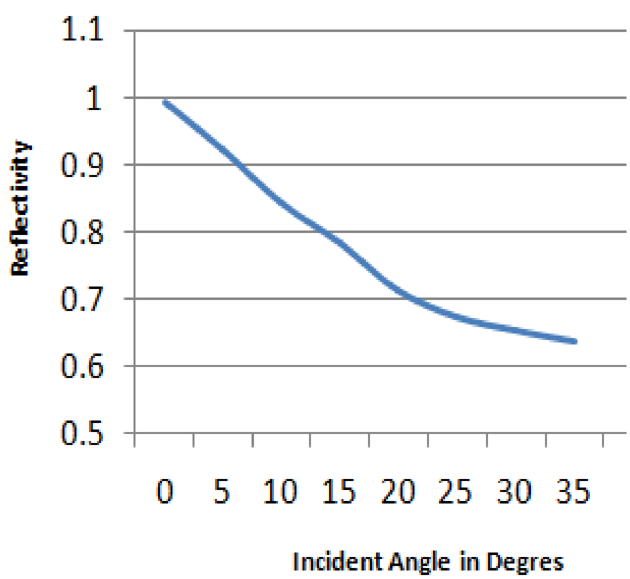

Fig 3.Simulated for TE- HCG with grating period (Λ) = 1170 nm, thickness (t_g) = 340 nm, duty cycle (η) = 0.65. Wavelength = 1550 nm.

Dependence of propagation loss on wavelength is shown in fig 4. RCWA results has shown that loss is minimum at 1550 nm wavelength and this has cleared from the results in fig 2. that at 1550nm the reflectivity is maximum and with maximum reflectivity the light has travelling in only zeroth mode and all other modes fade away which results in minimum loss (.031 dB/cm) that is shown in fig4.

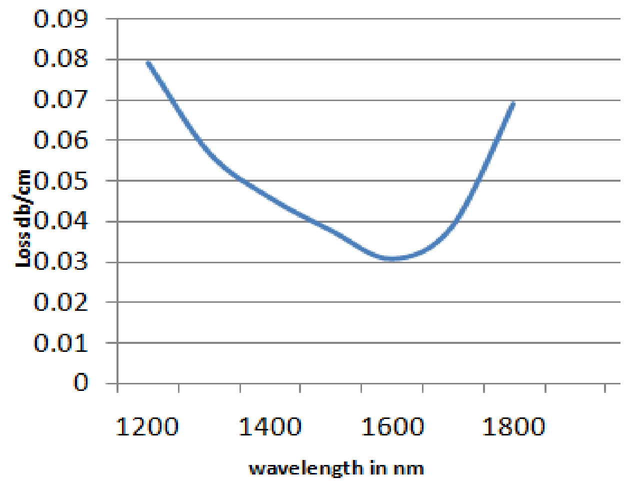

Fig 4. Simulated for TE- HCG with grating period (Λ) = 1170 nm, thickness (t_g) = 340 nm, duty cycle (η) = 0.65. Incident angle θ <<1

The propagation loss varies with change in incident angle is shown in fig 5. As mentioned before the reflectivity is maximum when propagation of light is parallel to HCG-HW structure. Loss in the waveguide is inversely proportional to reflectivity, so minimum loss (.031 dB/cm) is achieved when incident angle is <<1.

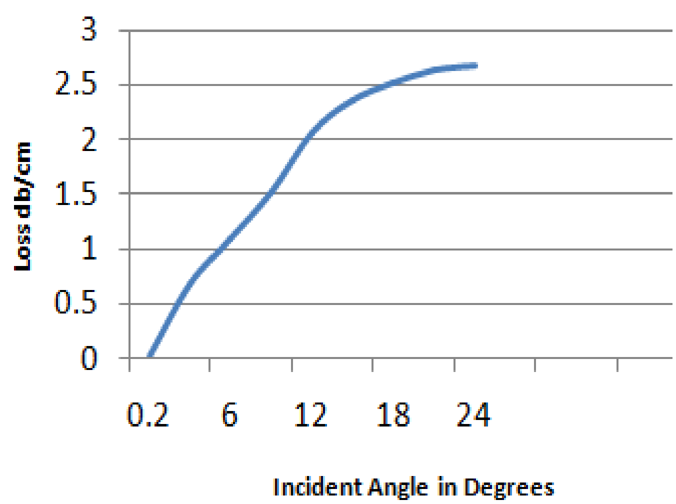

Fig 5.Simulated for TE- HCG with grating period (Λ) = 1170 nm, thickness (t_g) = 340 nm, duty cycle (η) = 0.65. Wavelength = 1550 nm

IV CONCLUSION

We presented a 3 dimensional high contrast grating hollow waveguide structure which possesses novel waveguide characteristics due to efficient confinement of light. For chip scale integrated platform for low loss, low non linearity and easy fabrication are of prime importance and this proposed waveguide provide all such properties. Waveguide propagation loss is 0.031 dB/cm was obtained by rigorous coupled wave analysis. Loss can reduce further by using higher core width. With these properties HCG-HW can used in chip scale integration off optical interconnects.

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