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Investigation of a Vertical Optical Coupler based on Trapezoidal grating for Symmetrical Coupling

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ABSTRACT

Coupling light from a single-mode fiber into a waveguide is a significant issue. Numerous remedies have been introduced to this issue. In this paper, we numerically investigate a trapezoidal grating-based vertical coupler for symmetrical coupling applications. The power efficiency in both horizontal directions is identical. The coupling efficiency for the coupler is 48.46%. Adding a reflection layer below the waveguide enhances the efficiency to 57.8%. The coupler shows promising results for symmetrical coupling applications.

Key words: Optical coupler, trapezoidal grating, symmetrical coupling.

1. INTRODUCTION

Highlight Modern optics is one of the fields where basic physics is intimately related to technical applications. Nowadays there is a silent revolution in the optical components: freely propagating beams are being replaced by guided waves, and refractive lenses are being replaced by diffractive lenses incorporating grating which controls the light wave direction. The grating coupler, an essential device in integrated optics, is used to connect fibers and planar waveguides deprived of transitional optical devices.

Vertical coupling provides a dense optical connection and takes advantage of economies of scale since it needs a tiny space comparing to edge coupling. These new components allow for much higher degrees of integration and miniaturization. This approach is gaining more and more importance in telecommunication as well as in sensor technology since all the devices in these fields are in the micro or even the nano range. It is challenging to couple the light from optical fibers into waveguides due to the size disparity between fibers and waveguides. Since the waveguide core thickness is only 100 –300 nm also the guided-mode is forcefully restricted in the core while the fiber core size is few micrometers.

Optical gratings couplers are used to overcome this challenge. Grating couplers have been broadly considered in literature [1] – [4]. One of the advantages of the grating couplers; that it can be positioned anyplace in the device and can simply be incorporated. In the grating-based couplers, the coupling occurs outside of the waveguide plane, which allows optical I/O's to inhabit any part of a planar lightwave circuit (PLC) rather than limited to the edge of a PLC.

One of the most attractive gratings profiles is the trapezoidal grating profile [5] – [9]. The fabrication of such a profile is less difficult than the perfect triangle profile [5]. Moreover, the trapezoidal profile reduces the fiber to fiber losses compared to the rectangular profile [6]. Diffraction grating with a trapezoidal profile shown advantages in many applications such as enhancing the efficiency in solar cells [7] – [8]. Furthermore, Micro-structured dielectric trapezoidal gratings are used in Terahertz Applications [9].

2. OPTICAL COUPLER SIMULATION

This section presents the simulation geometry of trapezoidal grating optical coupler. Also, it presents and discus the simulation results.

2.1 Simulation Geometry

Figure 1 shows the trapezoidal grating profile with different parameters. Such as, the grating period (Λ), fill factor (FF= d/Λ), depth (h) and slope angles (θ_1 and θ_2) of the gratings.

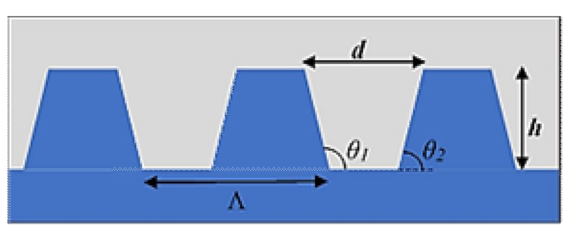

Figure 1: Trapezoidal grating profile

Figure 2 shows the simulation geometry with the different components and parameters. An FDTD tool integrated with a micro genetic algorithm is used in the simulation and analysis of the coupler.

The following parameters were used in the simulation. The fiber core radius is 8.3 µm, n_core =1.47 and n_cladding= 1.4647. The waveguide core is n =3.4 with a core thickness of 240 nm. The waveguide upper and lower claddings are n= 1.46 and n=1.444 respectively. The thicknesses of the waveguide upper and lower cladding are 1.355 µm and 1.005 µm respectively. The simulation region dimension is 32 µm X 3 µm with a Yee cell of (20nm x 20nm).

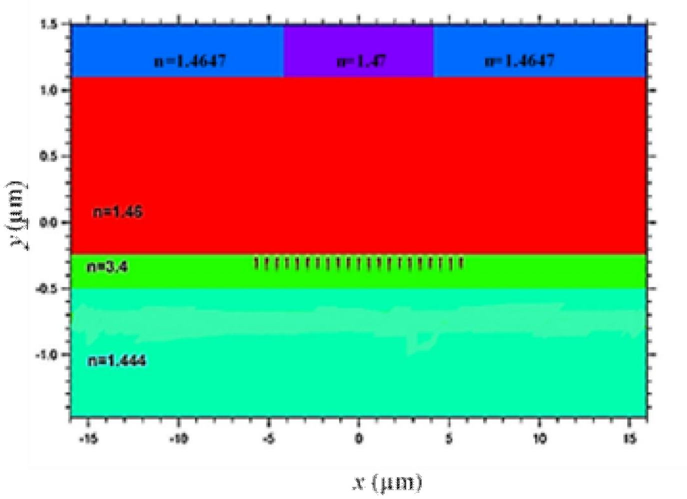

Figure 2: The simulation geometry under study.

2.2 Simulation Results

The optimized parameters of the trapezoidal gratings are: the period (Λ =0.5662 µm), the fill factor (FF= d/Λ= 0.292) and the grating depth (h) is 215 nm. The grating slope angels (see figure 1) are θ_1 = 125.26^o and θ_2 = 54.74^o. The simulation results for the previous parameters are shown in figure 3.

Figure 3 shows that most of the power launched from the fiber is coupled into the waveguide. Moreover, the figure shows that the coupling is symmetrical to the left and right of the waveguide (+*x* and -*x*-direction). Table 1 shows the power efficiency into the waveguide (+*x* and -*x*-direction) and reflected and transmitted power (+*y* and -*y*-direction respectively). The coupling efficiency is calculated using the mode overlap integral (MOI) [10].

As we can see from figure 3 and table 1 the coupler coupled then light in +*x* and -*x*-directions, into the waveguide, symmetrically. Therefore, this coupler is useful in applications that required such coupling. Moreover, it can be used in measurement and test systems. Also, in optical communication and monitoring devices.

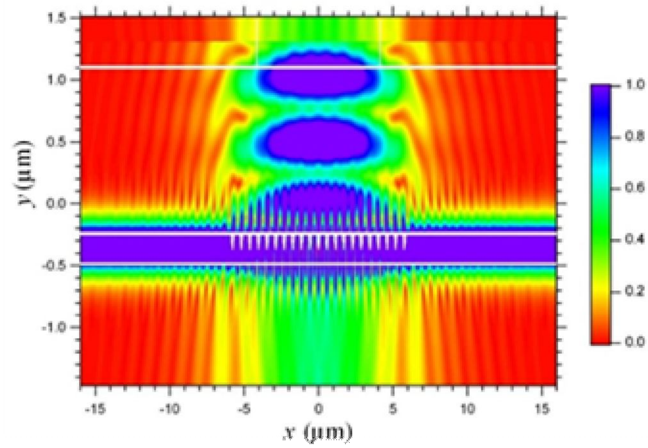

Figure 3: Plot of the field of the optimized grating structure.

Table 1 shows that more than 40% of the power is transmitted through or reflected from the waveguide core. In order to enhance the coupling efficiency into the waveguide, a reflection layer is added below the waveguide. This layer will reduce the transmitted power to the lower cladding. Therefore, it increases the coupling efficiency into the waveguide core.

Table 1: Power efficiency in the simulation geometry.

Power Efficiency (+x)	28.33%
Power Efficiency (-x)	28.33%
Power Efficiency (+y)	17.94%
Power Efficiency (-y)	25.00%
Coupling Efficiency	48.46%

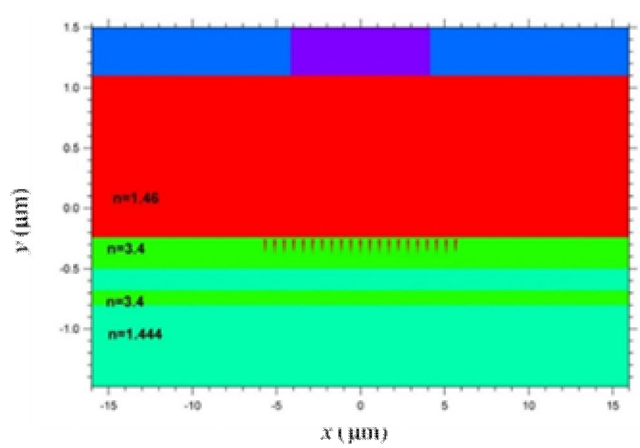

Figure 4: The simulation geometry with reflection layer added.

Figure 4 shows the modified simulation geometry after added the reflection layer. The optimized parameters of the trapezoidal gratings are: the period (Λ =0.5667 μm), the fill factor (FF= 0.315) and the grating depth is 222 nm. The grating angels (see figure 1) are θ_1 = 125.26^o degree θ_2 = 54.74^o. The optimized thickness of the reflection layer (n=3.4) is 102 nm. While the vertical distance between the waveguide core and the refection layer is 180 nm. The simulation results for the previous parameters are shown in figure 5. Table 2 shows the power efficiency in the modified geometry.

We can see from figure 5 and table 2 that the Si reflection layer reduces the transmitted power from 25% to almost 9%. Moreover, the coupling efficiency is enhanced to 57.8%.

Table 2: Power efficiency in the simulation modified geometry.

Power Efficiency (+x)	35.53%
Power Efficiency (-x)	35.53%
Power Efficiency (+y)	19.88 %
Power Efficiency (-y)	8.8 %
Coupling Efficiency	57.8%

While the power efficiency in both *x* directions is increased to 35.53%. that means adding the reflection layer enhances the power in the horizontal direction by 25.4%. while enhancing the coupling efficiency by 19.3%.

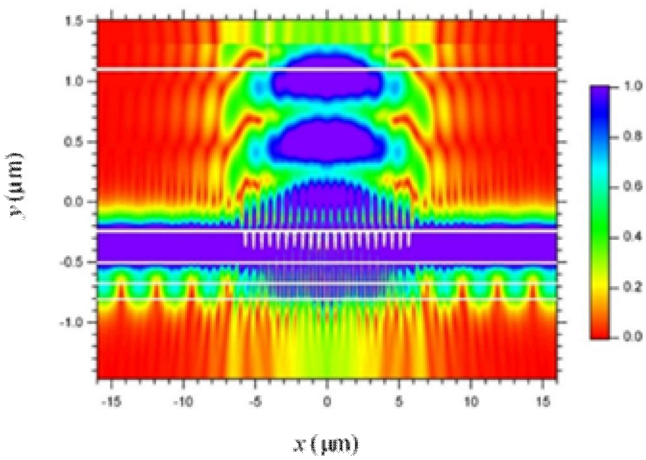

Figure 5: Plot of the field of the optimized grating structure.

3.CONCLUSION

This paper discusses the design and analysis of dielectric trapezoidal grating coupler for symmetrical coupling. The simulation results show that the power coupling efficiency is the same for both -*x* and +*x*-direction. The optimized values of the gratings provide a 48.46% coupling efficiency. In order to enhance this efficiency, a reflection layer is added to increase the coupling efficiency to 57.8%. Such coupler is appropriate for the testing of photonic devices. This coupler opens the door for new applications in the sensing based on the symmetrical coupling.

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