Performance Analysis of 1x2 Optical Power Splitter

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Abstract: - In this paper, the influence of the width of waveguide and the branching angle of the output arms on the output power of 1×2 optical splitter has been investigated in details. We showed that the output power is improved when the width increases for single mode transmission. In addition, at specified values the core and cladding refractive indices, approximately 50% input-to output power ratio is achieved at the output. Moreover, the output power can be controlled by adjusting the branching angle of the device.

Key-Words: - branching angle, optical power, optical splitter, waveguide width.

1 Introduction

Optical devices are very important components for photonic and optoelectronic optical applications due to their simple structure, low loss and wide optical bandwidth. These structures in term of splitter or coupler provide optical power splitting or combining respectively [1].

Optical splitters find application in optical fiber networks particularly for broadcast optical signal distribution. Power splitting in term of the optical branching waveguide is one of the elementary components of integrated optics, it is used to divide the incident optical power into output branches. Optical splitter plays a central role in passive optical distribution networks[9]. Furthermore, the device should meet practical requirement such as type of material, small size and wavelength dependency. [2].

Optical splitter provides the ability to create a variety of point-to-multipoint fiber optic networks. However, these devices suffer from high reflection and radiation loss due to branching complexity. It is known that the radiation loss increases with branching angle, and it may be quite significant if the angle exceeds specified value. Thus, in order to keeps the loss low the device should be designed with a small branching angle taking into account the influence of waveguide. It is known that long device suffer from high attenuation loss[6]. Though, these are generally undesirable because of the size of structures needed. Consequently, optimum design in term of geometrical dimensions is necessary to be performed in order to improve the overall performances, like optical losses and output power division ratio[7].

In this paper, we investigated the influence of waveguide width together with branching angle on the output power of optical power splitter. Considering single mode device we found that the output power increases with increasing of waveguide width at specified values of core and cladding refractive indices[8]. In addition, the output power of each output arm can be controlled by adjusting the corresponding angle. Equal power dividing ratio can be achieved with equal branching angles. This paper is organized as follows. In the next section a design of 1×2 optical power splitter is presented. Simulation results, performed by beam propagation method (BPM) software,[5] showing the influence of affected parameters are shown in section 3. Finally the paper is concluded in section 4. (Splitter) is designed. The influence of the width (w) of optical channel waveguide on the output power dividing ratio at specified values of core (n_{core}) and cladding (n_{cladd}) refractive indices and waveguide length is investigated in details. Further, optimum values of w, n_{core}, n_{cladd} are obtained that give approximately 50% output power dividing ratio.

2 Optimum design

Schematic view of the device used in this paper is shown in Fig.1. Principally, the waveguide is designed with length, L=500um, core n_{core}=1.5 and cladding n_{cladd} =1.48 refractive indices. The latter is modified, as will be shown later, in order to obtain relatively high output power.
Moreover, the wavelength is considered to be 1.55 um. This is the most promising wavelength for optical communications, because of the minimum attenuation in optical fiber.

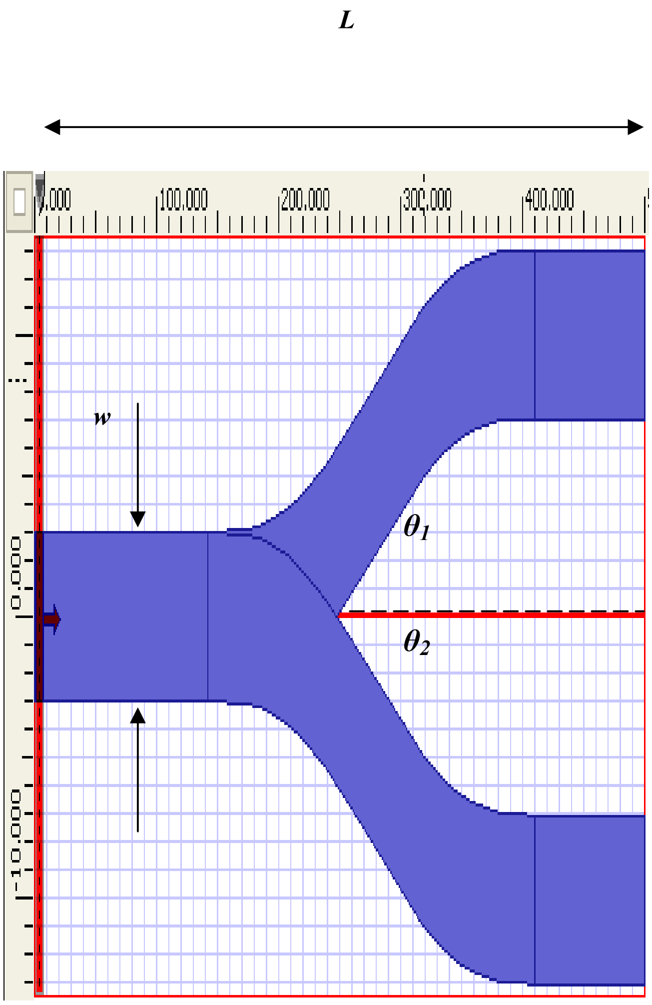

Fig. 1 Schematic view of 1x2 optical power splitter.

Initially, the branching angles of the two output arms θ_1 and θ_2 are assumed to be equaled with arbitrary value. Thus equal output power dividing ratio is expected to be achieved.
Generally, as mentioned before, the branching angle should be fixed small in order to decrease the excess loss due to the effective uptapering of the branches and to ensure that the optical splitter adiabatic, i.e. the local super mode does not couple to higher-order-modes.
The width of waveguide, assuming single mode operation, is changed in order to investigate its influence on the output power.

3 Results and discussion

A beam propagation method (BPM) software is used in order to get the desired output. The values of parameters used in simulation can be found in Table 1. Figs 2a through 2c show respectively the simulation results for normalized output power of the propagating optical beam inside the proposed structure for n_{core} =1.5 n_{cladd} = 1.48 and different values of waveguide width. Generally it can be noted that the output power decreases as the length of waveguide increases due to increasing of transmission loss, i.e. waveguide attenuation, as shown in Fig. 2 for w = 2μm. When the width increase to w = 4 and 6μm as shown in Figs. 2b and c respectively, the output power increases accordingly for single mode transmission.
As shown in Figs. 2, the output power increases as the waveguide width increases for single mode transmission. The output power is improved further, after the branching region, when the refractive of cladding layer changed to n_{cladd} = 1.35 as shown in Fig. 3a. The corresponding topographical map of optical field which is basically the electric field (E) in the electromagnetic waves derived by Maxwell's Equations is shown in Fig 3b. While Fig. 3c shows the variation of E with the dimensions of designed optical splitter.
The influence of branching angle on the output power of each arm is shown in Figs. 4, 5 and 6 where the branching angle of the arm 1, θ_1, is the parameter while the corresponding one of arm 2 is fixed to θ_2 = 5.13°. Fig. 4a shows the output power of the device for θ_1=2.866°. It can be noted that output power decreases quite sharply through the optical branching region due to scattering losses. In addition, the output power in arm 1 is higher than the one of arm 2 because $\theta_1 < \theta_2$. Moreover, the level of optical power in each arm can also be noted clearly as shown in Fig. 4b where it shows the power distribution laterally. According to that, the simulated measurements show that the output power for each arm as follows.

Output arm1: 0.623563 ≈ 62% (62%)

Output arm2: 0.359195 ≈ 36% (36%)

On the other hand, when $\theta_1 = \theta_2 = 5.13^{\circ}$ as shown in Fig. 5, the output power in the arm1 and 2 is the same (equal) because the scattering loss is the same for each branch. The simulated measurements of the output power give the following values

Output arm1: 0. 491379 ≈ 49% (49%)

Output arm2: 0. 491379 ≈ 49% (49%)

Finally when $\theta_1 > \theta_2$, i. e $\theta_1 = 9.115^{\circ}$ as shown in Fig. 6, the output power in arm 1 is less than the one of arm 2 because the scattering loss of the former is higher than the latter. The corresponding output powers of each arm have been measured as follows

Output arm1: 0.387931≈ 39% (39%)

Output arm2: 0.600575 ≈ 60% (60%)

The general relationship between the output power of arm1 and 2 with the branching angle θ_1 is depicted in Fig. 7. The remark that can be deduced from this figure is that the output power of each branch can be controlled by controlling of the corresponding angle. This is high of importance when considering of optical power splitter in optical networks.

Table 1 Parameters values used in simulation

Parameters	Input data
Substrate Length	500 µm
Substrate Width	38 µm
Refractive Index of substrate wafer, n1	1.48 and 1.35
Refractive Index of waveguide substrate wafer, n2	1.5
Wide guide wave	6 µm
Wavelength	1550 nm
Medium	Gaussian
Display Number	55
Polarization	TE and TM
BPM Solution	Paraxial
Border Method	Simple TBC
No of Mesh	20000

4 Conclusion

We have simulated the performance of 1×2 optical splitter using BPM method. This was done using a BPM-CAD waveguide optics modeling software system by the optiwave corporation. The influence of waveguide width and branching angle on the output power of optical splitter has been investigated. The fowling remarks can be concluded from this paper:

1. Long device may suffer from attenuation loss in addition to high fabrication cost.
2. The output power increases when the width of waveguide increases but the one should pay the price of multi-mode degradations.
3. The output power depends significantly on the branching angle due to the effect of scattering loss. An equal power dividing ratio can be obtained by fabricating the device with equal branching angle.
4. The values of core and cladding refractive indices should be optimized in order to achieve relatively high output optical power.

Acknowledgement

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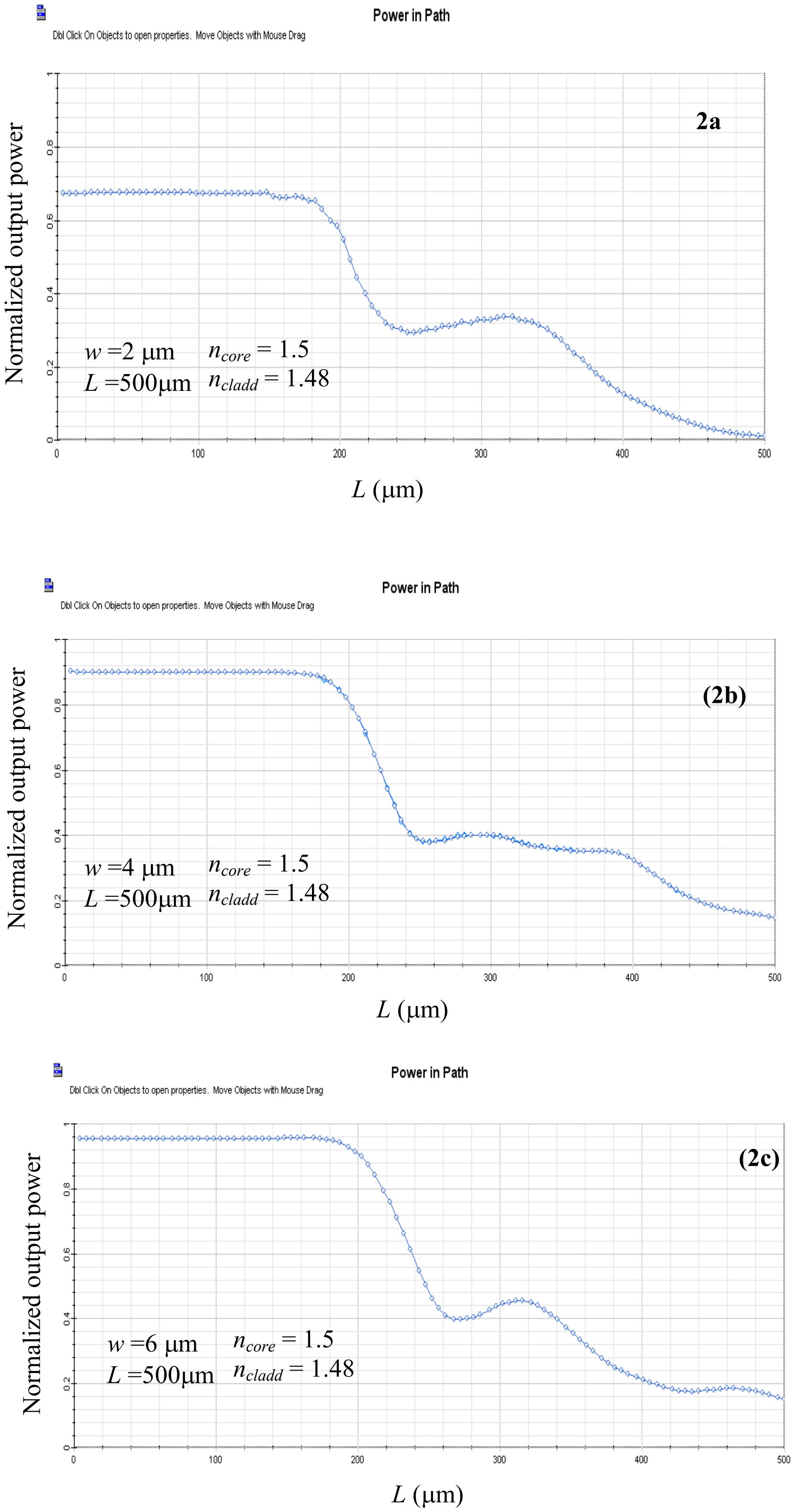

Fig 2 Normalized output power of the propagating optical beam inside the proposed structure of 1x2 optical splitter for the two branches for L = 500 µm and w= (a) 2 , (b) 4 and (c) 6µm.

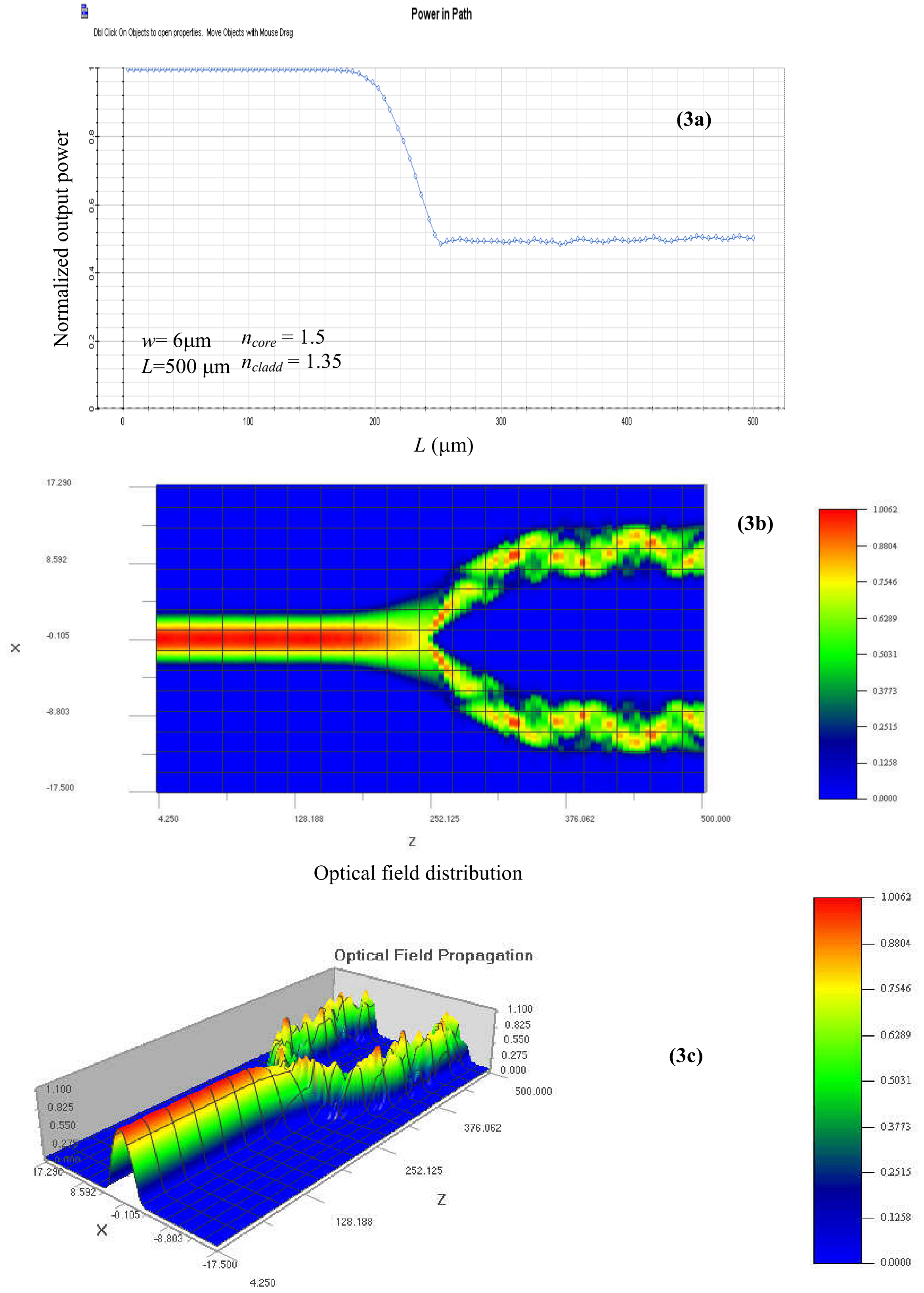

Fig 3 (a) Normalized output power of the propagating optical beam (b) and (c) The Top graphical map and 3D graphical representation of optical field respectively for n_{cladd} = 1.35.

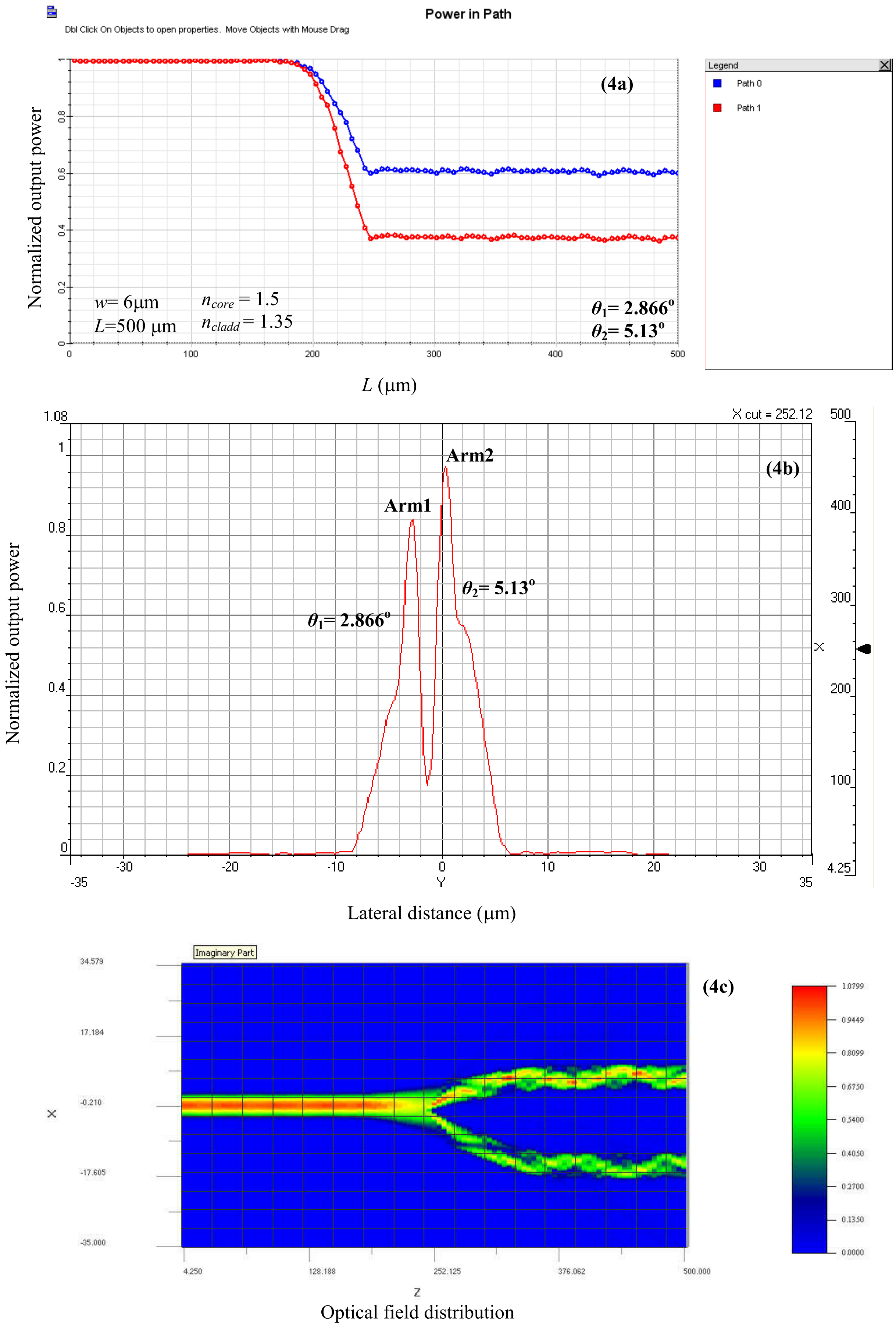

Fig 4 (a) Normalized output power of the propagating optical field (b) and (c) The lateral view and Top graphical map of optical field respectively for θ_1= 2.866° and θ_2= 5.13°.

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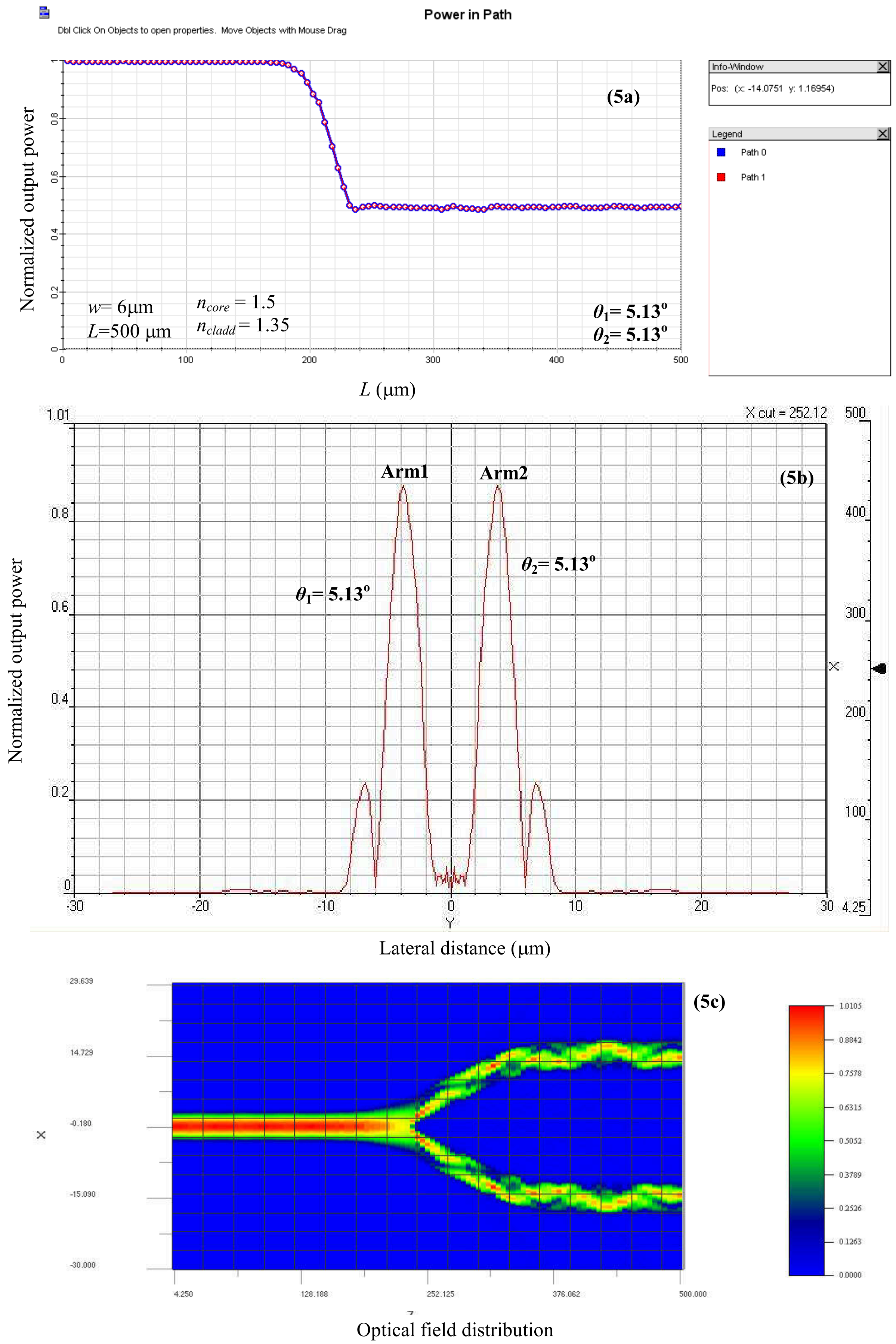
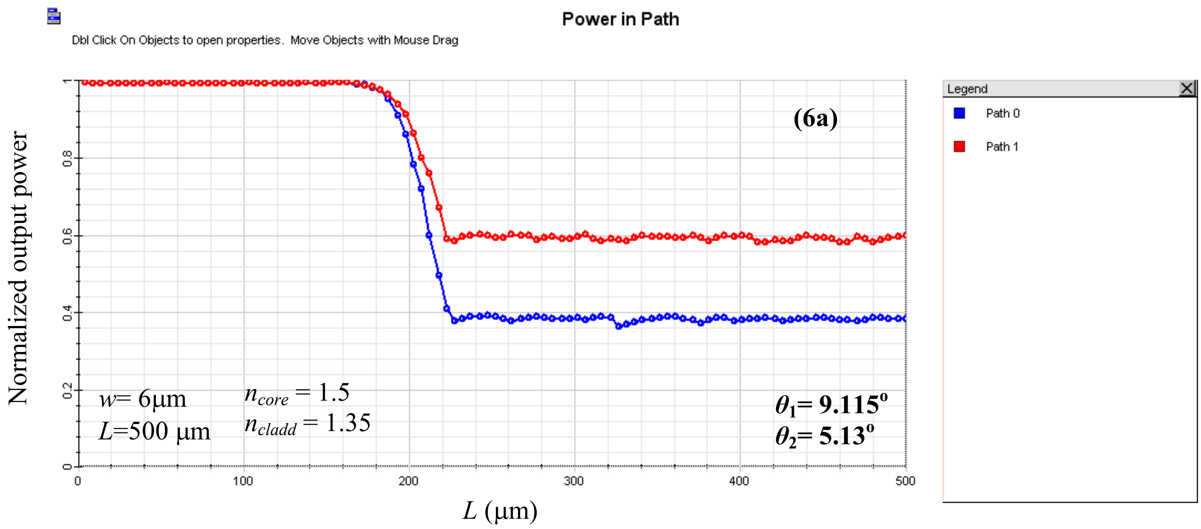
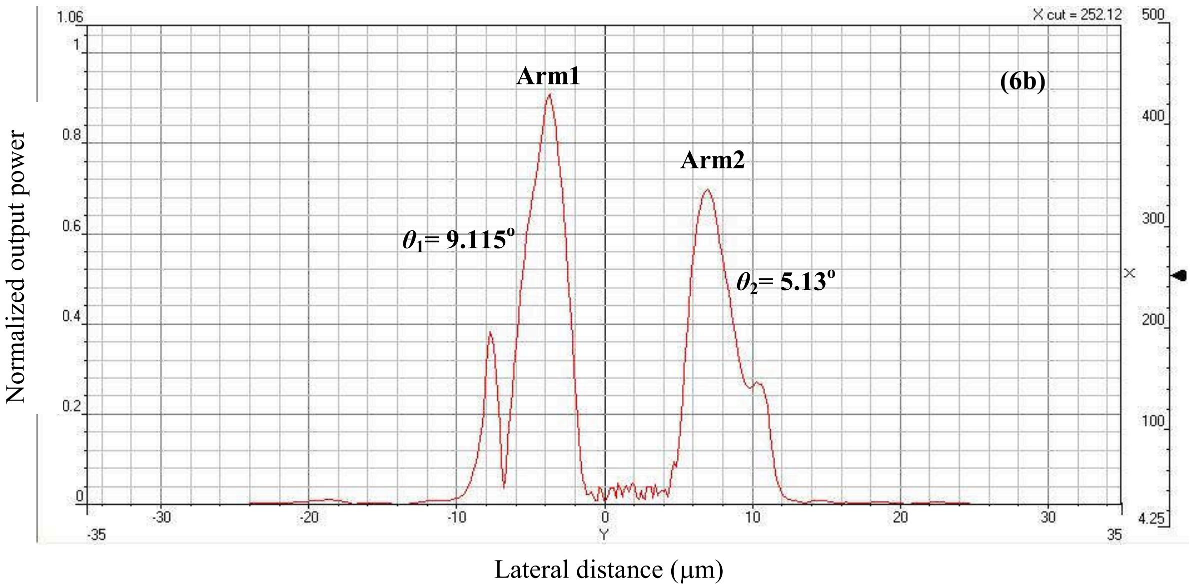
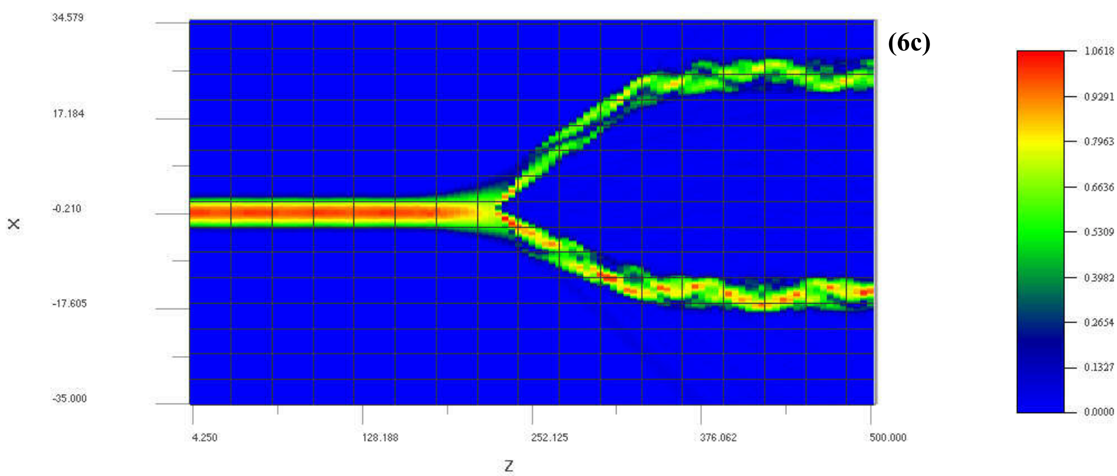


Fig. 5 is the same as Fig. 4 but for θ_1= 5.13° and θ_2= 5.13°.

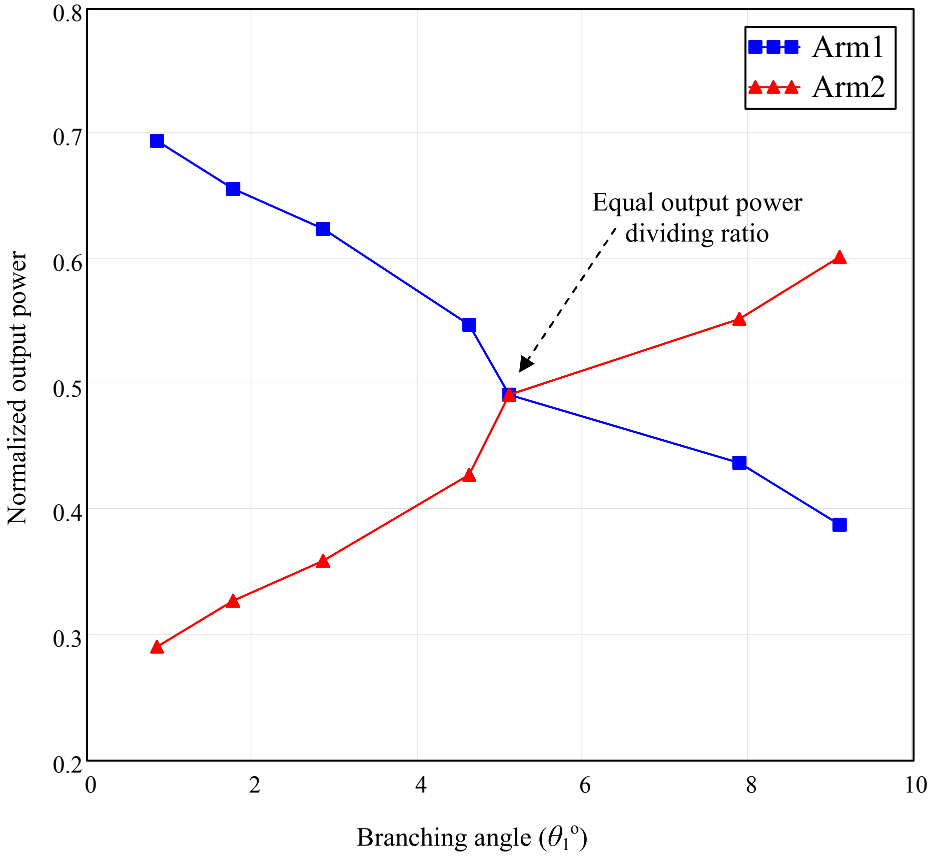






Optical field distribution

Fig. 6 is the same as Fig. 4 but for θ_1= 9.115° and θ_2= 5.13°.


0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
2
4
6
8
10
Arm1
Arm2
Equal output power dividing ratio
Normalized output power
Branching angle (θ_1°)