Principles of microwaves and wave guides

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Dielectric slab waveguide

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**Structure 1**

Geometry:

The structure consists of rectangular symmetrical slab wave guide of clad and core as core diameter is 3um and the whole wave guide is 10 um height and 10 um width as shown in figure (1).

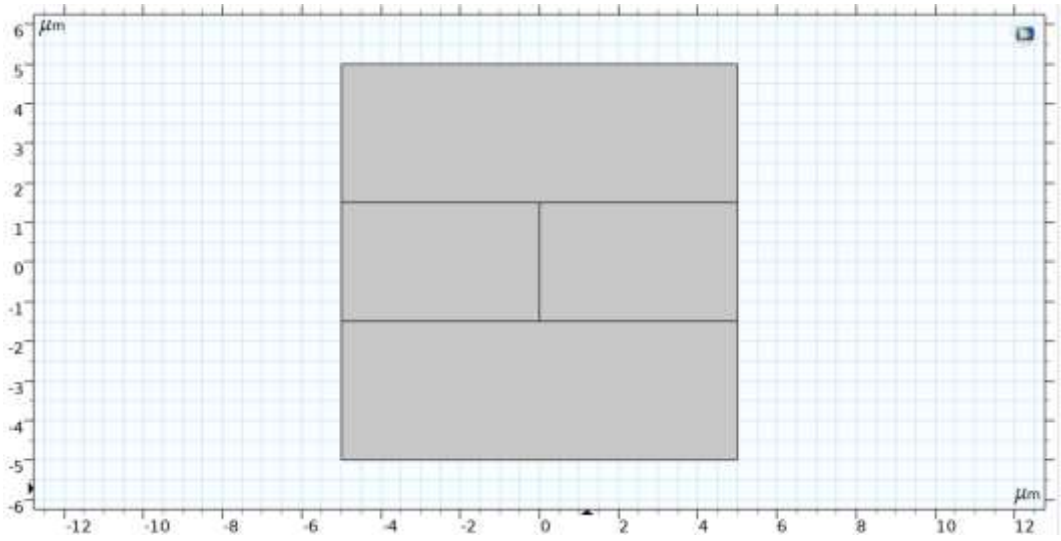


Fig (1). Geometry of the waveguide on COMSOL simulator

Parameters:

The core of the wave guide is made of silicon with refractive index equals 3.44 into two parts and the clad made of silicon dioxide with refractive index of 1.44.

The wave-length applied is 1.55 um as the frequency equals c_const/1.55[um].

Electromagnetic wave, frequency domain:

The applied electric filed is three_component vector and we want to get the fundmental TM mode.

Two ports are applied for the input and the output as shown in figures (2,3).

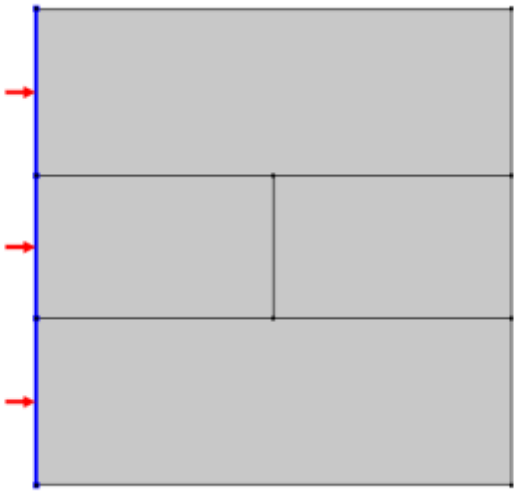

Fig (2). Input port

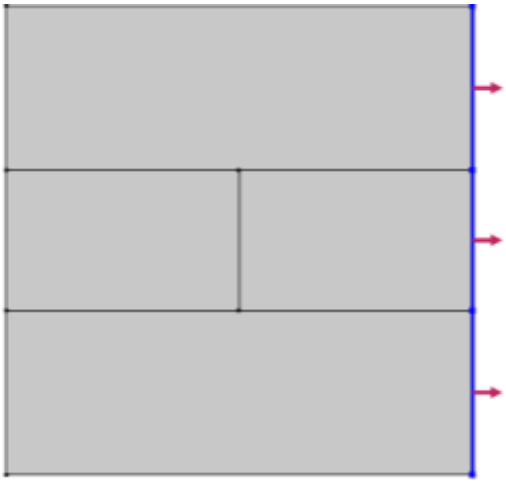

Fig (3). output port

Meshing:

Extremely sine meshing is applied on the structure as shown in figure (4).

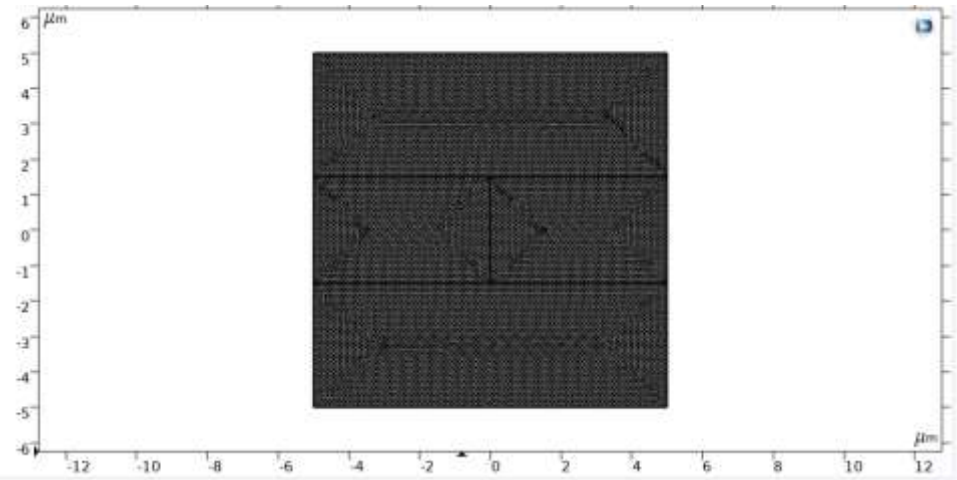


Fig (4). meshing

Study:

Here boundary mode analysis is applied for each port and the value to search around is n_core, also frequency domain is applied with the frequency (1.19341E14 Hz).

Results:

Figure (5) shows norm electric field mode analysis.

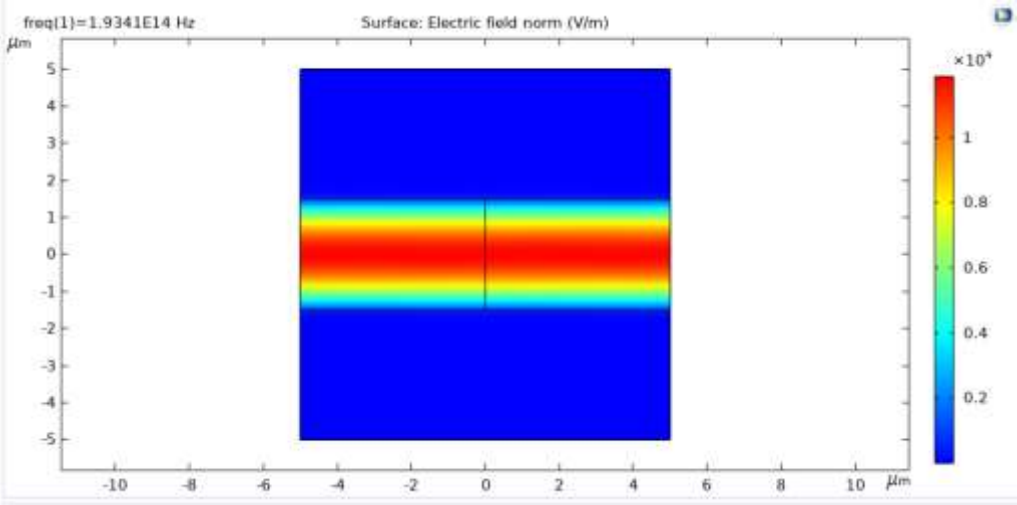


Fig (5). Electric field norm(V/m)

Figure (6) shows norm electric field z-component.

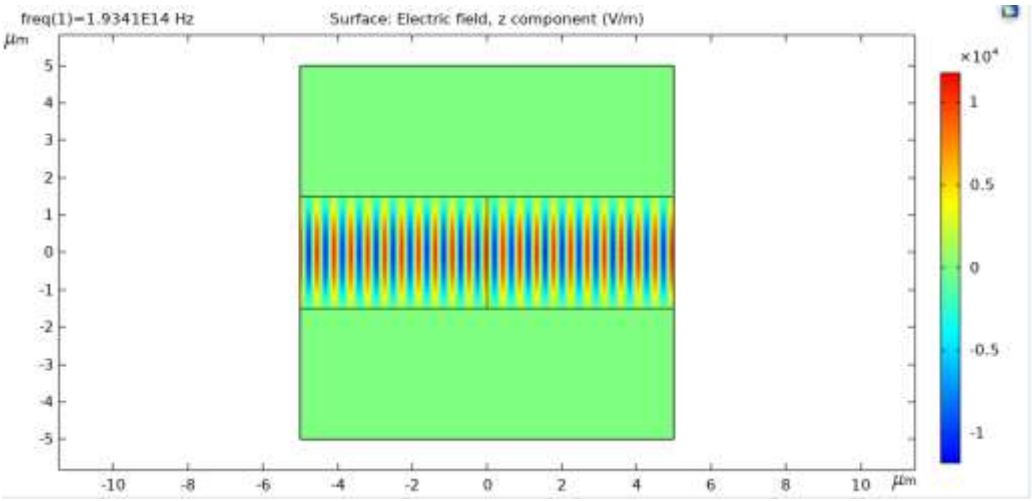


Fig (6). TM Electric field z-component(V/m)

And figure (7) represents the profile of electric field.

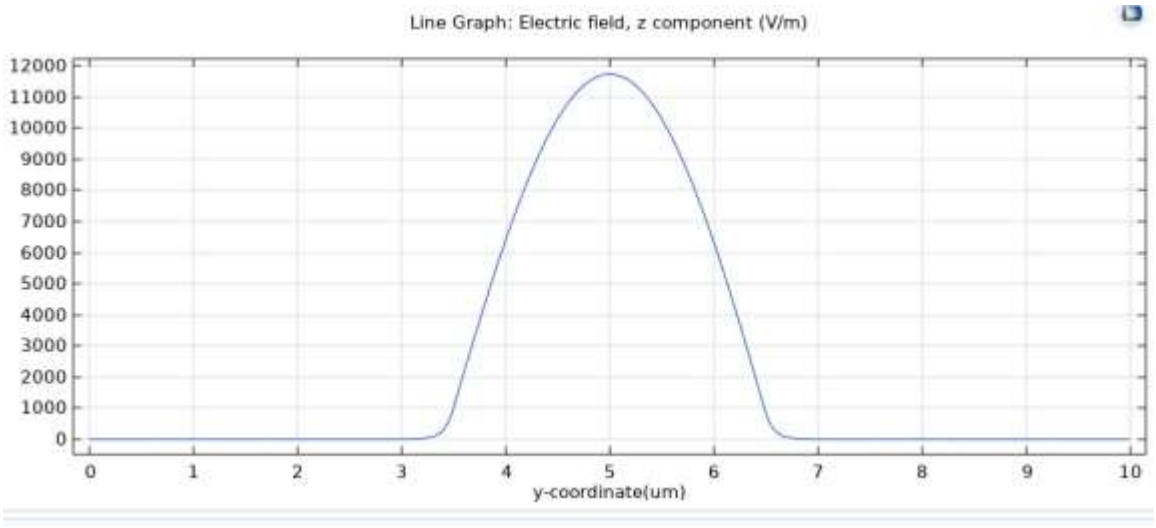


Fig (7). Electric field z-component(V/m)

From these results we can obtain n_effective, transmission and reflection that are shown in table 1.

| freq (Hz) | abs(ewfd.S11) (1) | abs(ewfd.S21) (1) | Total reflectance (1) | Total transmittance (1) | Effective mode index (1) | Effective mode index (1) |
|---|---|---|---|---|---|---|
| 1.9341E14 | 7.4978E-4 | 1.0000 | 5.6217E-7 | 1.0000 | 3.4312 | 3.4312 |

Table (1)

Since we are testing the reflection and transmission between the two boundaries which have the same refractive index, so we don't expect a significant value of reflection, so transmission value equals 1 and reflection equals nearly to zero.

**Structure 2**

Geometry:

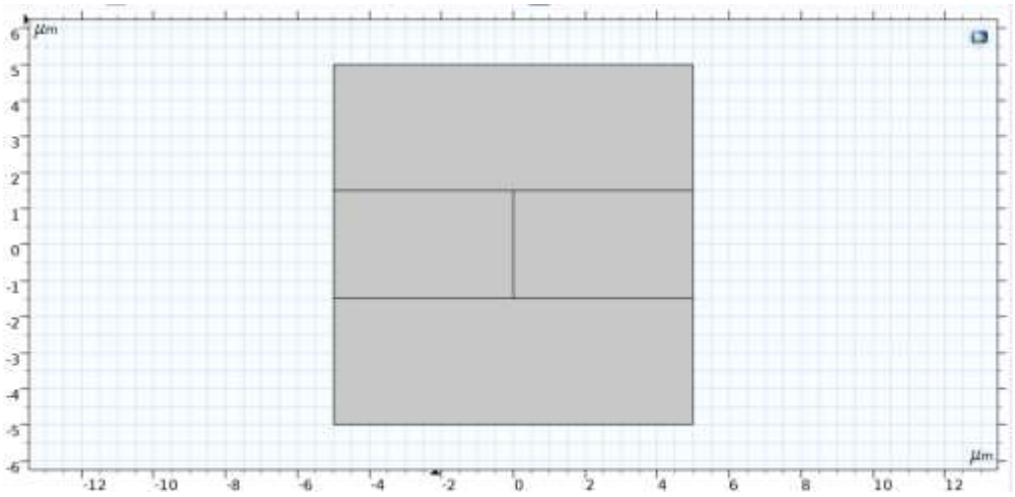


Fig (8). Geometry of the second structure.

Materials:

As the silicon dioxide core is divided to two parts each one with different refractive index, so the clad is the same silicon with n=1.44. and the core is divided to core1 with n=3.5 and core2 with n=3.44.

Electromagnetic wave, frequency domain:

Two ports are applied as the input and output ports as shown in figure in figure 9 and 10.

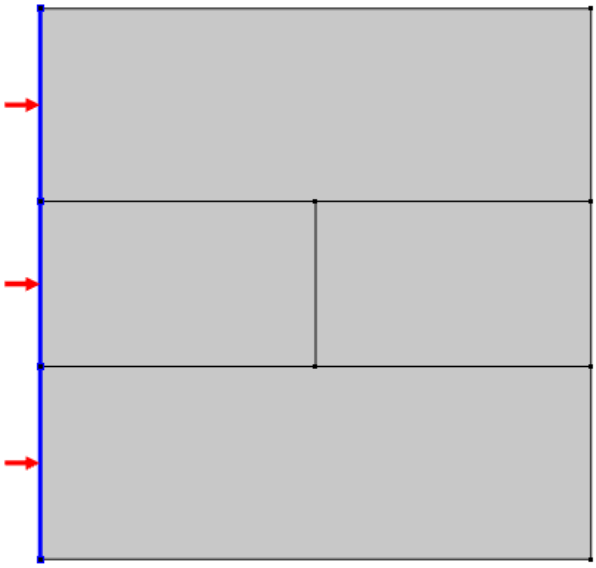

Fig (9). Port1 of the second structure.

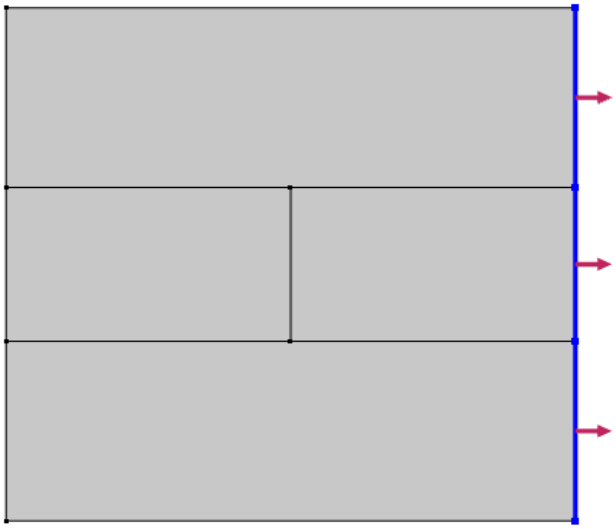

Fig (10). Port2 of the second structure.

Meshing:

Extremely fine meshing.

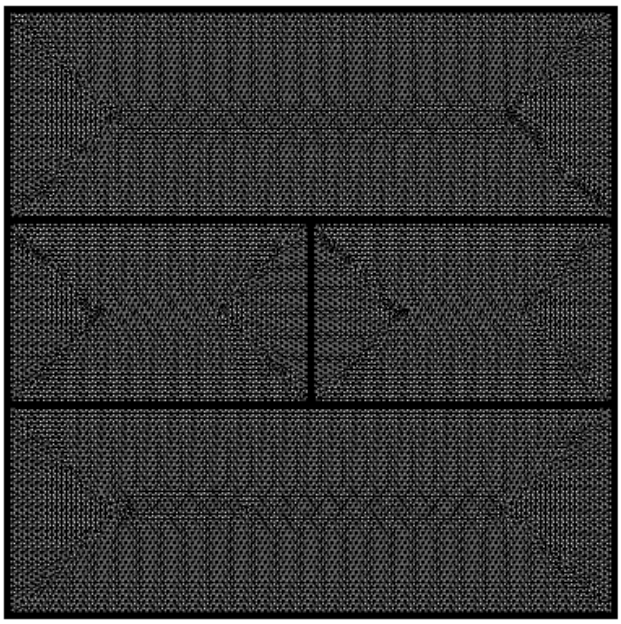

Fig (11). Meshing.

Results:

At the same frequency, the electric field components are plotted as shown in next two figures.

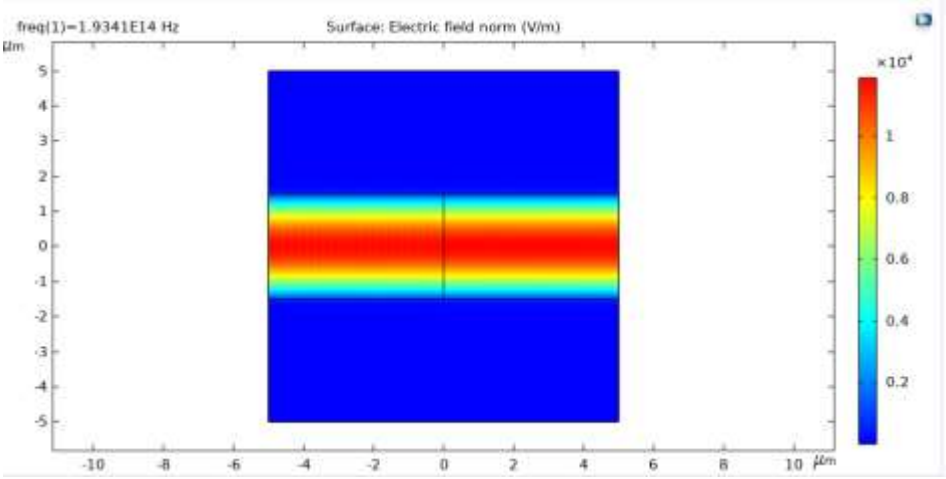


Fig (12). Normal electric field.

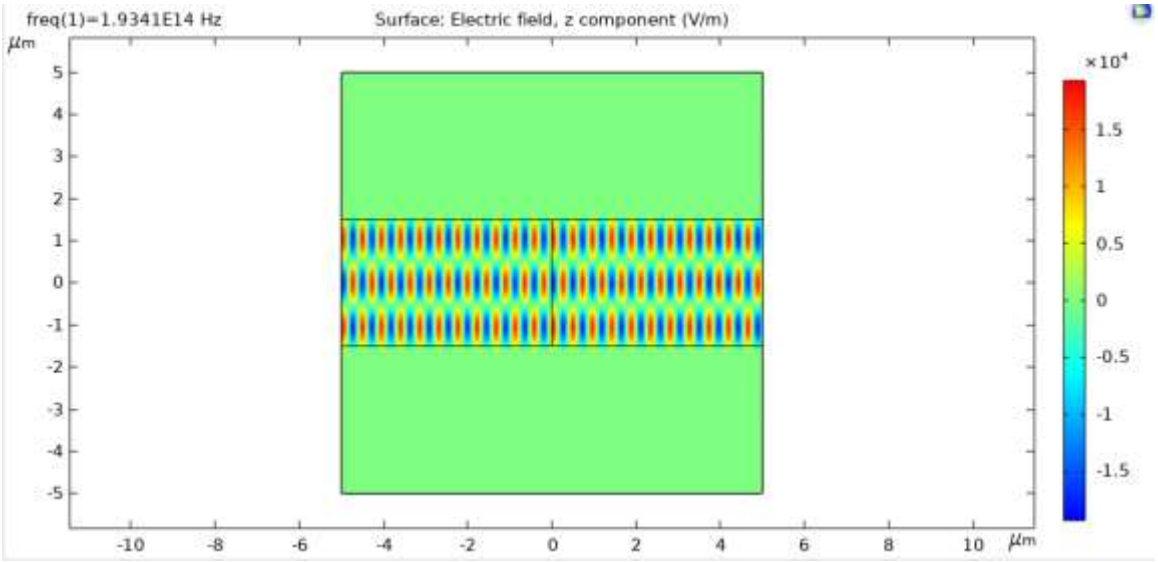


Fig (13). TM z-component electric field.

And for the reflection and transmission, it's noticed here that transmittance is less than 1 and reflection increased a small amount as shown in table2.

| freq (Hz) | abs(ewfd.S11) (1) | abs(ewfd.S21) (1) | Total reflectance (1) | Total transmittance (1) | Effective mode index (1) | Effective mode index (1) |
|---|---|---|---|---|---|---|
| 1.9341E14 | 0.0097183 | 0.99995 | 9.4445E-5 | 0.99991 | 3.4914 | 3.4312 |

Table (2). reflection and transmission

**Structure3:**

It has the same geometry of the last structure.

Materials:

Here the core materials are reversed as core is divided to core1 with n=3.44 and core2 with n=3.5.

Meshing:

The same meshing of the last structure.

Results:

At the same frequency, electric field is plotted and reflection and transmission are calculated.

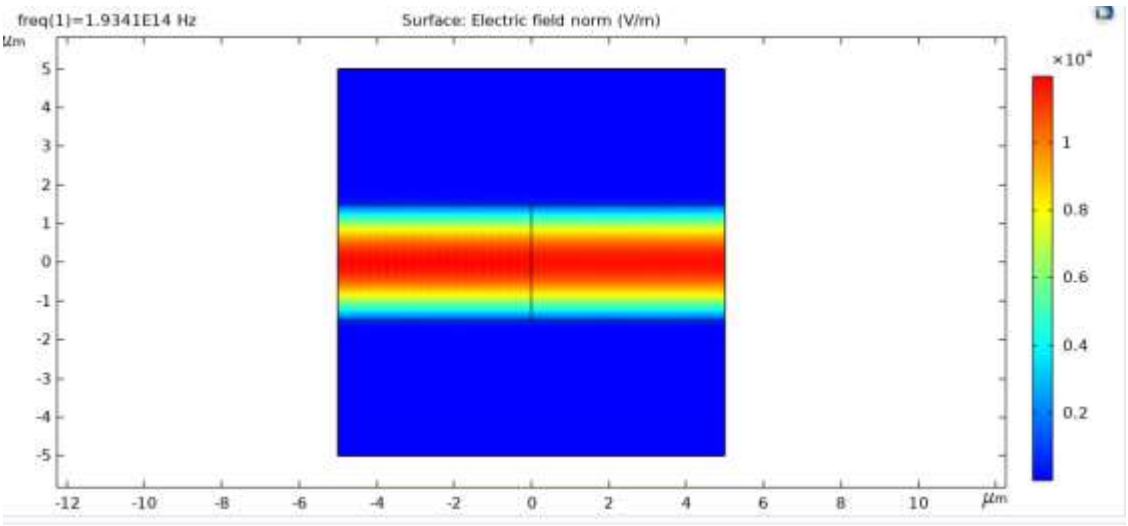


Fig (14). normal electric field of structure3.

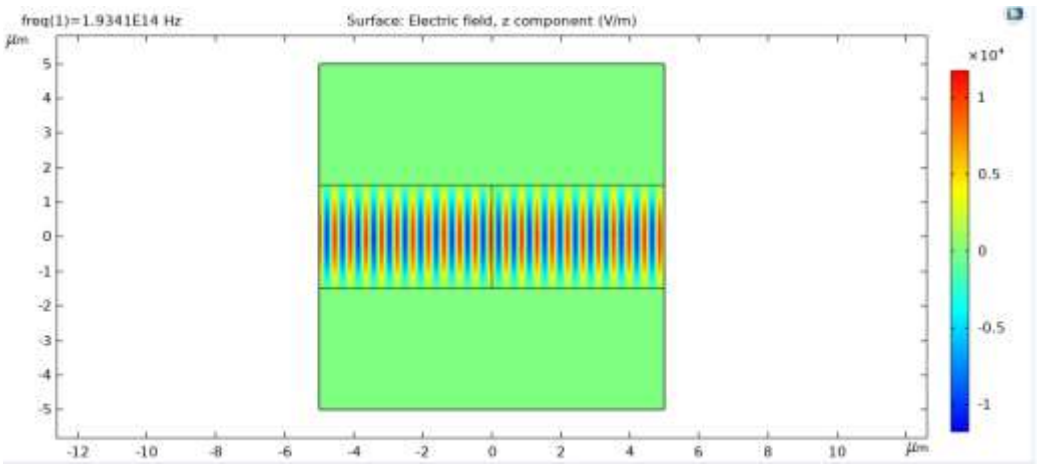


Fig (15).TM z-component electric field of structure3.

Table 3 shows reflection and transmission as transmission is reduced with a very small factor compared to structure2 values.

| freq (Hz) | abs(ewfd.S11) (1) | abs(ewfd.S21) (1) | Total reflectance (1) | Total transmittance (1) | Effective mode index (1) | Effective mode index (1) |
|---|---|---|---|---|---|---|
| 1.9341E14 | 0.010137 | 0.99995 | 1.0276E-4 | 0.99990 | 3.4312 | 3.4914 |

Table (3). reflection and transmittance

**Structure 4:**

Geometry:

core 1 is 3 um and second core is 2 um.

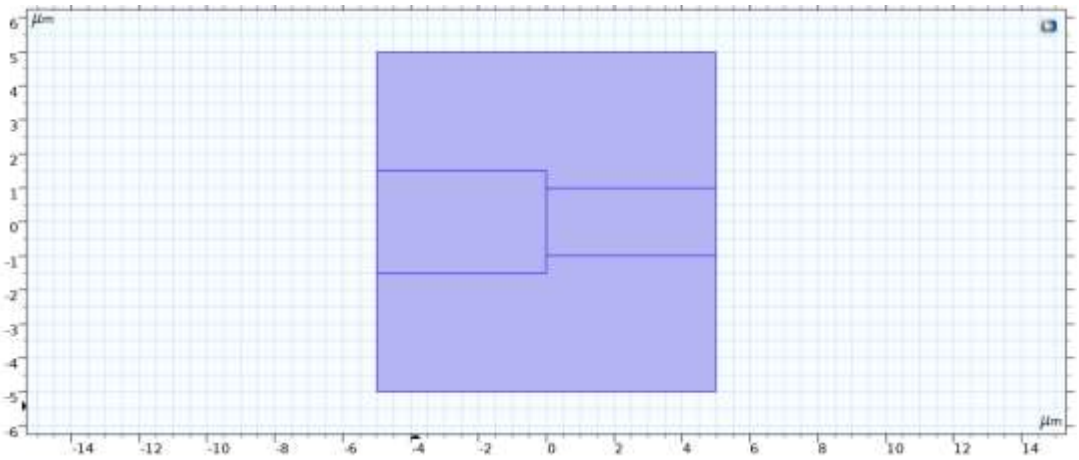

Fig (16). Structure4 geometry

Materials:

Same as the structure 3 materials as core is divided to core1 with n=3.44 and core2 with n=3.5.

Meshing:

Extremely fine meshing.

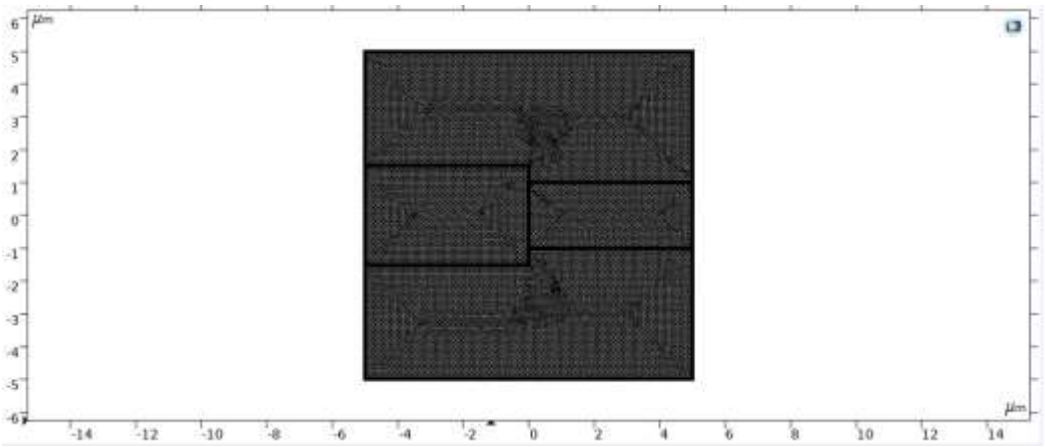

Fig (17). Structure4 meshing

Results:

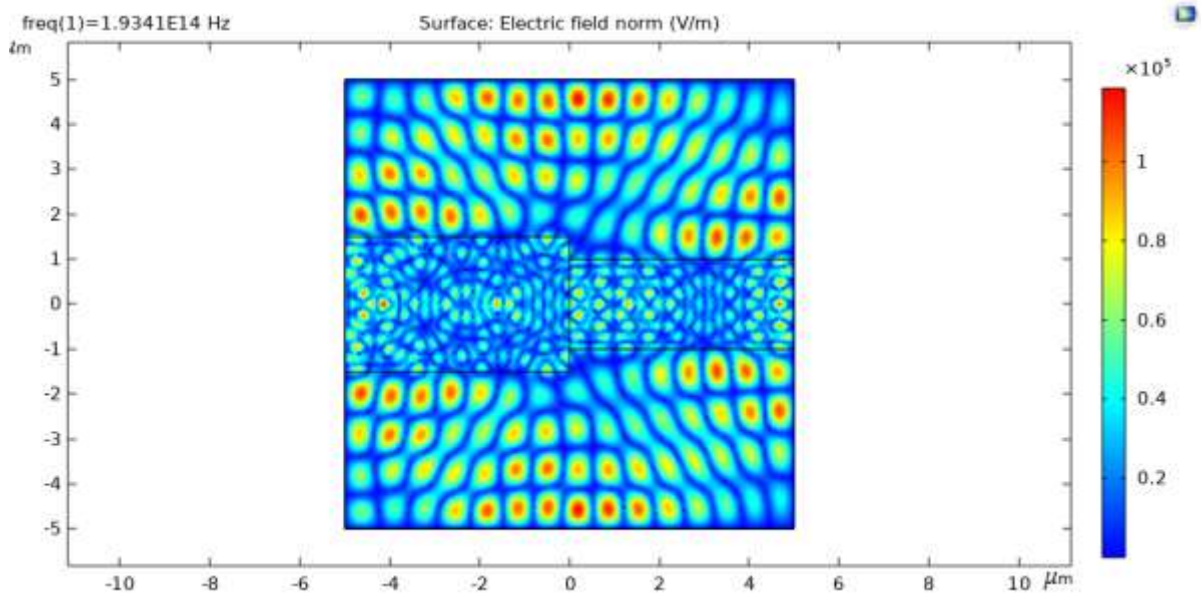


Fig (18). normal electric field of structure4.

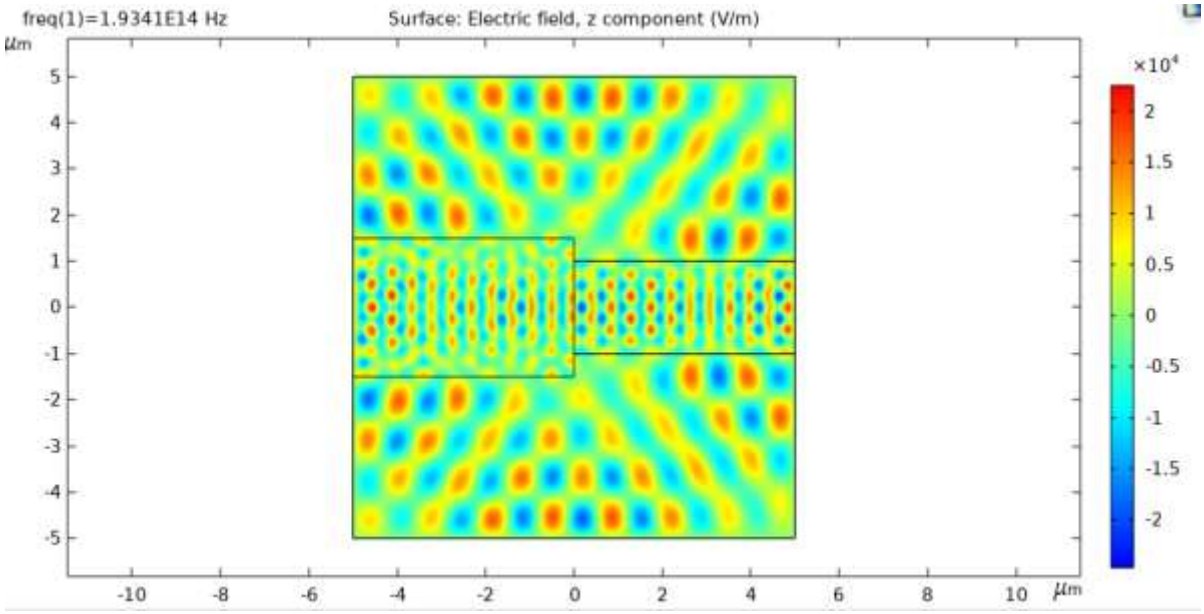


Fig (19).TM z-component electric field of structure4.

transmission and reflection are shown at table 4.

| freq (Hz) | abs(ewfd.S11) (1) | abs(ewfd.S21) (1) | Total reflectance (1) | Total transmittance (1) | Effective mode index (1) | Effective mode index (1) |
|---|---|---|---|---|---|---|
| 1.9341E14 | 0.32762 | 0.94481 | 0.10734 | 0.89266 | 3.4312 | 3.4815 |

Table4.transmission and reflection

In this structure due to the change in the geometry, it's noticed that reflection increased and transmission decreased in considerable values.

**Comment**:

In structure 1 we didn't face any reflection (or a very small value that can be neglected) due to the passage of wave in the same refractive index.

But in the next three structures where the wave pass form one index to another it faces the situation of partial transmittance of wave and pert of it get reflected back as the percentage of transmitted to reflected depend on the refractive index of the two materials passing through.

In a dielectric slab waveguide, as you go from a high refractive index core to a lower refractive index core, the transmittance generally decreases while the reflectance increases compared with the one with no change in the refractive index inside the core.

We can see the difference between structure 2 and 3 is that structure 3 transmittance is quite less than structure 2 transmittance as in structure 3 we go from less to higher refractive index core.

In structure 4, there is a change in the geometry we see the change in the transmittance is considerable and there is a value of reflection.