ZEWAIL CITY: UNIVERSITY OF SCIENCE AND TECHNOLOGY

Principles of Microwaves and Waveguides: Course Project Report

NANENG 430 – Spring 2020

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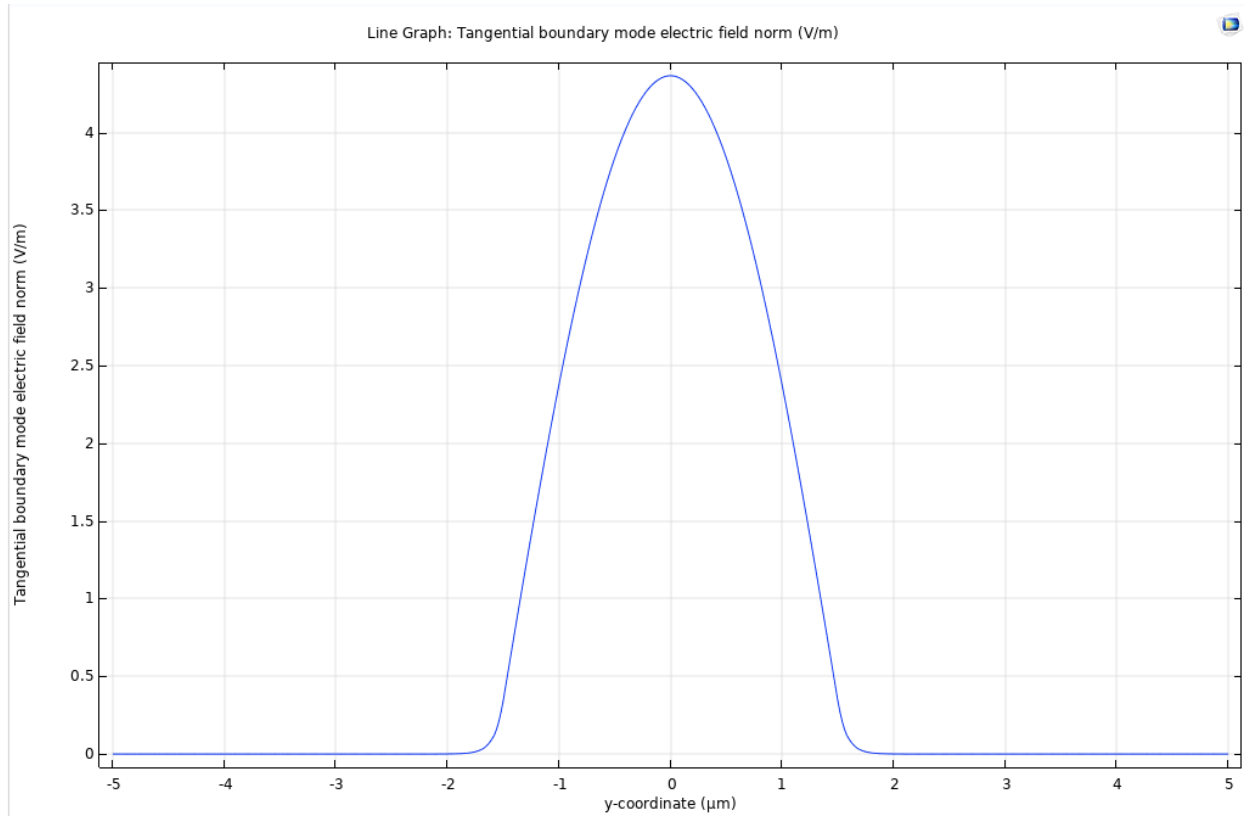**5/4/2020**

I.   Contents

II.   A)

A.   The Fundamental TM Mode at port 1:

Line Graph: Tangential boundary mode electric field norm (V/m)

B.   Global Evaluation settings

Settings

Global Evaluation

= Evaluate ▼

Label: Global Evaluation 2

▼ Data

Data set: Solution 1 (sol1)   ▼

Parameter selection (freq):   All   ▼

▼ Expressions   ✚ ▼   ▶ ▼

Expression	Unit	Description
abs(emw.S11)	dB	abs(emw.S11)
abs(emw.S21)	dB	abs(emw.S21)
emw.neff_1	1	Effective mode index
emw.neff_2	1	Effective mode index

C.   Table calculation

freq (1)	abs(emw.S11) (dB)	abs(emw.S21) (dB)	Effective mode index (1)	Effective mode index (1)	
1.9341448903225806E14	7.352880570194706E-4	0.9999997296757004	3.4312343239544405	3.431234323954441	

D.   Neff

$$neff = 3.4312343239544405$$

E.   Normalized Electric Field Intensity
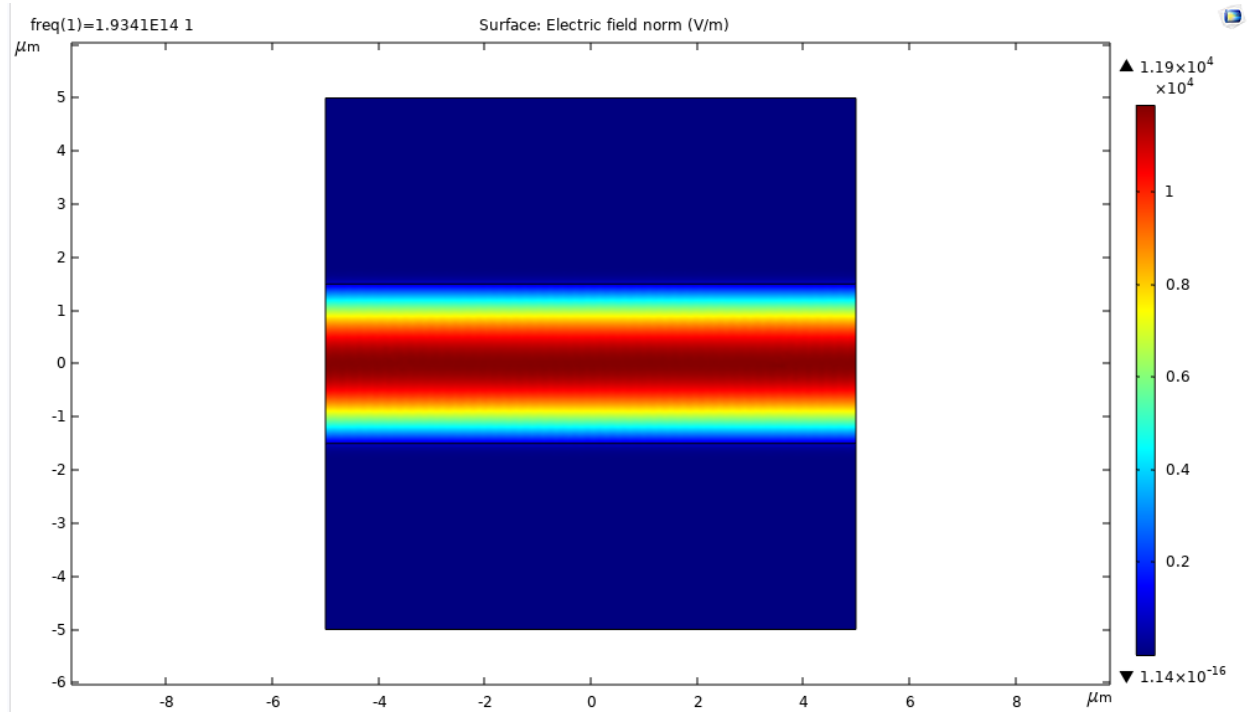
F.   Reflection and Transmission Calculations

$$abs(S_{11}) = 7.352880570194706E\text{-}4$$
$$abs(S_{21}) = 0.9999997296757004$$

G.   Comments

- The Neff calculated for all cases is that at the input port
- Neff is very close to the refractive index of the core material which is expected for a waveguide. This is explained in the normalized electric field plot as it is zero outside the waveguide. Accordingly, the electromagnetic wave is entirely enclosed in the waveguide, from the eq. $n_{eff} = \frac{c\beta}{\omega} = \frac{c\beta}{2\pi f}$, Neff depends on the wave parameters.
- S_{11} (reflection) is very small compared to S_{21} (transmission) which is very high explained as an outcome of the matching between the two cores (both have the same material and dimensions) so it is the same as having no middle interface (as shown) which perfectly guide the TM fundamental mode in the core with very high transmission.

III.   B)

### A.   The Fundamental TM Mode at port 1:
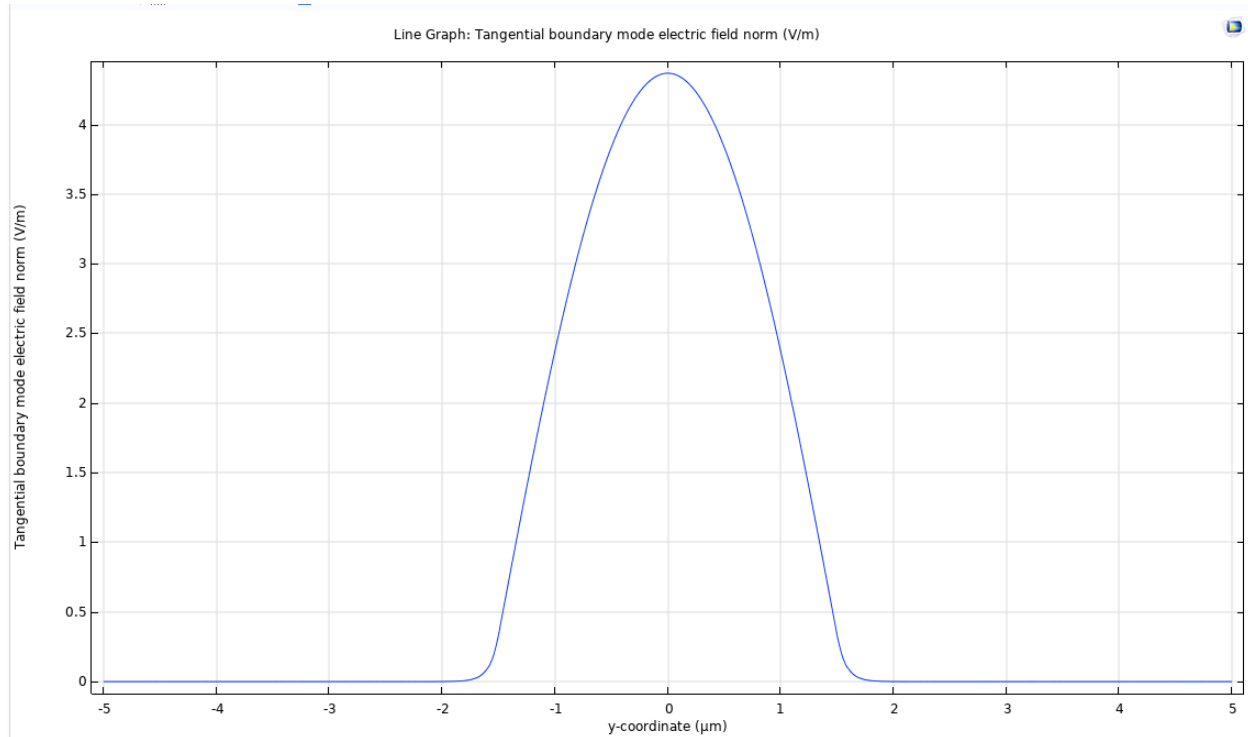
Line Graph: Tangential boundary mode electric field norm (V/m)

B.   Table calculation

freq (1)	abs(emw.S11) (dB)	abs(emw.S21) (dB)	Effective mode index (1)	Effective mode index (1)
1.9341448903225806E14	0.00971827686429086	0.9999527764323647	3.4913669737377515	3.431234323955028

C.   Neff

$$neff = 3.4913669737377515$$

D.   Normalized Electric Field Intensity
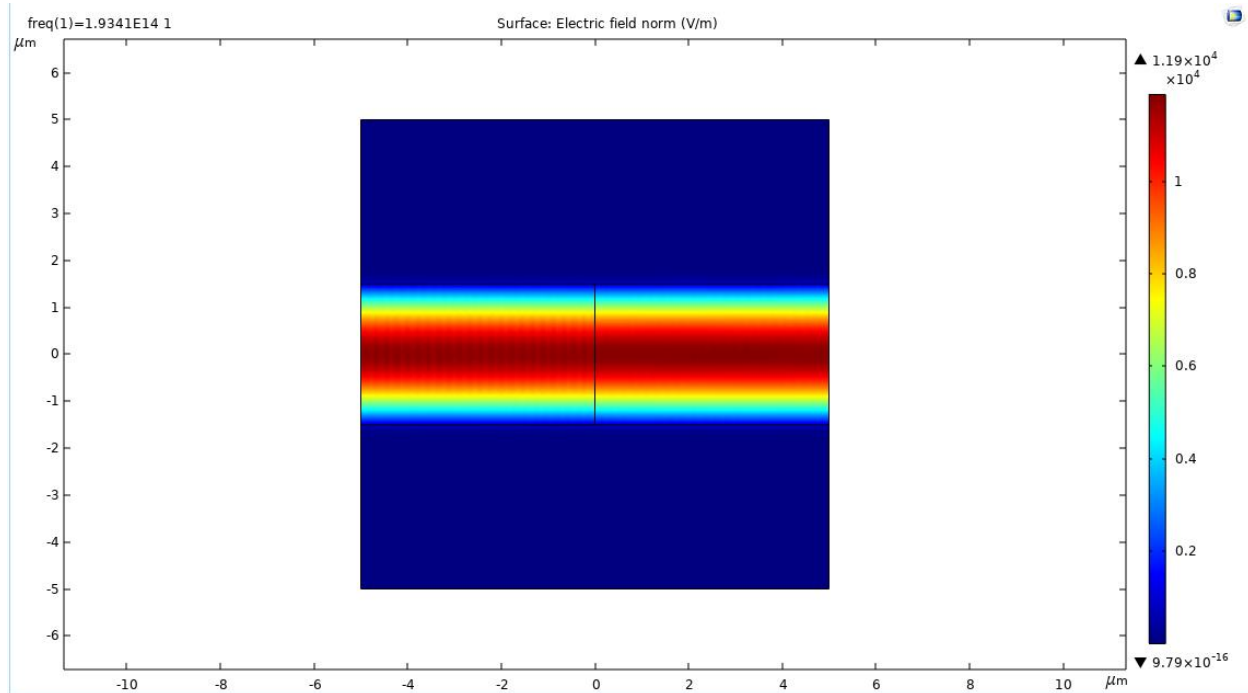
E.   Reflection and Transmission Calculations

$$abs(S11) = 0.00971827686429086$$
$$abs(S21) = 0.9999527764323647$$

F.   Comments

- Neff is very close to the refractive index of the first core material (left)
- Similar to case 1, $S11$ (reflection) is very small compared to $S21$ (transmission). However, it is higher than case 1 due to the slight difference between the two cores at the interface
- The high concentration of the norm E-field in the center of the waveguide shows that the waveguide achieves perfectly guided transmission of the TM fundamental mode in the cores with high efficiency
- The standing waves observed in the first core (Left) indicate the weak reflection that has taken place

IV.   C)

### A.   The Fundamental TM Mode at port 1:
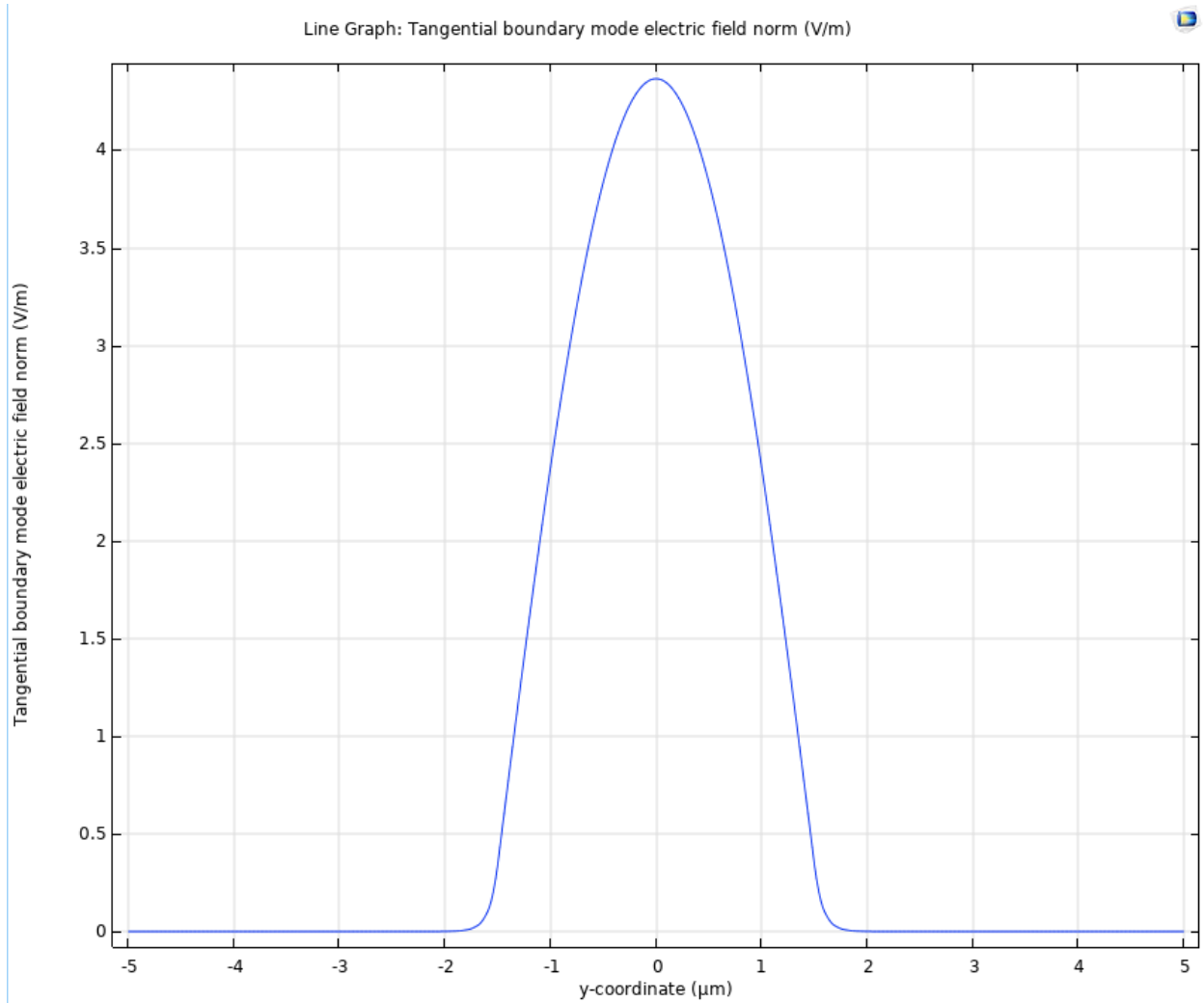
Line Graph: Tangential boundary mode electric field norm (V/m)

B.   Table calculation

freq (1)	abs(emw.S11) (dB)	abs(emw.S21) (dB)	Effective mode index (1)	Effective mode index (1)
1.9341448903225806E14	0.010136907187487994	0.999948620236395	3.4312343239550276	3.49136697373775533

C.   Neff

$$neff = 3.4312343239550276$$

D.   Normalized Electric Field Intensity
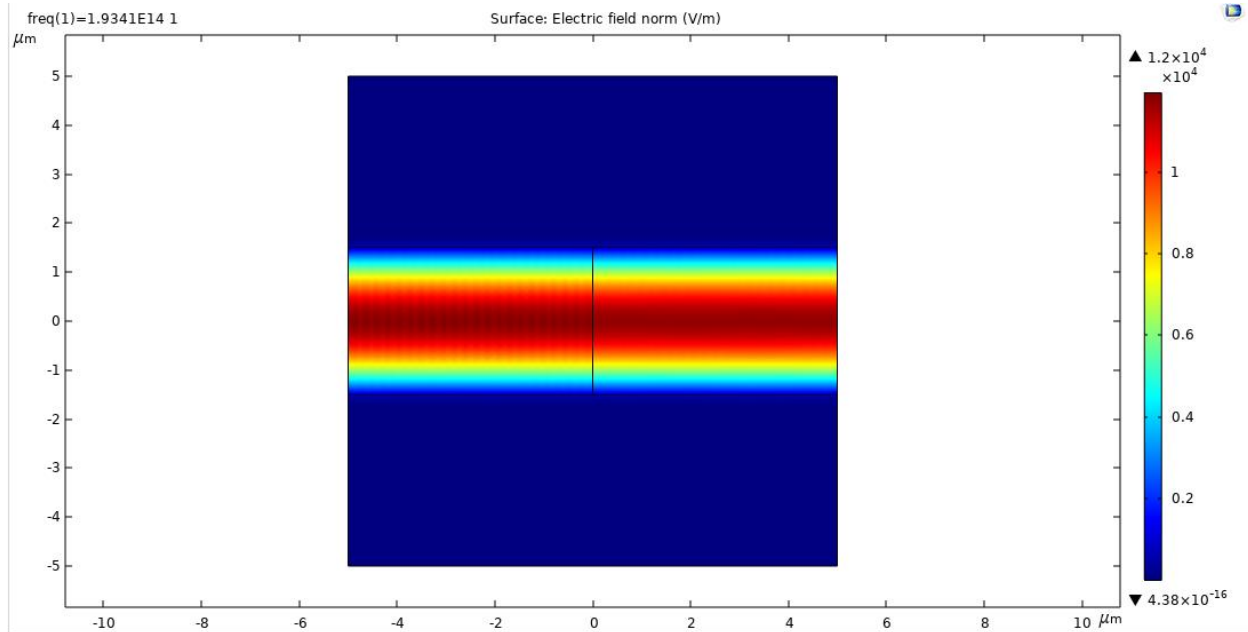
E.   Reflection and Transmission Calculations
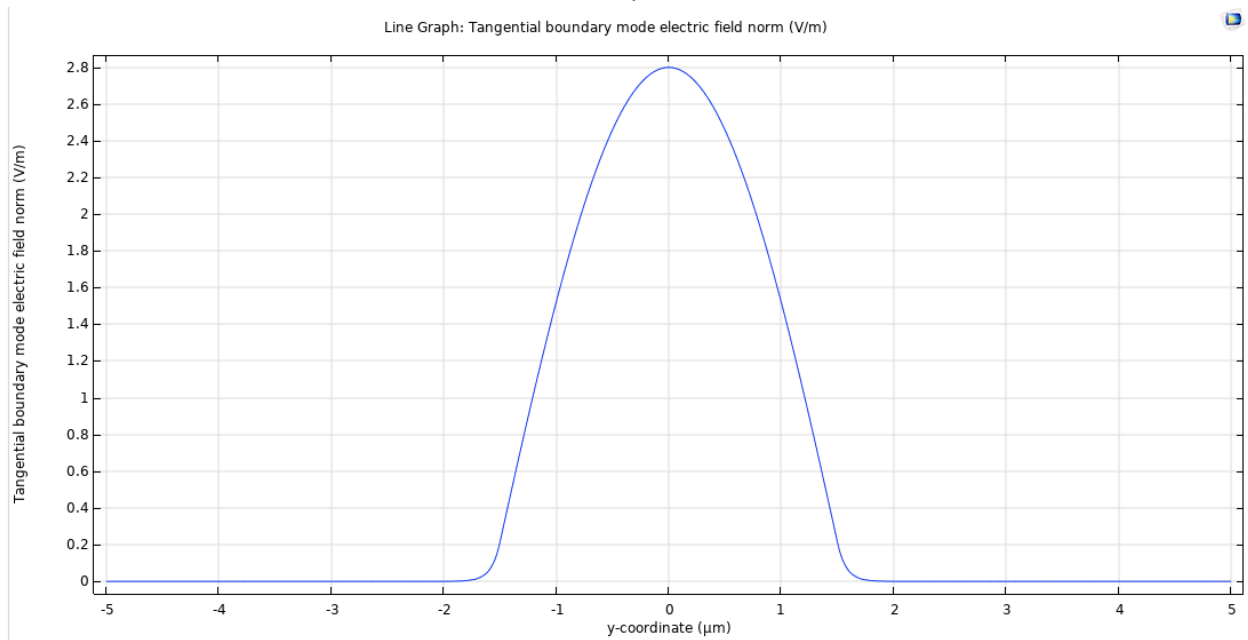
$$abs(S_{11}) = 0.010136907187487994$$
$$abs(S_{21}) = 0.999948620236395$$

F.   Comments

- Neff is very close to the refractive index of the first core material (left)
- Similar to case 1, S_{11} (reflection) is very small compared to S_{21} (transmission). However, it is higher than case 1 due to the slight difference between the two cores at the interface
- The high concentration of the norm E-field in the center of the waveguide shows that the waveguide achieves perfectly guided transmission of the TM fundamental mode in the cores with high efficiency
- The standing waves observed in the first core (Left) indicate the weak reflection that has taken place
- There is almost no difference than results shown in case 2, except that effective mode calculation (1 & 2) are swapped in this case compared to case 2 which is expected.

V.   D)

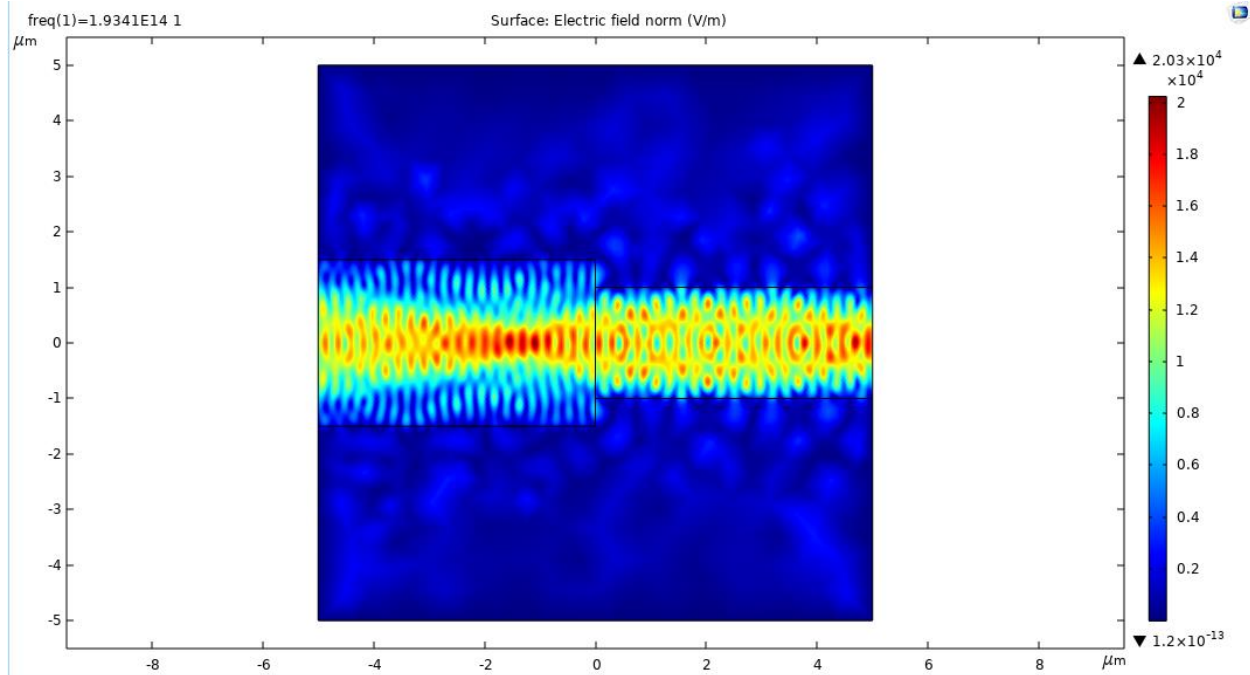### A.   The Fundamental TM Mode at port 1:

Line Graph: Tangential boundary mode electric field norm (V/m)

B.   Table calculation

freq (1)	abs(emw.S11) (1)	abs(emw.S21) (1)	emw.neff_1 (1)	emw.neff_2 (1)
1.9341448903225806E14	0.07004469984662373	0.9975438536843331	3.4913680764793864	3.4212065450565916

C.   Neff

$$neff = 3.4913680764793864$$

D.   Normalized Electric Field Intensity

E.   Reflection and Transmission Calculations

$$abs(S_{11}) = 0.07004469984662373$$
$$abs(S_{21}) = 0.9975438536843331$$

F.   Comments

- Neff is very close to the refractive index of the first core material (left)
- Compared to other cases, some power is dissipated outside the waveguide in this case so not perfectly guided in this structure
- Since the structure is not uniform as in previous cases, the E-field norm is also not uniform
- It is worth mentioning, sum of reflection and transmission values do not sum to 1 (S_{11}+ S_{21} = 1.06758855353) which is an indicator that there is mismatch between the two cores