

Edge Coupler

Moisés de Araújo Oliveira

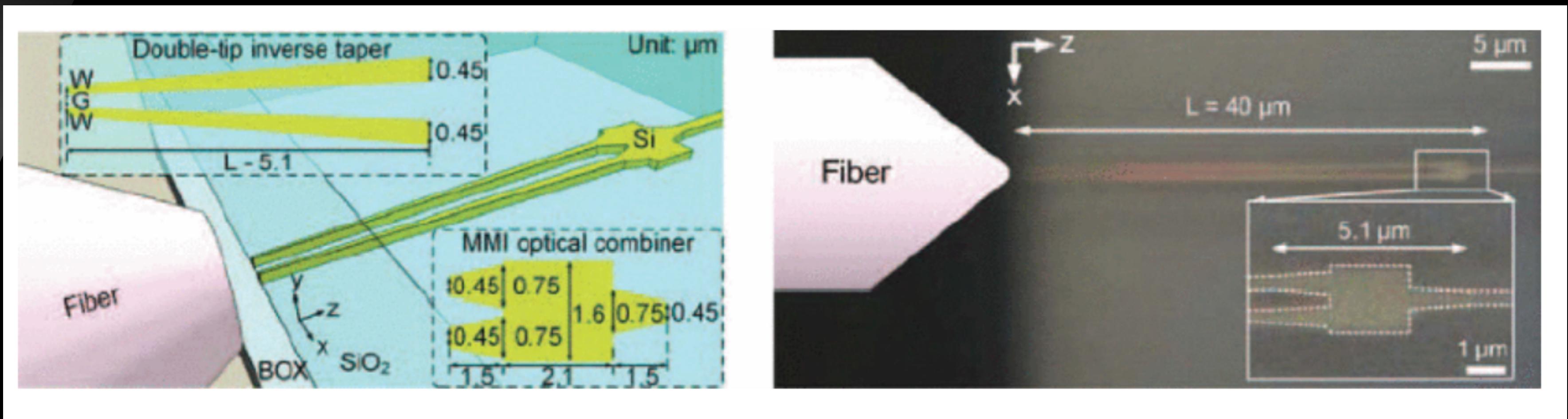
Referência

J. Wang et al., "Low-loss and misalignment-tolerant fiber-to-chip edge coupler based on double-tip inverse tapers," 2016 Optical Fiber Communications Conference and Exhibition (OFC), Anaheim, CA, USA, 2016, pp. 1–3.

Double-tip Inverse Taper

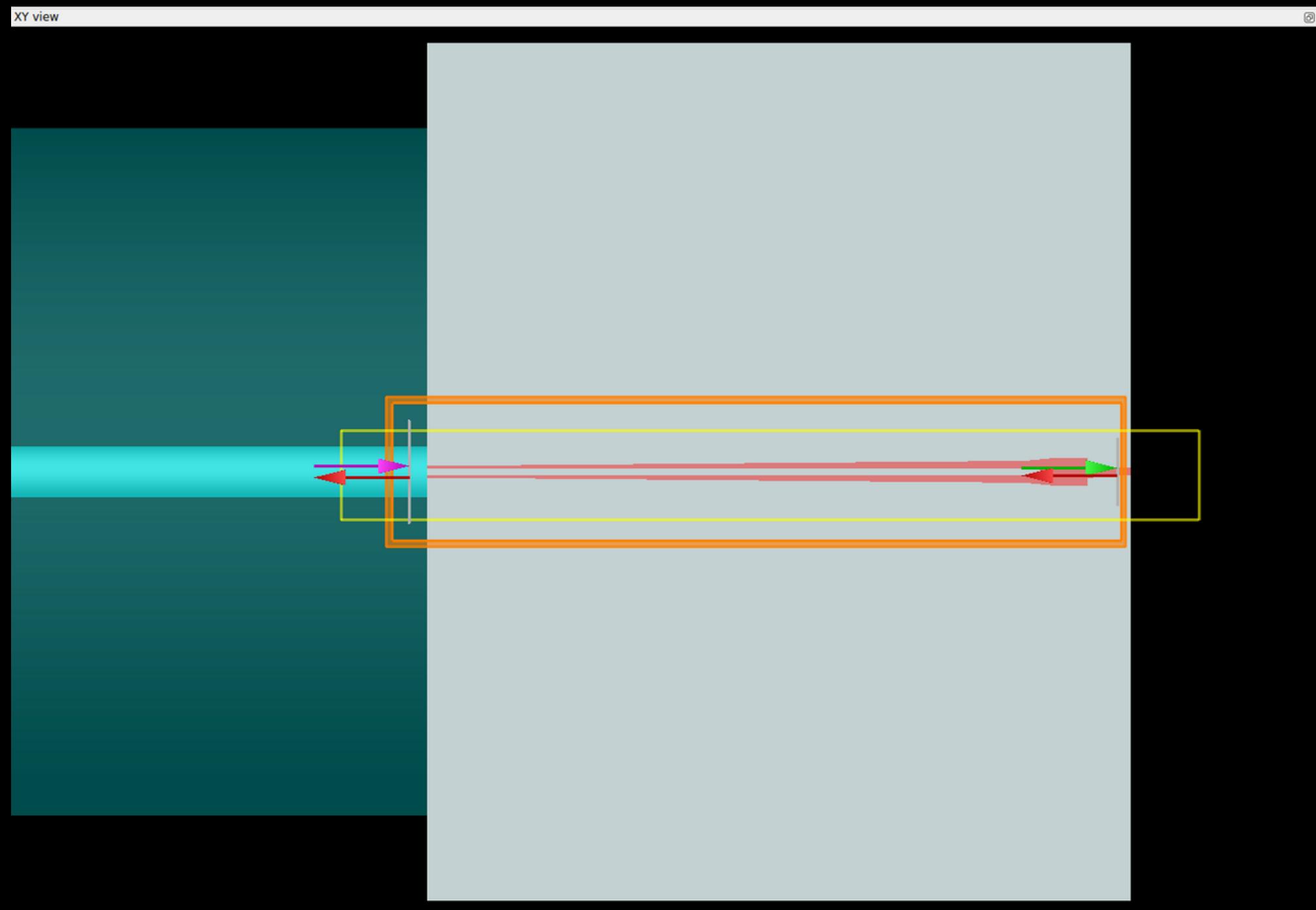
- maior grau de liberdade para design
- maior coeficiente de acoplamento
- tolerância ao desalinhamento
-

Design



semana 1

Design - FDTD



FDTD SETTINGS

name FDTD

General Geometry Mesh settings Boundary conditions Advanced options

dimension 3D
simulation time (fs) 1200
simulation temperature (K) 300

background material <Object defined dielectric>
index 1

name FDTD

General Geometry Mesh settings Boundary conditions Advanced options

PML settings

x min bc	PML
x max bc	PML
y min bc	PML
y max bc	PML
z min bc	PML
z max bc	PML

allow symmetry on all boundaries

Bloch boundary conditions

set based on source angle
bloch units bandstructure
kx
ky
kz

extend structure through pml
 auto scale pml parameters

name FDTD

General Geometry Mesh settings Boundary conditions Advanced options

x (μm) 19.25 x min (μm) -2
x span (μm) 42.5 x max (μm) 40.5

y (μm) 0 y min (μm) -4
y span (μm) 8 y max (μm) 4

z (μm) 0 z min (μm) -5
z span (μm) 10 z max (μm) 5

General Geometry Mesh settings Boundary conditions Advanced options

mesh type auto non-uniform
Mesh accuracy

mesh accuracy 5

High accuracy.
Please check memory requirements before running simulations.

Time step

dt stability factor 0.99
dt (fs) 0.0367515

Minimum mesh step settings

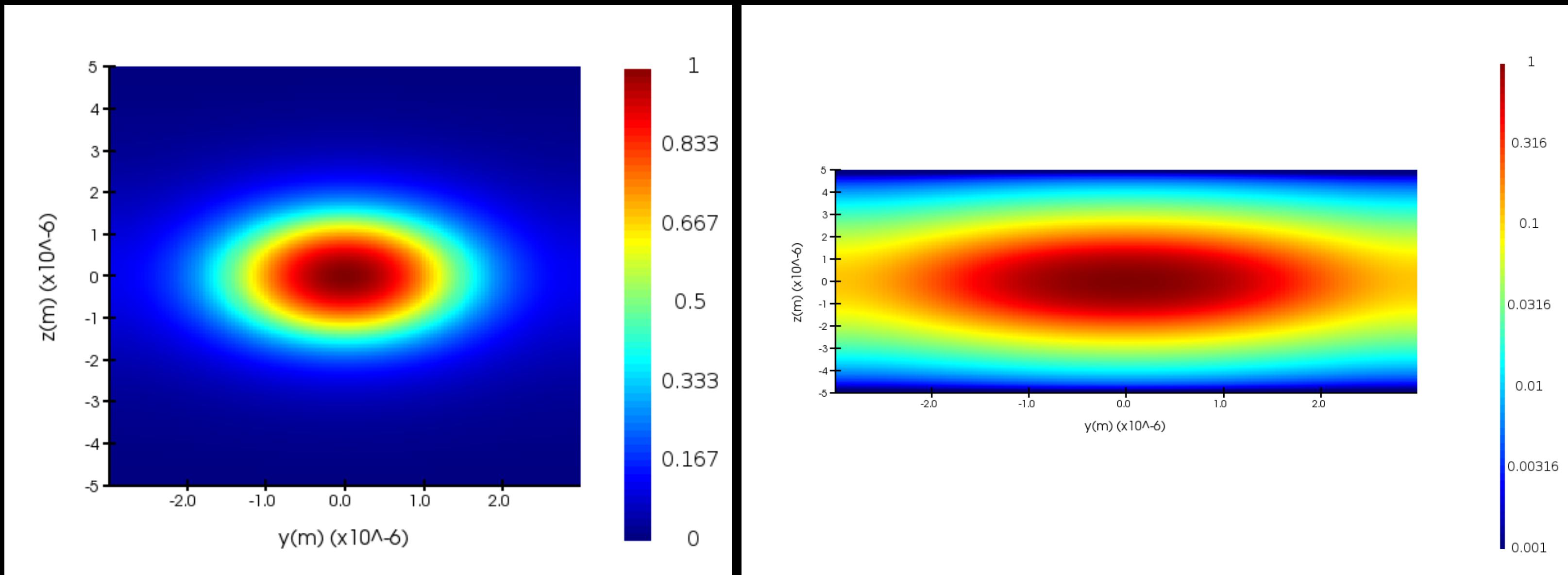
min mesh step (μm) 0.00025

Mesh refinement

mesh refinement conformal variant 0

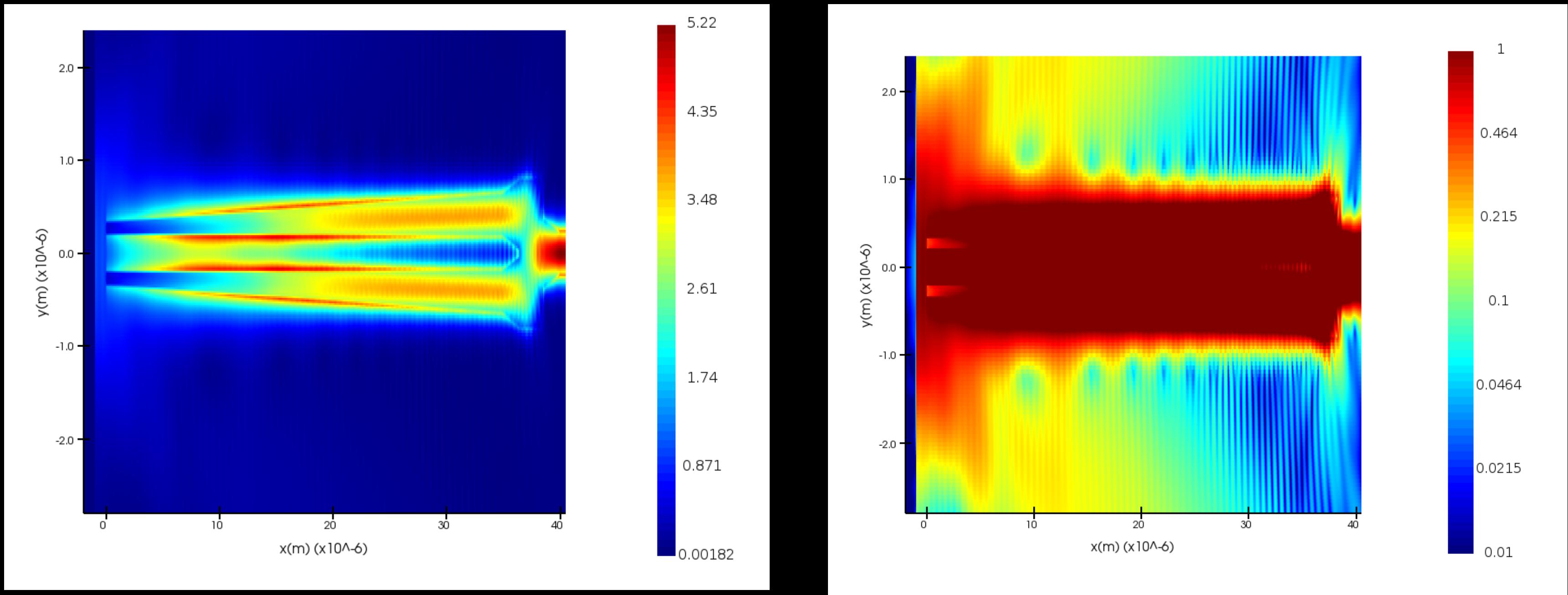
[How do I choose?](#)

TE MODE INPUT FIELD IN THE FIBER

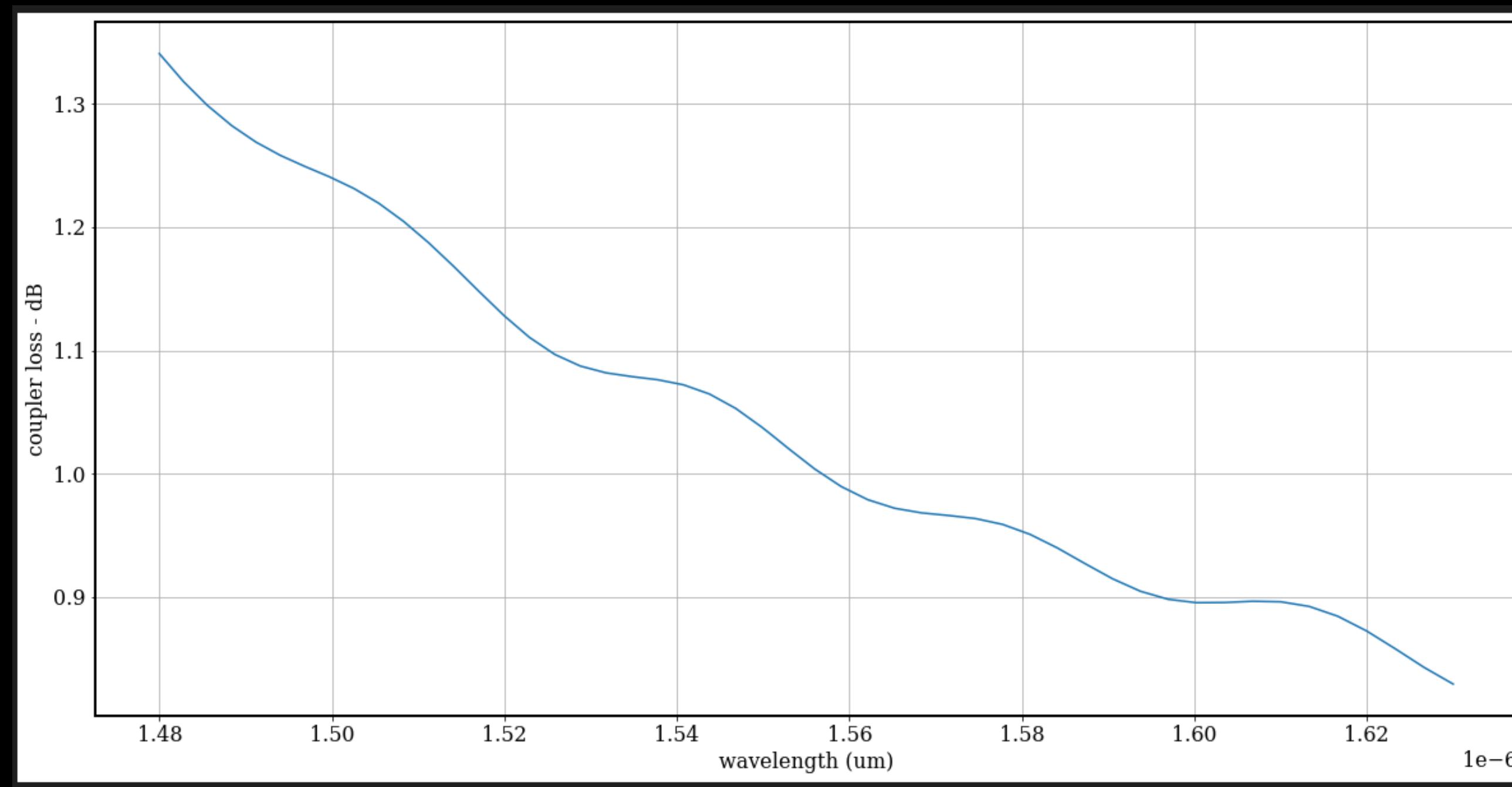


y span = 6 um
z span = 10 um

DISTRIBUIÇÃO DE CAMPO

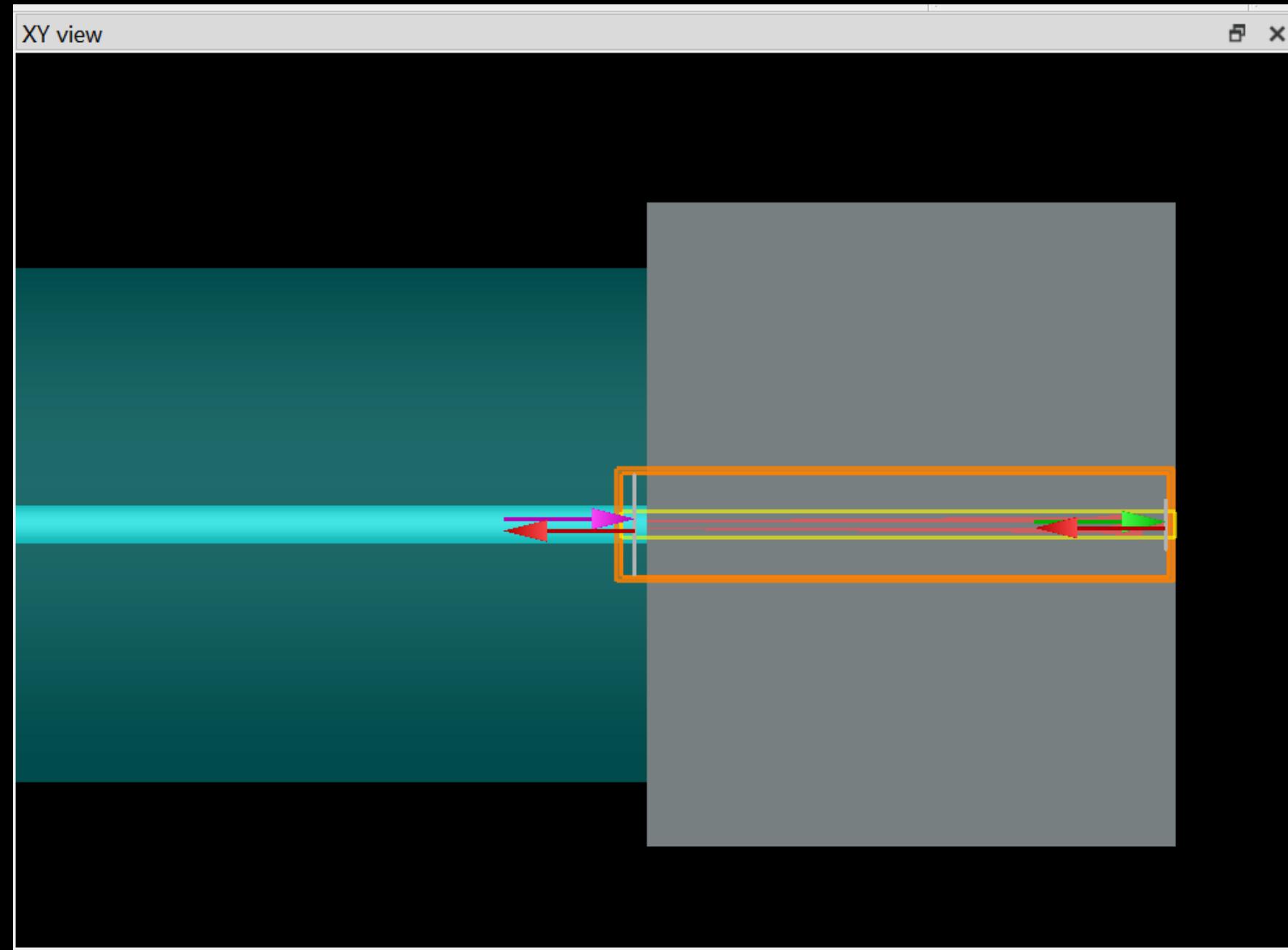


COUPLING LOSS



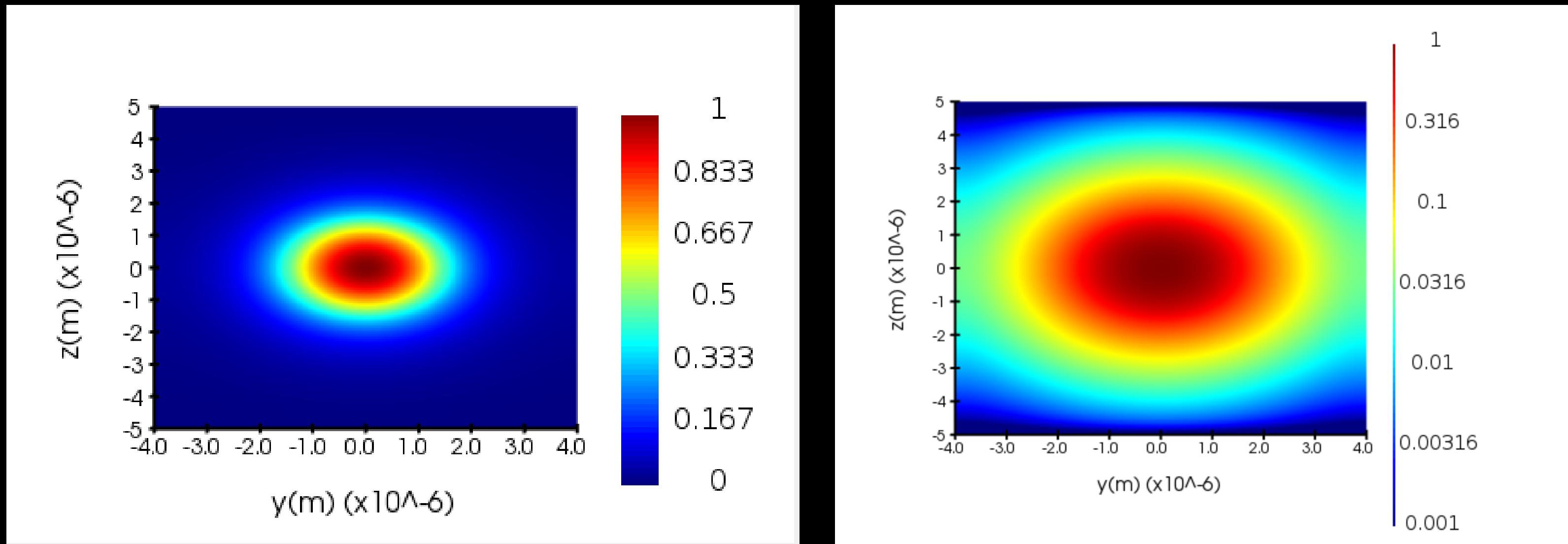
semana 2

06/03 - 17/03



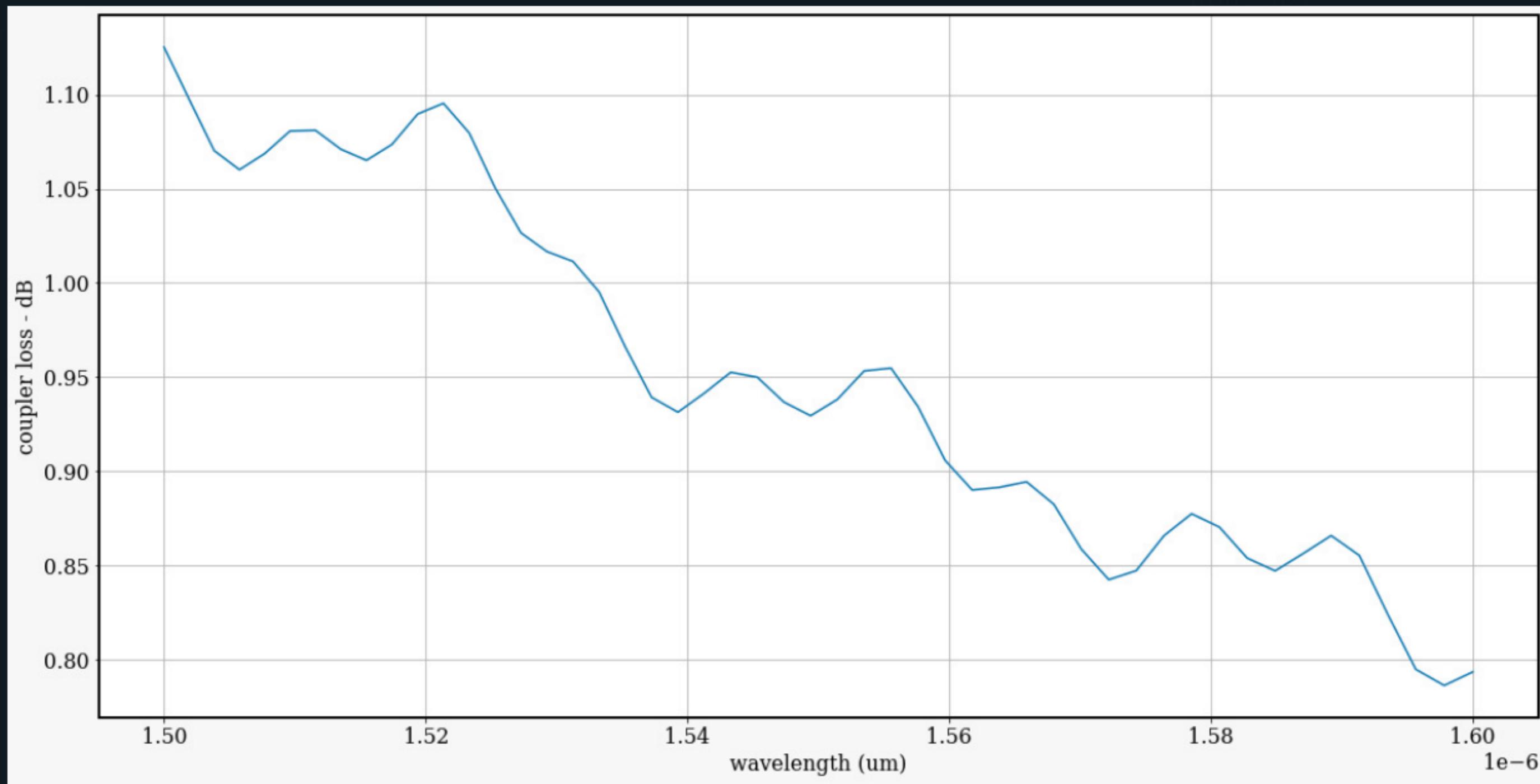
- o yspan da porta de entrada foi aumentada para 8um
- a condição de fronteira para z min foi mudada para symmetric
- o mesh utilizado foi de 5

TE MODE INPUT FIELD IN THE FIBER



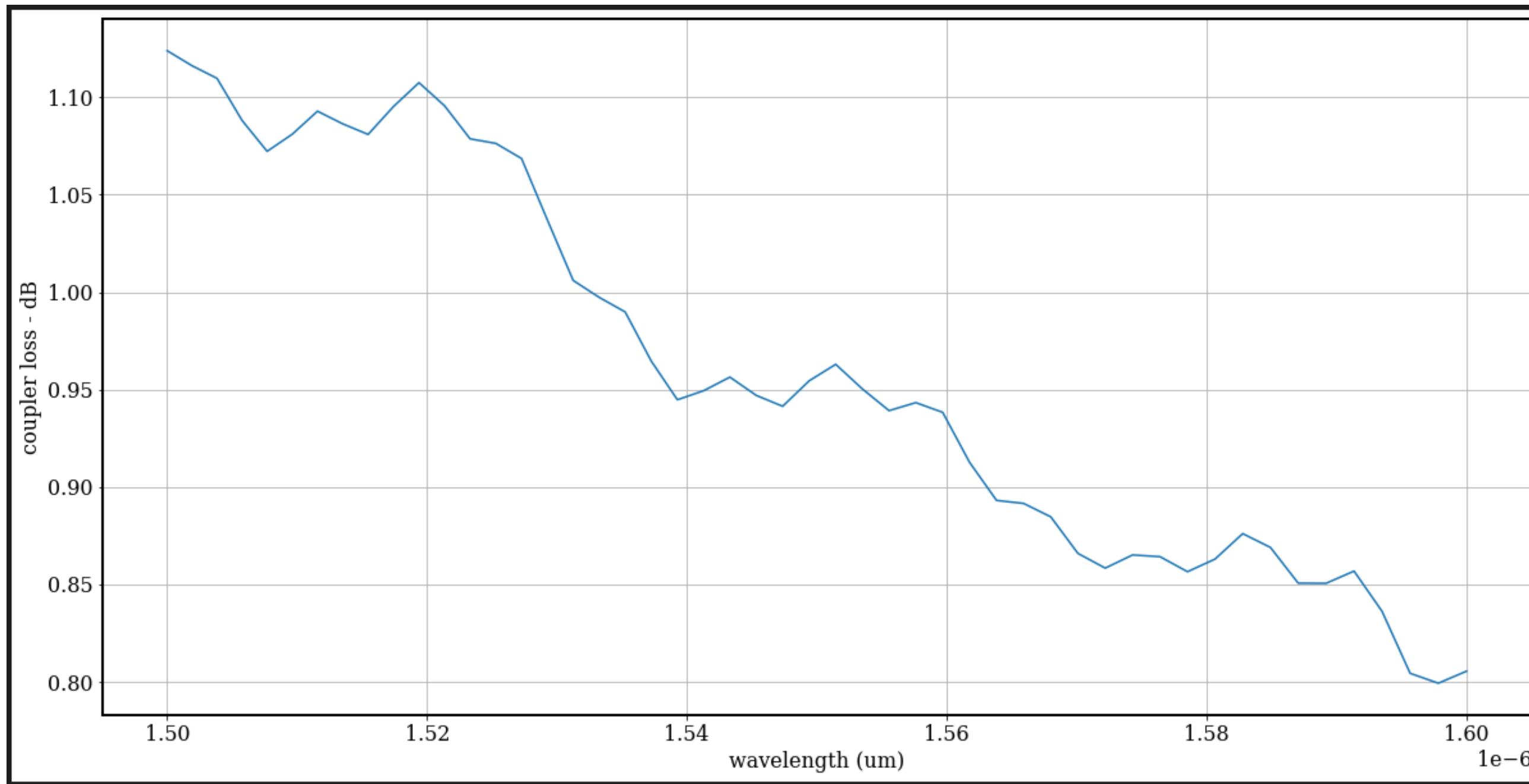
y span = 8 um
z span = 10 um

COUPLING LOSS



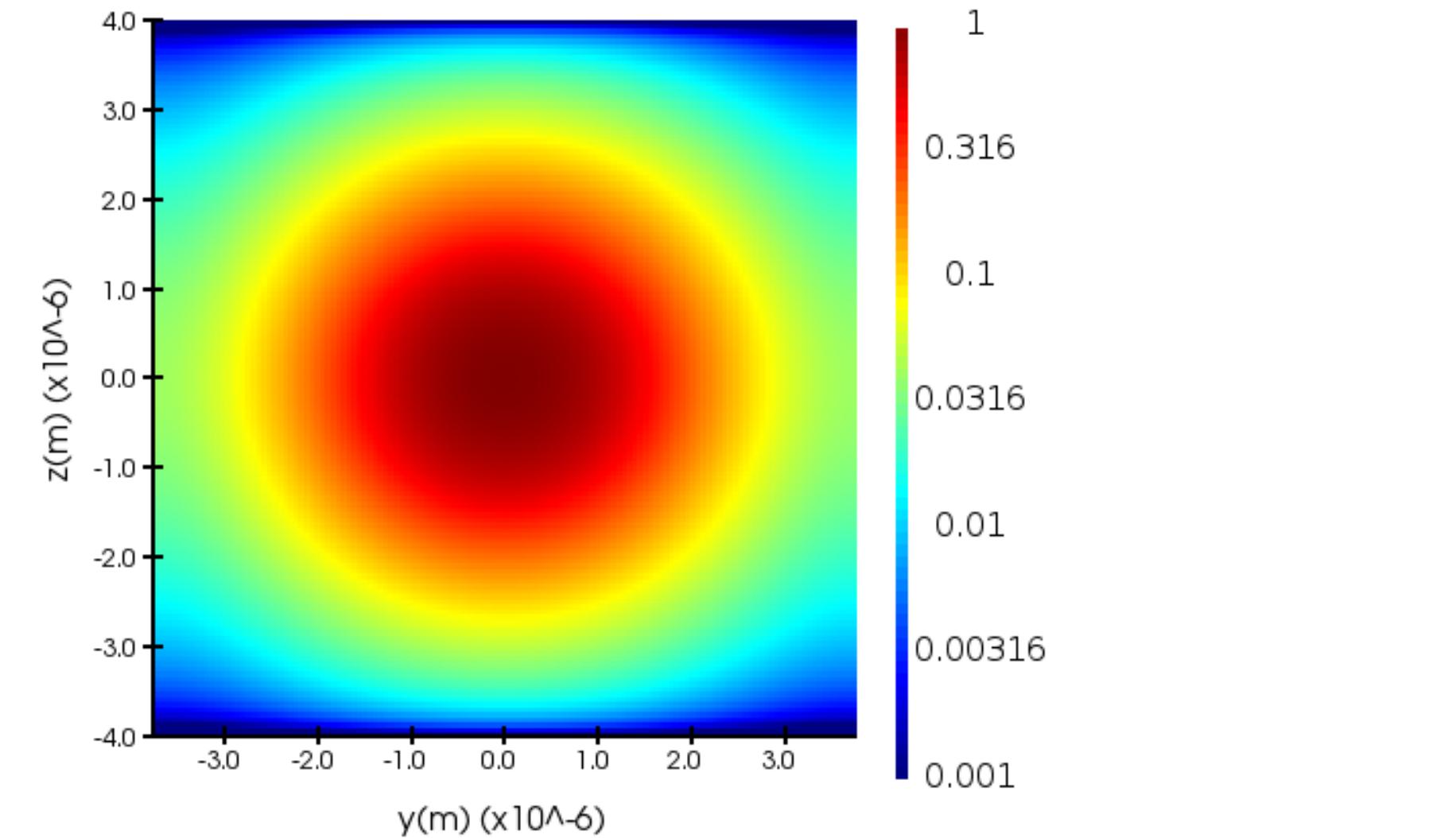
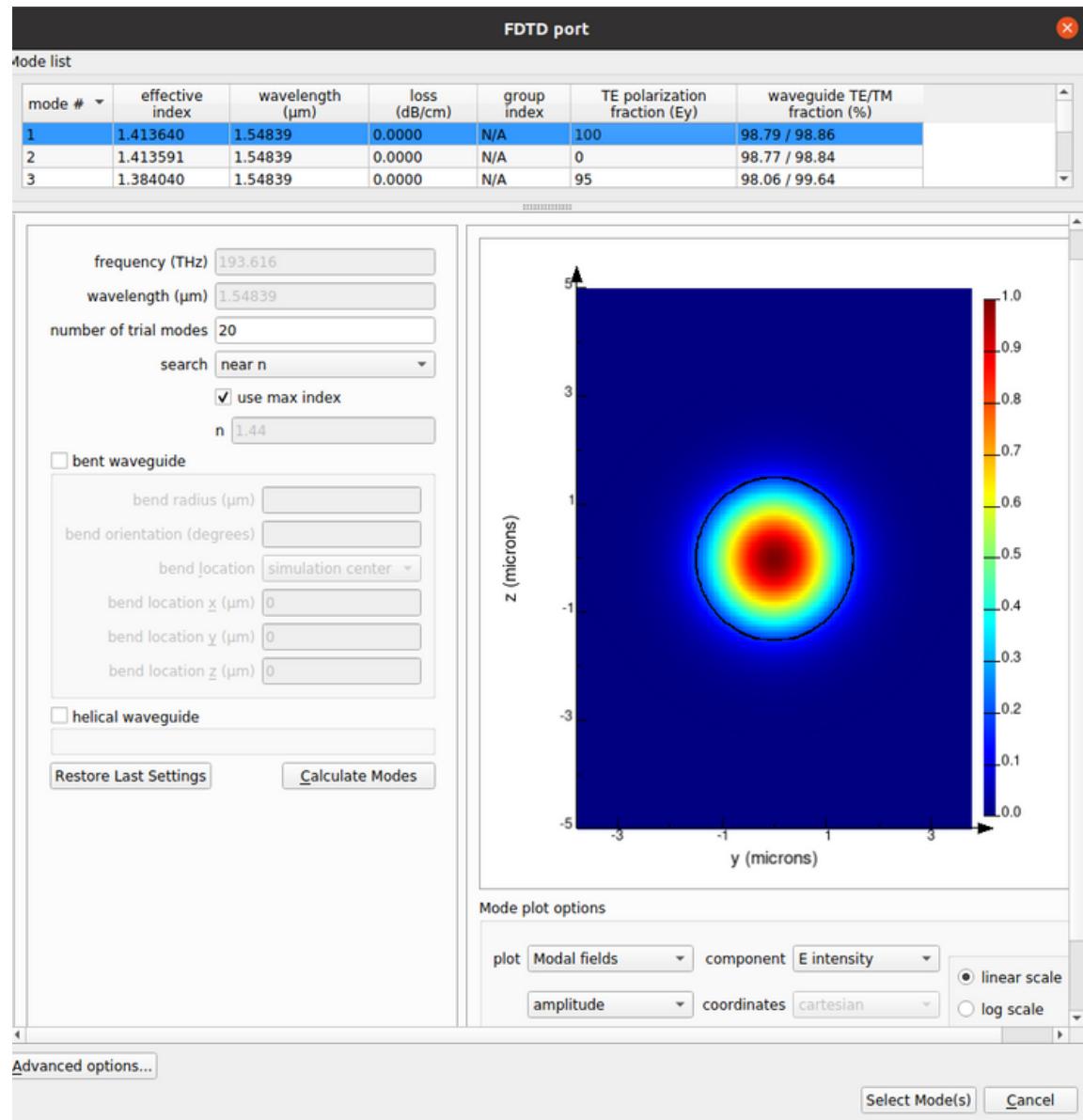
- o autoshutoff level foi de $5e-4$
- simulation time estava em 1200 fs
- o problema para esse caso foi a convergência da simulação

- **setando o DT STABILITY FACTOR para 0.95**
- **aumentando o simulation time para 1500 fs**

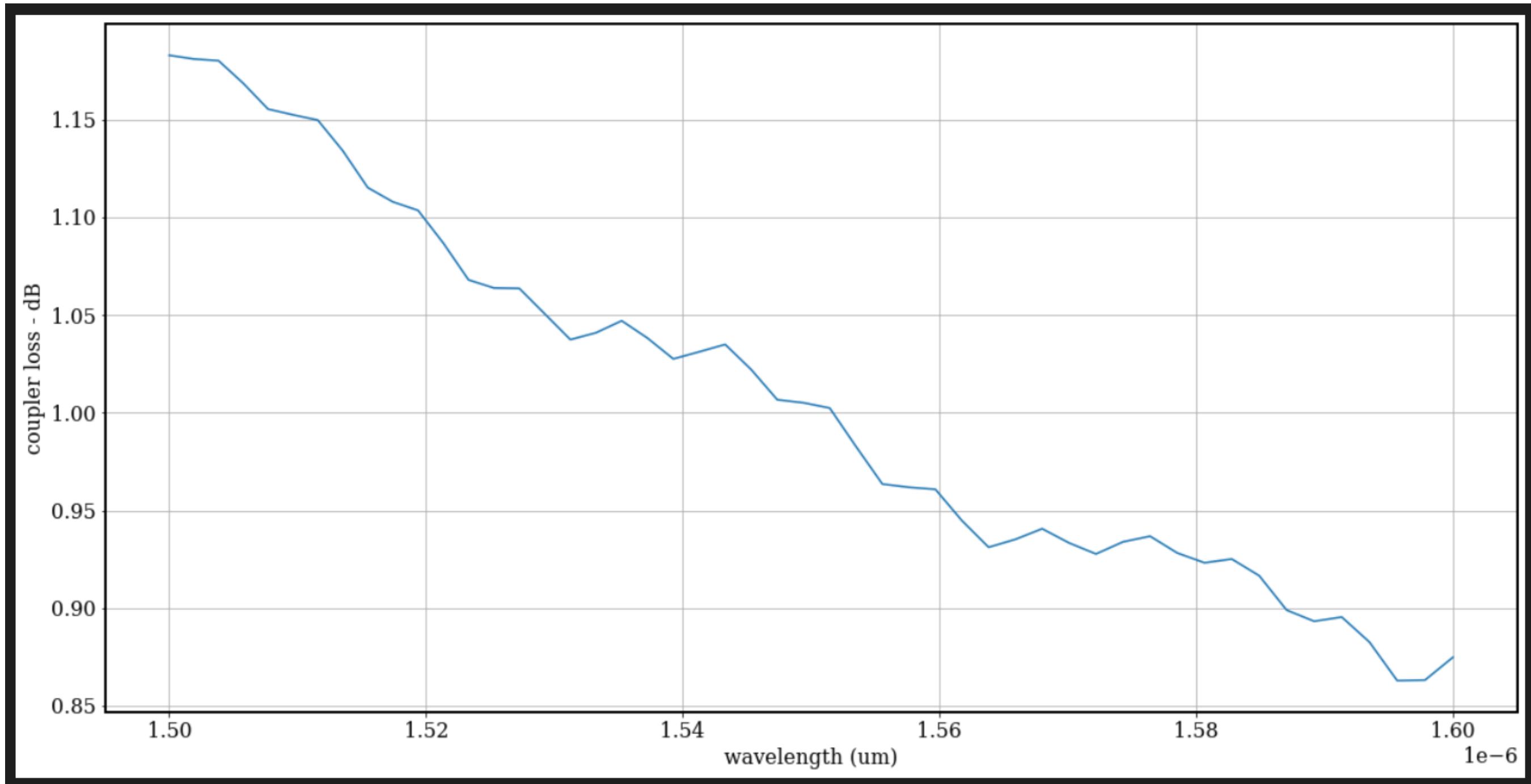


- **o autoshutoff level foi de 3.3e-4**
- **mais uma vez temos um problema na convergência**

- **mudando o zspan da porta de excitação para 8um**
- **setando a condição de fronteira em zmin para PML**



- **setando o mesh para 3**
- **deixando o simulation time em 1500 fs**
- **DT stability factor em 0.99**

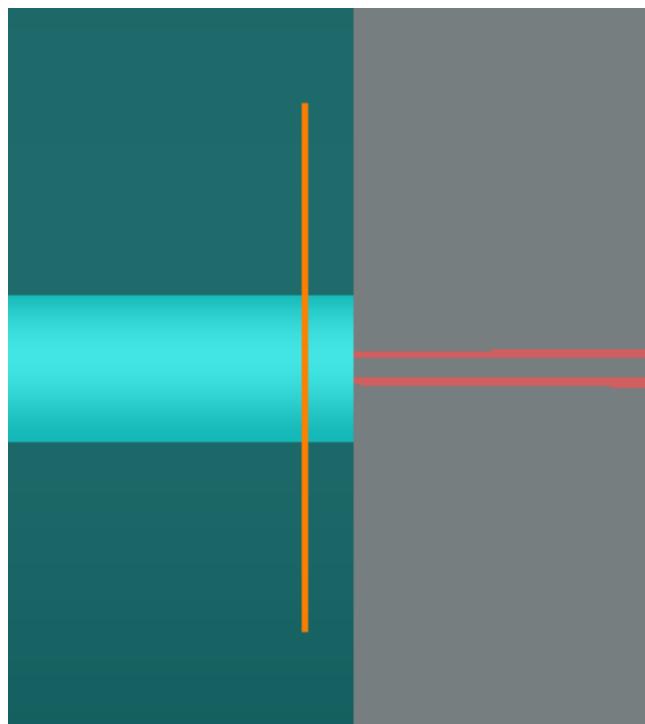


- o autosutoff level foi em torno de 2.2e-4
- mais uma vez temos um problema na convergência

SEMANA 3

17/03 - 24/03

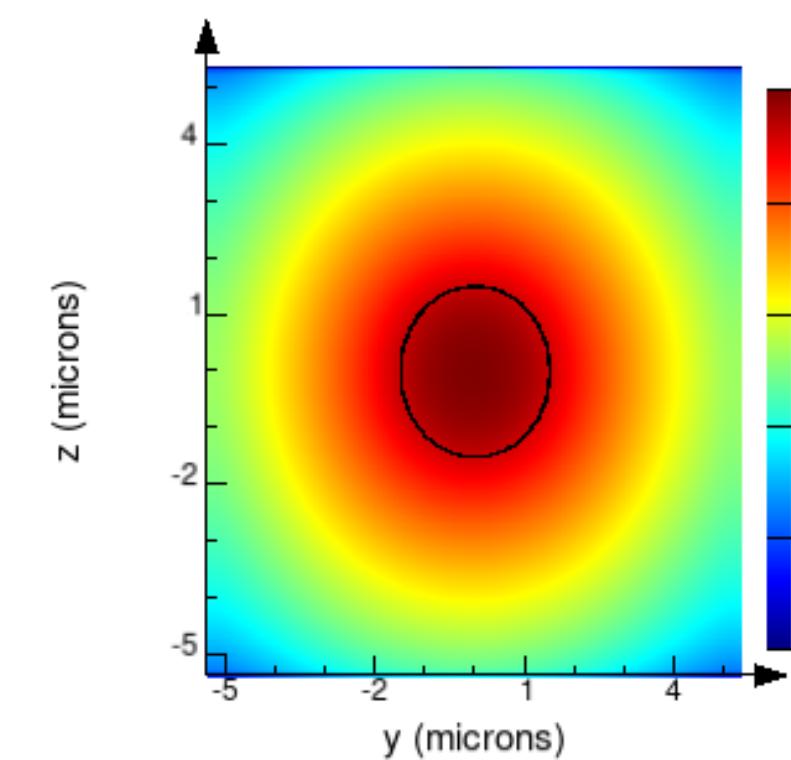
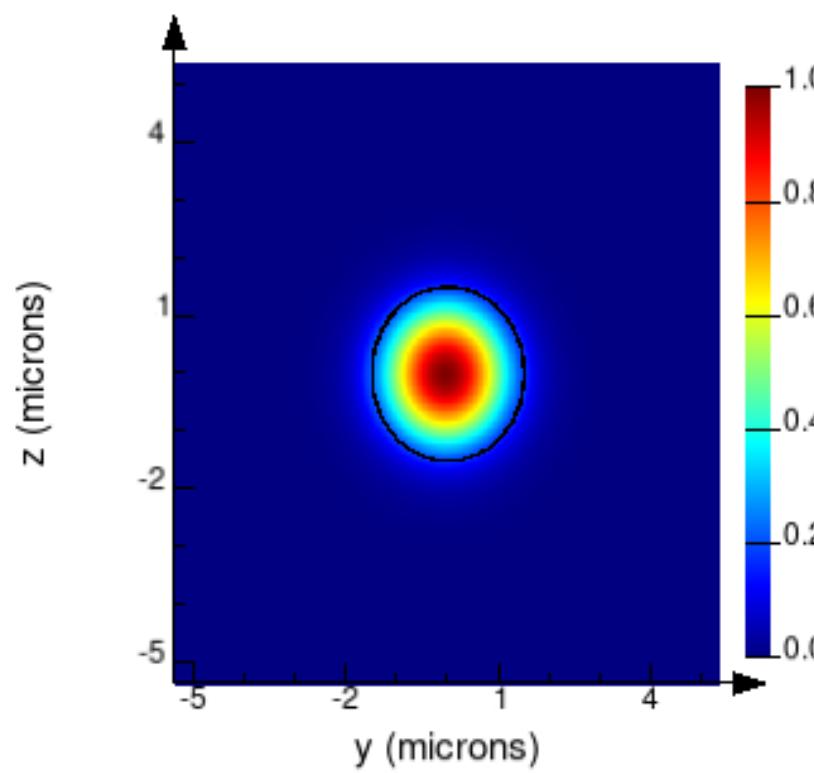
INPUT PORT NO FDE



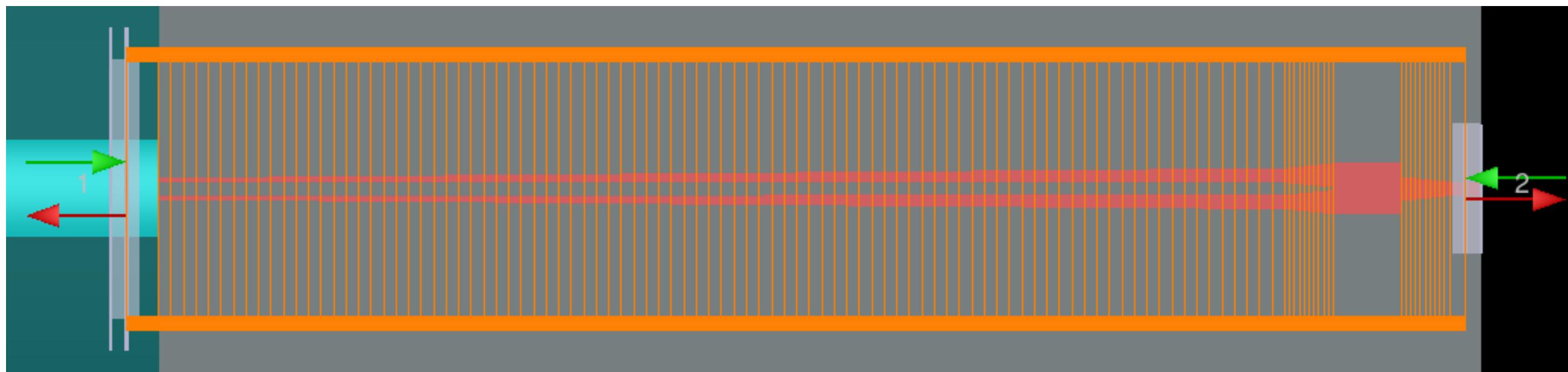
Geometria da fibra:

- **core radius = 1.5 um**
- **n_{core} = 1.44**
- **cladding radius = 20 um**
- **n_{cladding} = 1.383**
- **MFD = 3.3 um**

- **Análise inicial com:**
- **mesh cells = 300**
- **yspan = 10 um**
- **z span = 10 um**
- **Z min BC = Symmetric**
- **Z max BC = PML**
- **Y min BC = PML**
- **Y max BC = PML**
- **min step mesh = 1e-6**

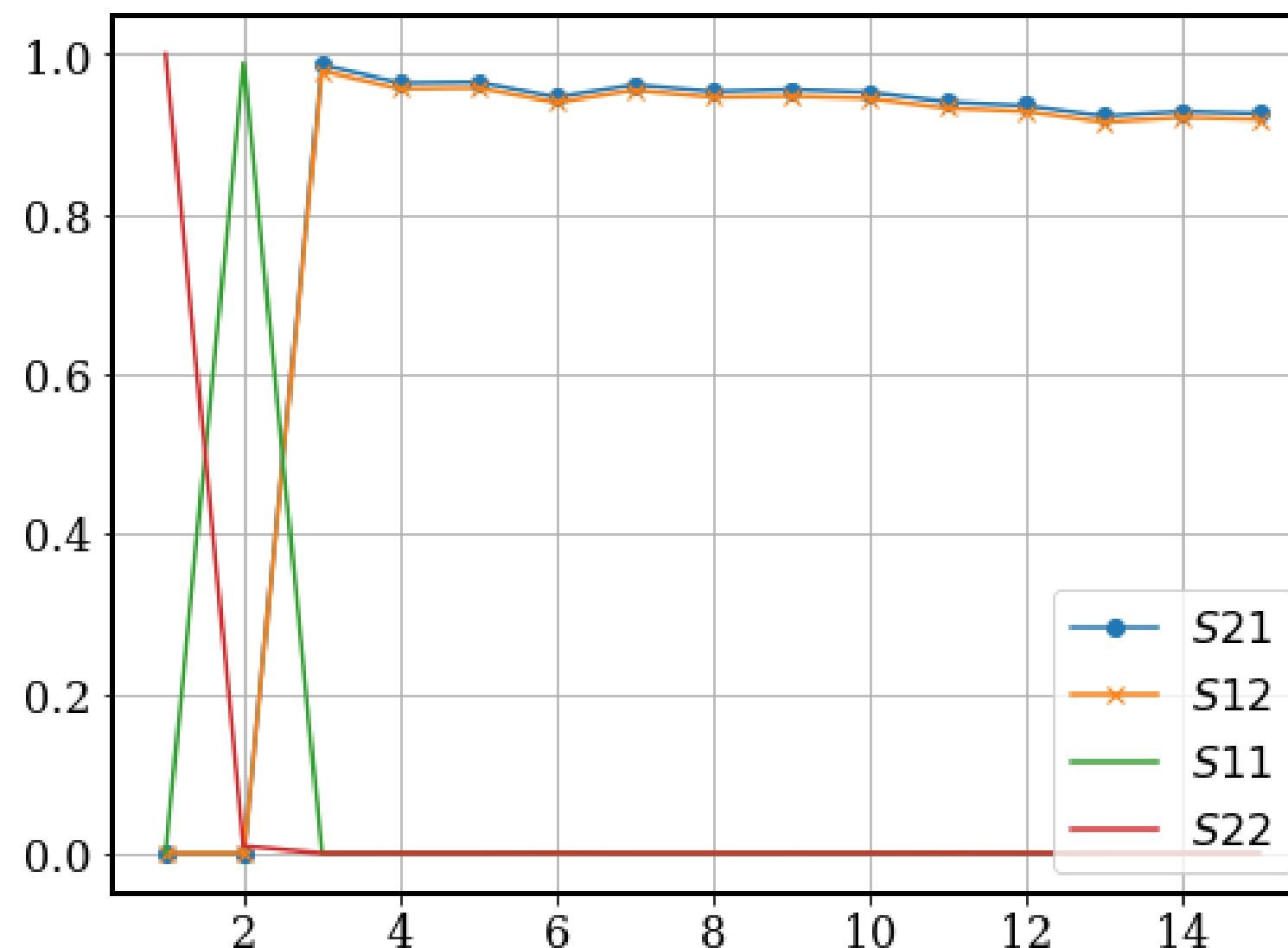


SIMULAÇÃO NO EME



SOI waveguide

mode convergence sweep



cell group definition

group spans (μm)	cells	subcell method	modes	custom	cell range	start (μm)
1 1	1	none	15	default	[1]	-1
2 34.9	90	CVCS	15	default	[2 ... 91]	-6.66134e-16
3 1.5	10	CVCS	15	default	[92]	34.9
4 2.1	1	none	15	default	[102]	36.4
5 1.5	10	CVCS	15	default	[103	38.5
6 0.5	1	none	15	default	[113]	40

EME SETTINGS:

- y min BC = PML
- y max BC = PML
- z min BC = Symmetric
- z max BC = PML
- y span = 10 um
- z span = 10 um
- min mesh step = 1e-6

Port 1 settings:

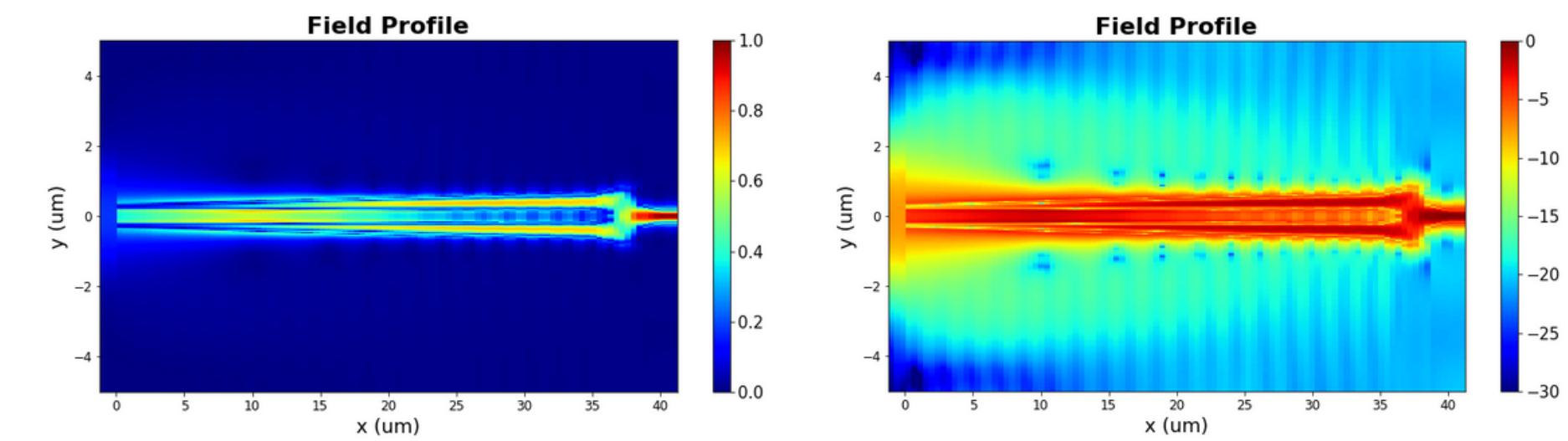
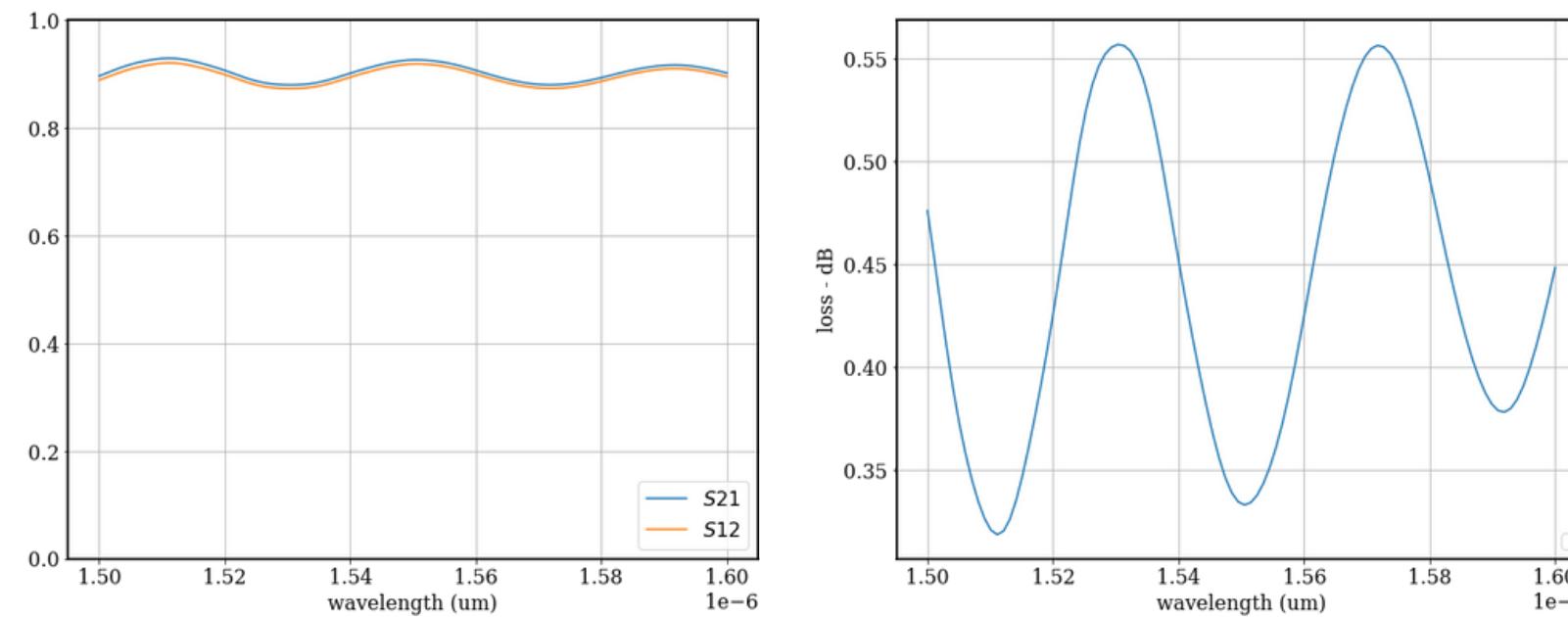
- y span = 10 um
 - z span = 10 um
- Port 2 settings:**
- y span 4 um
 - z span = 4 um

Silica Geometry:

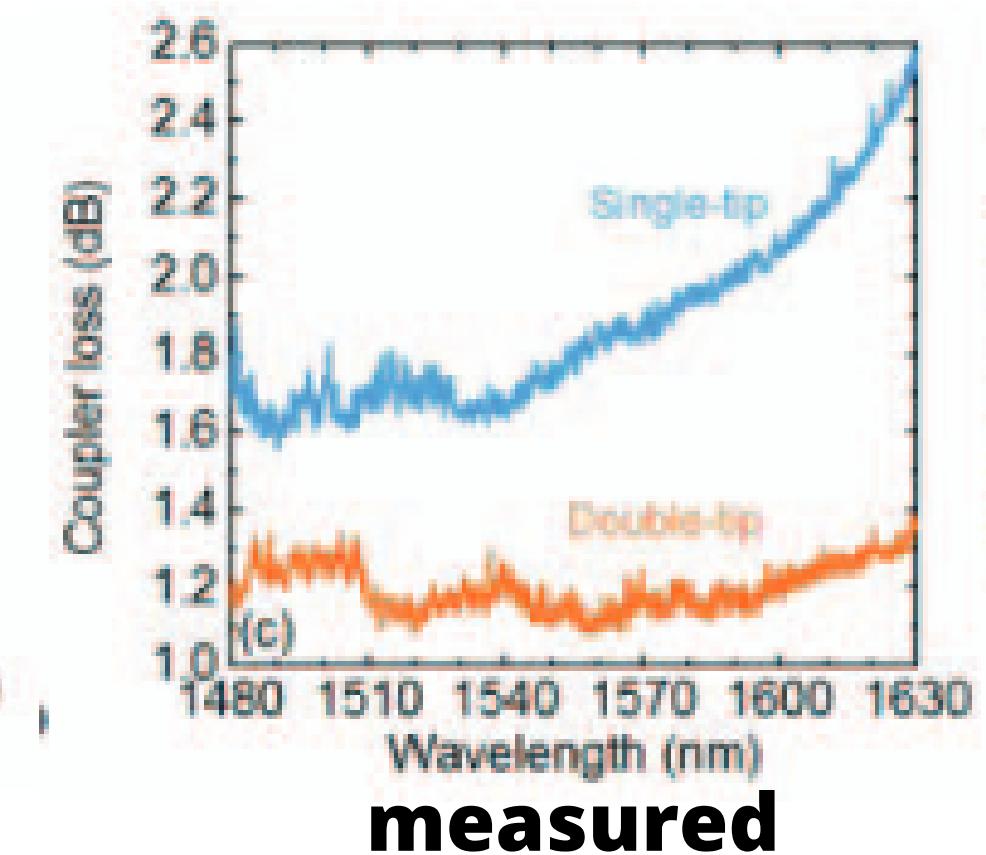
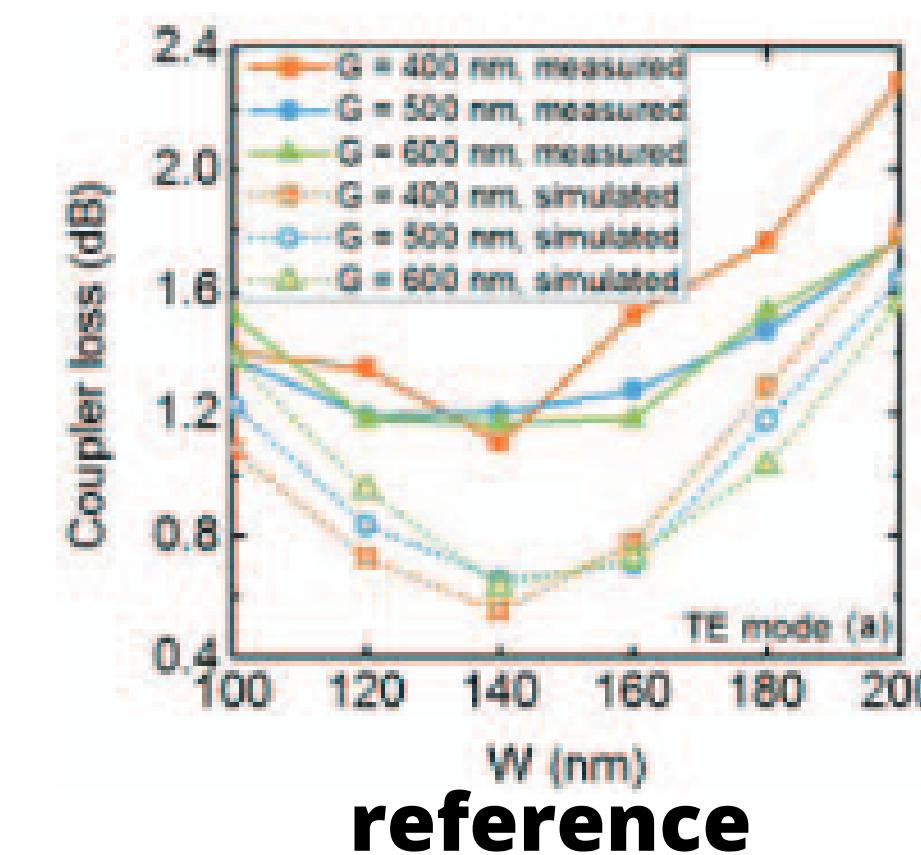
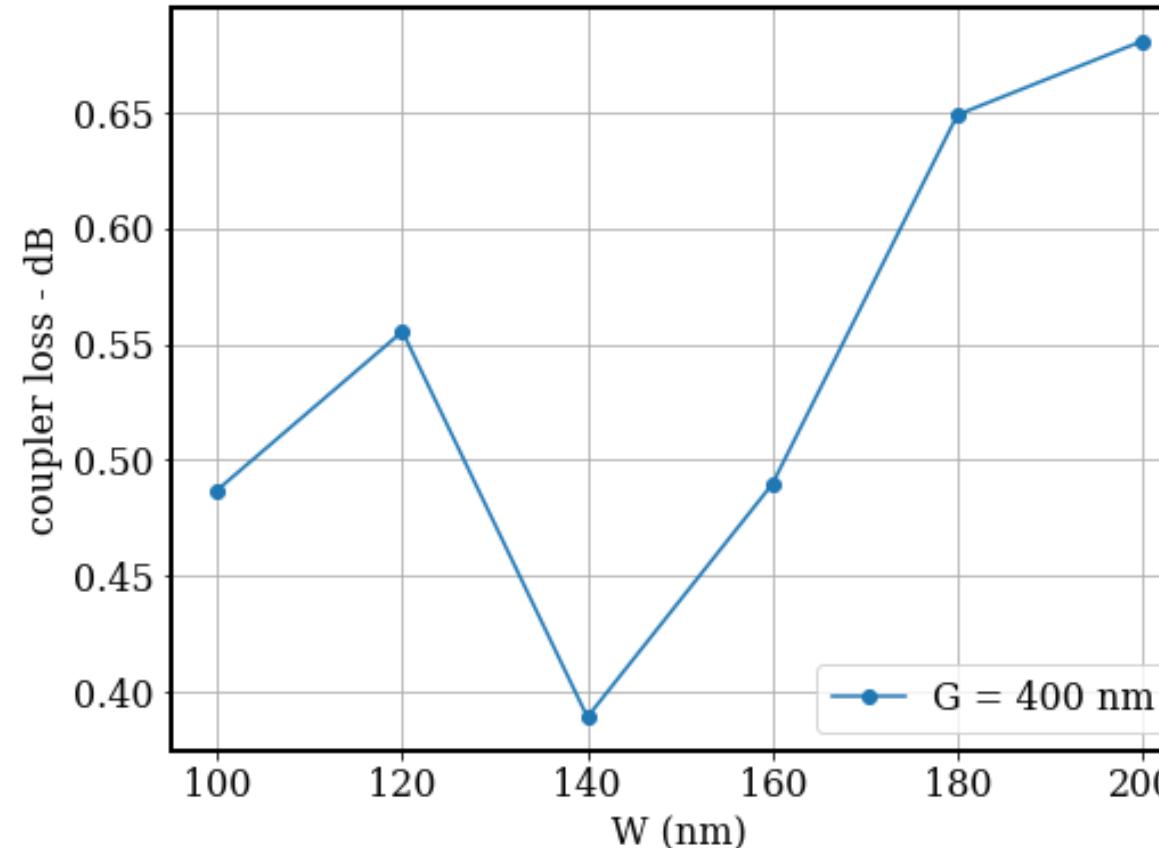
- Z max = 10 um
- Z min = -10 um

Results

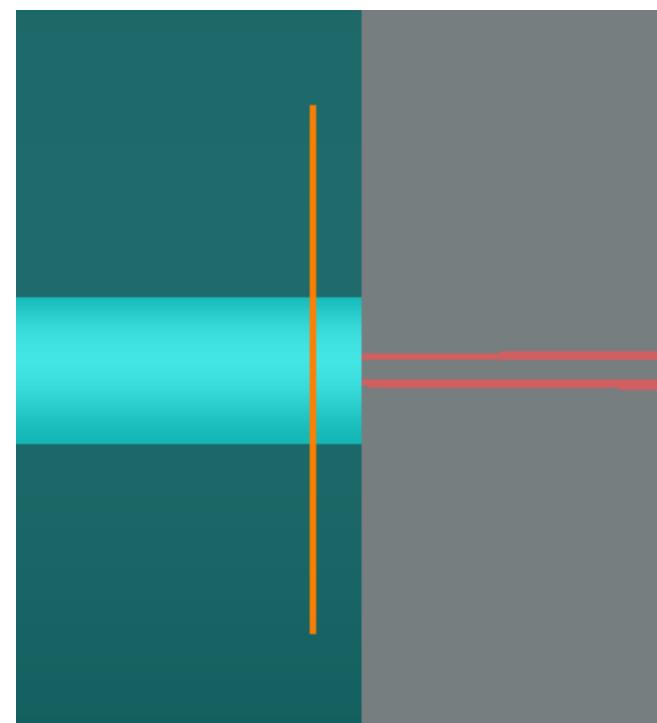
Wavelength sweep



W sweep



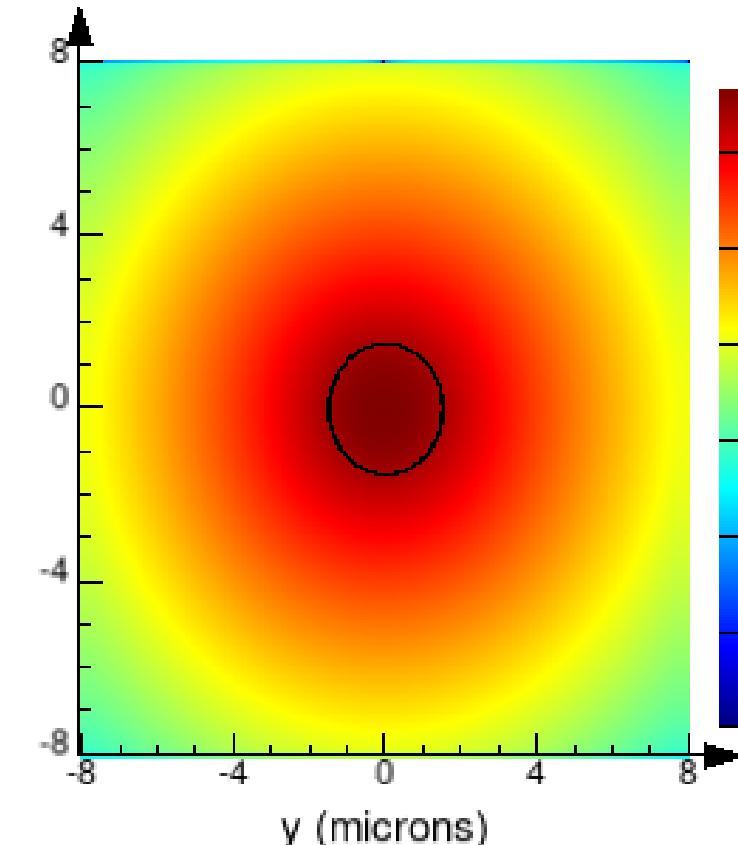
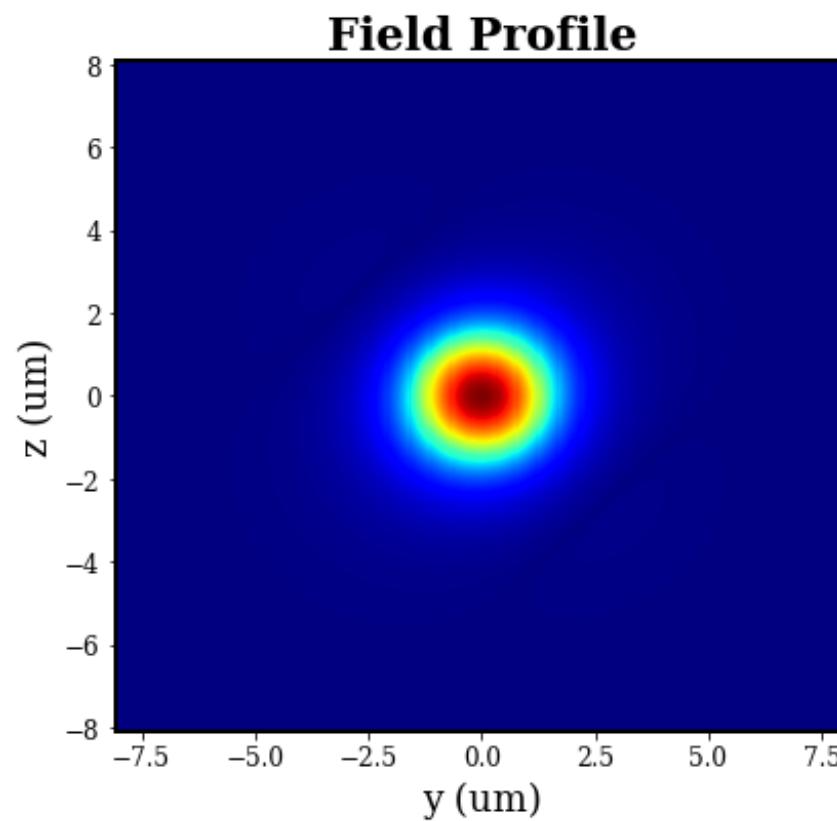
INPUT PORT NO FDE - 2



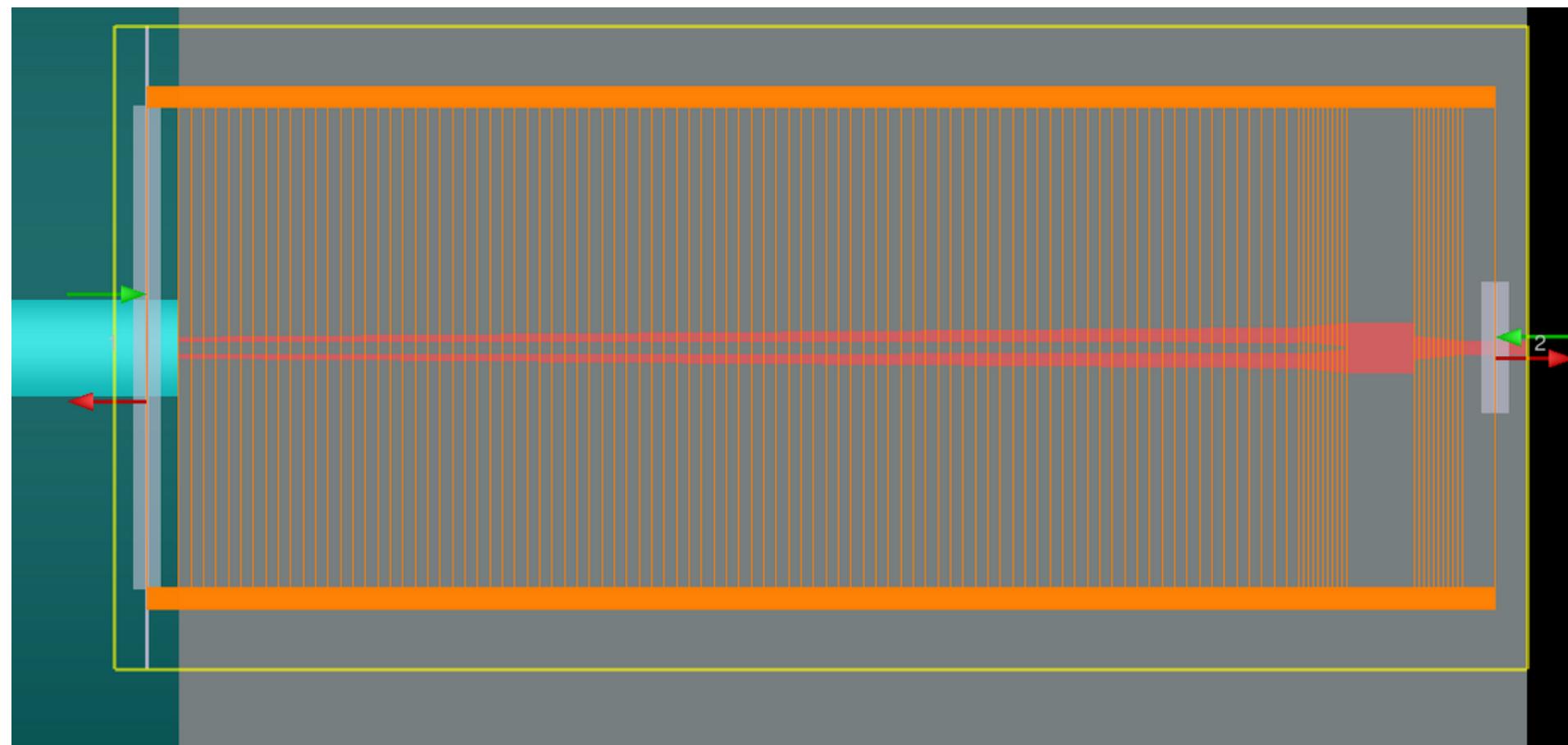
Geometria da fibra:

- **core radius = 1.5 um**
- **n_{core} = 1.44**
- **cladding radius = 20 um**
- **n_{cladding} = 1.383**
- **MFD = 3.3 um**

- **mesh cells = 300**
- **yspan = 15 um**
- **z span = 15 um**
- **Z min BC = Symmetric**
- **Z max BC = PML**
- **Y min BC = PML**
- **Y max BC = PML**
- **min step mesh = 1e-6**



SIMULAÇÃO NO EME - 2



SOI waveguide

EME SETTINGS:

- **y min BC = PML**
- **y max BC = PML**
- **z min BC = Symmetric**
- **z max BC = PML**
- **y span = 15 um**
- **z span = 15 um**
- **min mesh step = 1e-6**

Port 1 settings:

- **y span = 15 um**
- **z span = 15 um**

Port 2 settings:

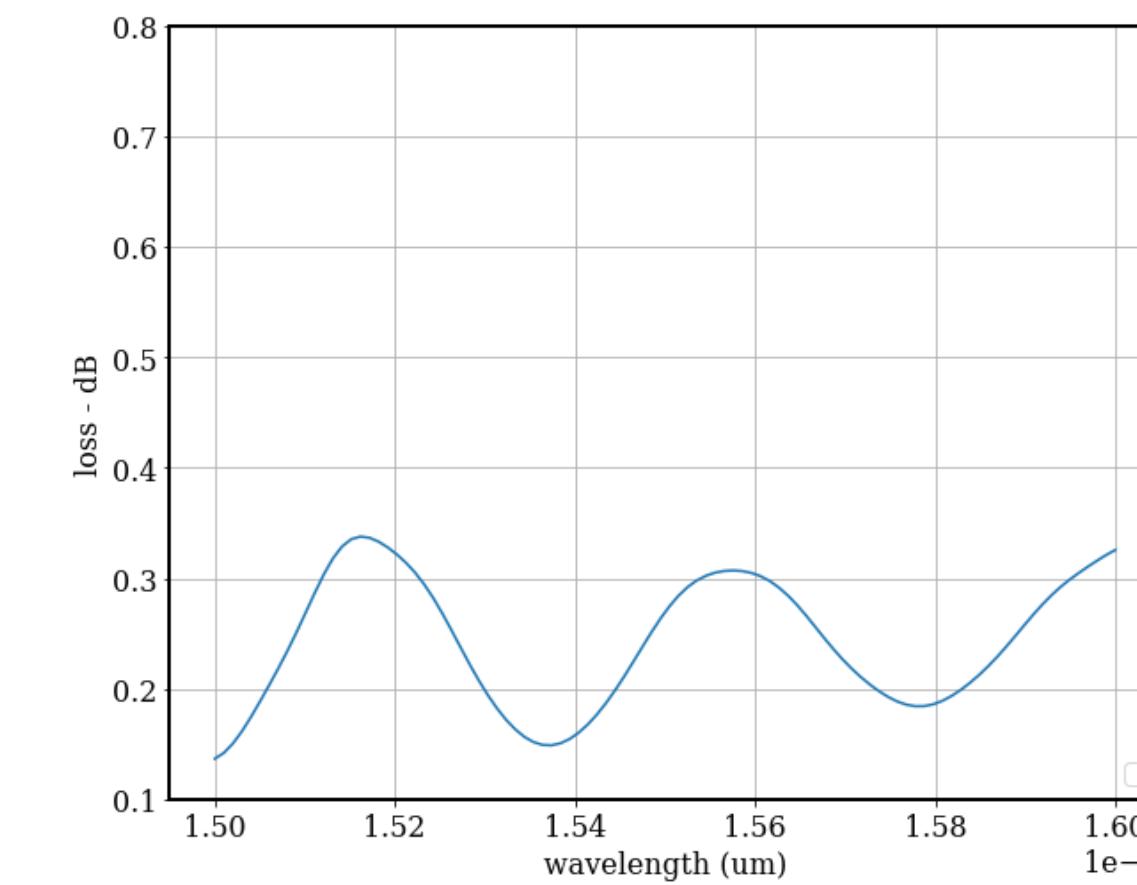
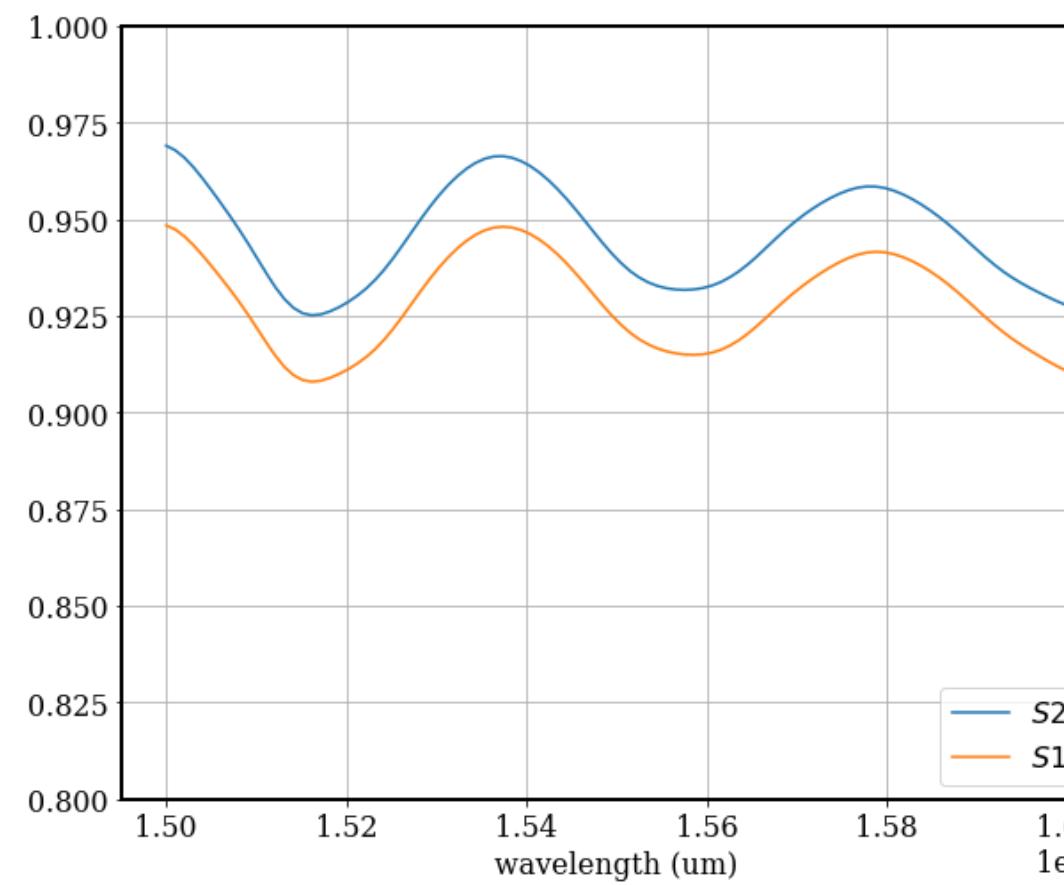
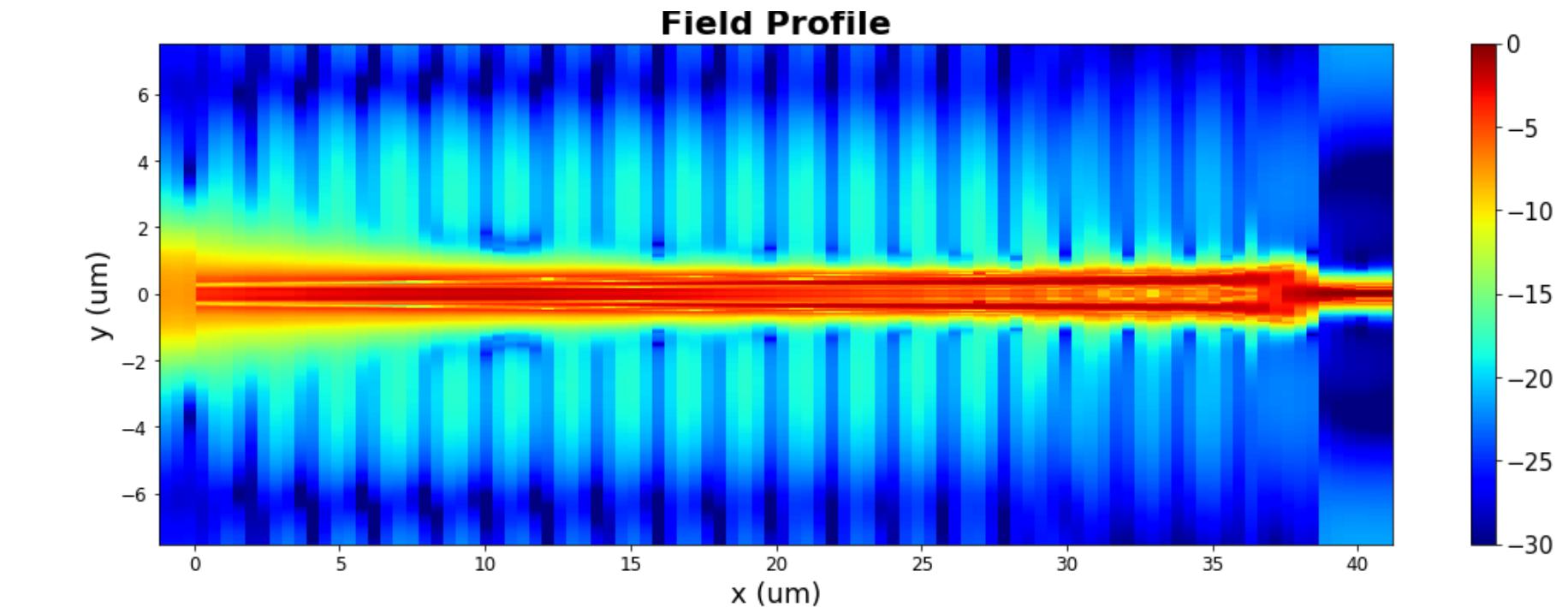
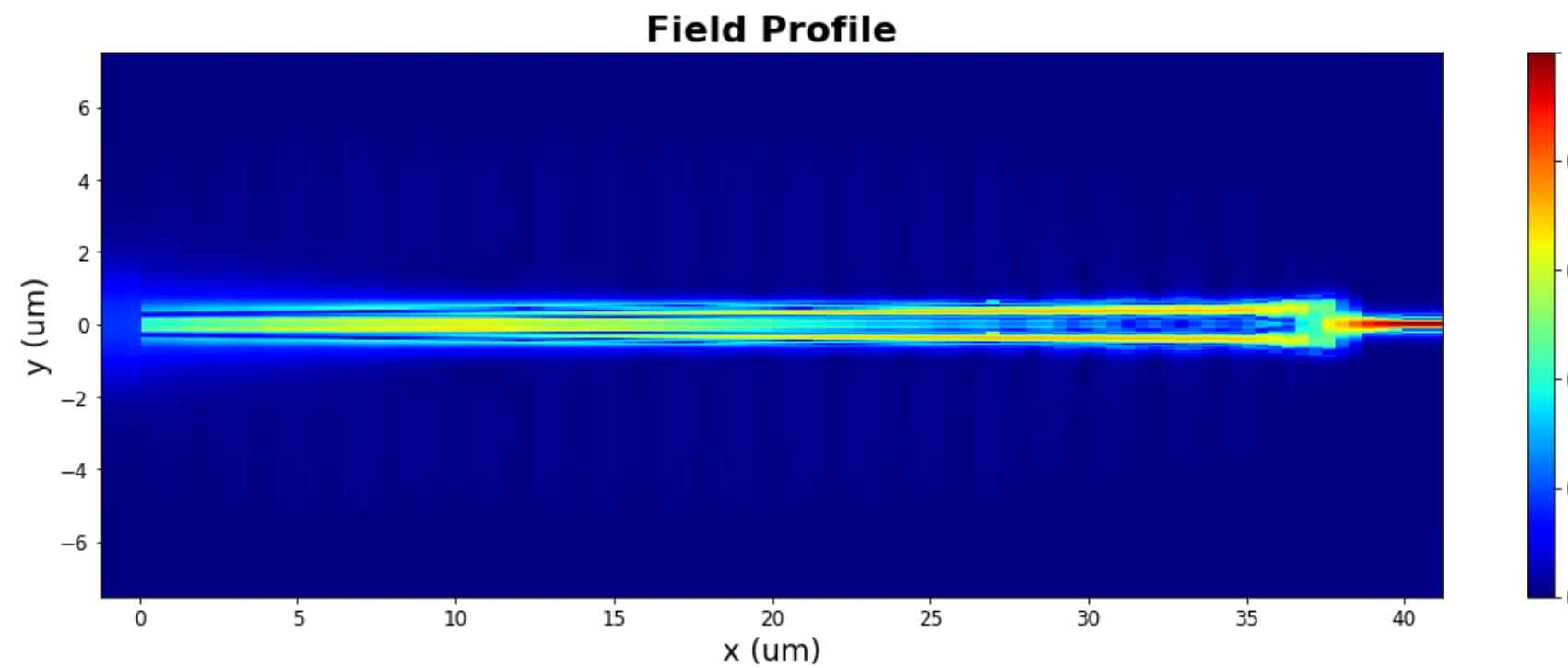
- **y span 4 um**
- **z span = 4 um**

group spans (μm)	cells	subcell method	modes	custom	cell range	start (μm)
1 1	1	none	15	default	[1]	-1
2 34.9	90	CVCS	15	default	[2 ... 91]	-6.66134e-16
3 1.5	10	CVCS	15	default	[92]	34.9
4 2.1	1	none	15	default	[102]	36.4
5 1.5	10	CVCS	15	default	[103	38.5
6 1	1	none	15	default	[113]	40

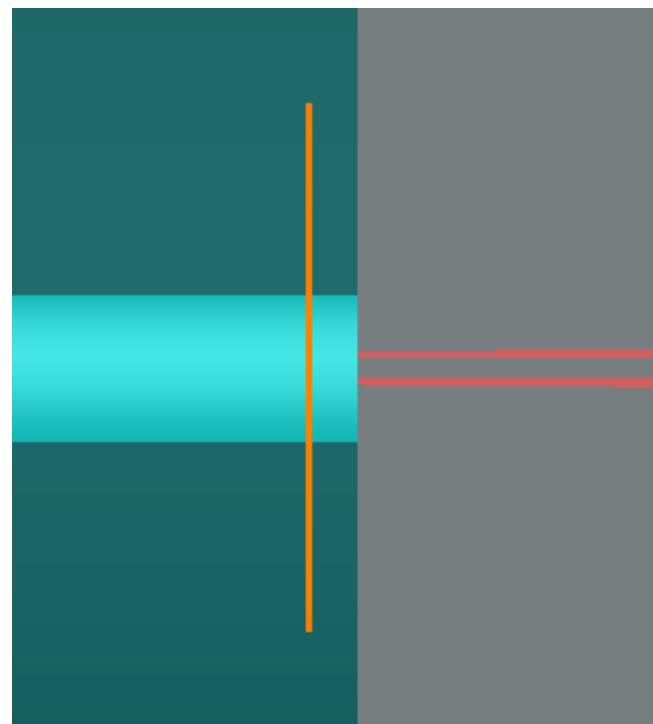
mudanças:

- a porta 2 foi afastada mais 0.5 um depois do taper
- as portas foram aumentadas para 15 um em Z e em Y

Results



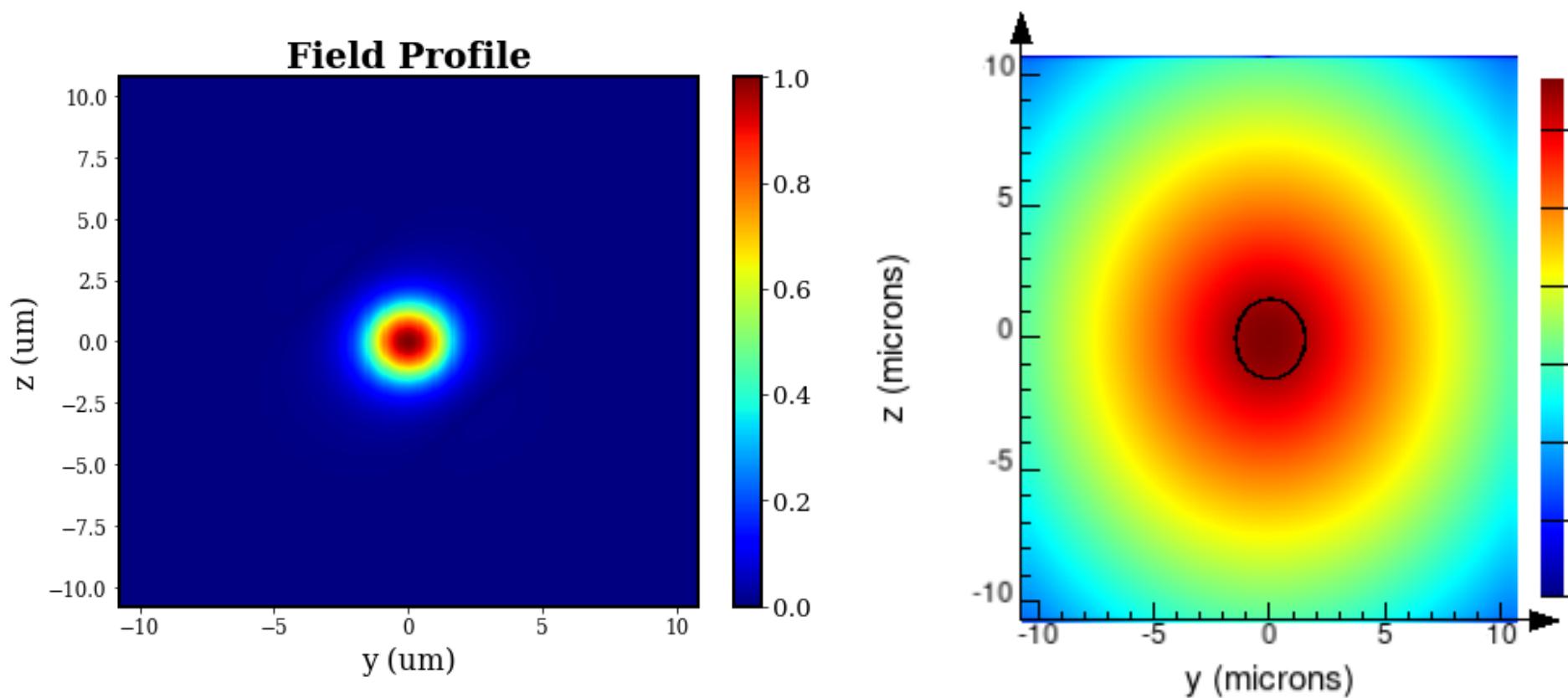
INPUT PORT NO FDE - 3



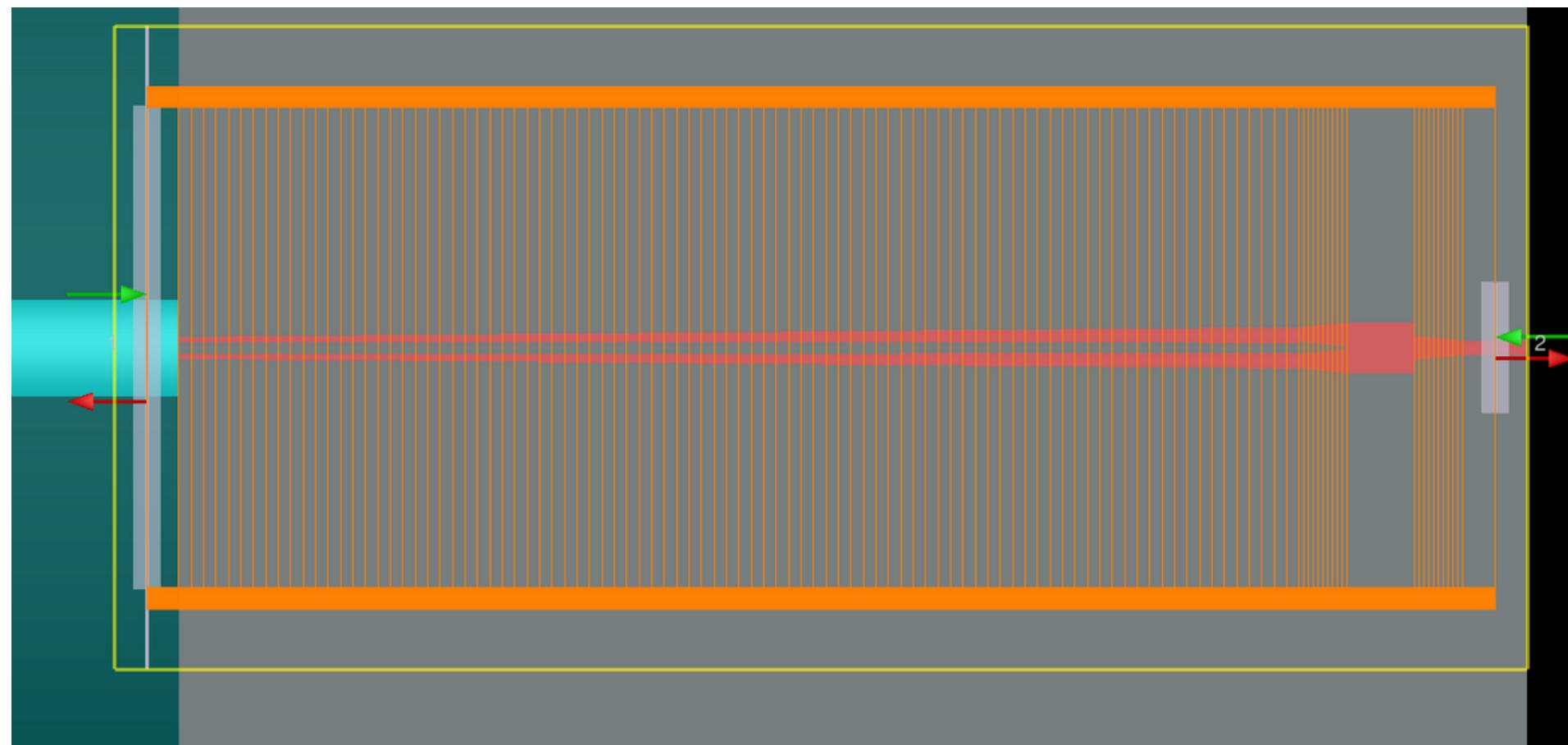
Geometria da fibra:

- **core radius = 1.5 um**
- **n_{core} = 1.44**
- **cladding radius = 20 um**
- **n_{cladding} = 1.383**
- **MFD = 3.3 um**

- **mesh cells = 300**
- **yspan = 20 um**
- **z span = 20 um**
- **Z min BC = Symmetric**
- **Z max BC = PML**
- **Y min BC = PML**
- **Y max BC = PML**
- **min step mesh = 1e-6**



SIMULAÇÃO NO EME - 3



EME SETTINGS:

- **y min BC = PML**
- **y max BC = PML**
- **z min BC = Symmetric**
- **z max BC = PML**
- **y span = 20 um**
- **z span = 20 um**
- **min mesh step = 1e-6**

Port 1 settings:

- **y span = 20 um**
- **z span = 20 um**

Port 2 settings:

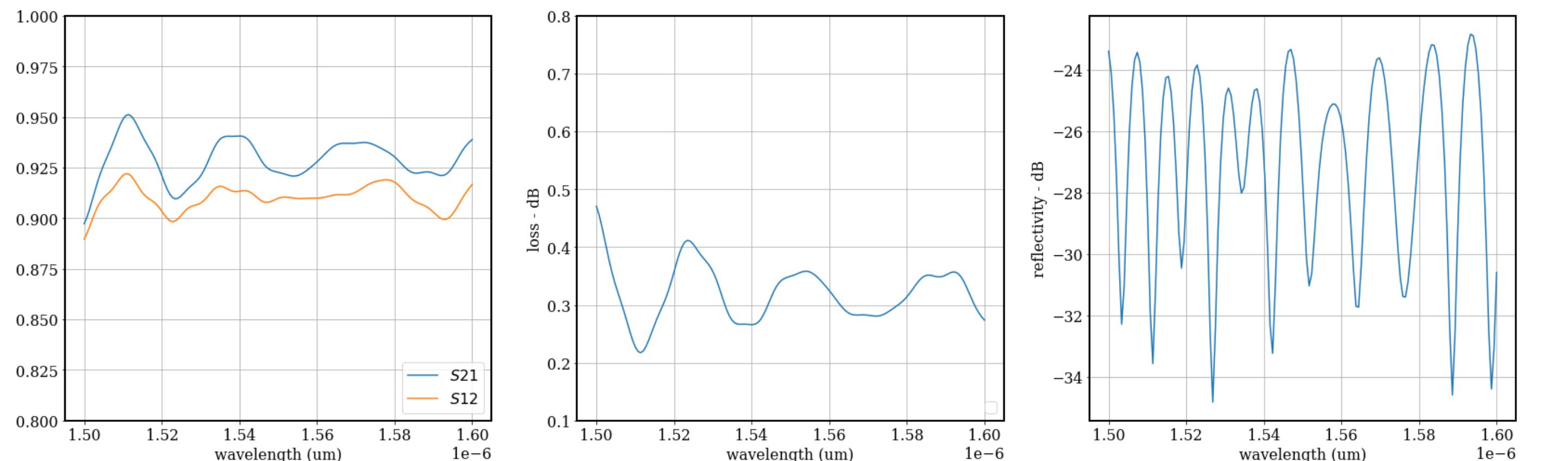
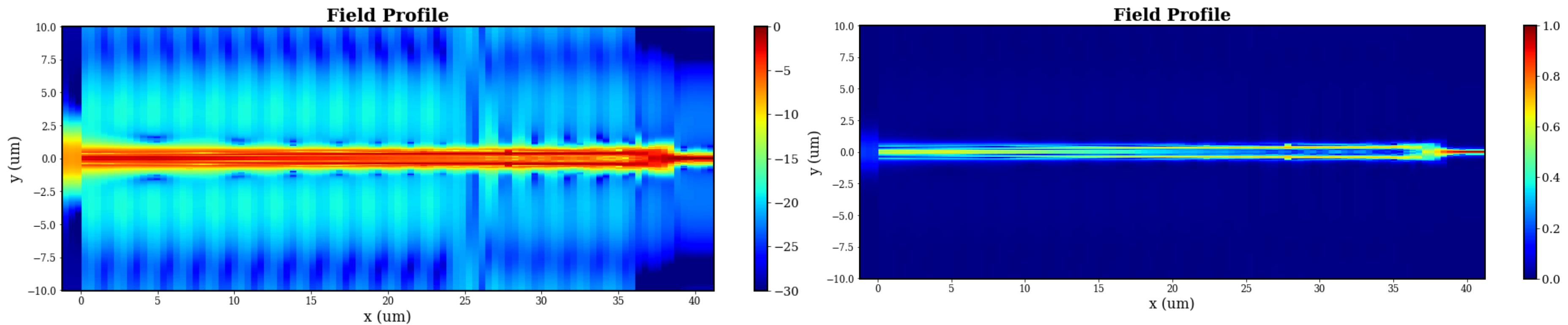
- **y span 4 um**
- **z span = 4 um**

group spans (μm)	cells	subcell method	modes	custom	cell range	start (μm)
1 1	1	none	15	default	[1]	-1
2 34.9	90	CVCS	15	default	[2 ... 91]	-6.66134e-16
3 1.5	10	CVCS	15	default	[92]	34.9
4 2.1	1	none	15	default	[102]	36.4
5 1.5	10	CVCS	15	default	[103	38.5
6 1	1	none	15	default	[113]	40

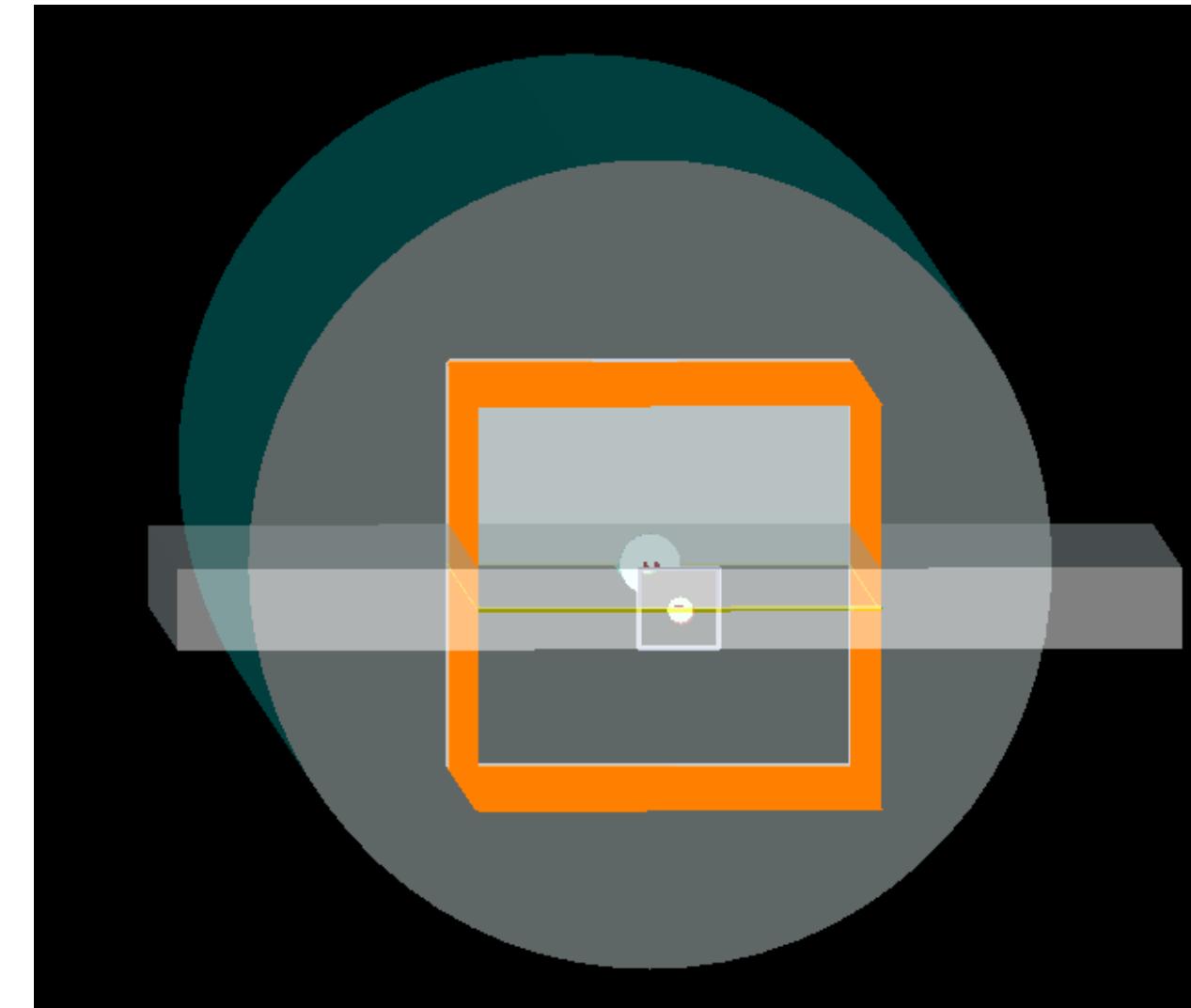
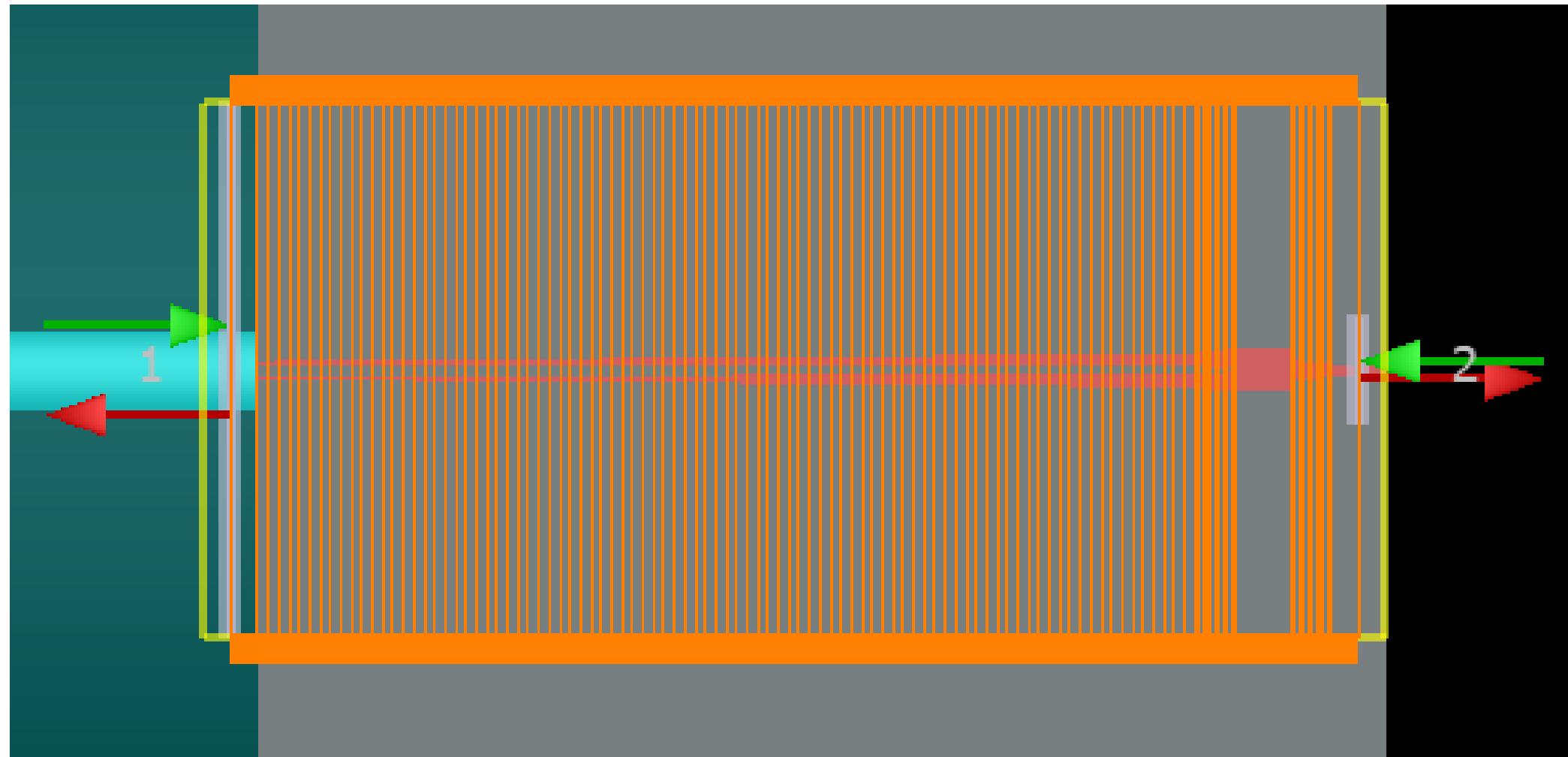
mudanças

- **as portas foram aumentadas para 20 um em Z e em Y**

Results



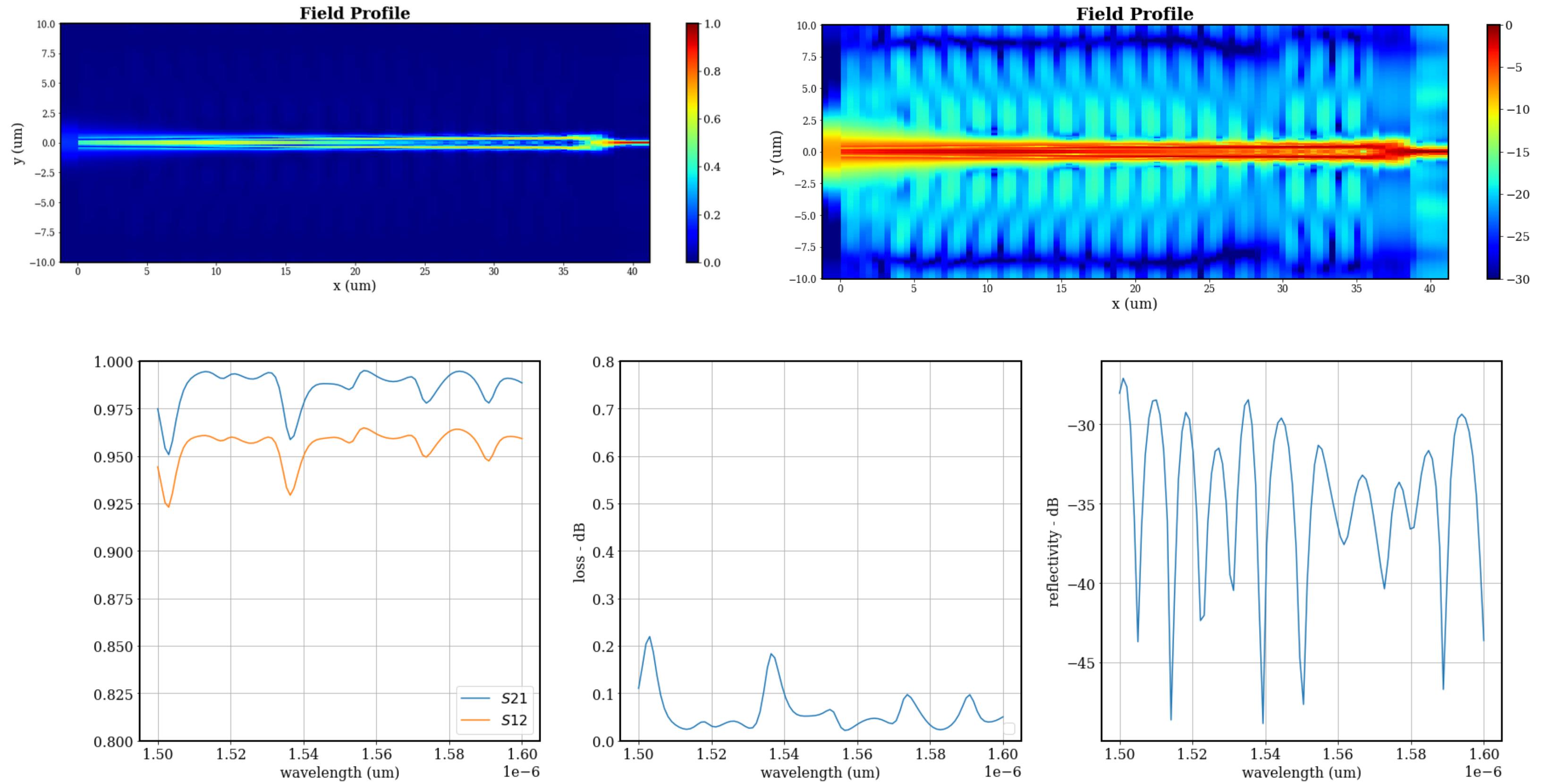
SIMULAÇÃO EME - 4



mudanças:

- a altura da sílica foi mudada para 4 um, ou seja:
- $z \text{ max SiO}_2 = 2 \text{ um}$
- $z \text{ min SiO}_2 = -2 \text{ um}$

Results



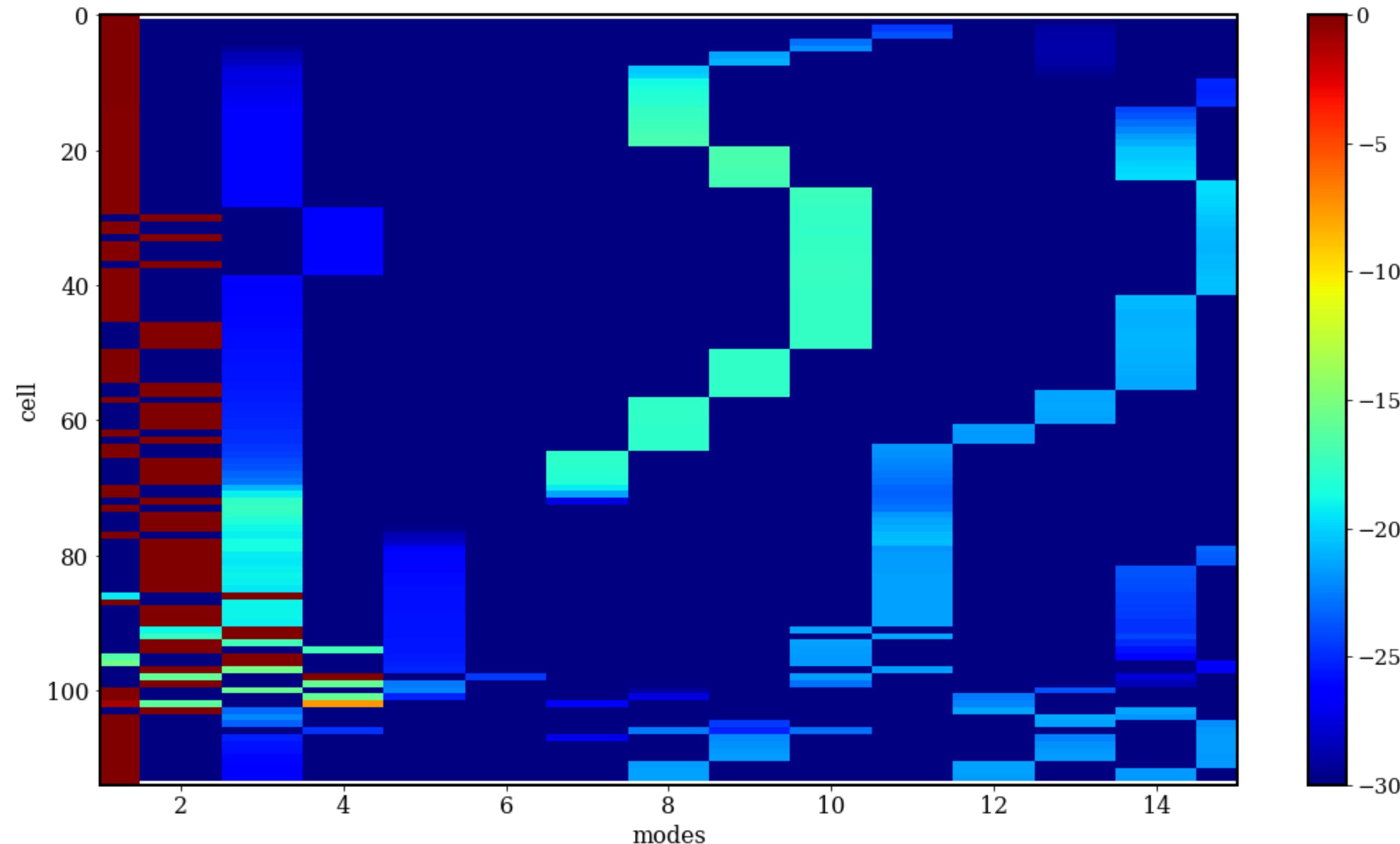
O que fazer na próxima semana:

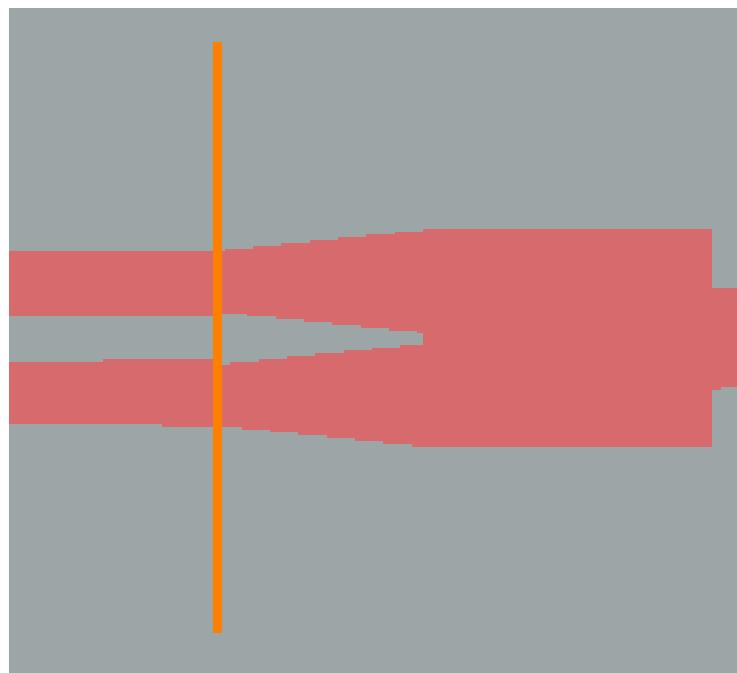
- adicionar mesh para melhorar a precisão;**
- analisar a quantidade de modos;**
- excitar a porta de entrada um pouco mais para a esquerda;**

SEMANA 4

27/03

Análise da expansão dos modos no EME



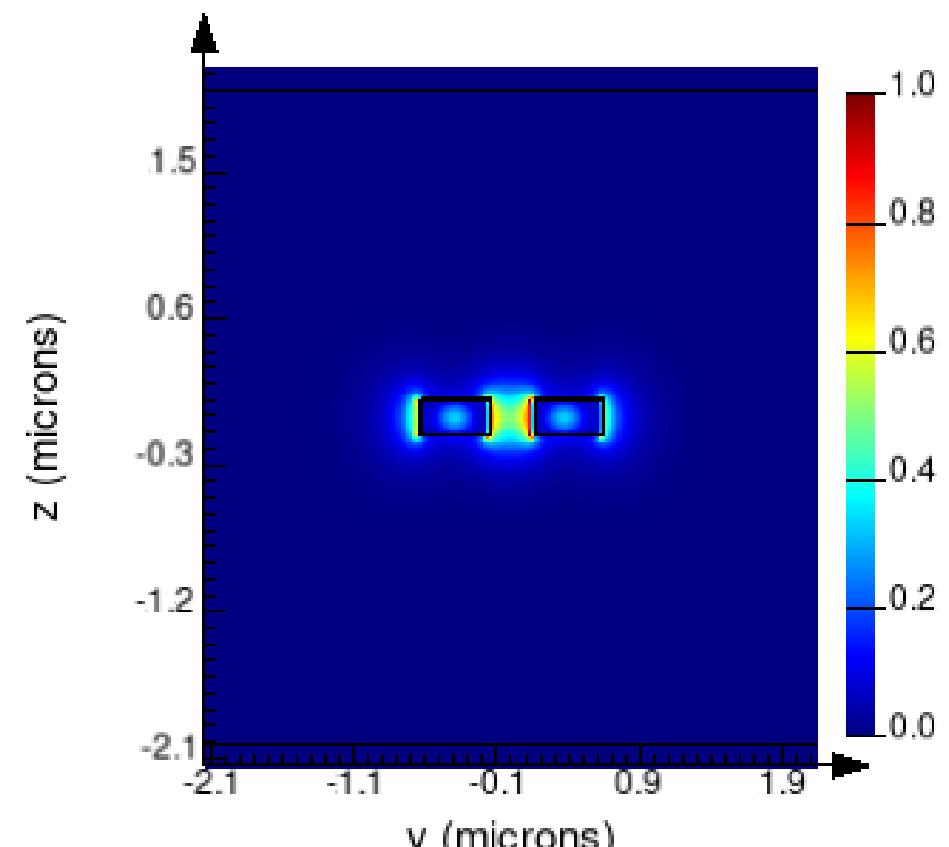


FDE settings:

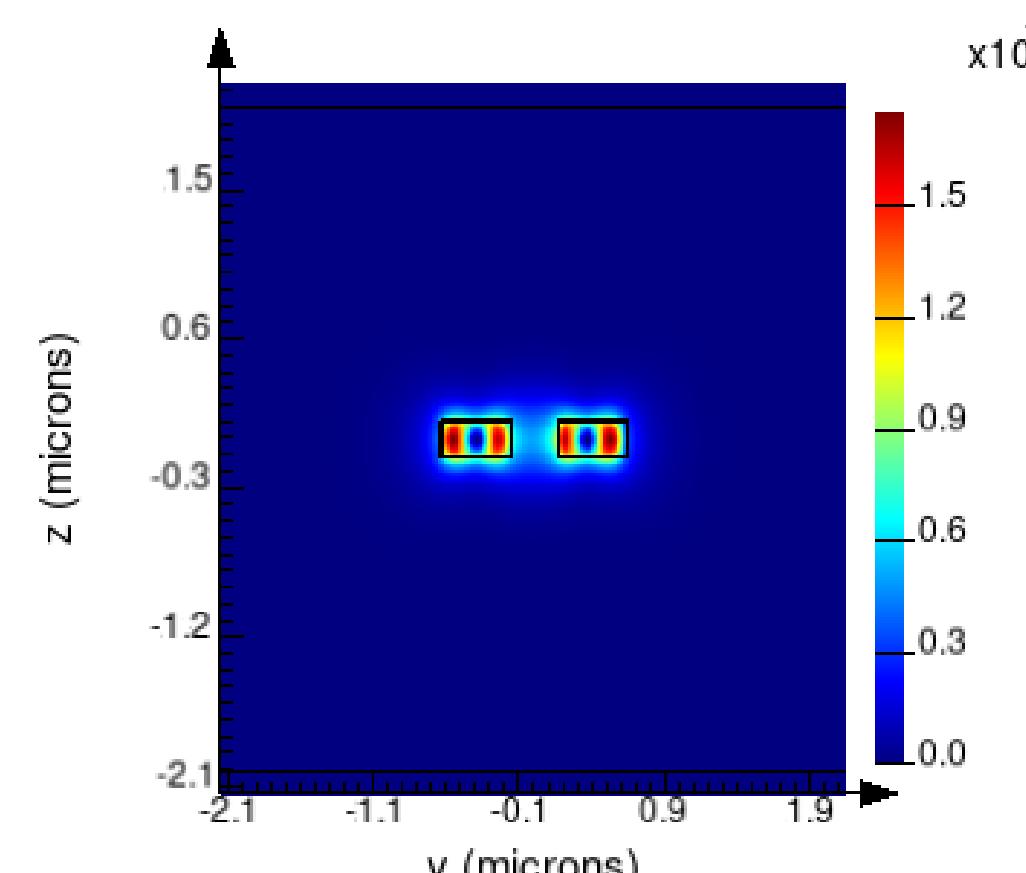
- **mesh cells = 300**
- **min mesh step = 1 um**
- **y span = 4 um**
- **z span = 4 um**
- **x min BC = PML**
- **x max BC = PML**
- **z min BC = symmetric**
- **z max BC = PML**

mode #	effective index	wavelength (μm)	loss (dB/μm)	group index	TE polarization fraction (Ey)	waveguide TE/TM fraction (%)	effective area (μm^2)
1	2.416458-6.373468e-13i	1.55	-2.2441e-11	4.236734+3.774631e-11i	98	76.77 / 81.93	0.390368
2	2.407769-7.759328e-13i	1.55	-2.7320e-11	4.314418+4.727859e-11i	98	73.29 / 82.12	0.377897
3	1.505913-5.854333e-05i	1.55	-0.0020613	2.531925+0.001870818i	78	86.34 / 95.9	0.860996

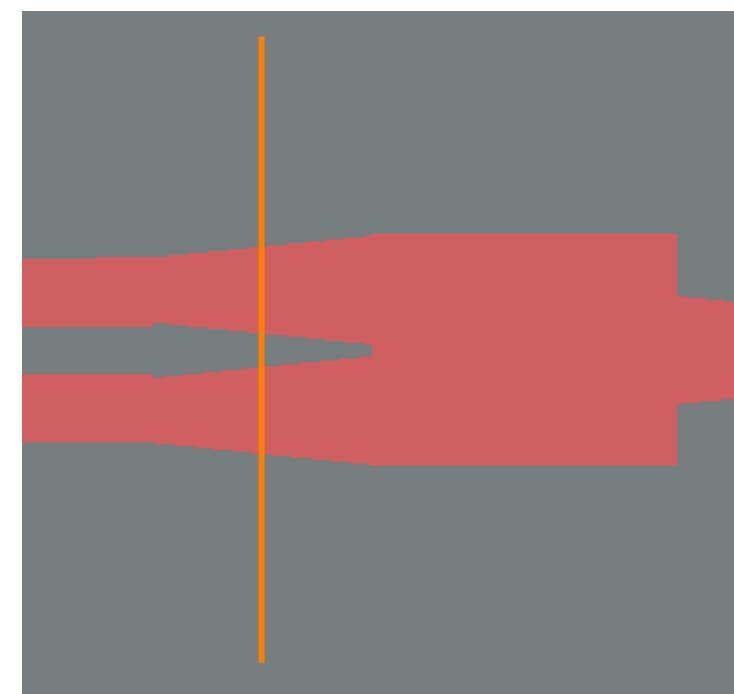
3 modos



E intensity



H intensity

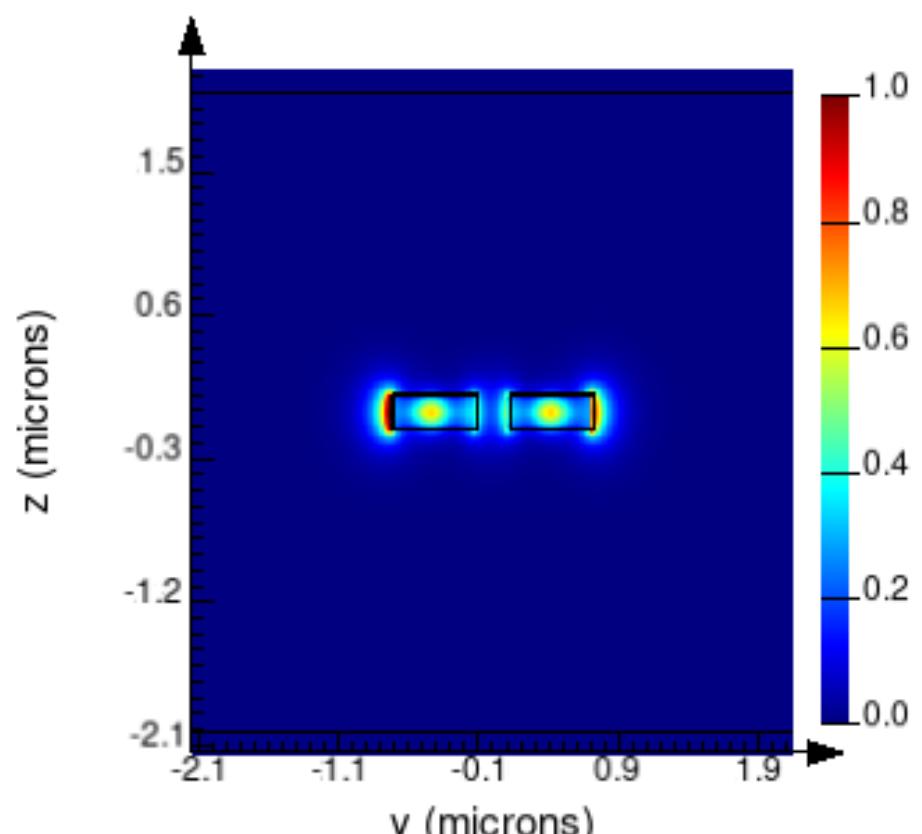


FDE settings:

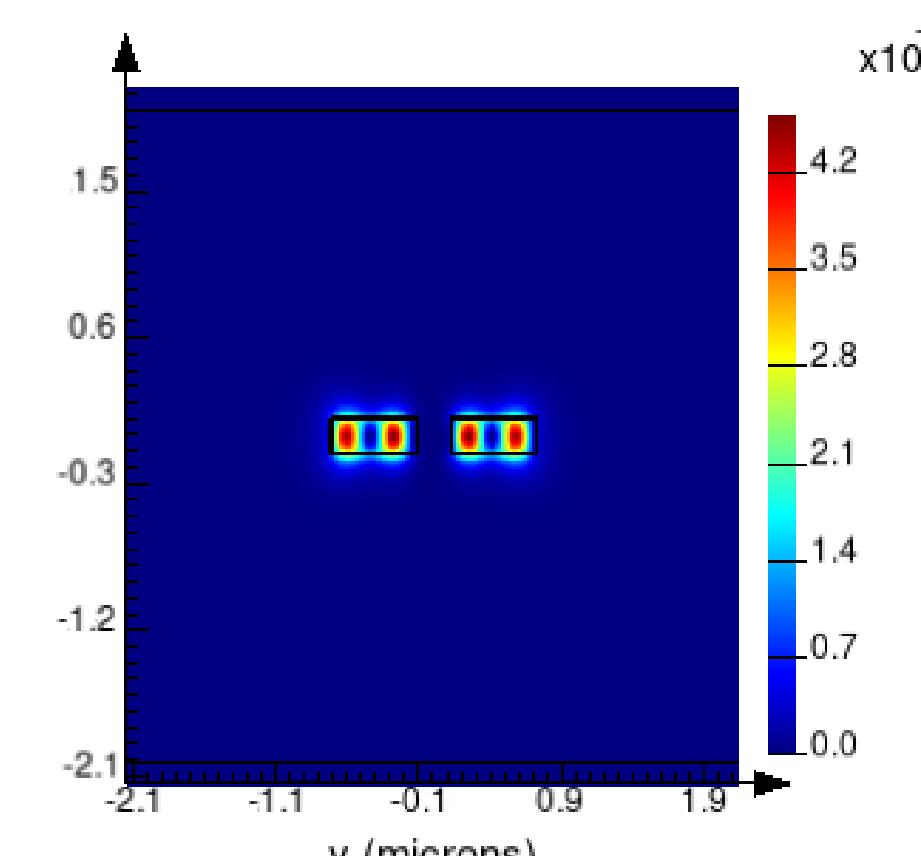
- **mesh cells = 300**
- **min mesh step = 1 um**
- **y span = 4 um**
- **z span = 4 um**
- **x min BC = PML**
- **x max BC = PML**
- **z min BC = symmetric**
- **z max BC = PML**

mode #	effective index	wavelength (μm)	loss (dB/μm)	group index	TE polarization fraction (Ey)	waveguide TE/TM fraction (%)	effective area (μm ²)
1	2.570440-8.738315e-14i	1.55	-3.0767e-12	4.071527+4.832290e-12i	99	83.72 / 81.48	0.381344
2	2.562985-1.040434e-13i	1.55	-3.6633e-12	4.124173+5.868569e-12i	99	80.96 / 81.71	0.367248
3	1.756712-3.116810e-07i	1.55	-1.0974e-05	3.914023+1.643663e-05i	90	73.01 / 89.82	0.555239
4	1.621758-8.340393e-06i	1.55	-0.00029366	4.433981+0.0005938841i	79	60.26 / 91.32	0.805949

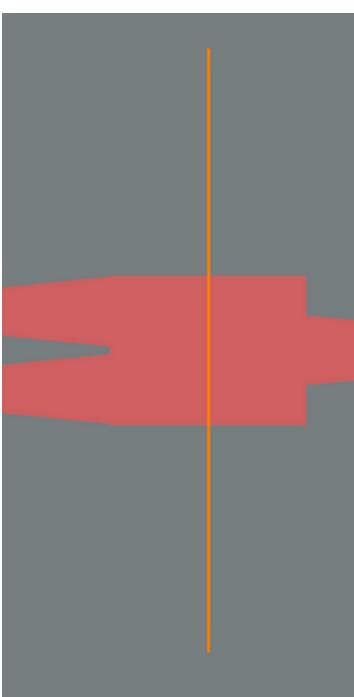
→ 4 modos



E intensity



H intensity

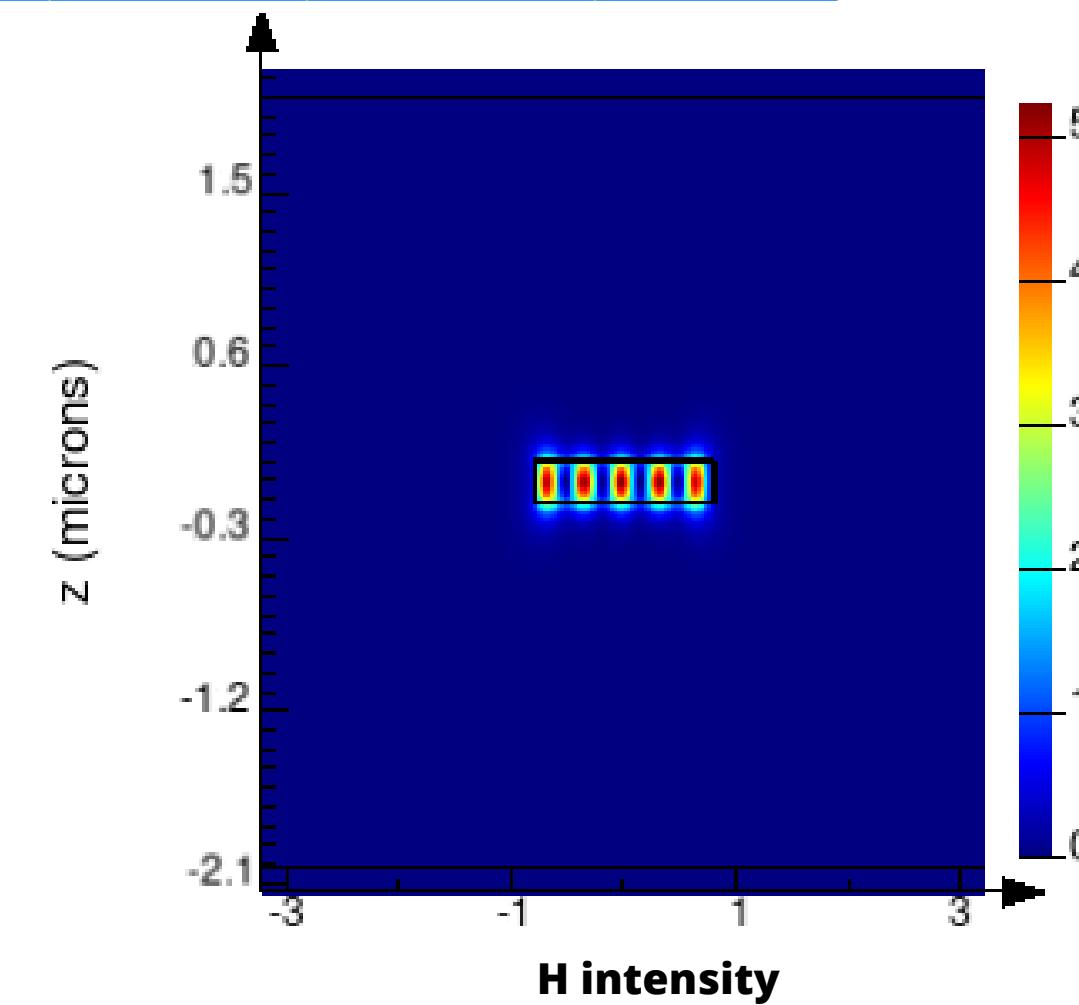
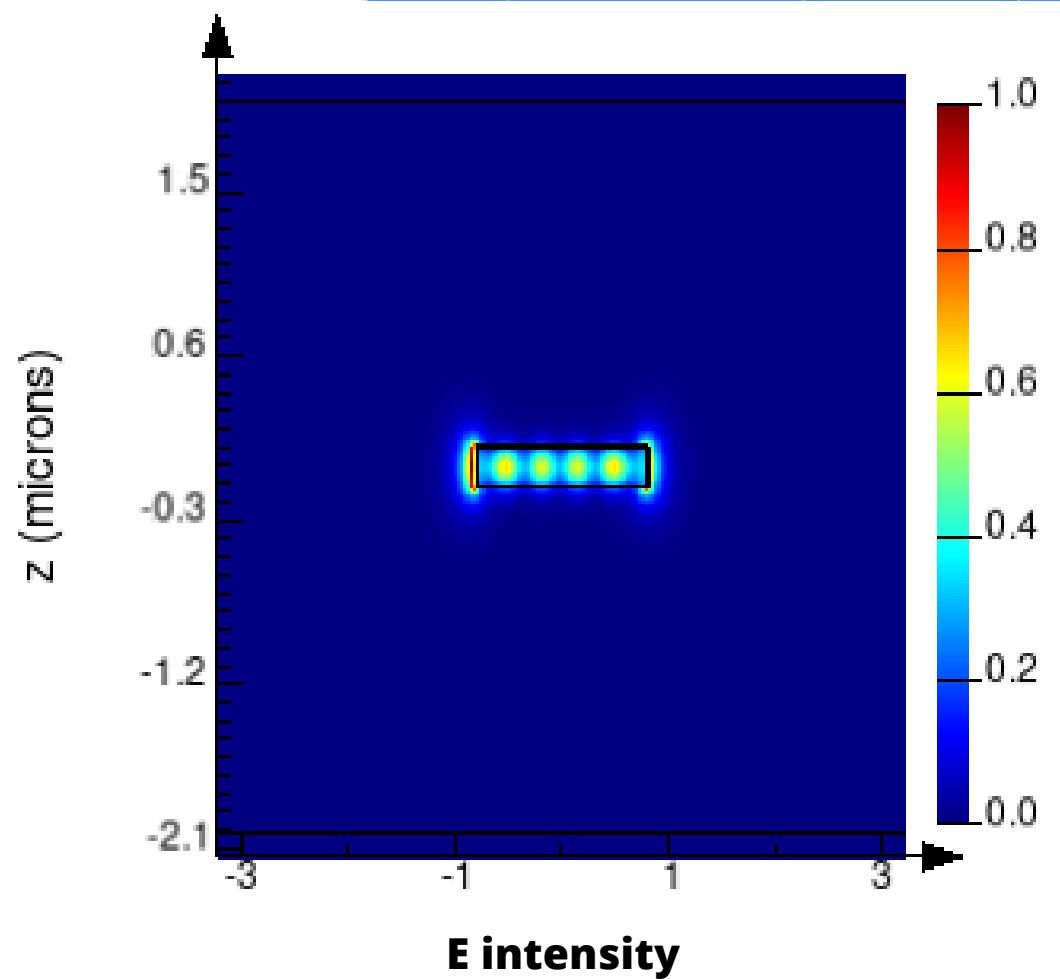


FDE settings:

- **mesh cells = 300**
- **min mesh step = 1 um**
- **y span = 6 um**
- **z span = 4 um**
- **x min BC = PML**
- **x max BC = PML**
- **z min BC = symmetric**
- **z max BC = PML**

mode #	effective index	wavelength (μm)	loss (dB/μm)	group index	TE polarization fraction (Ey)	waveguide TE/TM fraction (%)	effective area (μm^2)
1	2.807480-2.724317e-17i	1.55	-9.5922e-16	3.799903-4.819787e-17i	100	97.17 / 80.18	0.340047
2	2.683610+1.993777e-17i	1.55	7.0200e-16	3.966929-6.370270e-17i	100	88.86 / 81.53	0.390215
3	2.465595+9.965803e-17i	1.55	3.5089e-15	4.290861-4.872888e-15i	99	75.73 / 83.85	0.477971
4	2.132534+6.450899e-14i	1.55	2.2713e-12	4.846383-5.851398e-12i	98	59.9 / 87.21	0.584533
5	1.670151+1.182091e-08i	1.55	4.1621e-07	5.173806-1.424904e-06i	90	53.59 / 91.75	0.715125

5 modos





FDE settings:

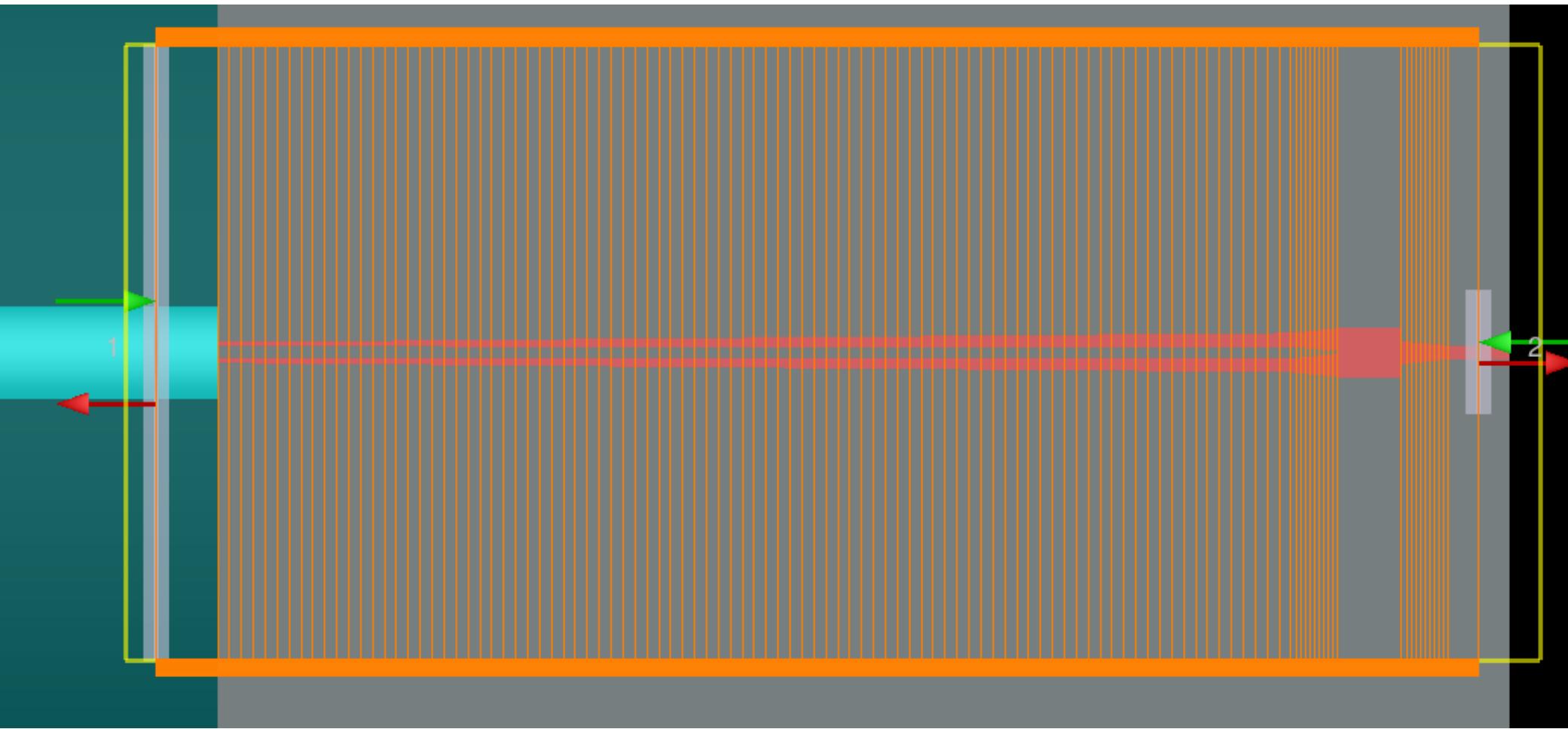
- **mesh cells = 300**
- **min mesh step = 1 um**
- **y span = 4 um**
- **z span = 4 um**
- **x min BC = PML**
- **x max BC = PML**
- **z min BC = symmetric**
- **z max BC = PML**

mode # ▾	effective index	wavelength (μm)	loss (dB/μm)	group index	TE polarization fraction (Ey)	waveguide TE/TM fraction (%)	effective area (μm^2)
1	2.566876-6.723617e-17i	1.55	-2.3674e-15	4.100431+7.155844e-15i	99	82.21 / 81.59	0.187208
2	1.689372-1.393547e-07i	1.55	-4.9066e-06	4.163597+1.102186e-05i	85	66.23 / 90.42	0.422887
3	1.388701-0.001124242i	1.55	-0.039584	1.548771+0.006533826i	1	94.01 / 98.05	9.43643

→ **2 modos**

symmetric = 1 modo TE

PML = 2 modos, 1 TE e outro TM

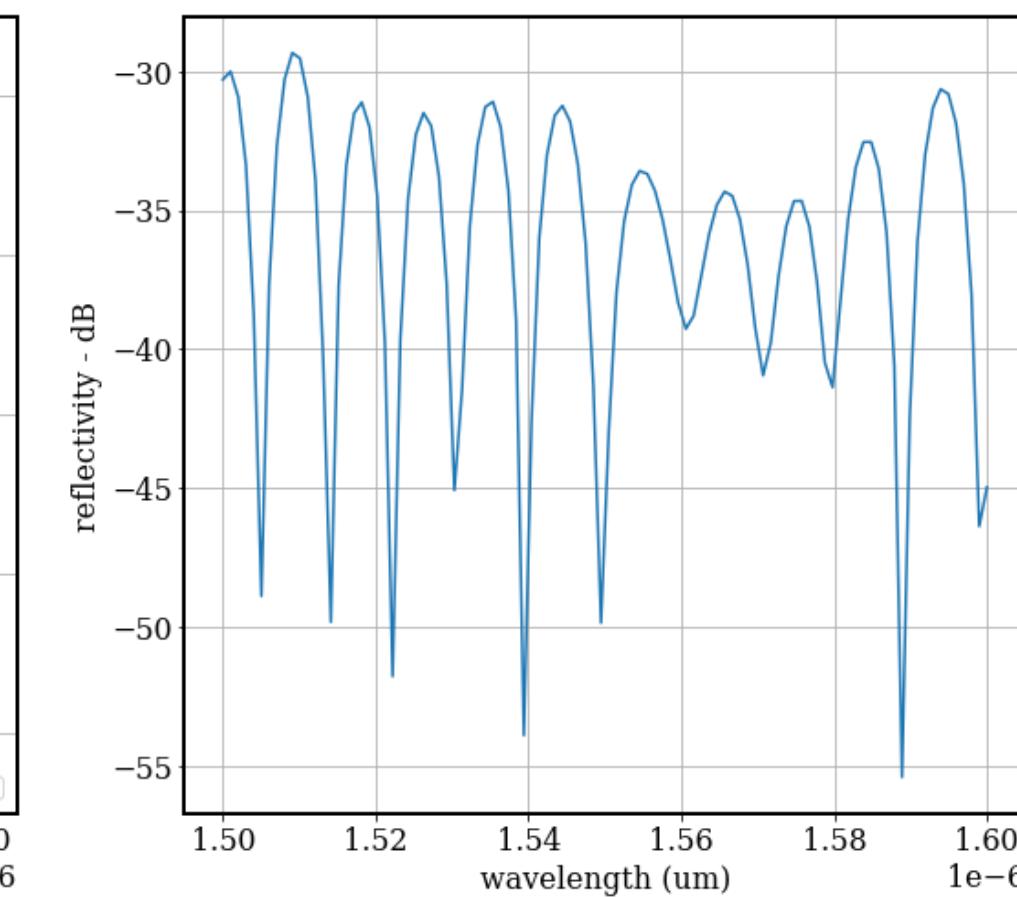
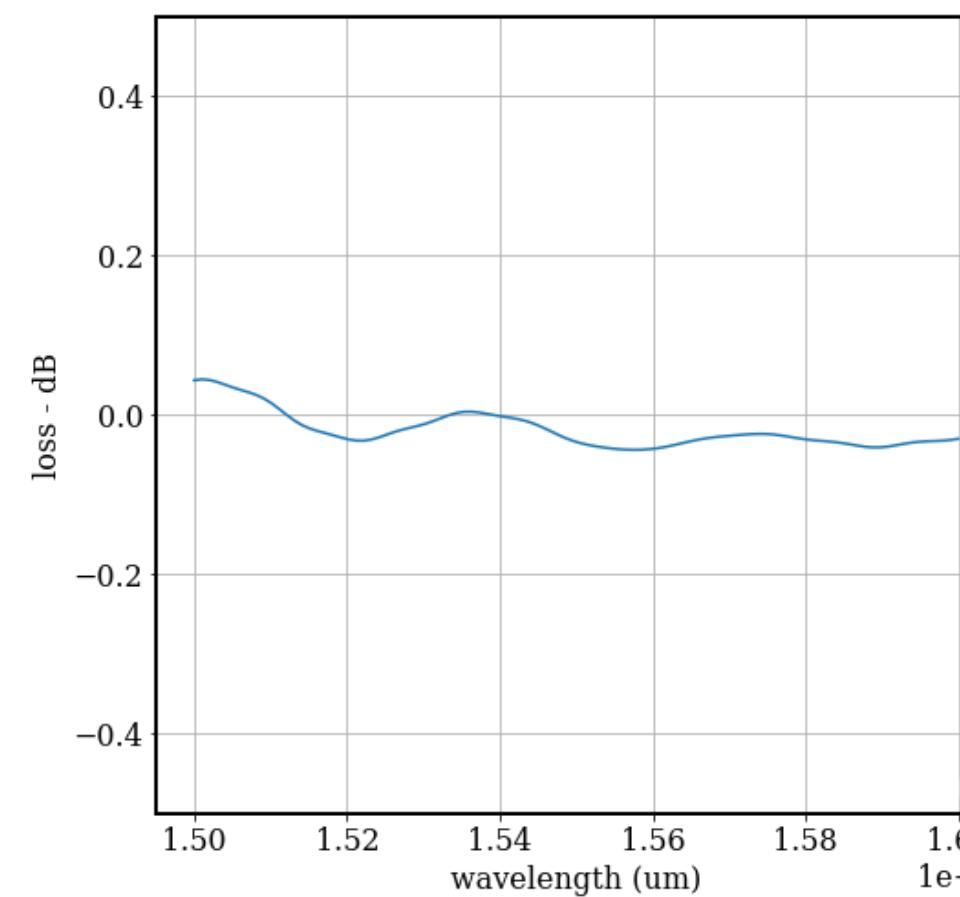
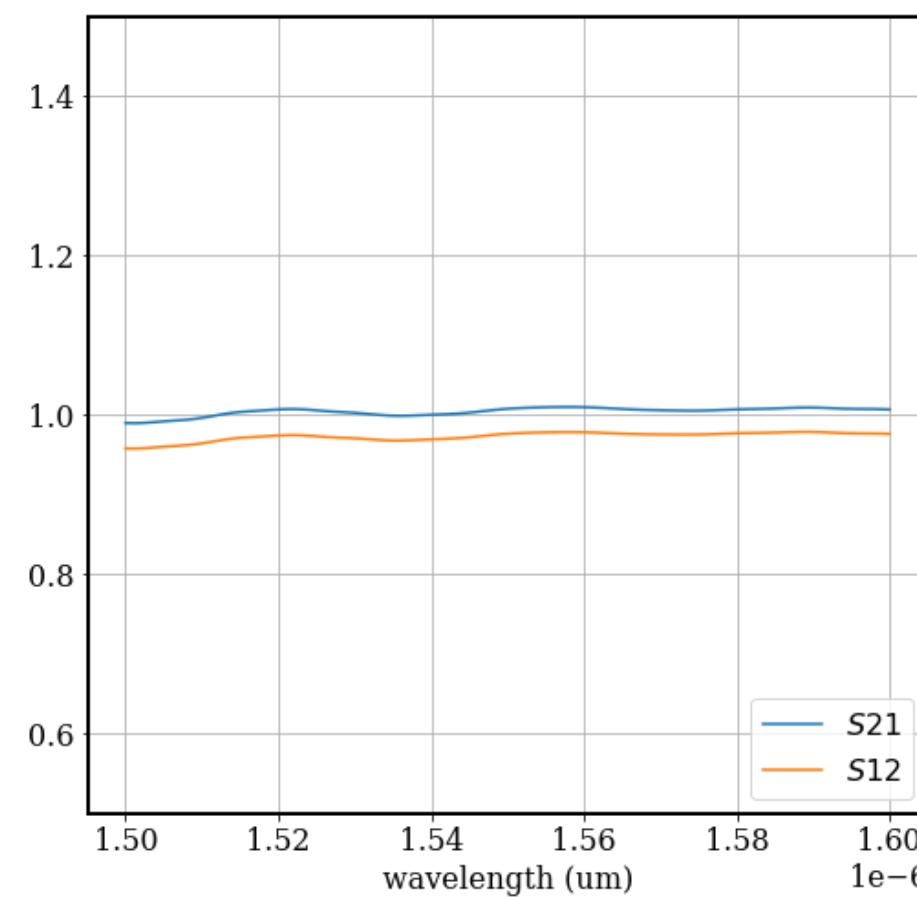
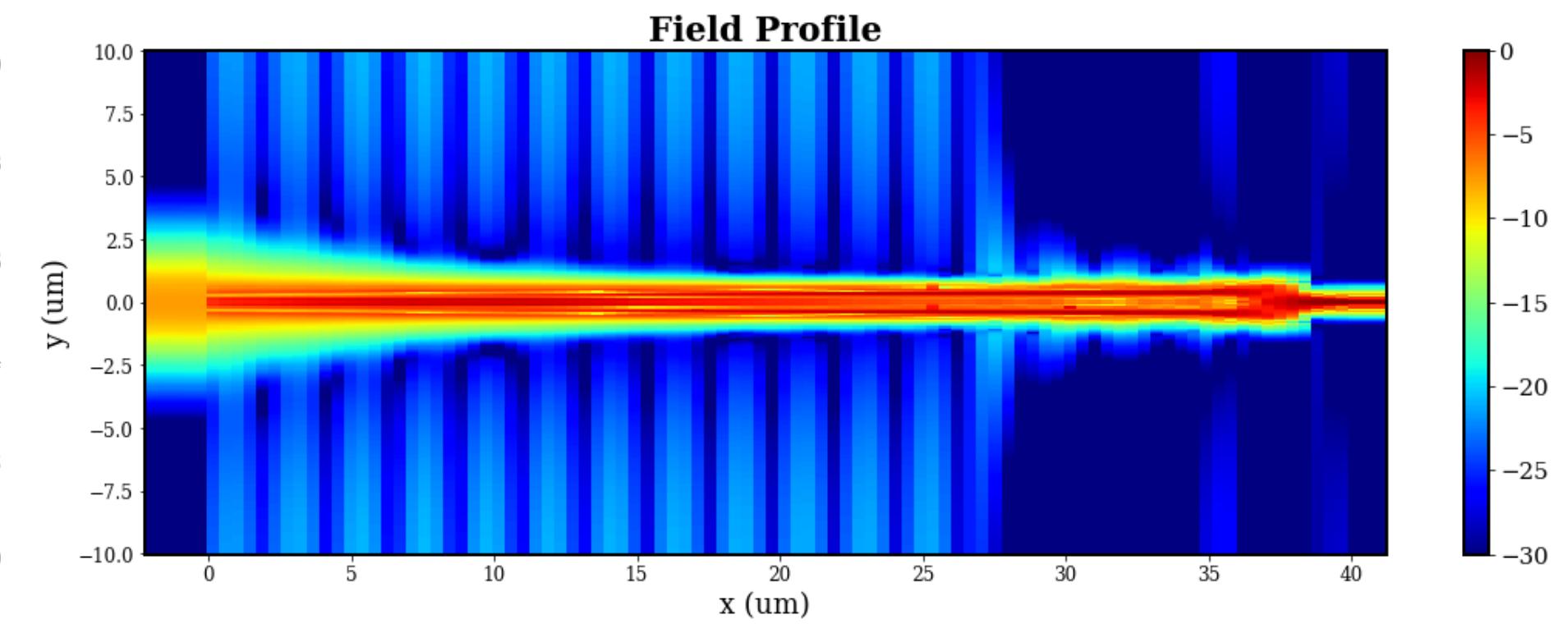
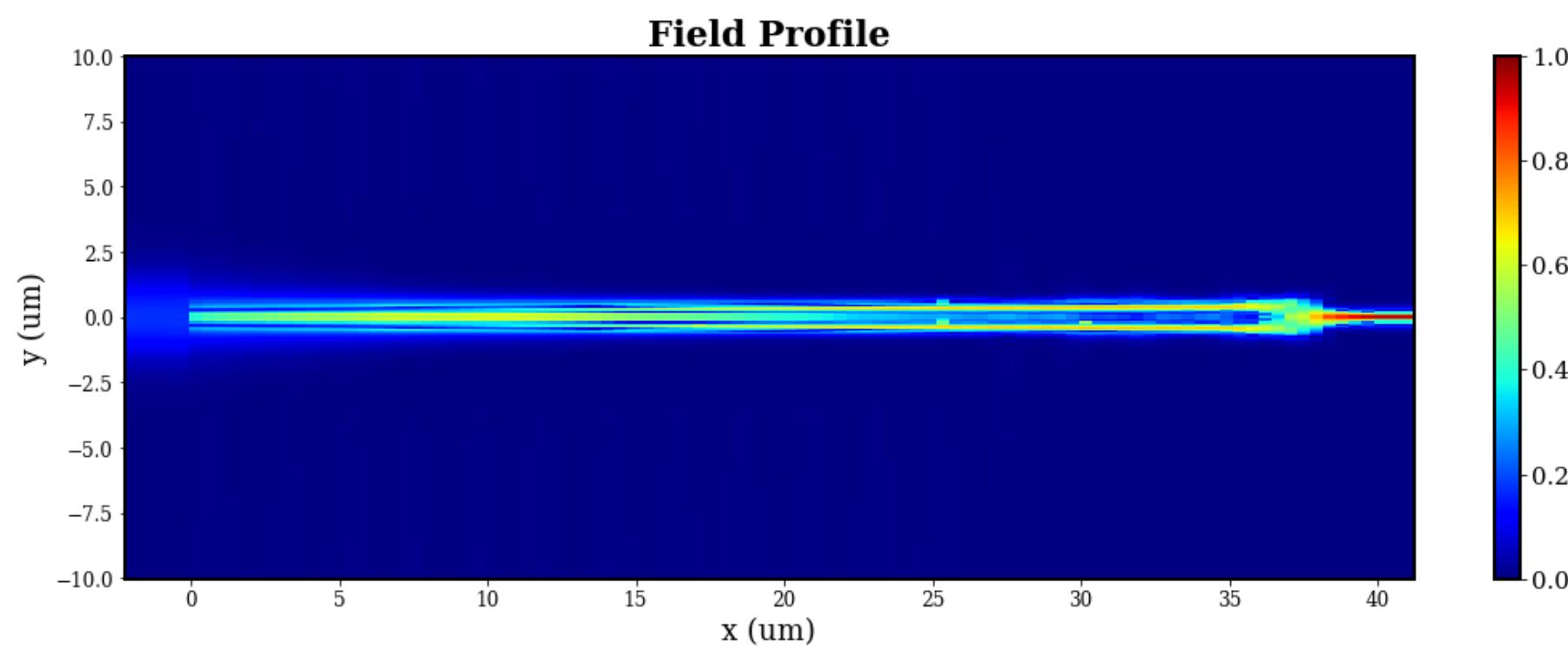


	group spans (μm)	cells	subcell method	modes	custom	cell range	start (μm)
1	2	1	none	2	default	[1]	-2
2	34.9	90	CVCS	4	default	[2 ... 91]	-1.33227e-15
3	1.5	10	CVCS	5	default	[92]	34.9
4	2.1	1	none	6	default	[102]	36.4
5	1.5	10	CVCS	3	default	[103	38.5
6	1	1	none	2	default	[113]	40

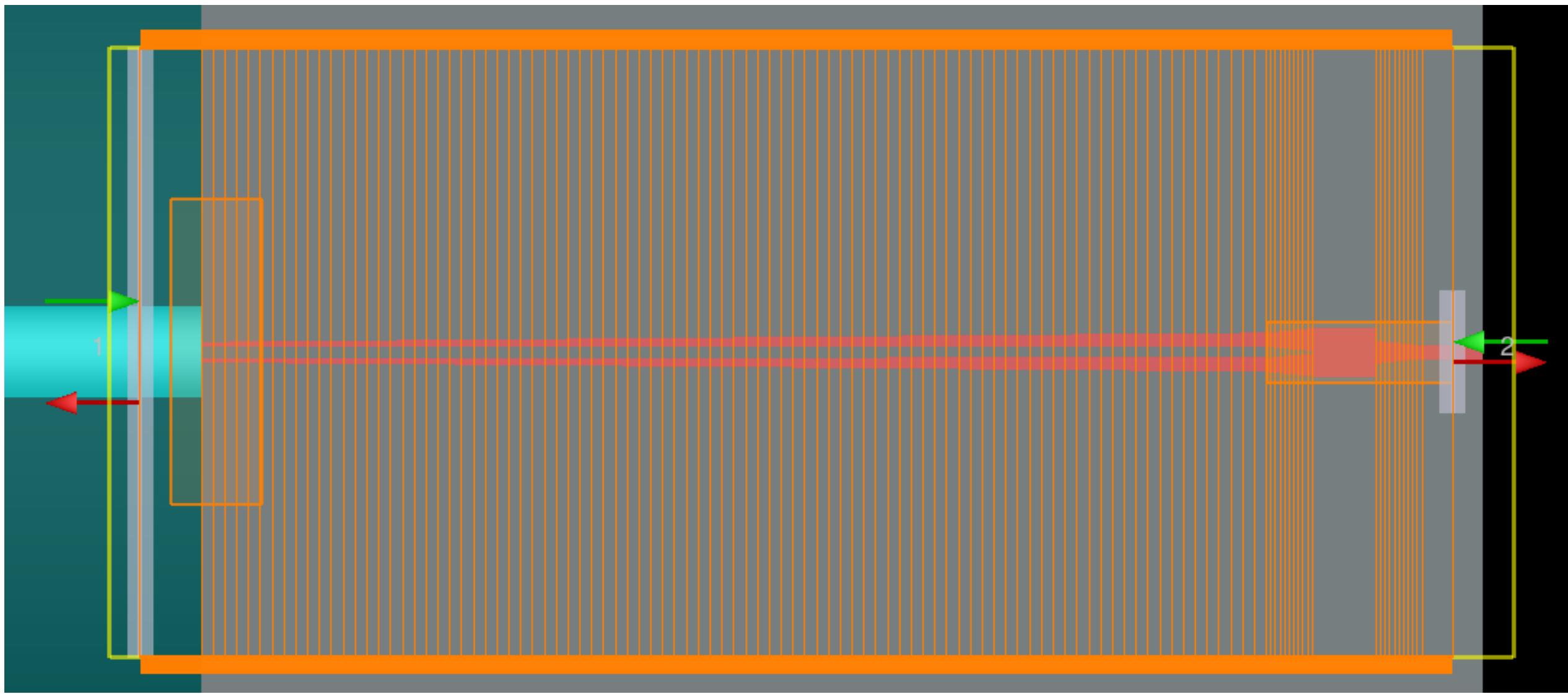
mudanças:

- **quantidade de modos ajustada**
- **a porta input foi afastada mais 1 um**

Resultados



Adicionando mesh



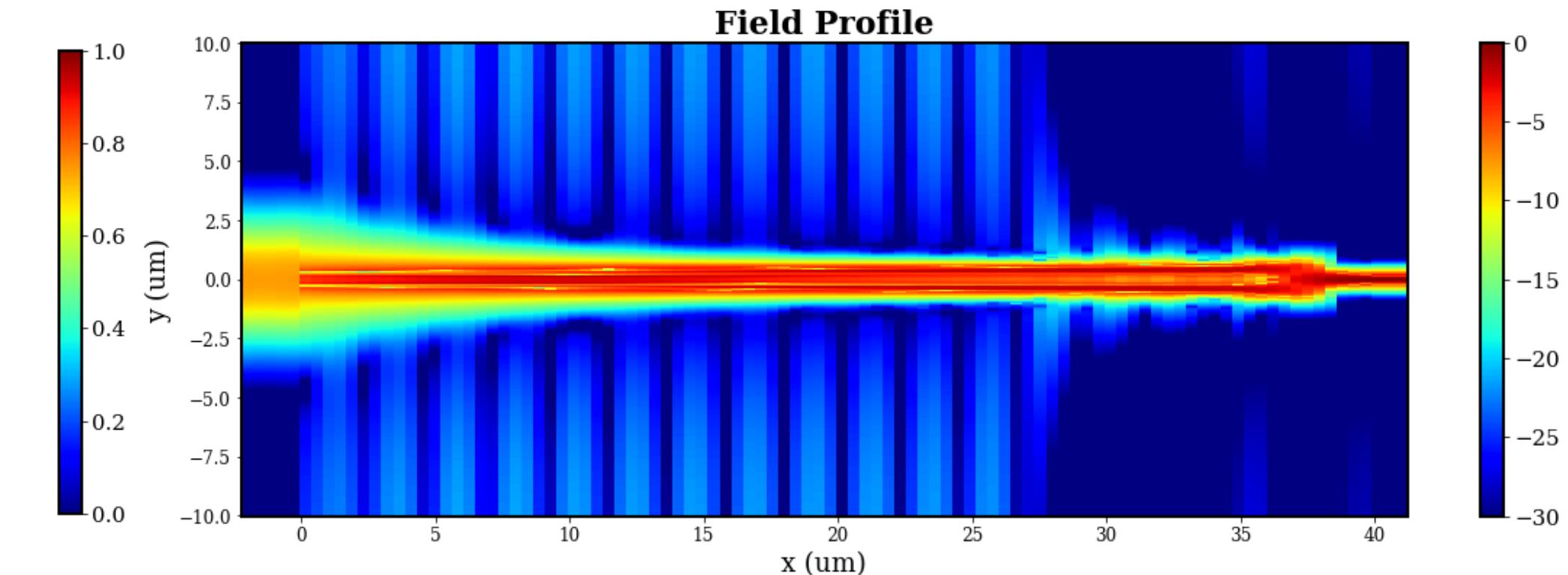
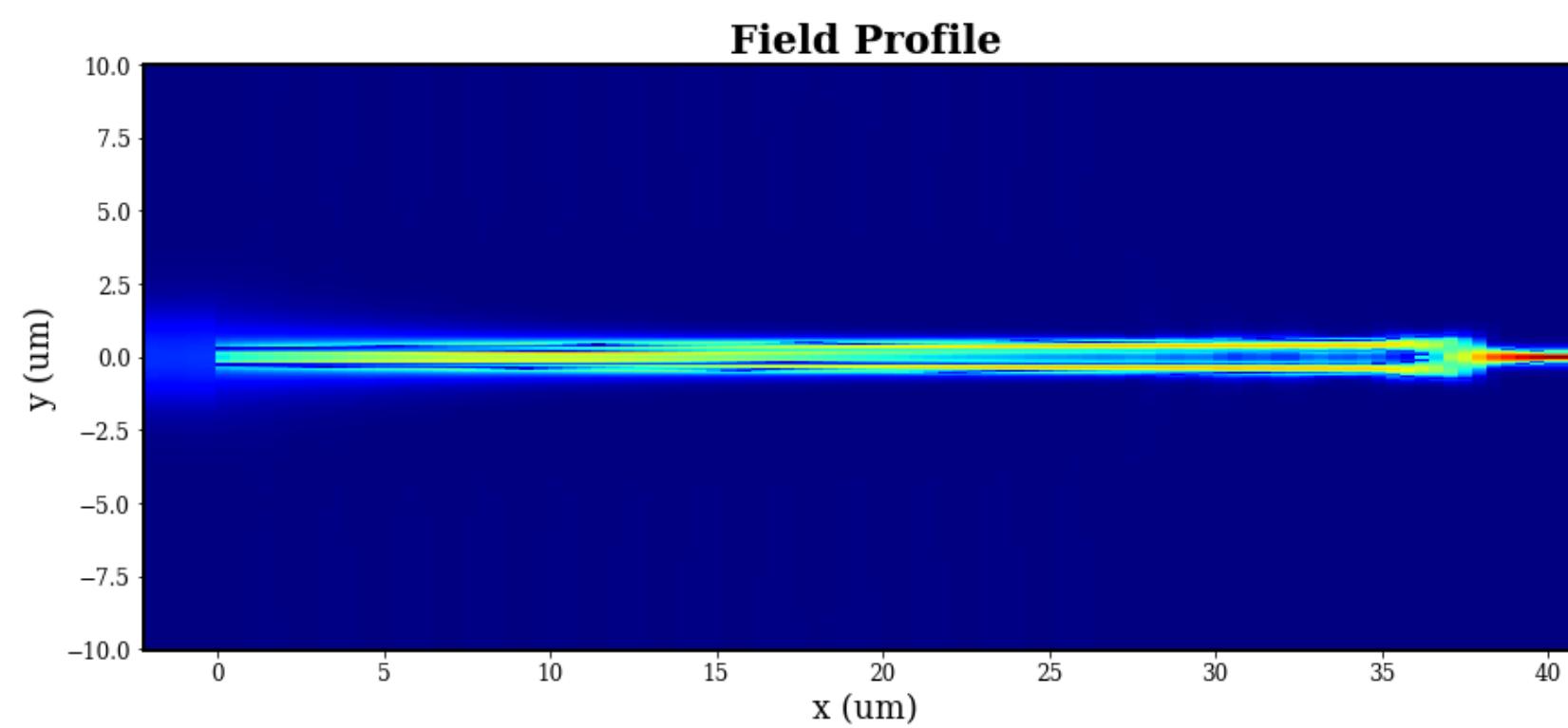
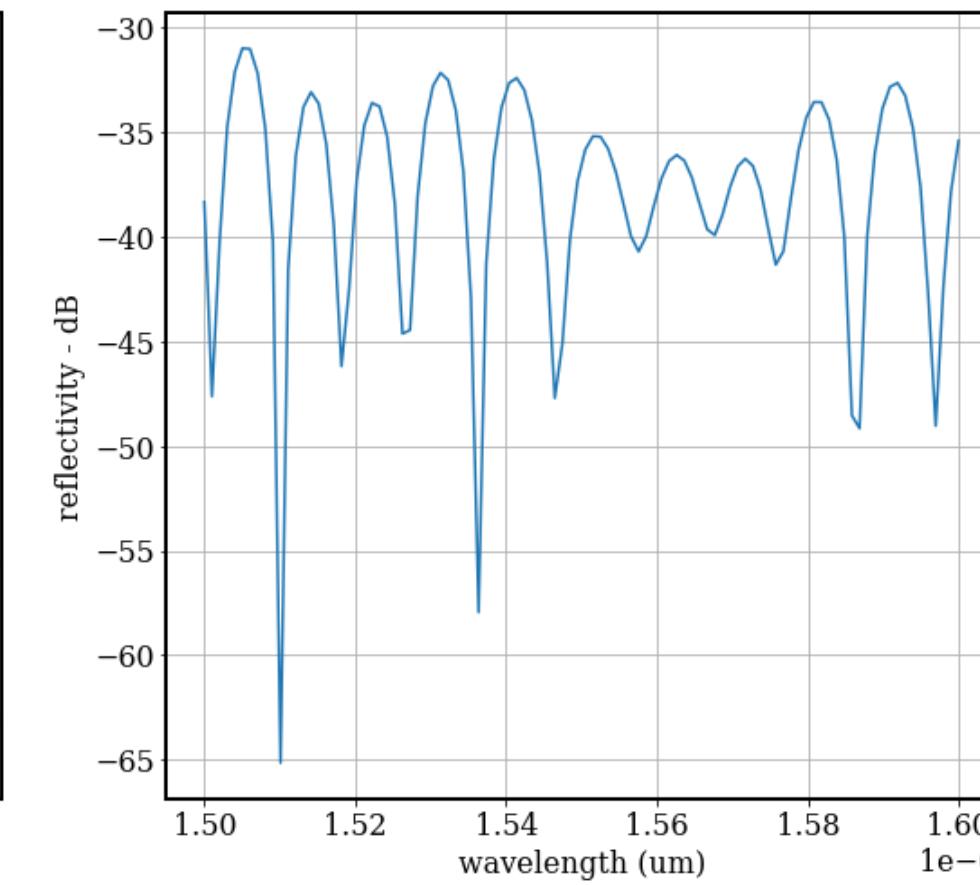
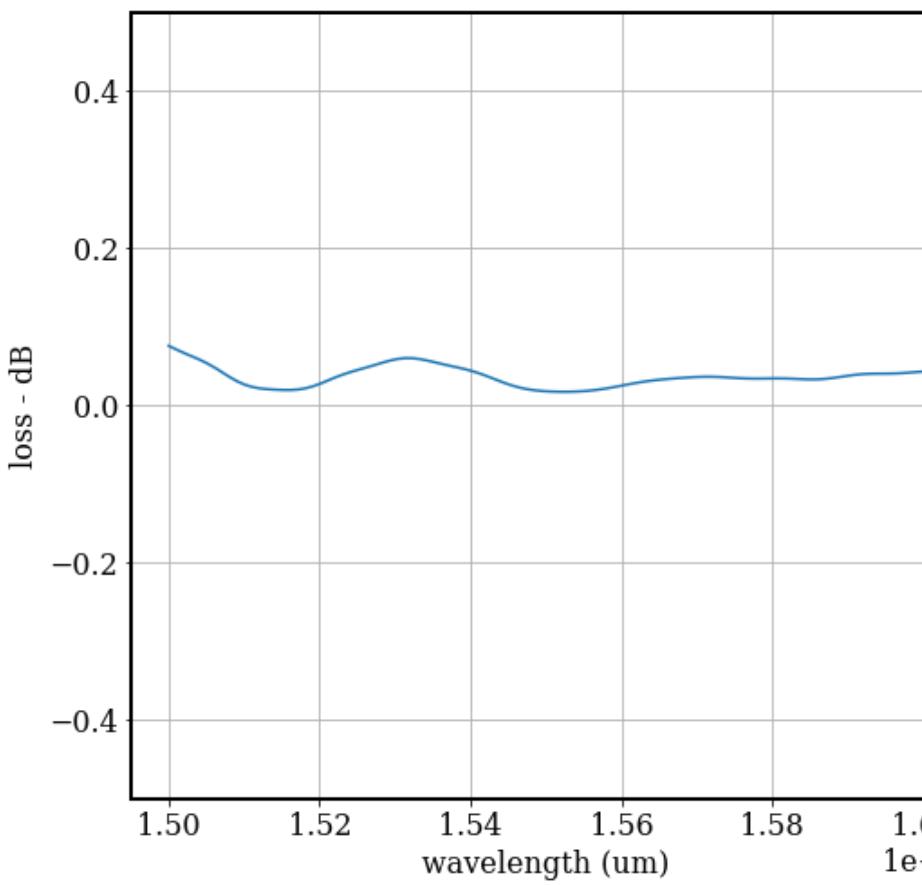
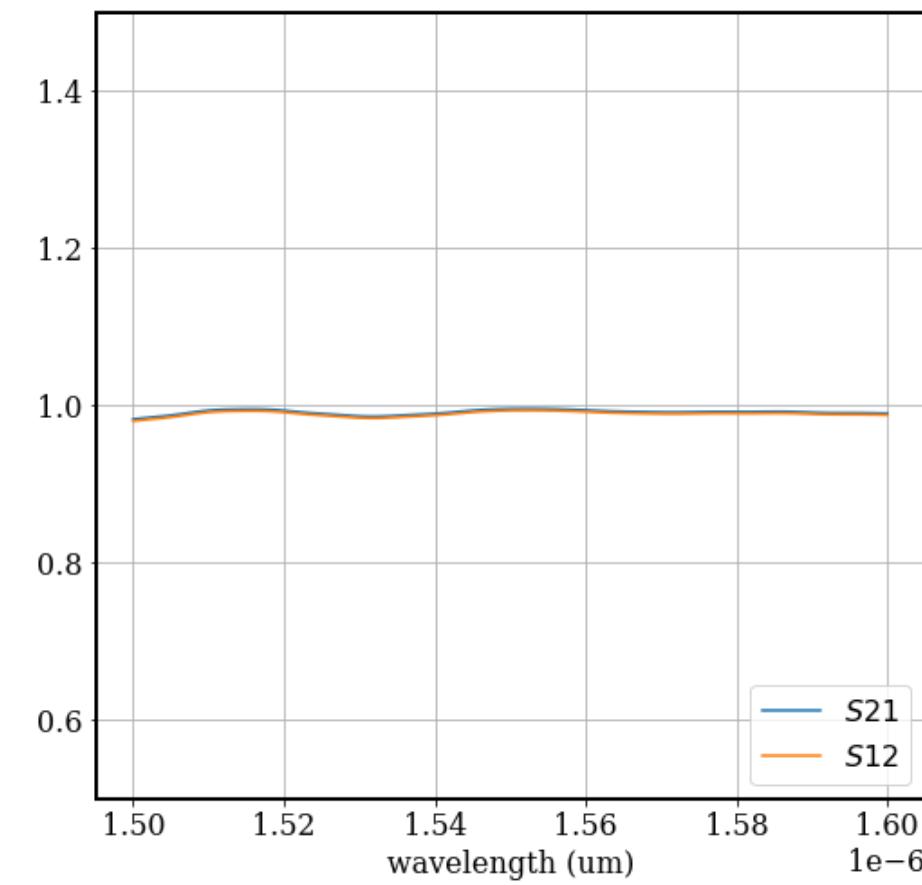
configurações do mesh 1:

- **dy = 0.02 um**
- **dz = 0.02 um**
- **x span = 3 um**
- **y span = 10 um**
- **z span = 2 um**

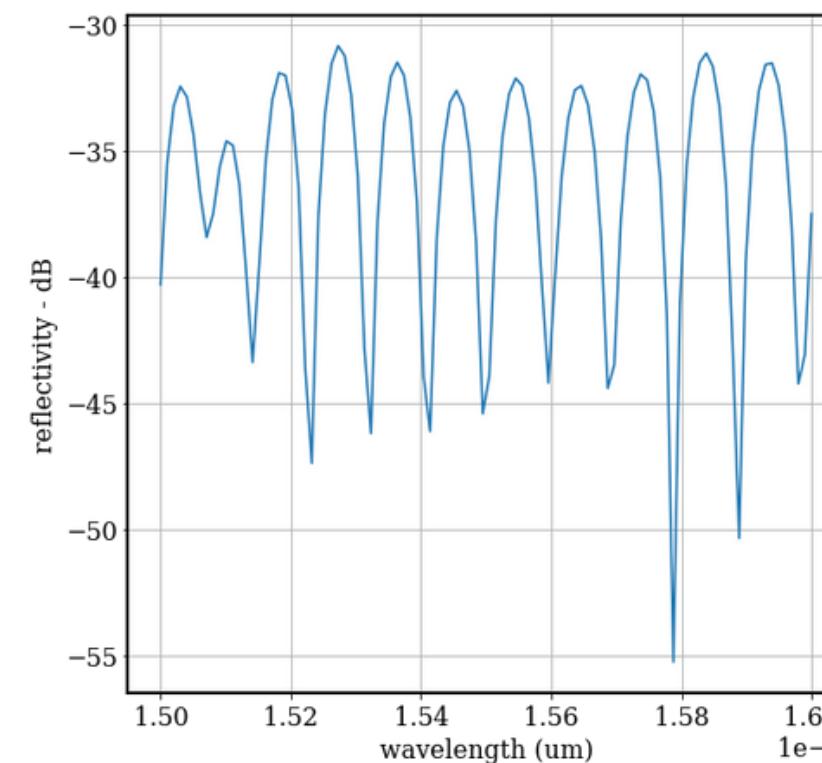
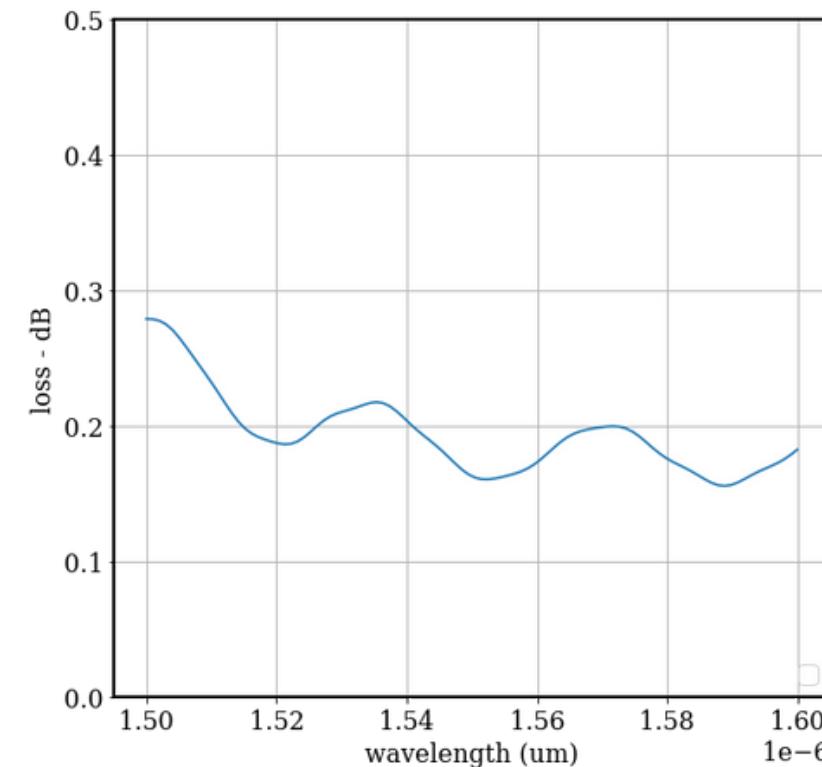
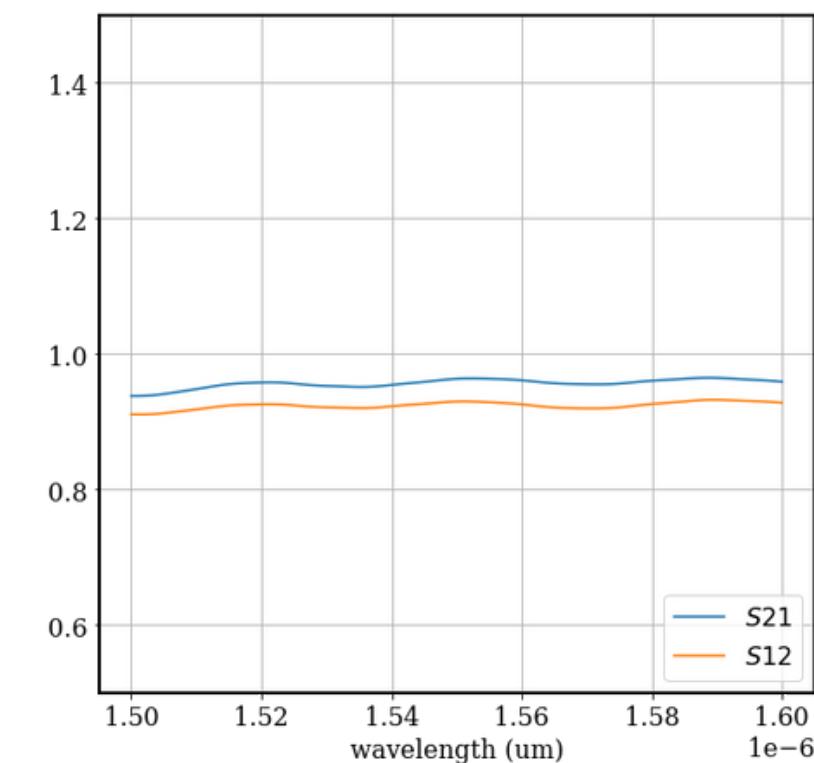
configurações do mesh 2:

- **dy = 0.02 um**
- **dz = 0.02 um**
- **x span = 6.1 um**
- **y span = 2 um**
- **z span = 2 um**

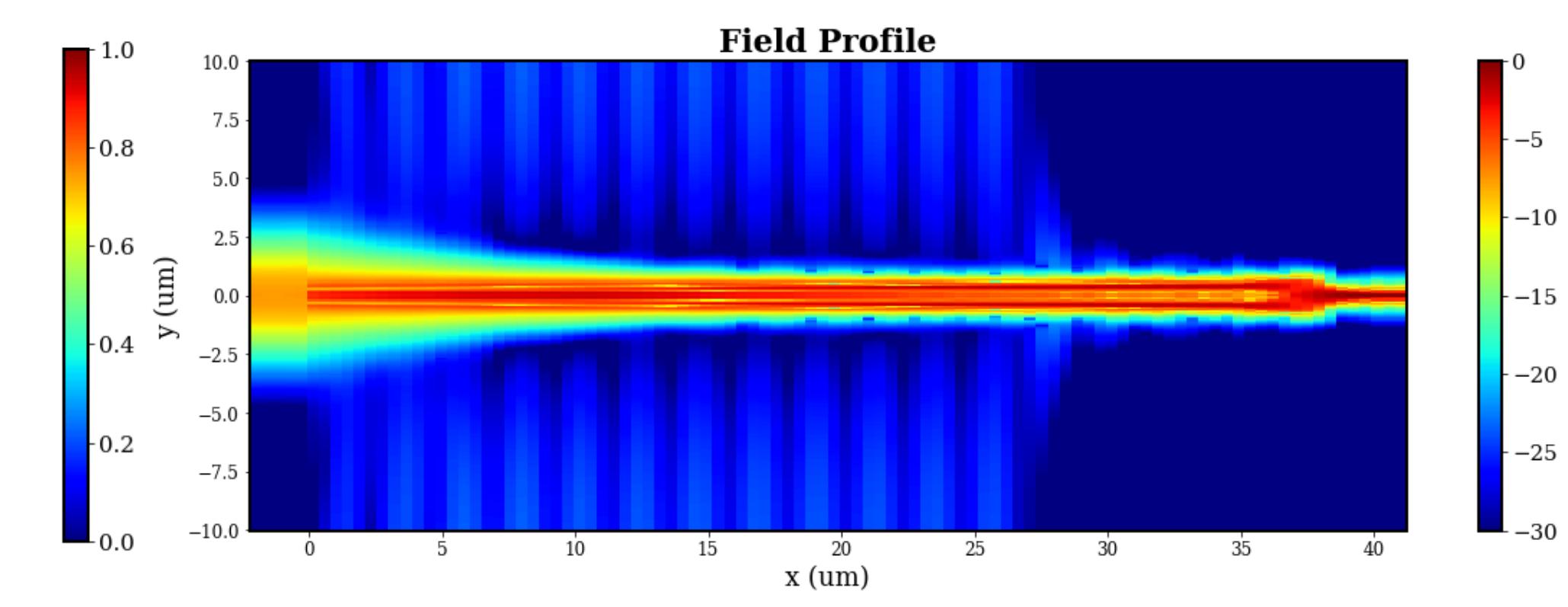
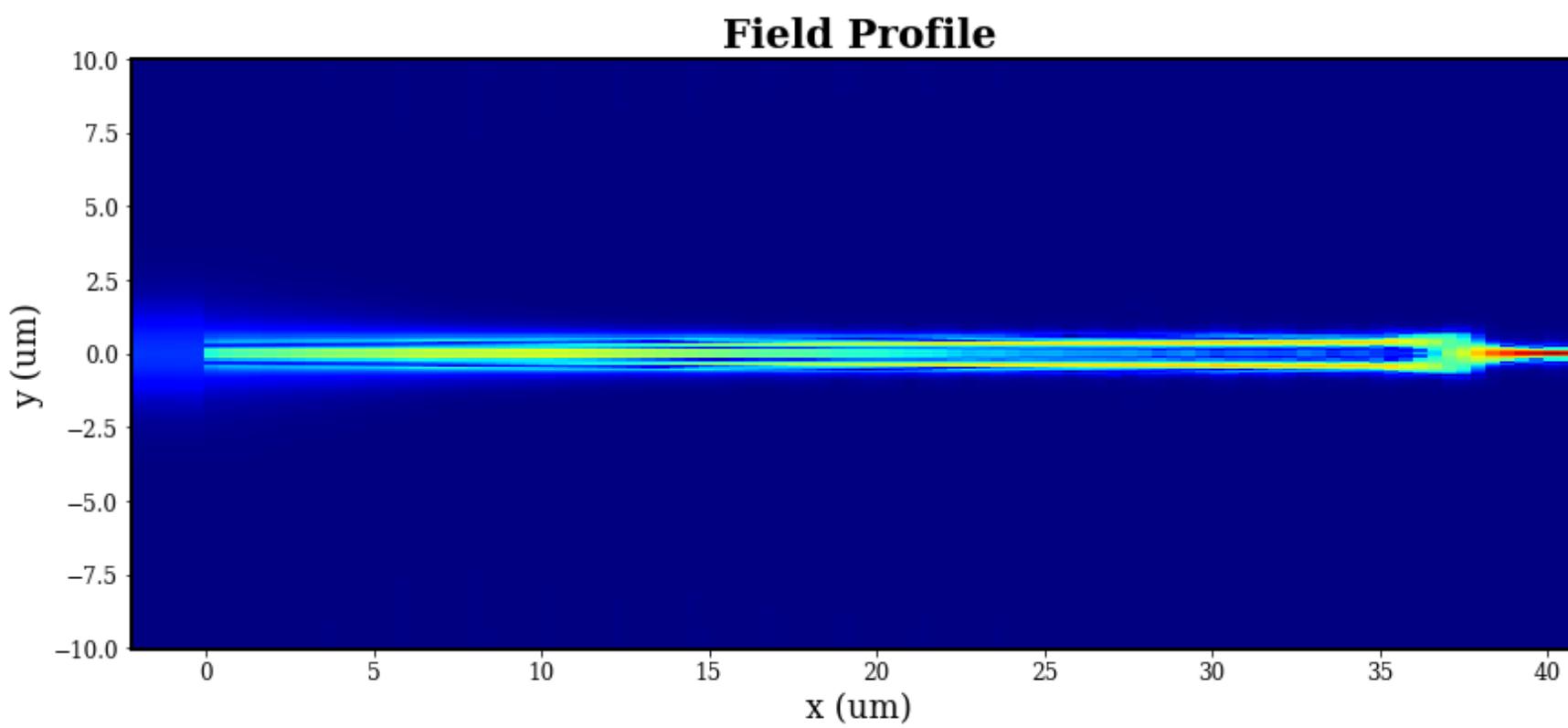
Resultados



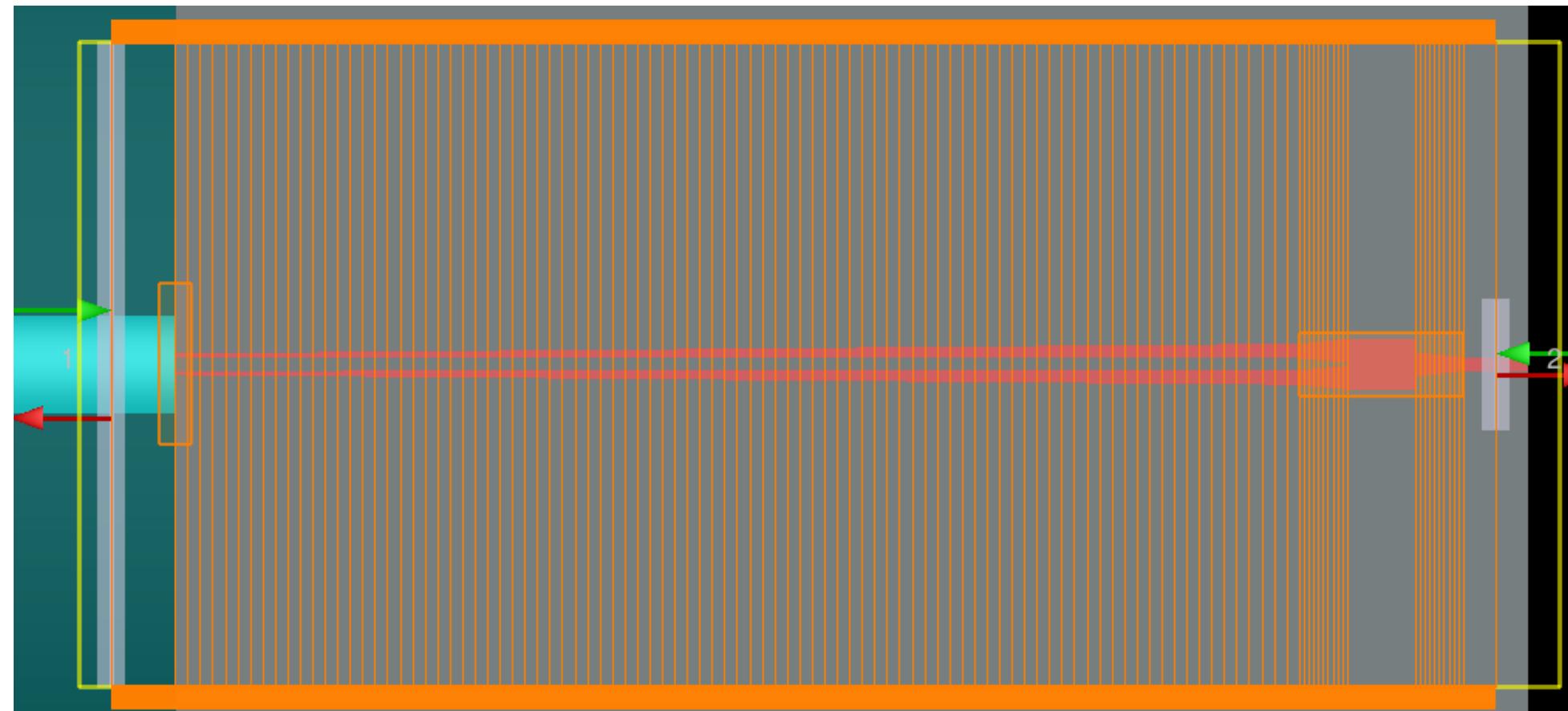
tirando a simetria e ajustando o número de modos



group spans (μm)	cells	subcell method	modes
1 2	1	none	2
2 34.9	90	CVCS	6
3 1.5	10	CVCS	7
4 2.1	1	none	9
5 1.5	10	CVCS	4
6 1	1	none	3

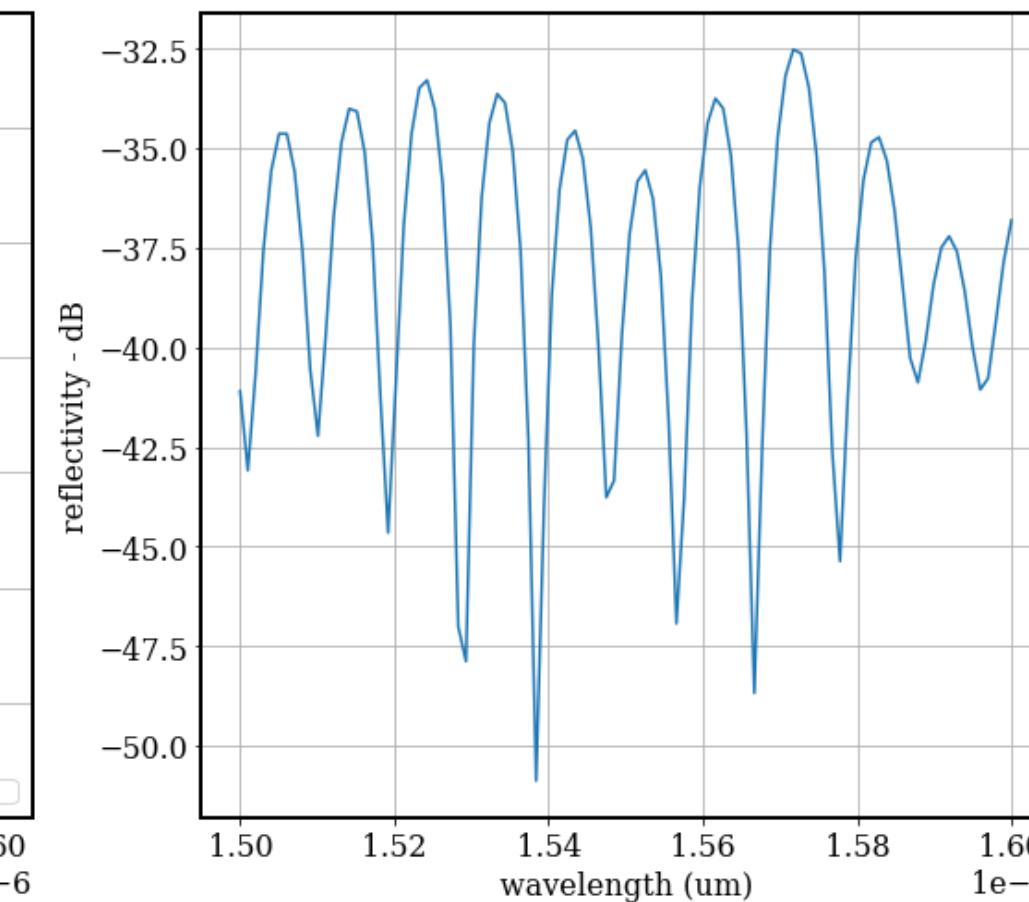
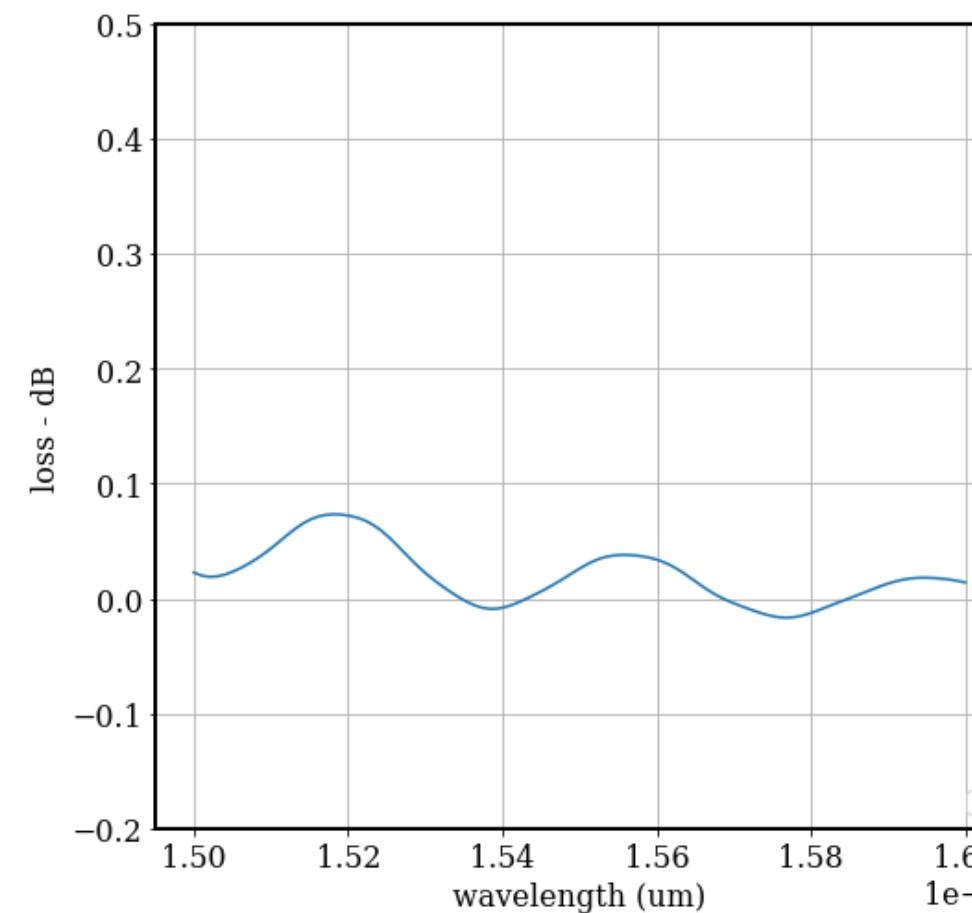
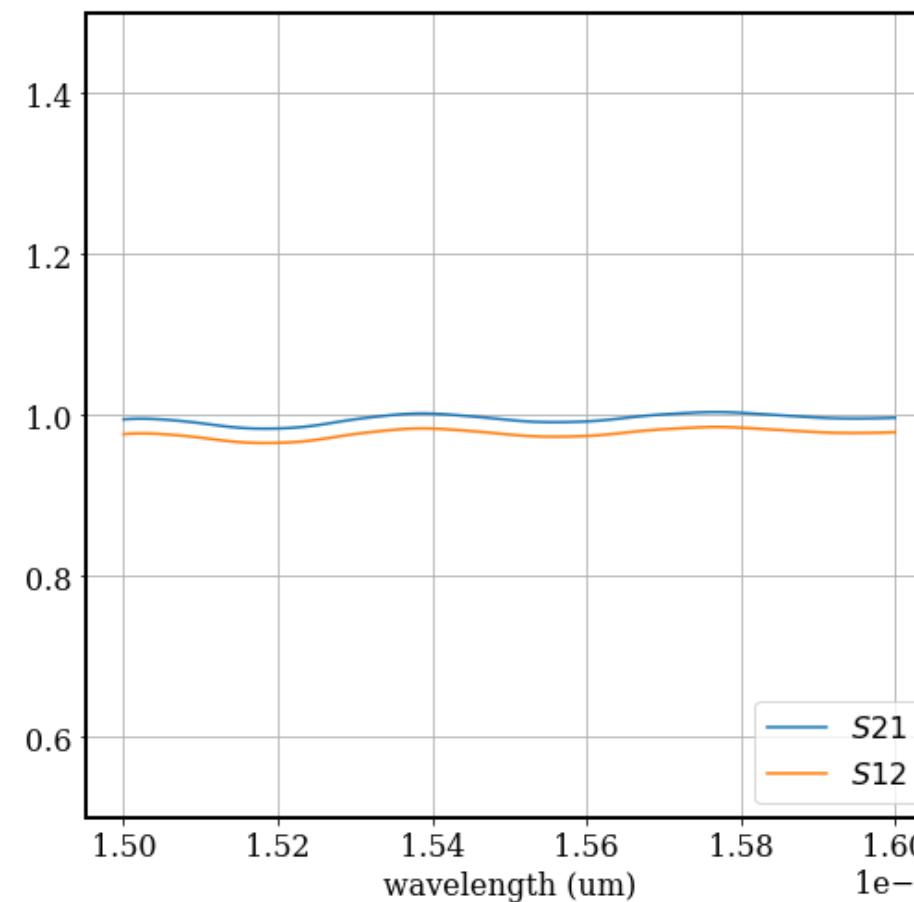


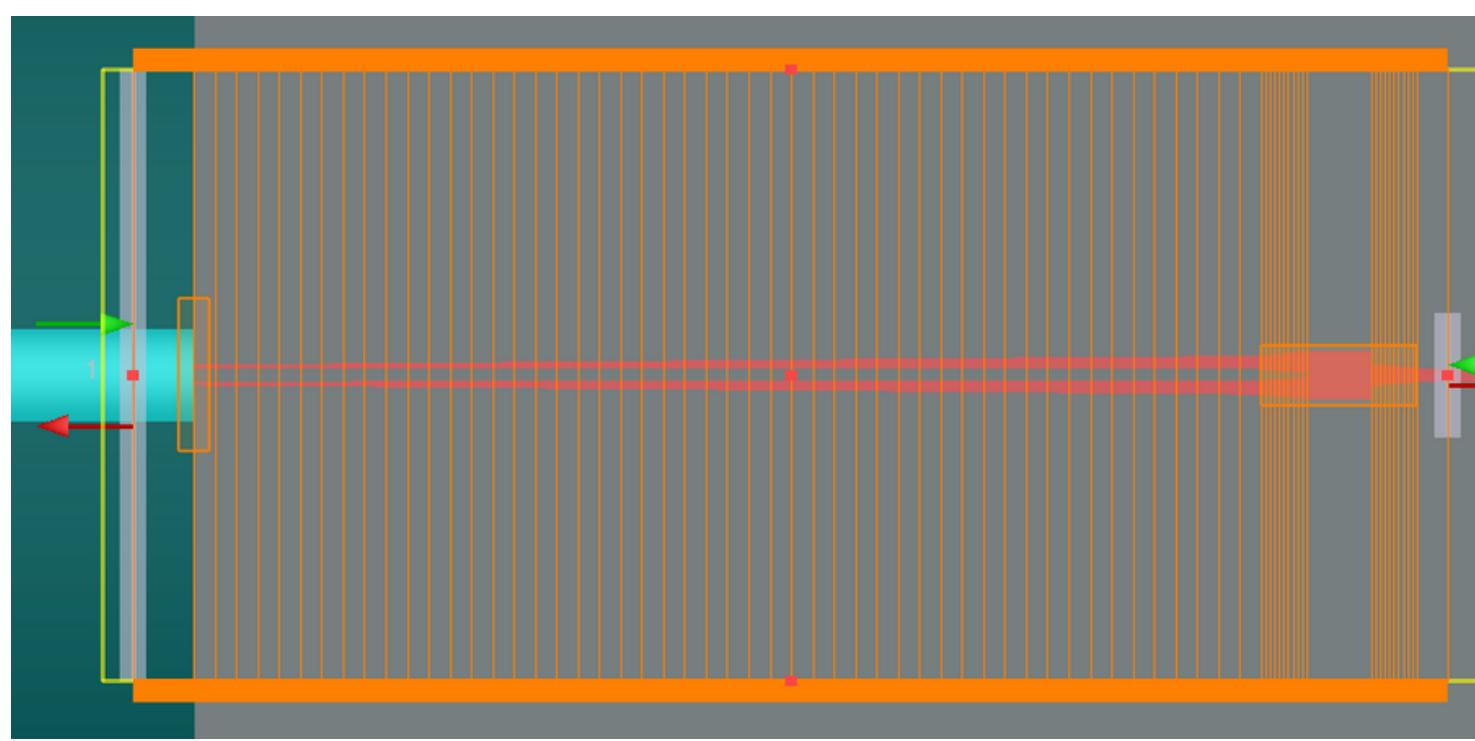
semana 5



group spans (μm)	cells	subcell method	modes
1 2	1	none	2
2 34.9	90	CVCS	6
3 1.5	10	CVCS	7
4 2.1	1	none	9
5 1.5	10	CVCS	4
6 1	1	none	3

- mesh cells Y = 400
- mesh cells Z = 400
- input mesh:
 - x span = 1 um
 - y span = 5 um
 - z span = 2 um
 - dy = 0.05 um
 - dz = 0.05 um
- output mesh:
 - x span = 5.1 um
 - y span = 2 um
 - z span = 2 um
 - dy = 0.05 um
 - dz = 0.05 um





group spans (μm)	cells	subcell method	modes
1 2	1	none	2
2 34.9	50	CVCS	6
3 1.5	10	CVCS	7
4 2.1	1	none	9
5 1.5	10	CVCS	4
6 1	1	none	3

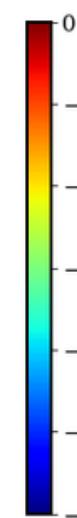
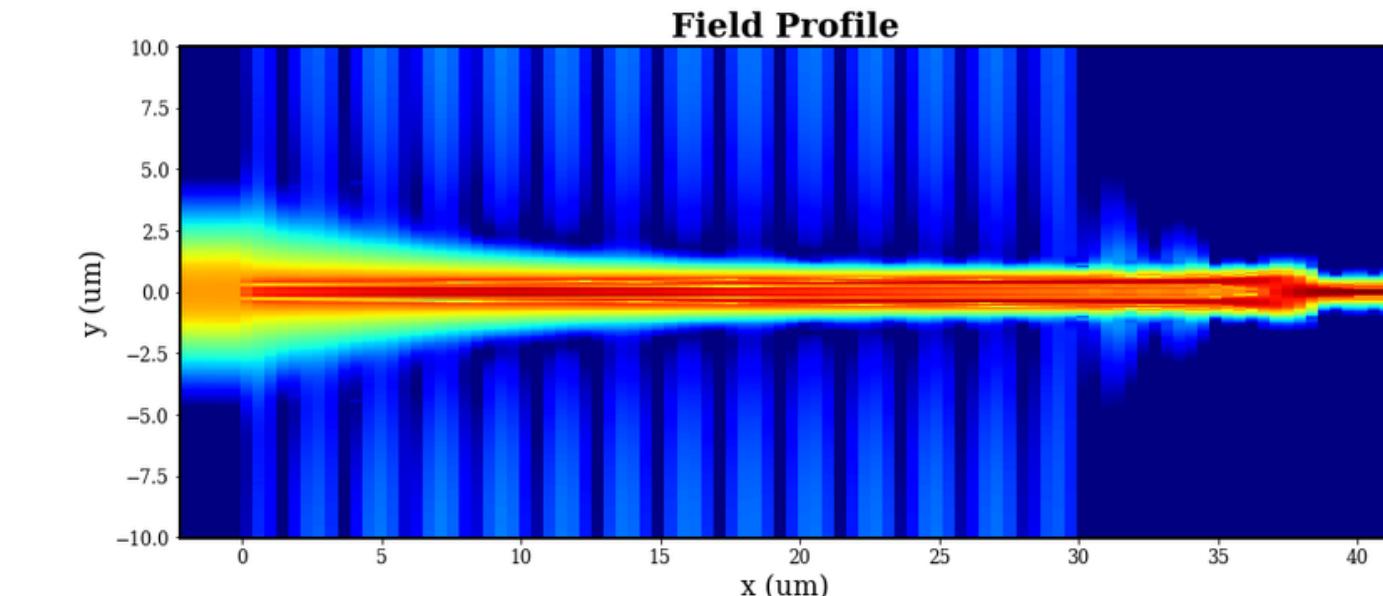
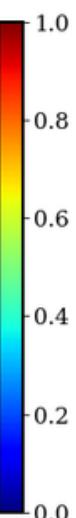
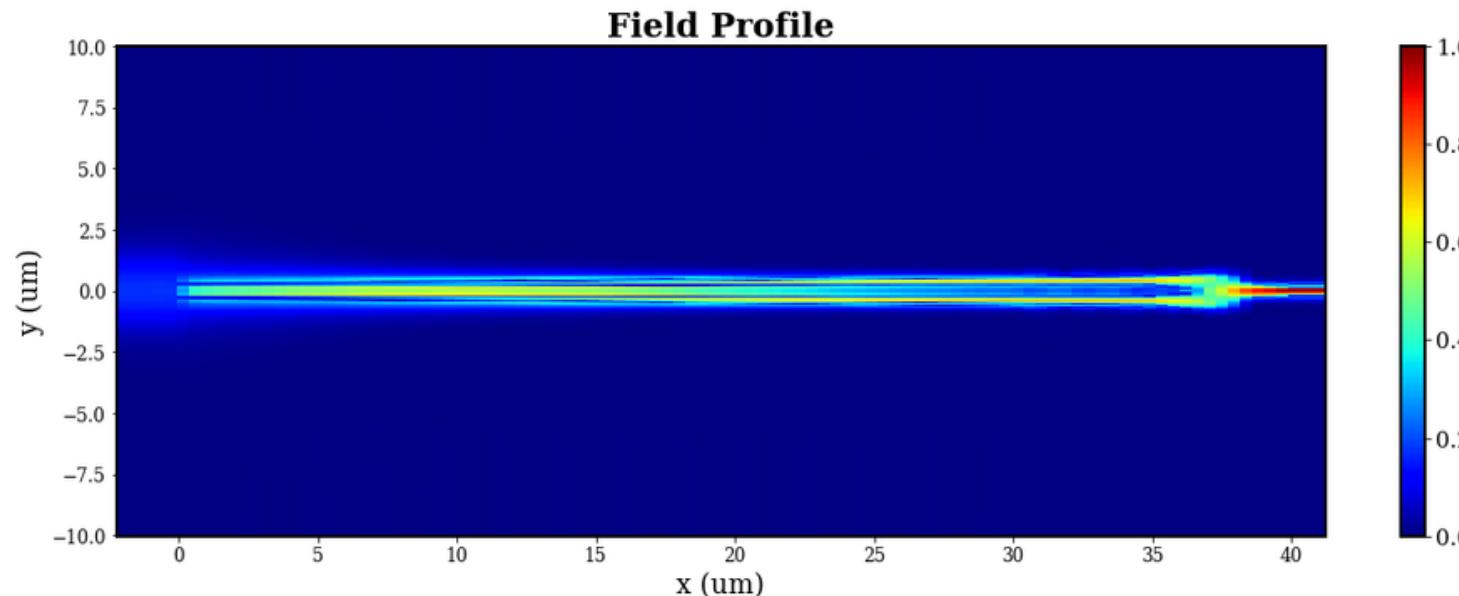
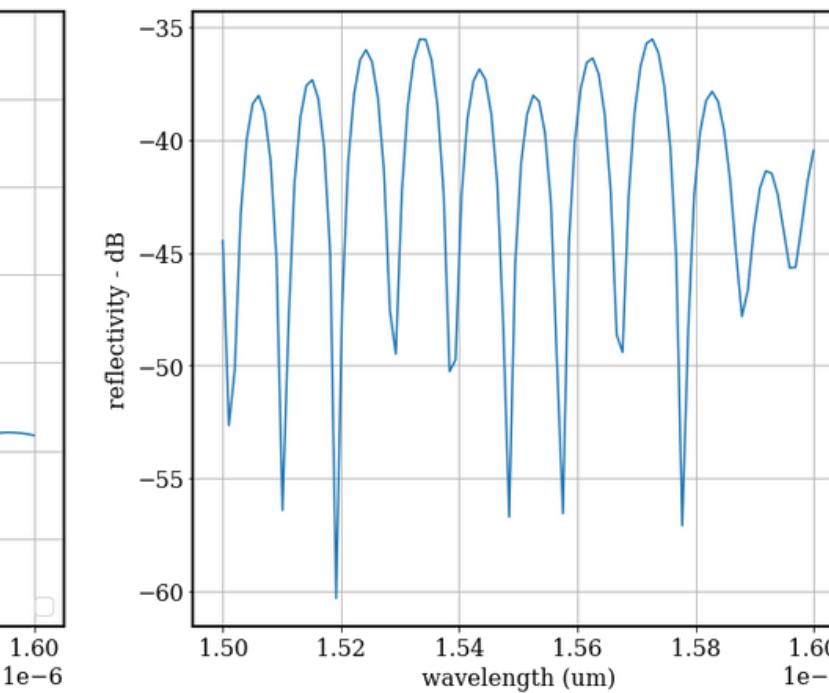
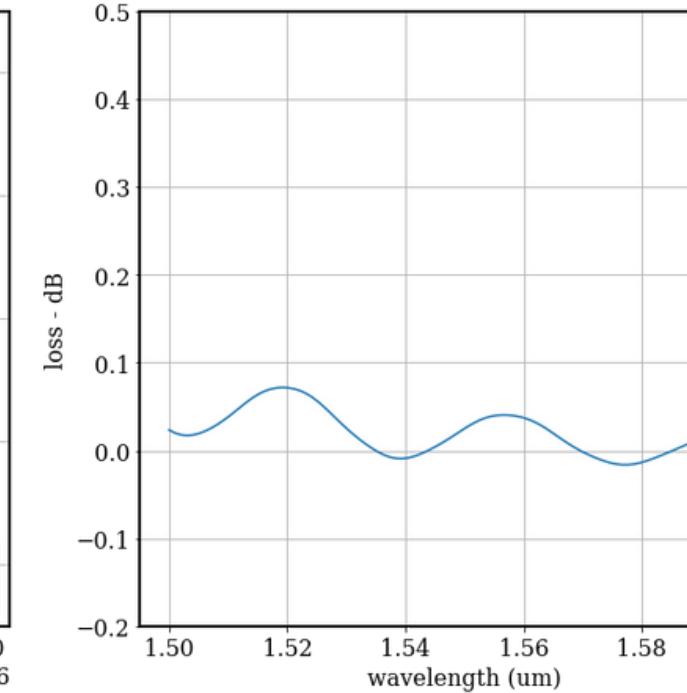
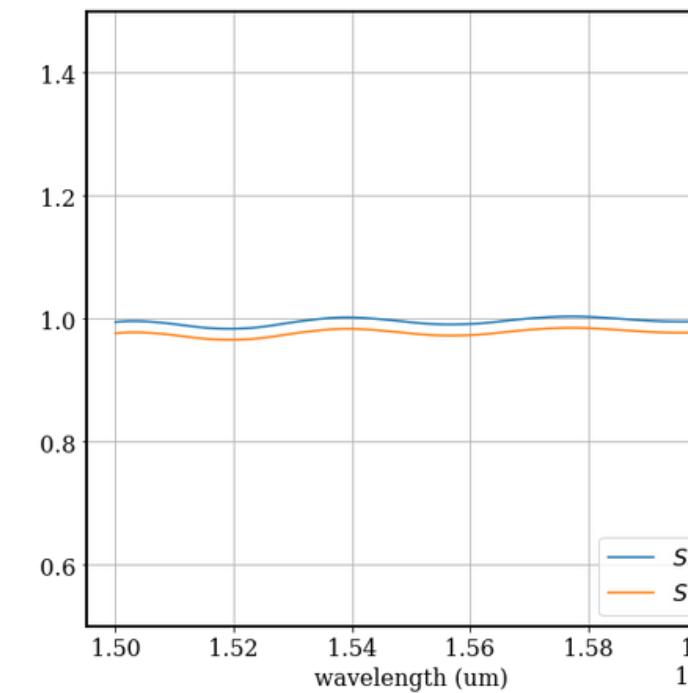
- mesh cells Y = 400
- mesh cells Z = 400

input mesh:

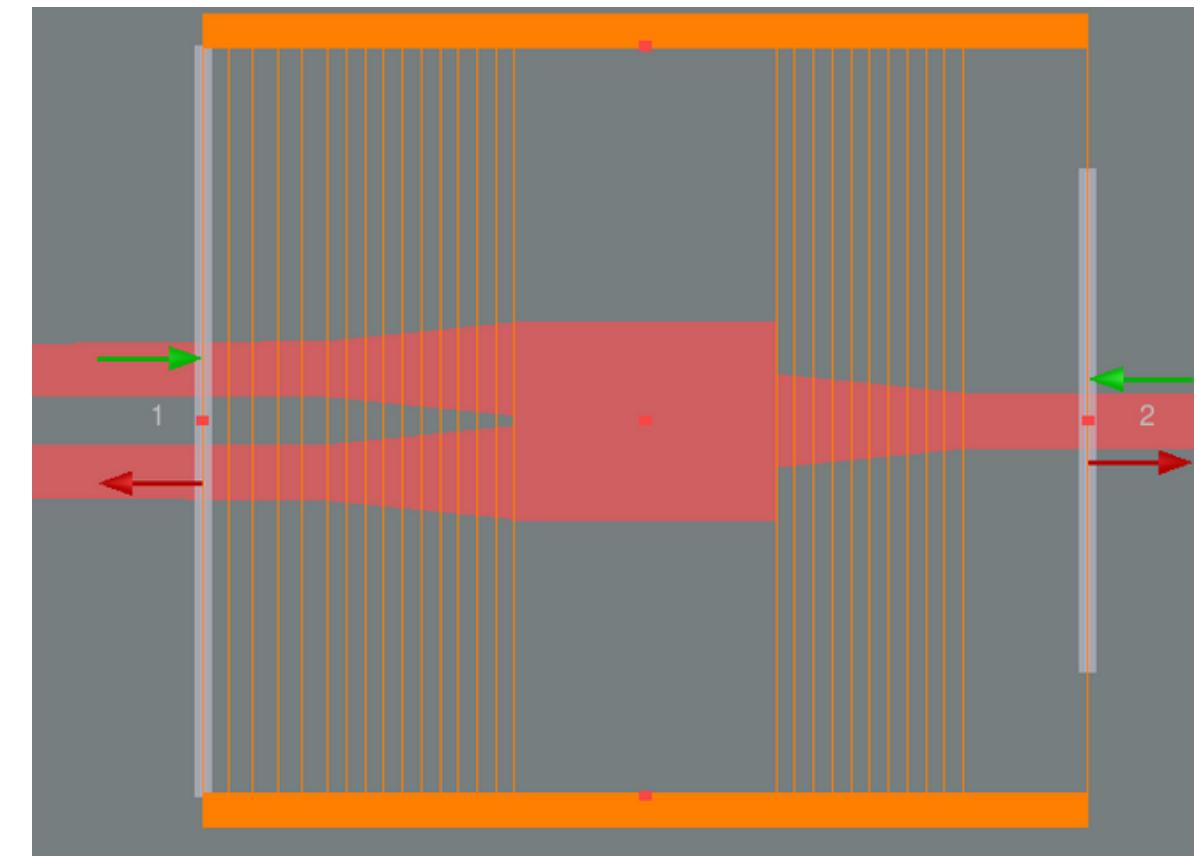
- x span = 1 μm
- y span = 5 μm
- z span = 2 μm
- dy = 0.05 μm
- dz = 0.05 μm

output mesh:

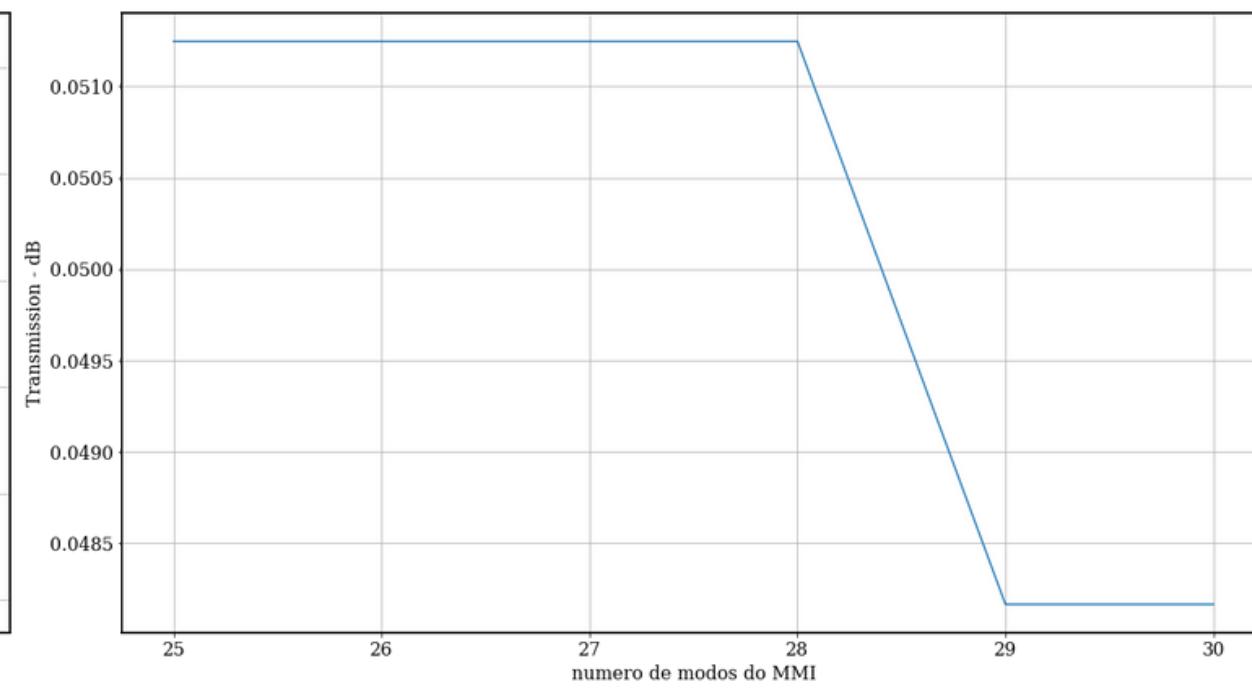
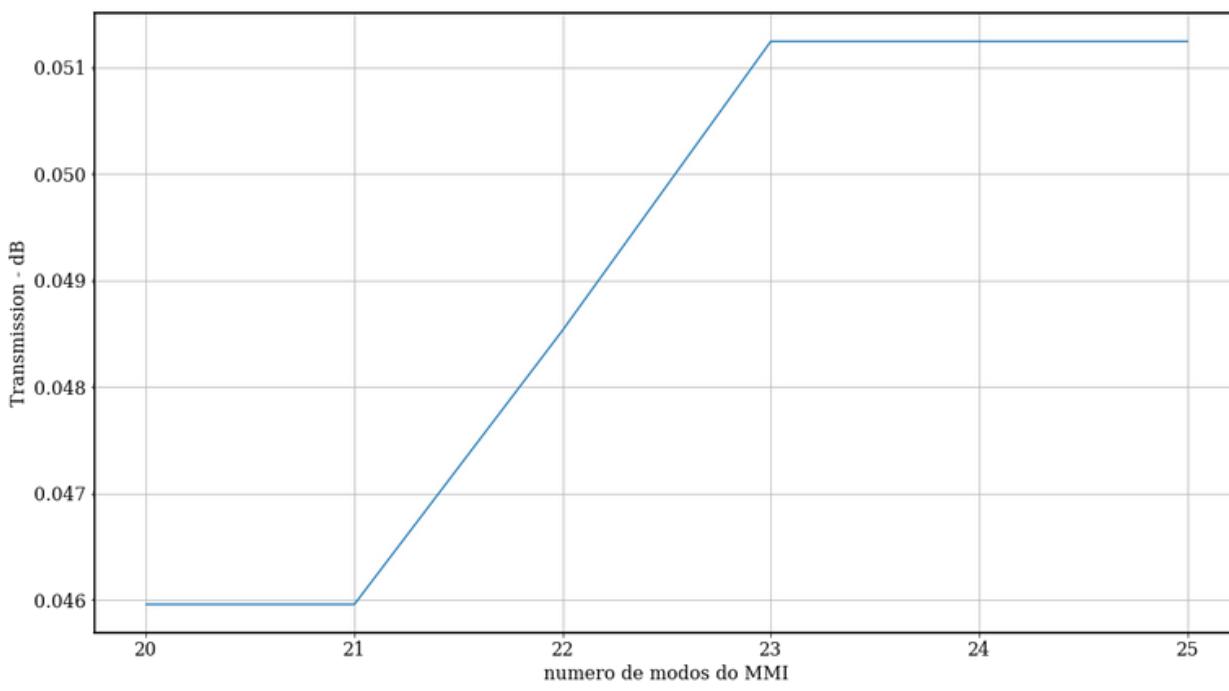
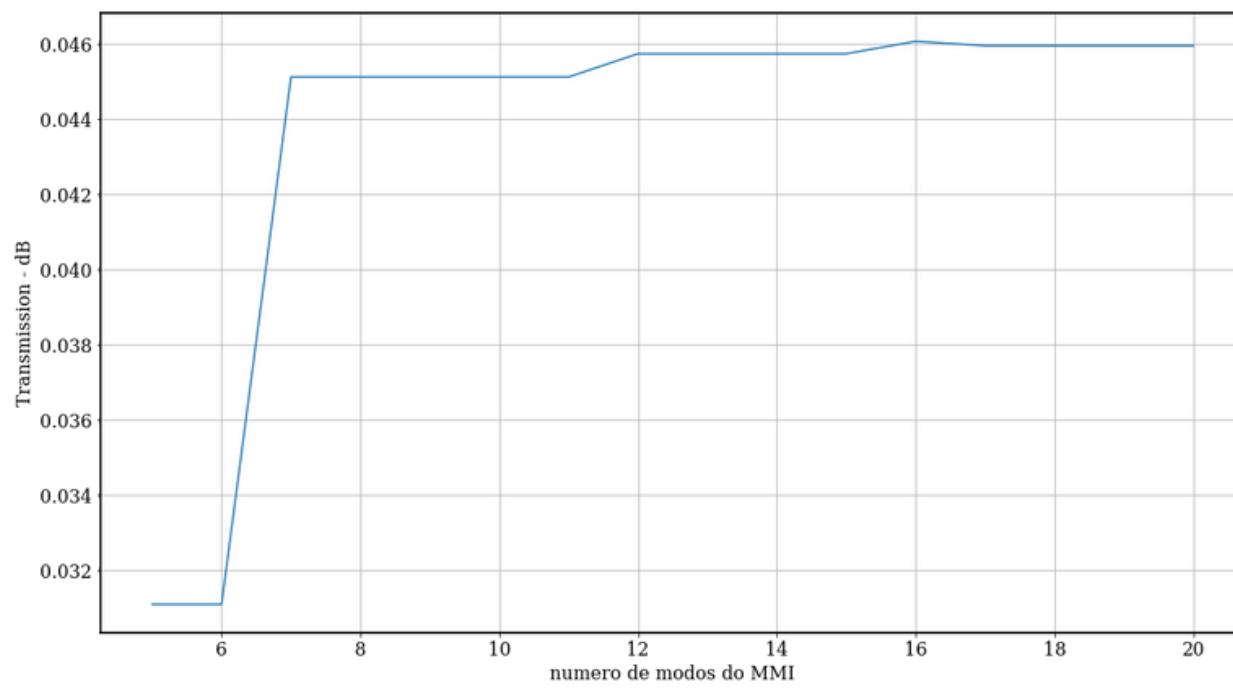
- x span = 5.1 μm
- y span = 2 μm
- z span = 2 μm
- dy = 0.05 μm
- dz = 0.05 μm



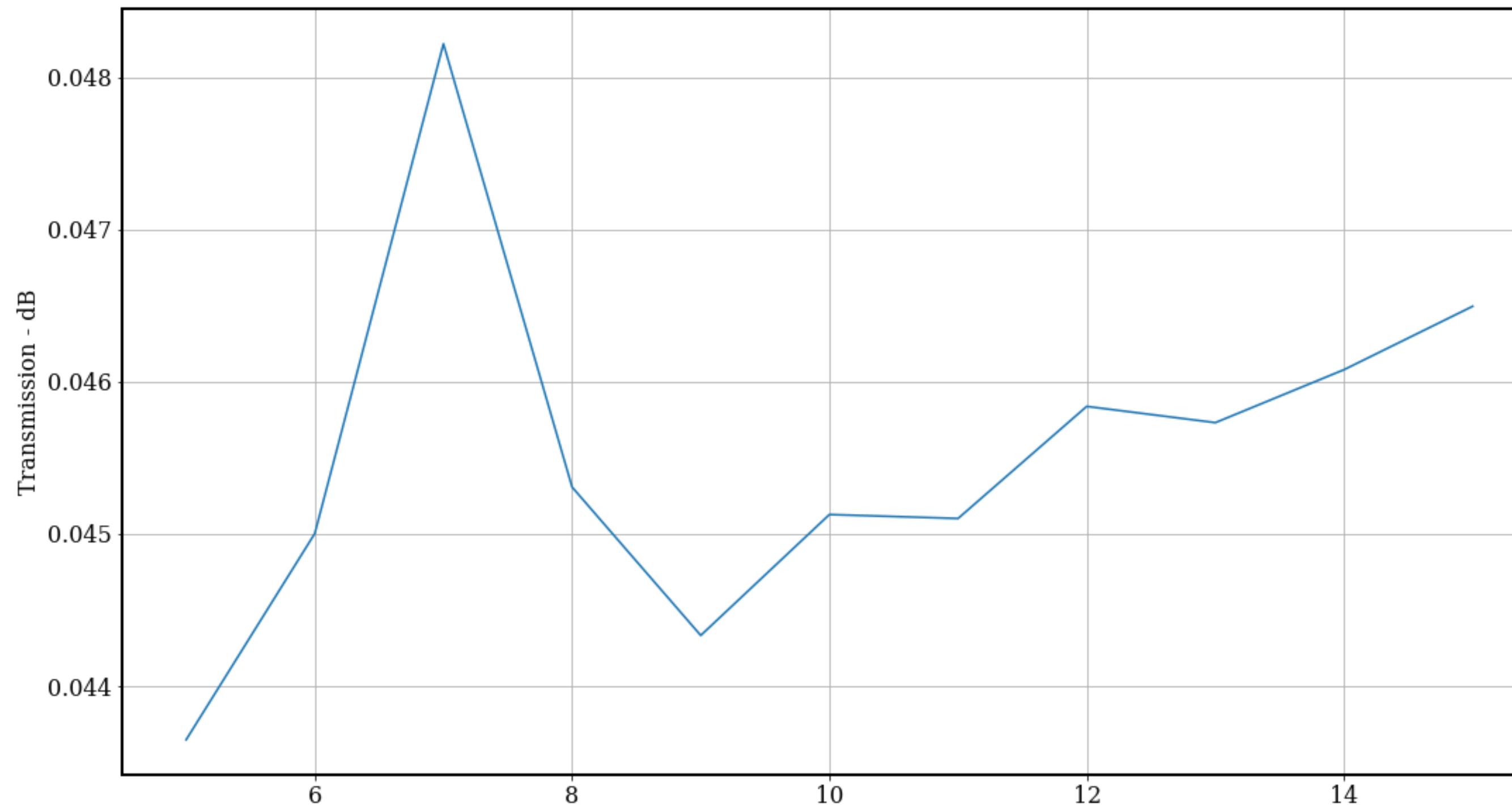
**simulação do MMI separadamente
convergencia tamanho das portas
convergencia de celulas na região central
convergência em Z**



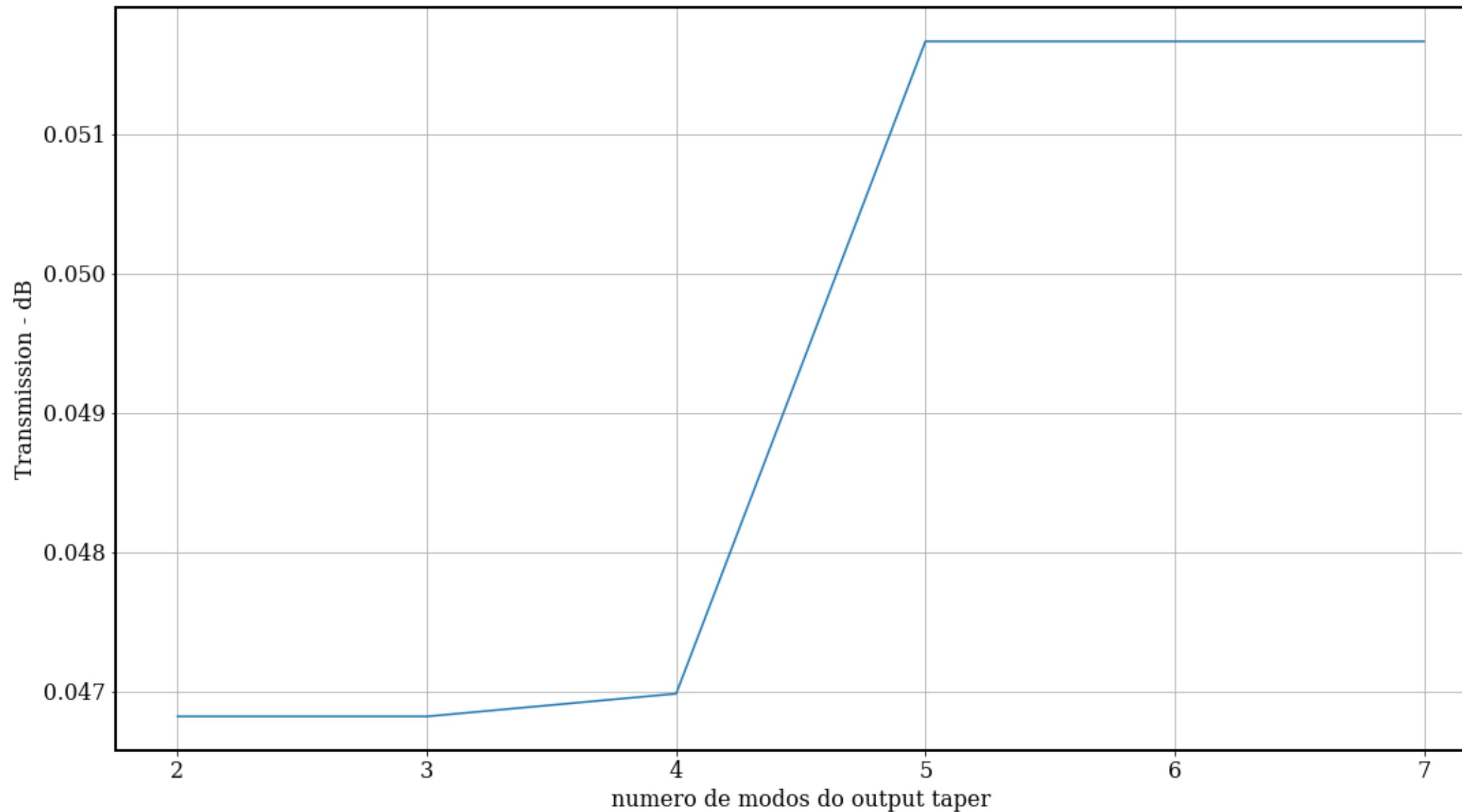
group spans (μm)	cells	subcell method	modes
1 1	5	CVCS	6
2 1.5	10	CVCS	7
3 2.1	1	none	10
4 1.5	10	CVCS	4
5 1	1	none	3

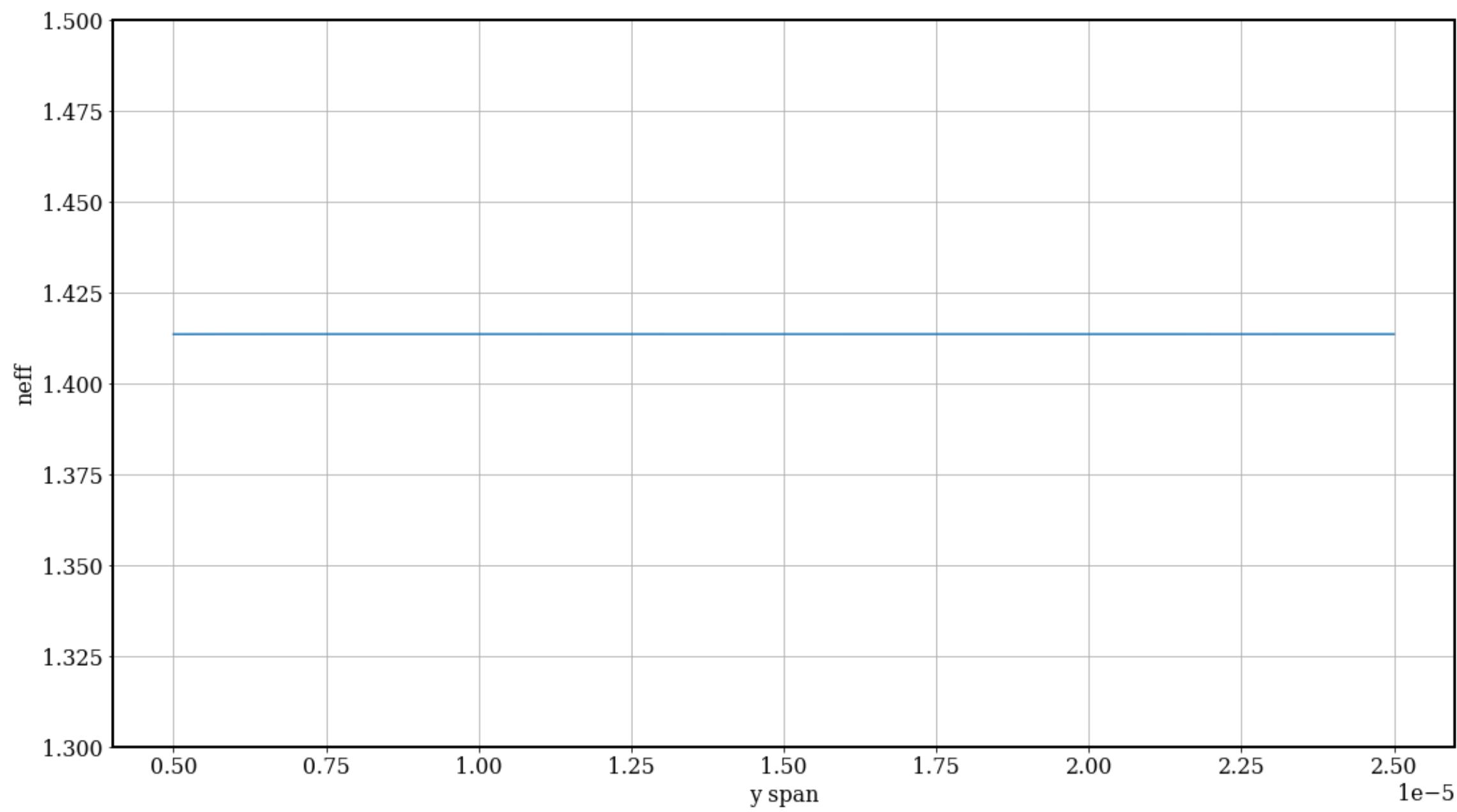
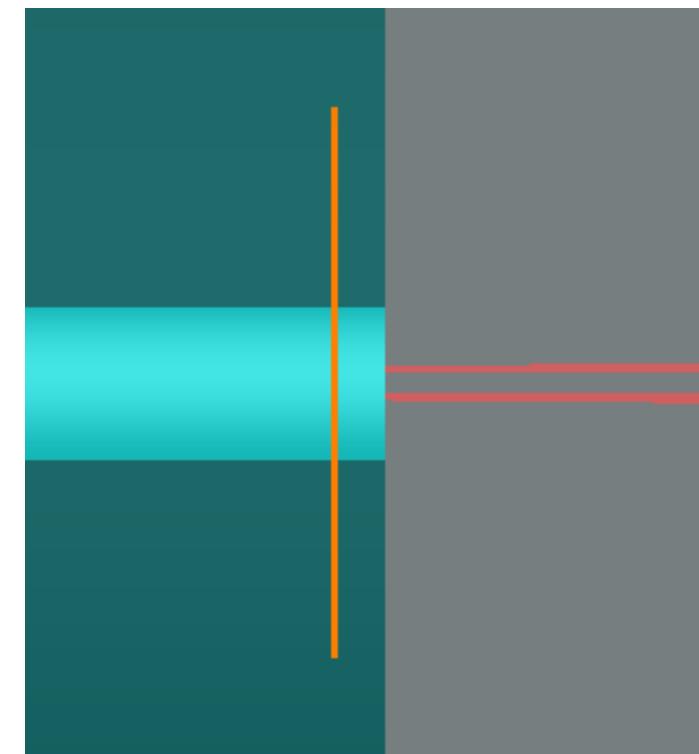


sweep do número de células da região dos tapers

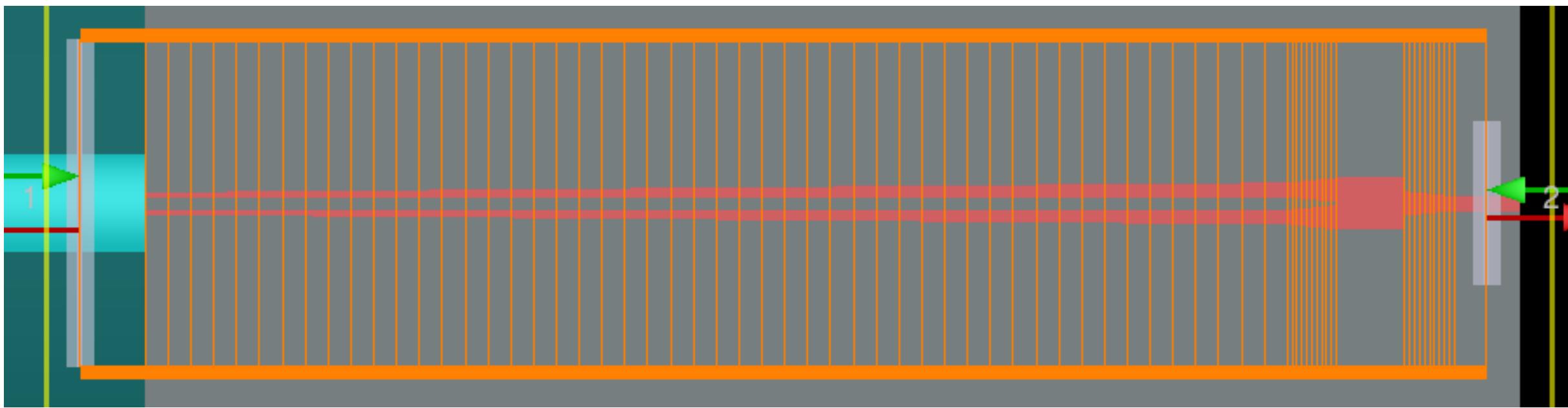


sweep do número de modos da região do taper de saída





SIMULAÇÃO NO EME



SOI waveguide

EME SETTINGS:

- **y min BC = PML**
- **y max BC = PML**
- **z min BC = Symmetric**
- **z max BC = PML**
- **y span = 10 um**
- **z span = 10 um**
- **min mesh step = 1e-6**
- **mesh cells = 450**

Port 1 settings:

- **y span = 10 um**
- **z span = 10 um**

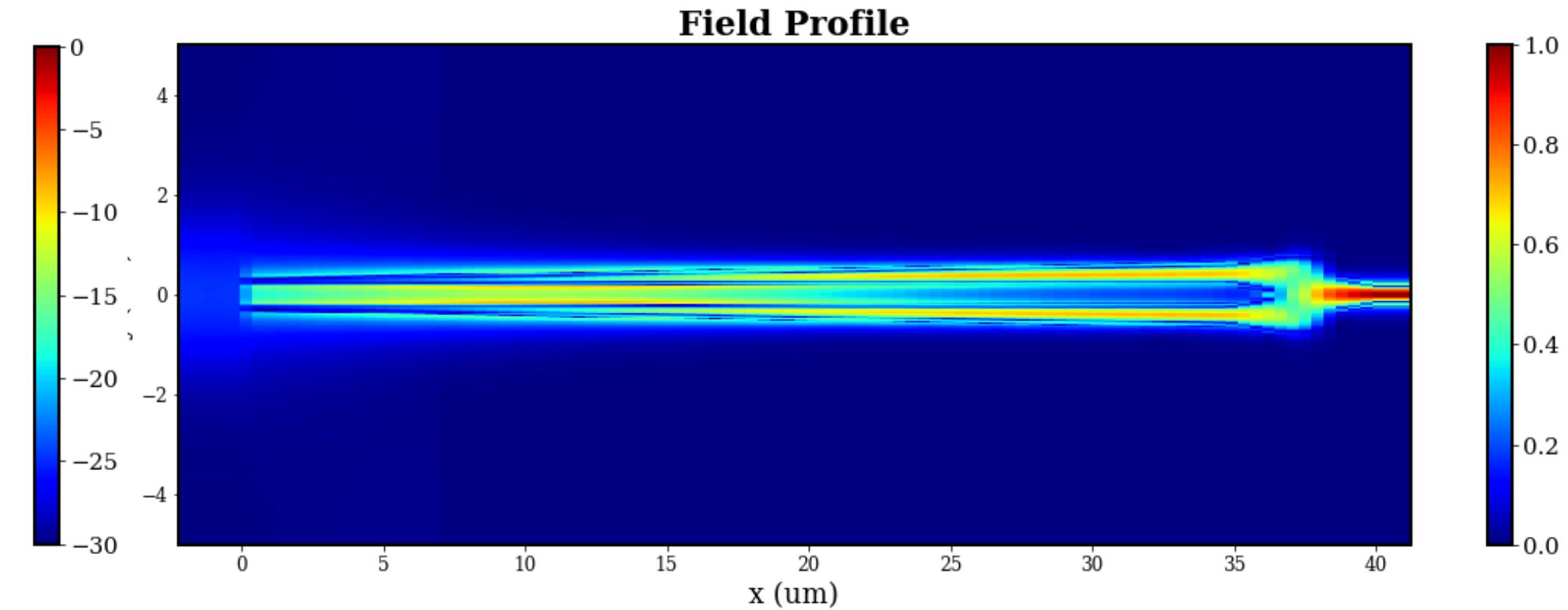
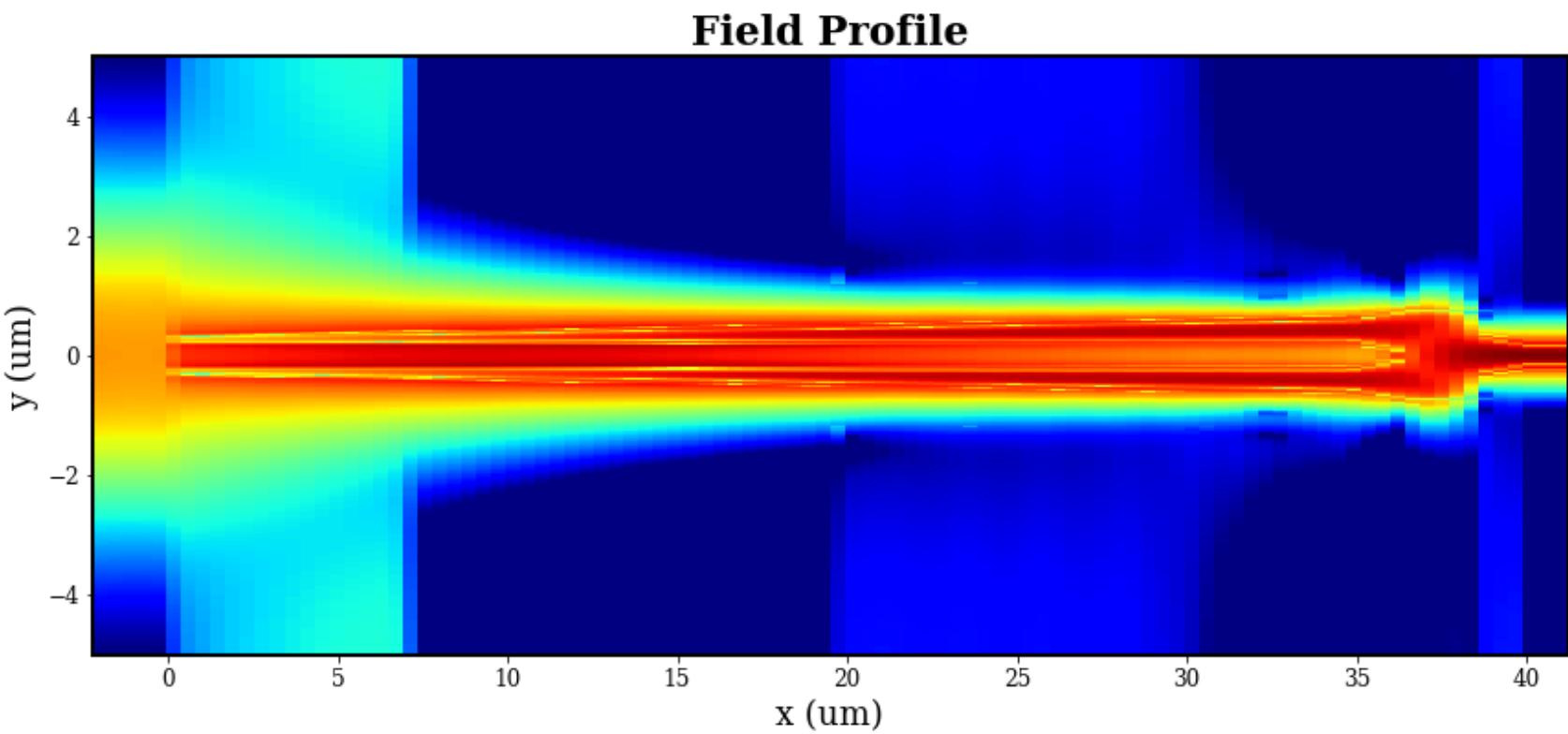
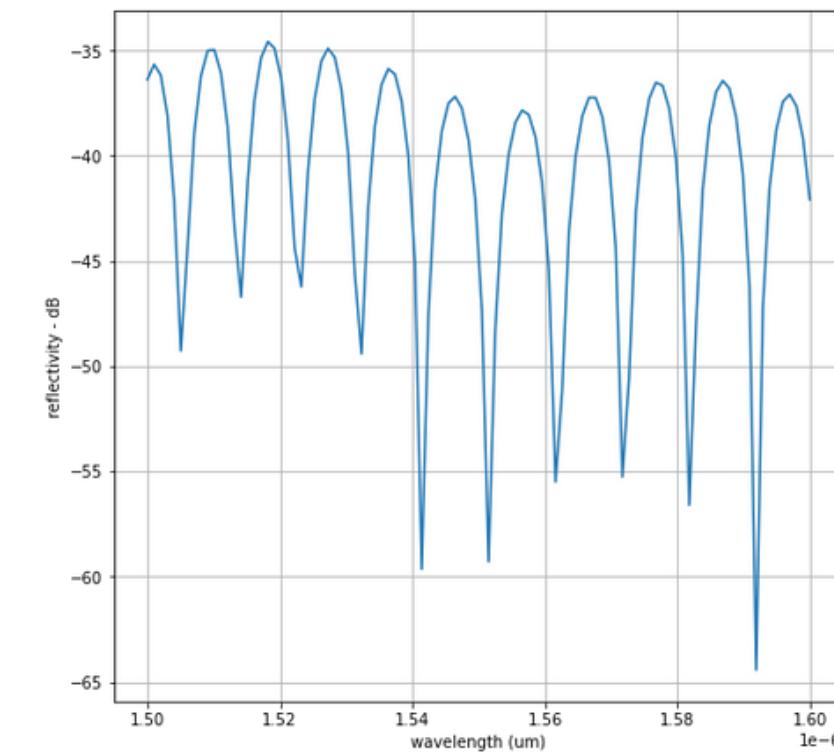
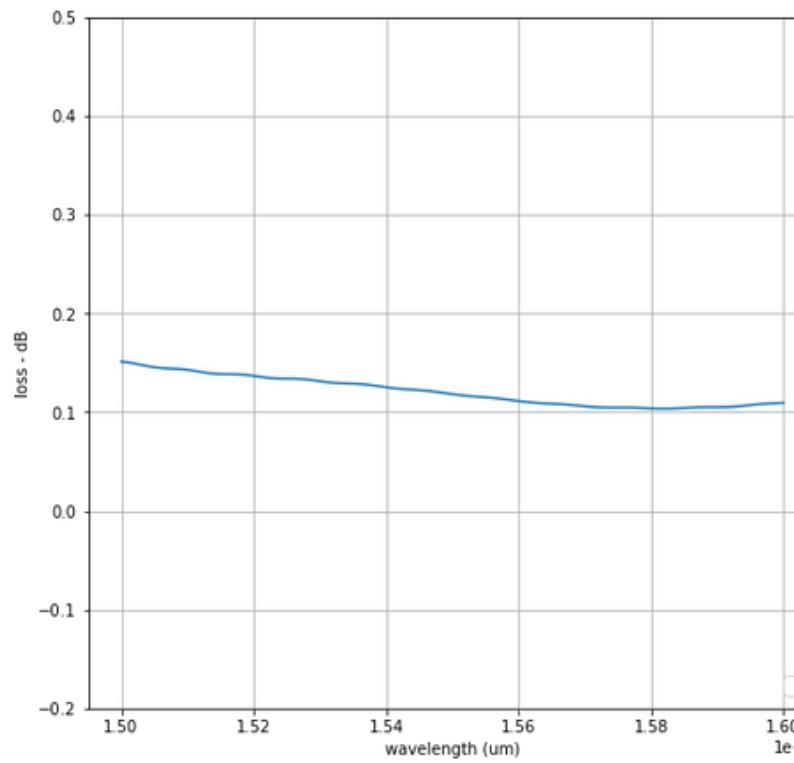
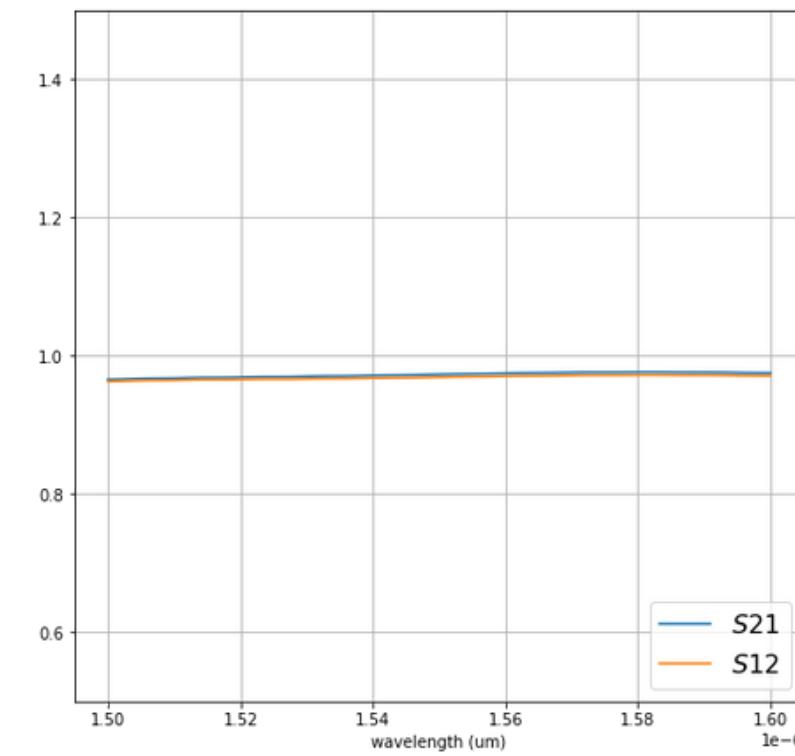
Port 2 settings:

- **y span = 4 um**
- **z span = 4 um**

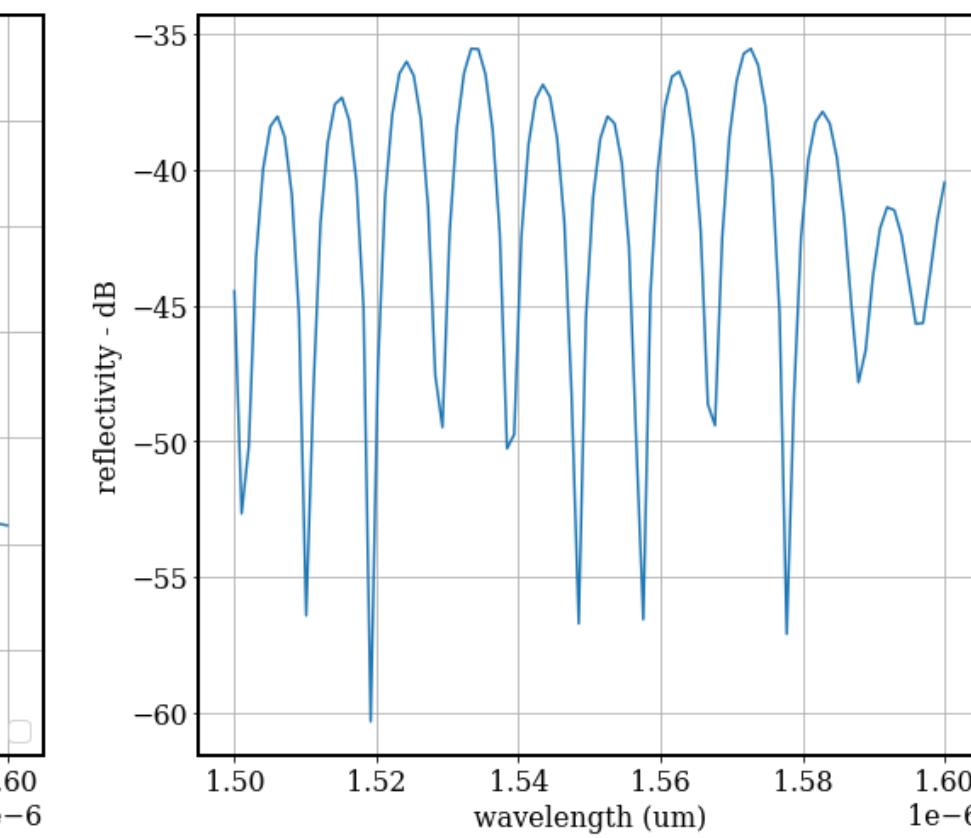
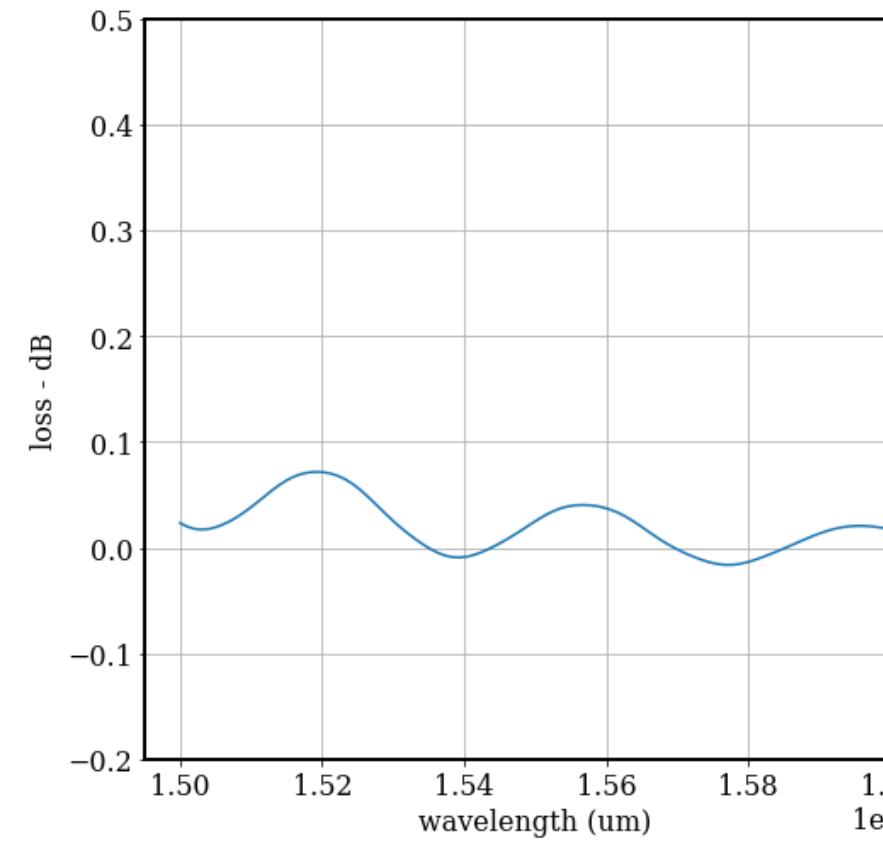
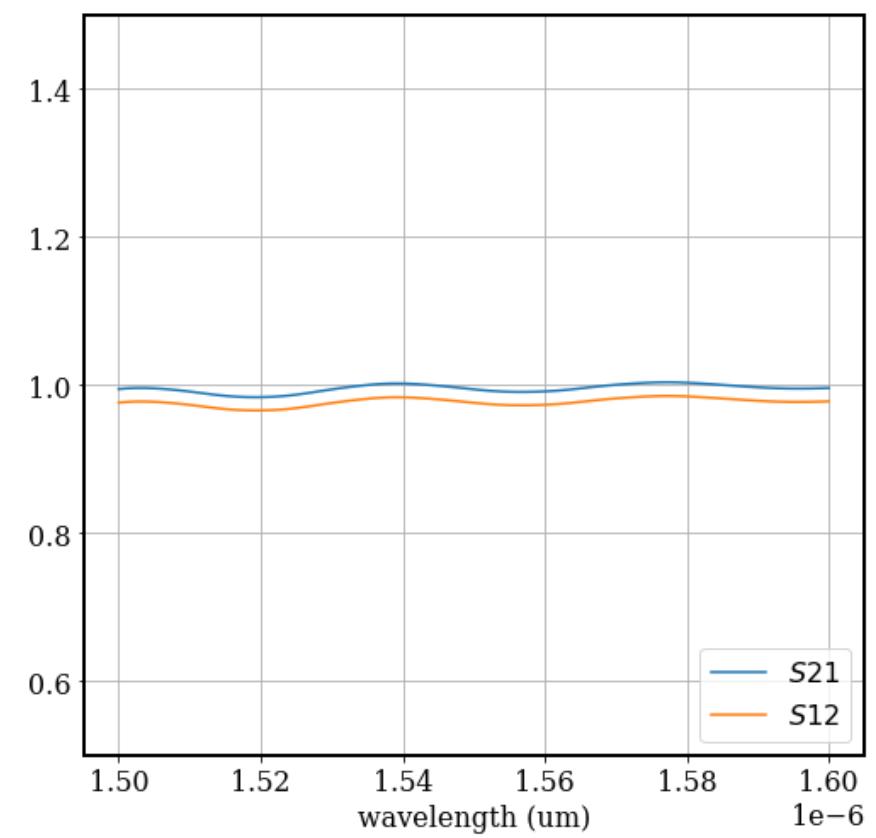
	group spans (μm)	cells	subcell method	modes
1	2	1	none	2
2	34.9	50	CVCS	6
3	1.5	10	CVCS	7
4	2.1	1	none	20
5	1.5	10	CVCS	5
6	1	1	none	3

mudanças

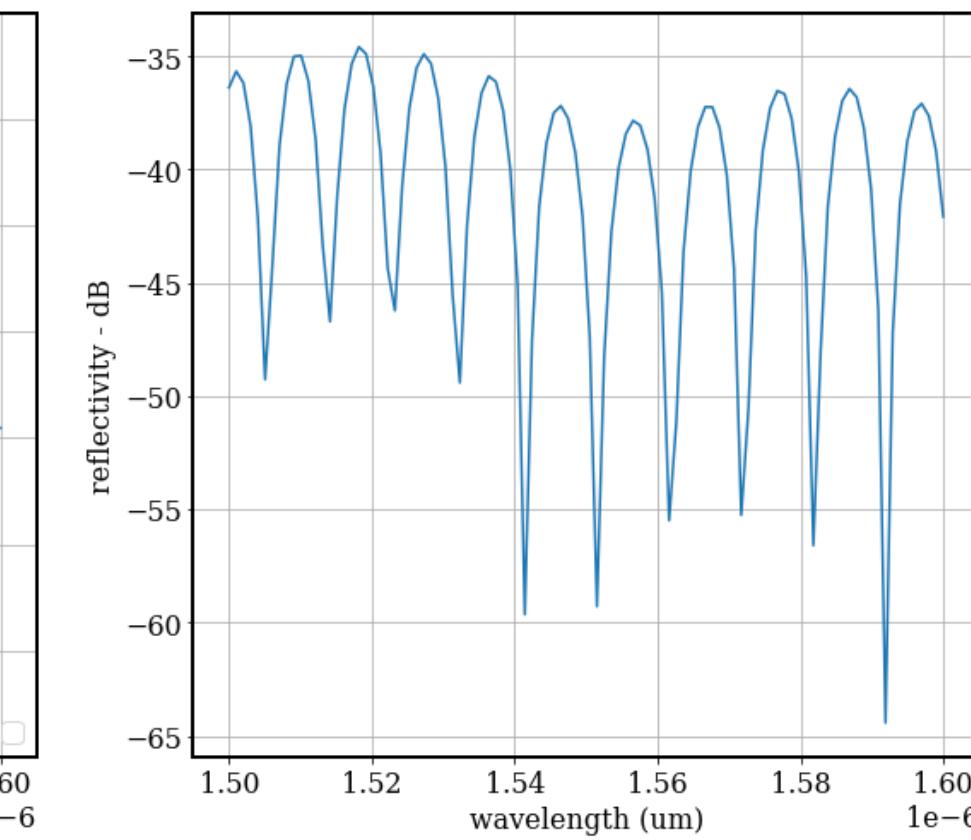
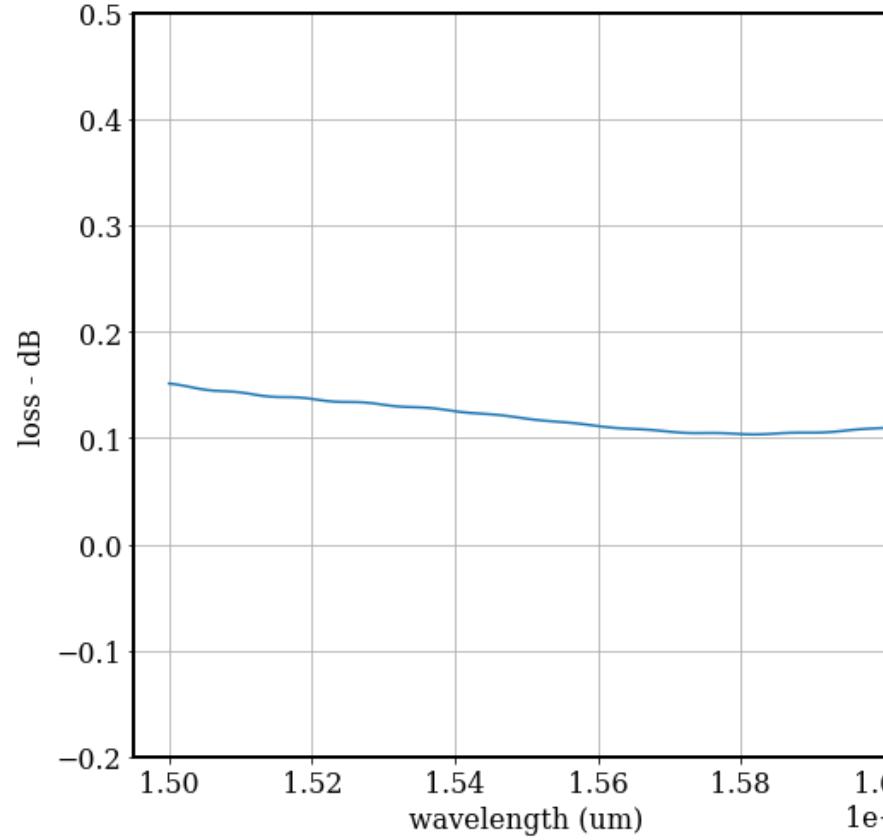
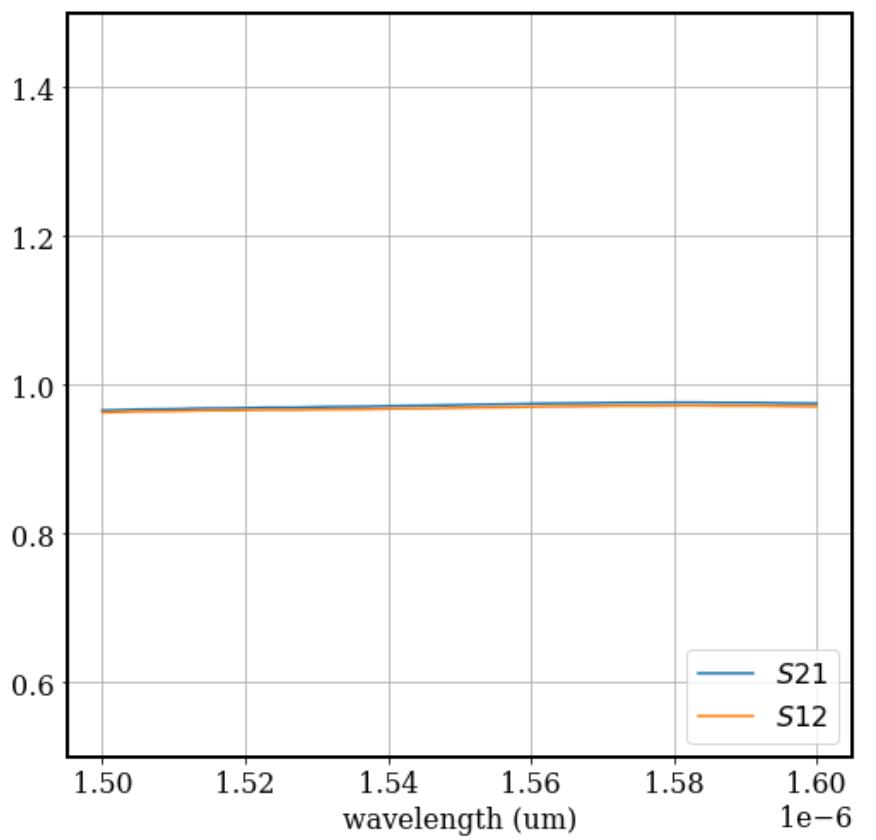
- as portas foram ajustadas para 10 um em Z e em Y
- o número de modos e células foram ajustados



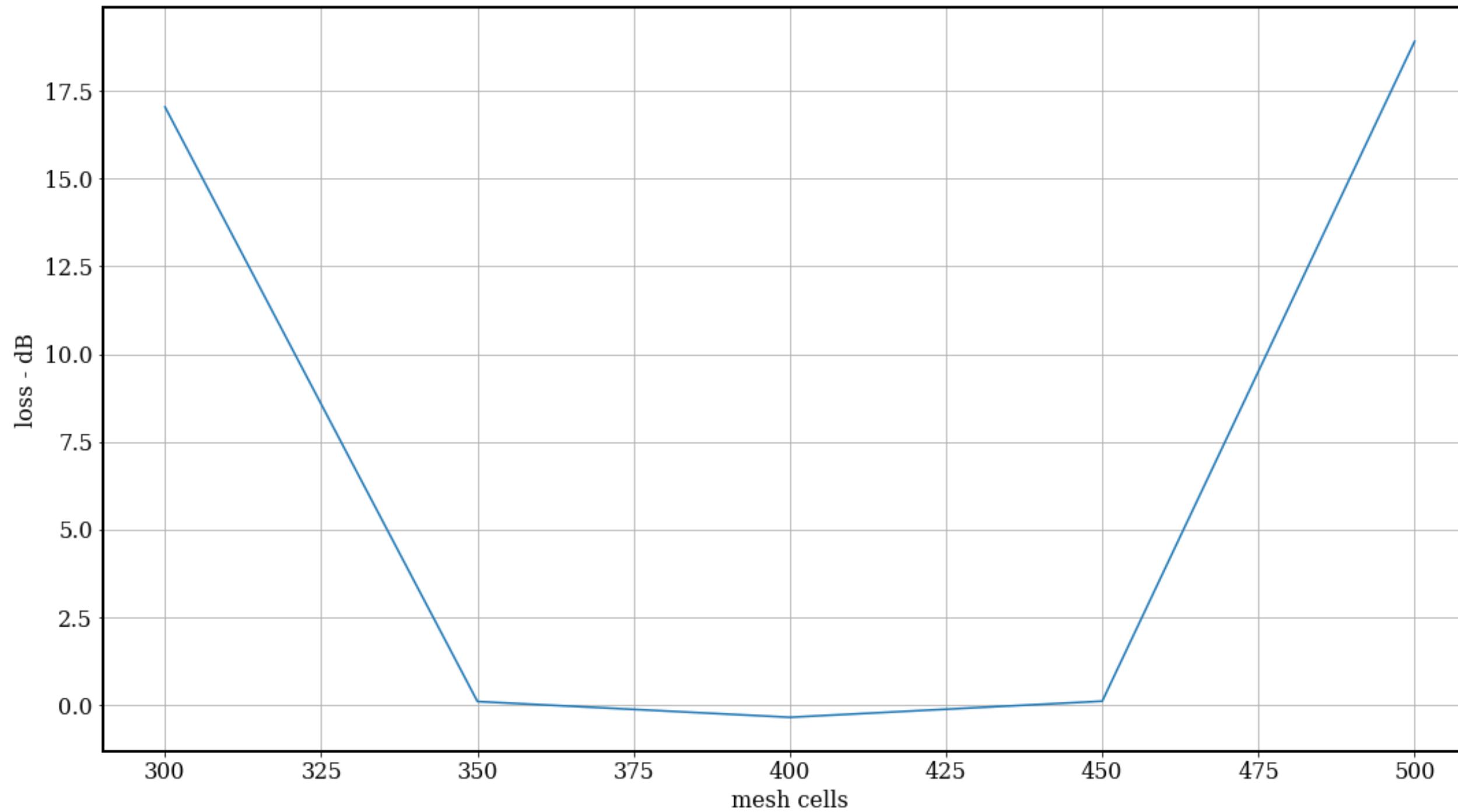
resultado antigo



resultado novo

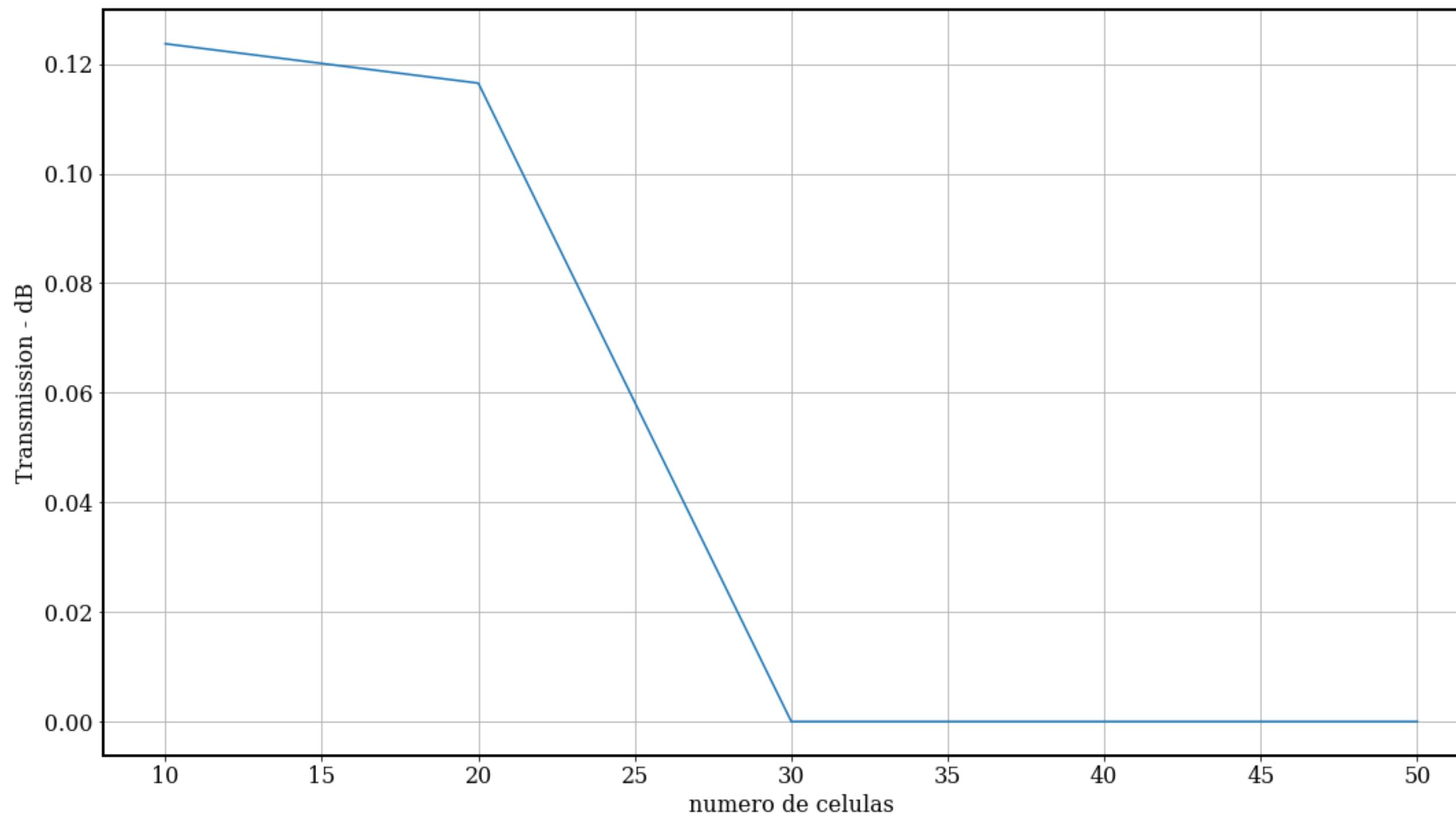


sweep do mesh cells

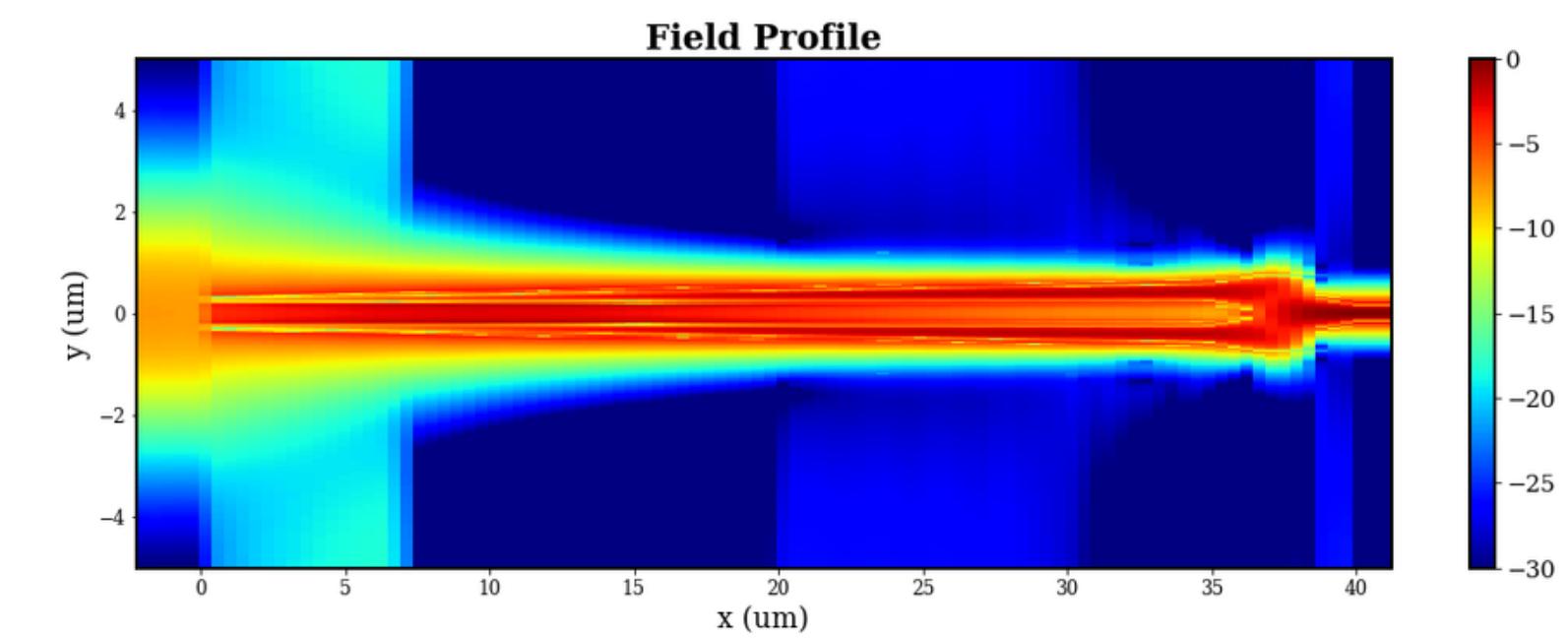
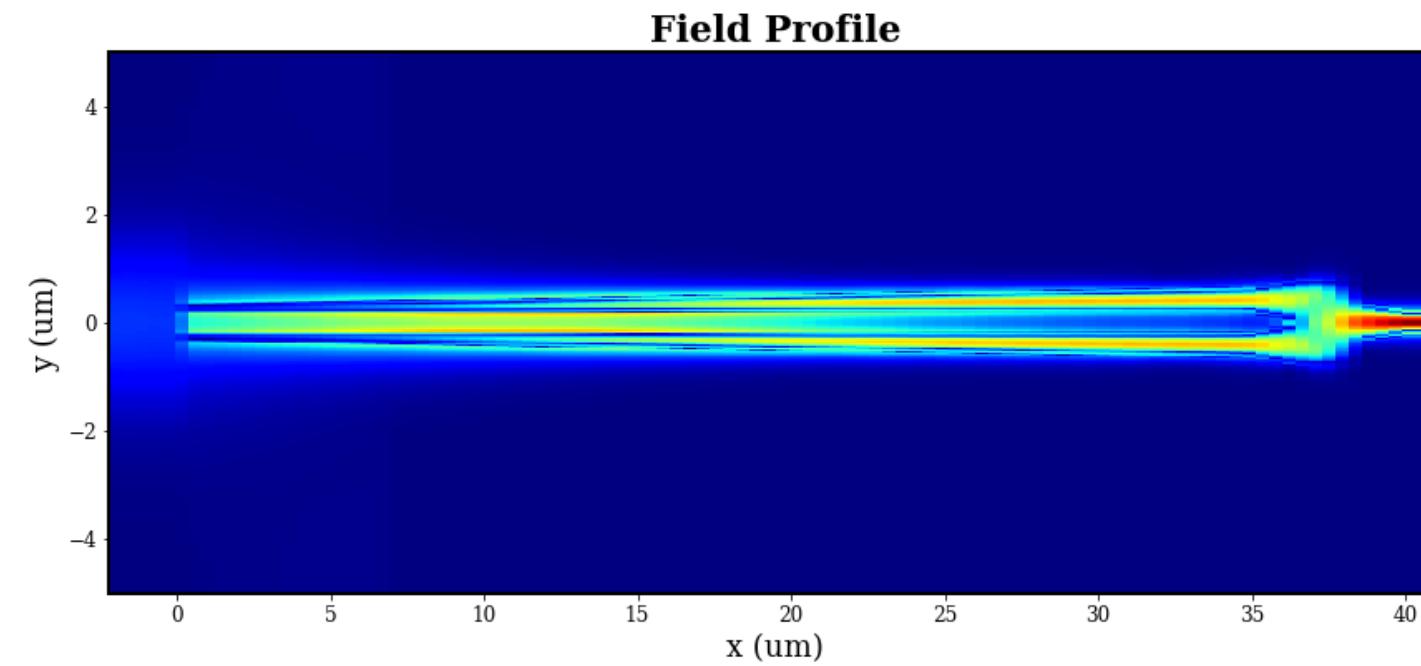
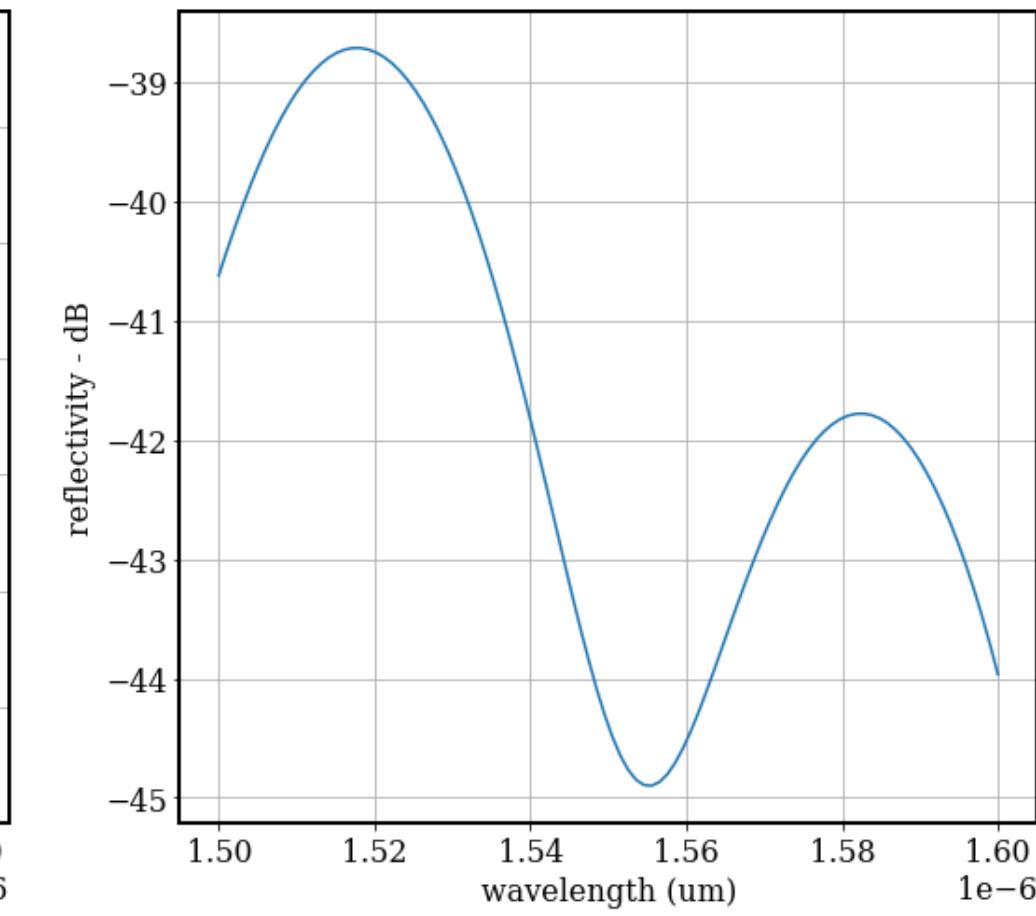
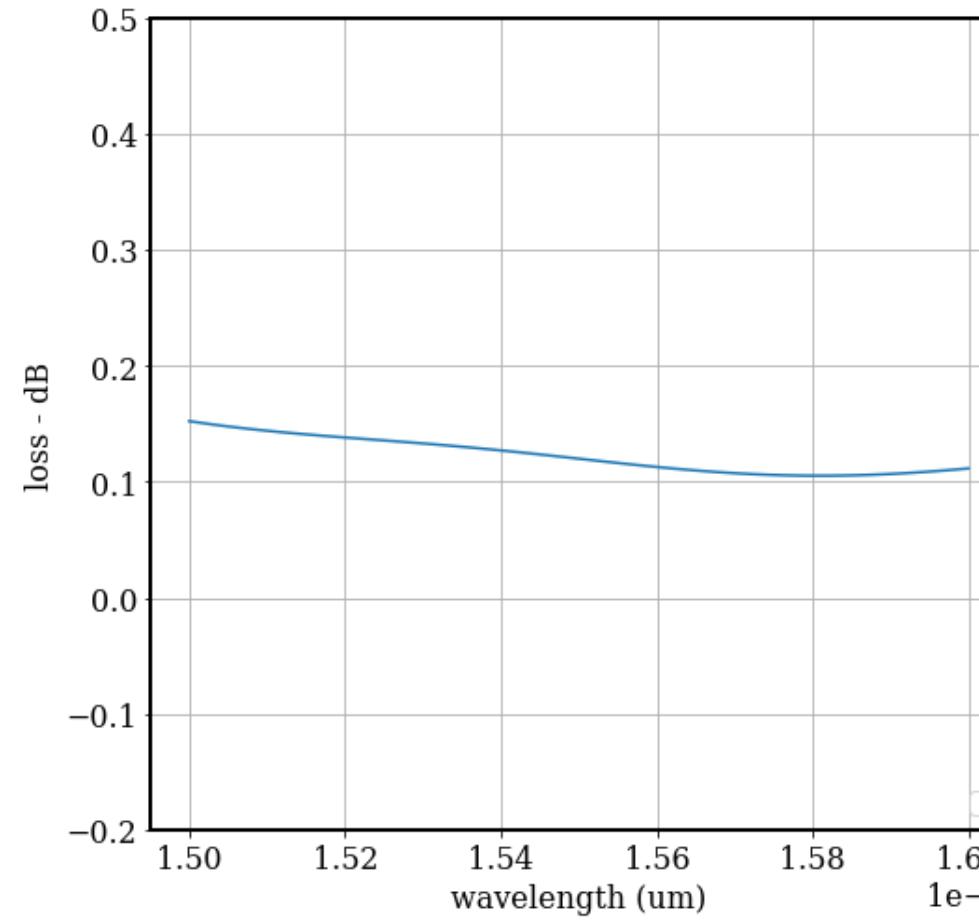
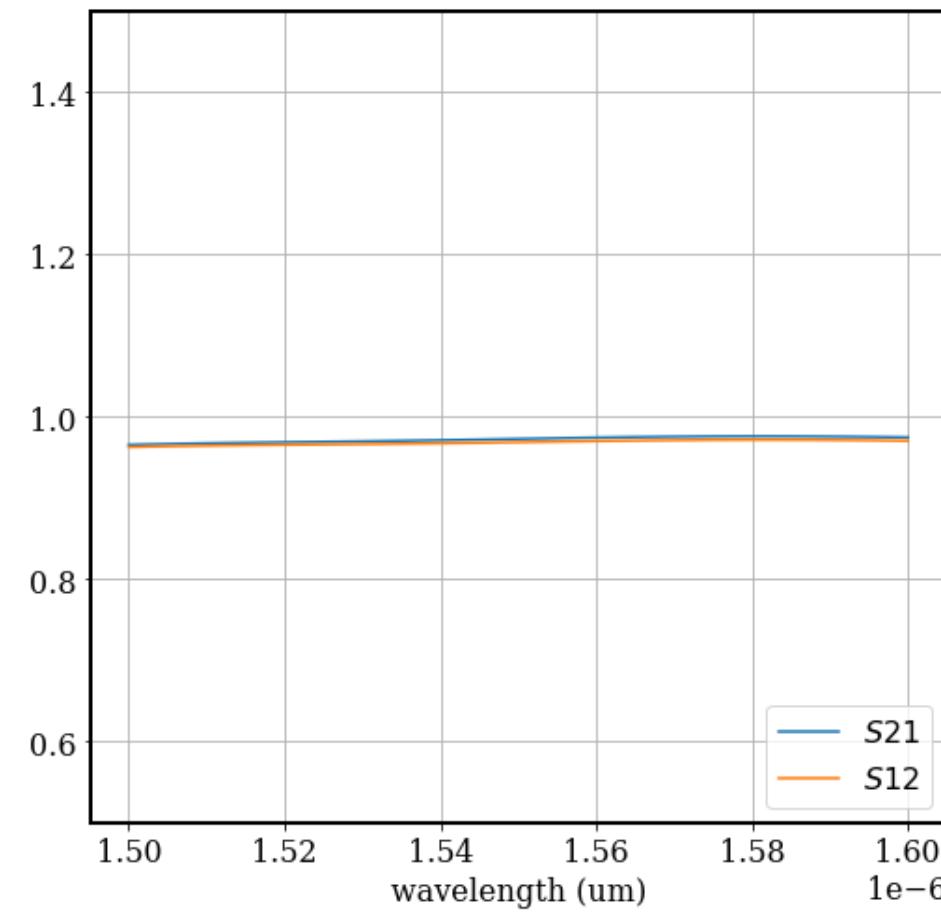


mesh cells y = mesh cells z

sweep do número de células na região dos tapers



mesh no acoplador



mesh no acoplador e no MMI

