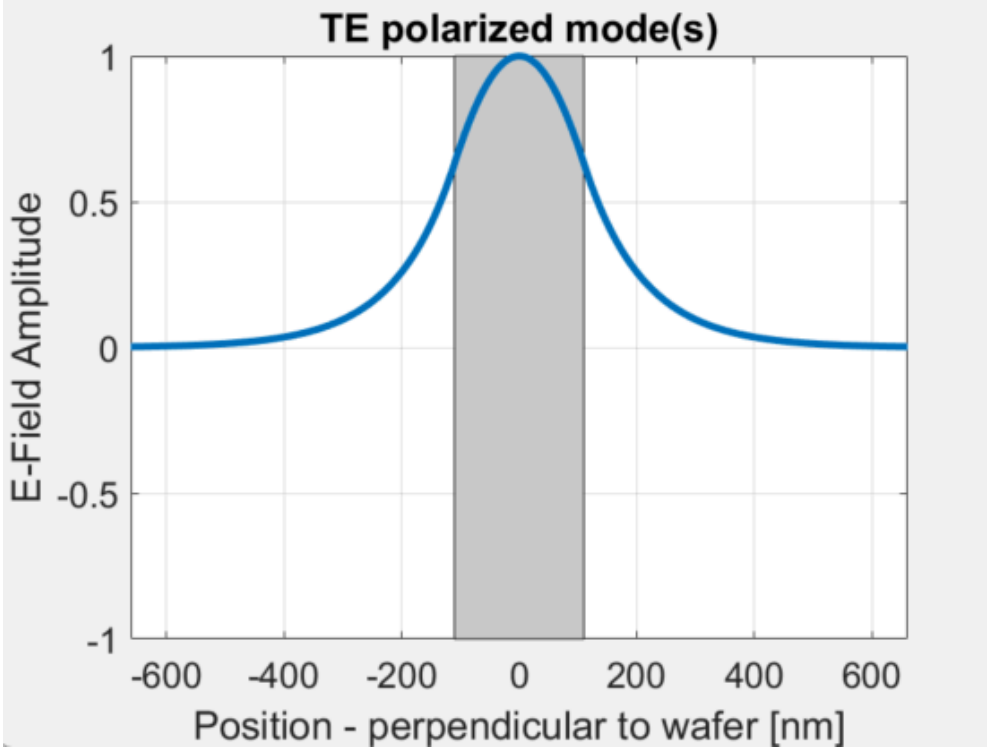
Chip 1

Why a thickness of 220nm is used for waveguides and how it impacts the TE modes?
Thickness = 220nm
Mode: The EM field that can propagate through the slab waveguide.
Modes can be classified as TE (E field is perpendicular to direction of propagation) or TM B field is perpendicular to direction of propagation. Each mode has a effective index which determines how light propagates through the waveguide. Thinner waveguides support fewer modes than thicker waveguides. Supporting one mode reduces losses and enhances confinement.

TE Polarization Mode Profile using Matlab script wg_1D_slab.m:
We want the waveguide to support one mode only and not multiple, as you increase the thickness it may support more modes.



```
Effective index value(s) of the TE mode(s):   2.84185
Effective index value(s) of the TM mode(s):   2.04889
```

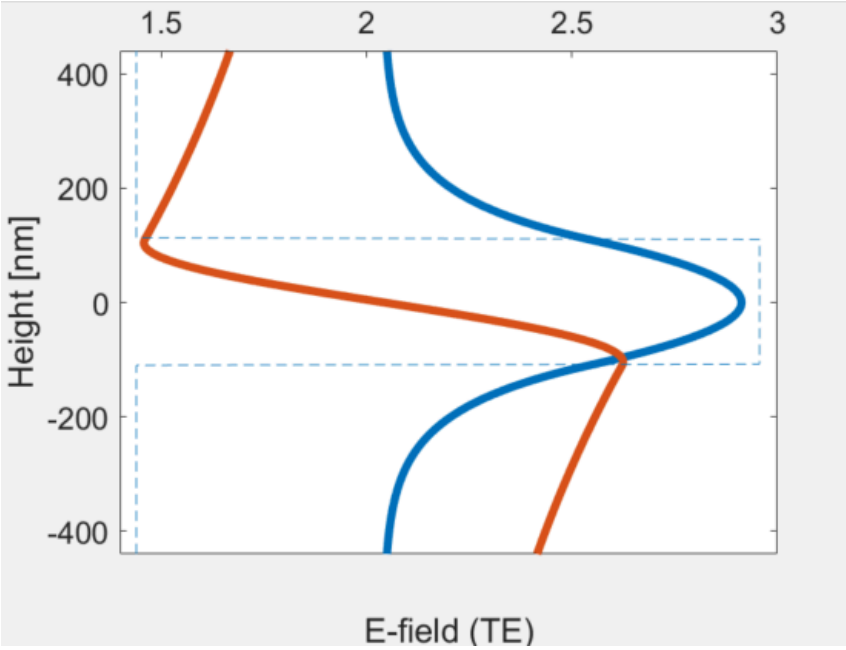
Effective Index Method:Calculating the Effective Index and Mode Solution For a Slab

Using wg_EIM_profile_main.m

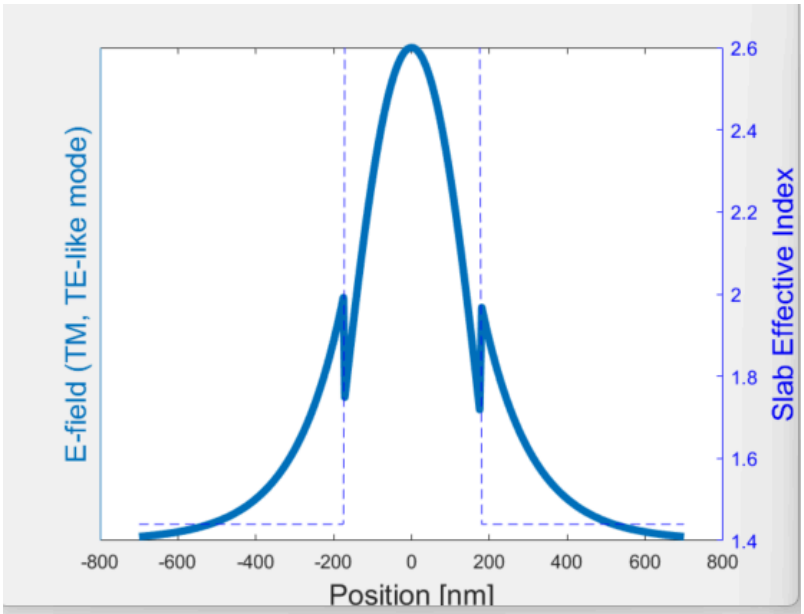
With parameters:

```
[neff_TEwg] = wg_EIM_profile(1.31e-6, 0.22e-6, 0.35e-6, 0, 3.47, 1.44, 1.44, 100, 2);
(lambda, t, w, t_slab, n_core, n_clad, n_oxide, pts, M)
```

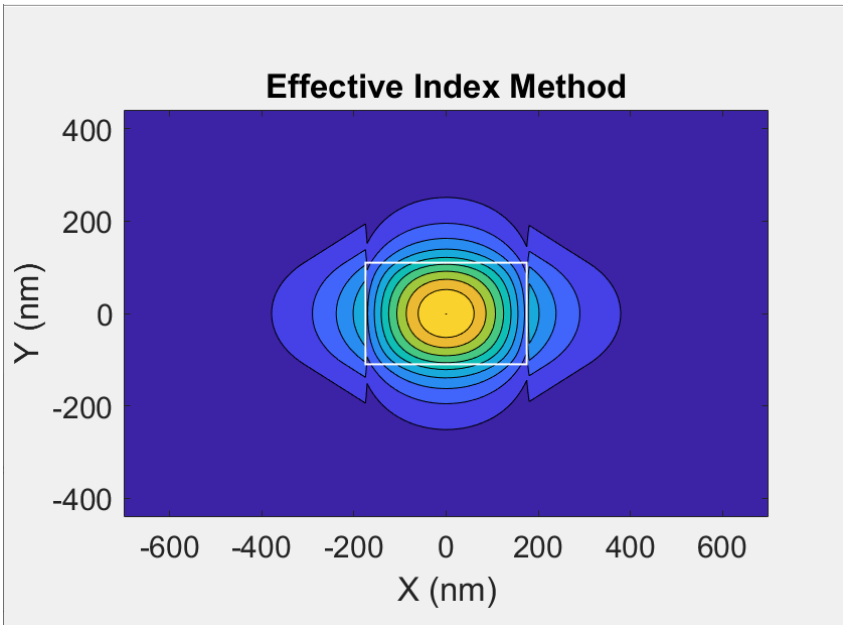
```
Slab Mode and effective index found:
```



Procedure repeat but in the in plane direction. Slab effective index is used as the input into the second step: This provides the effective index of the 2D waveguide:



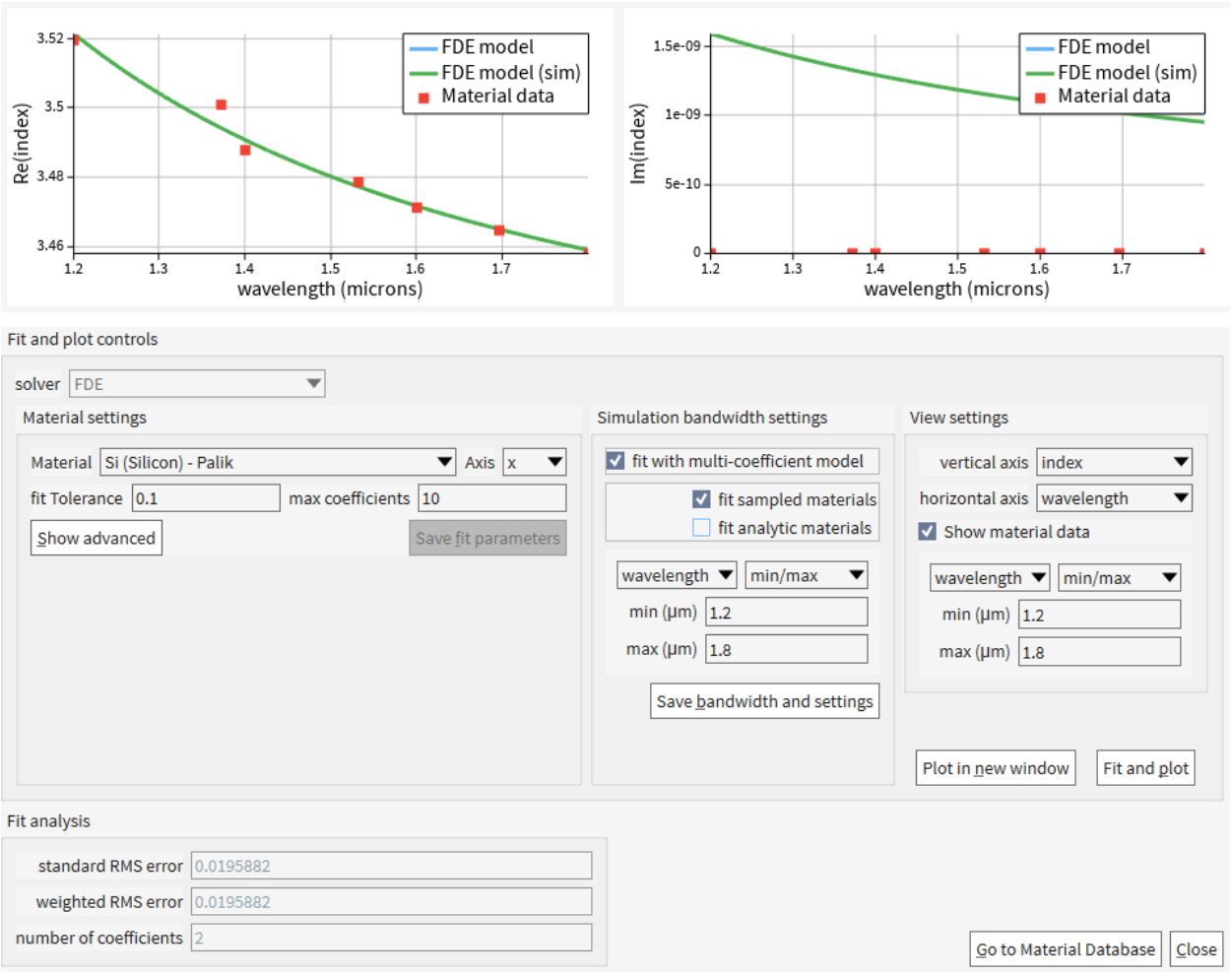
2D Mode Profile:



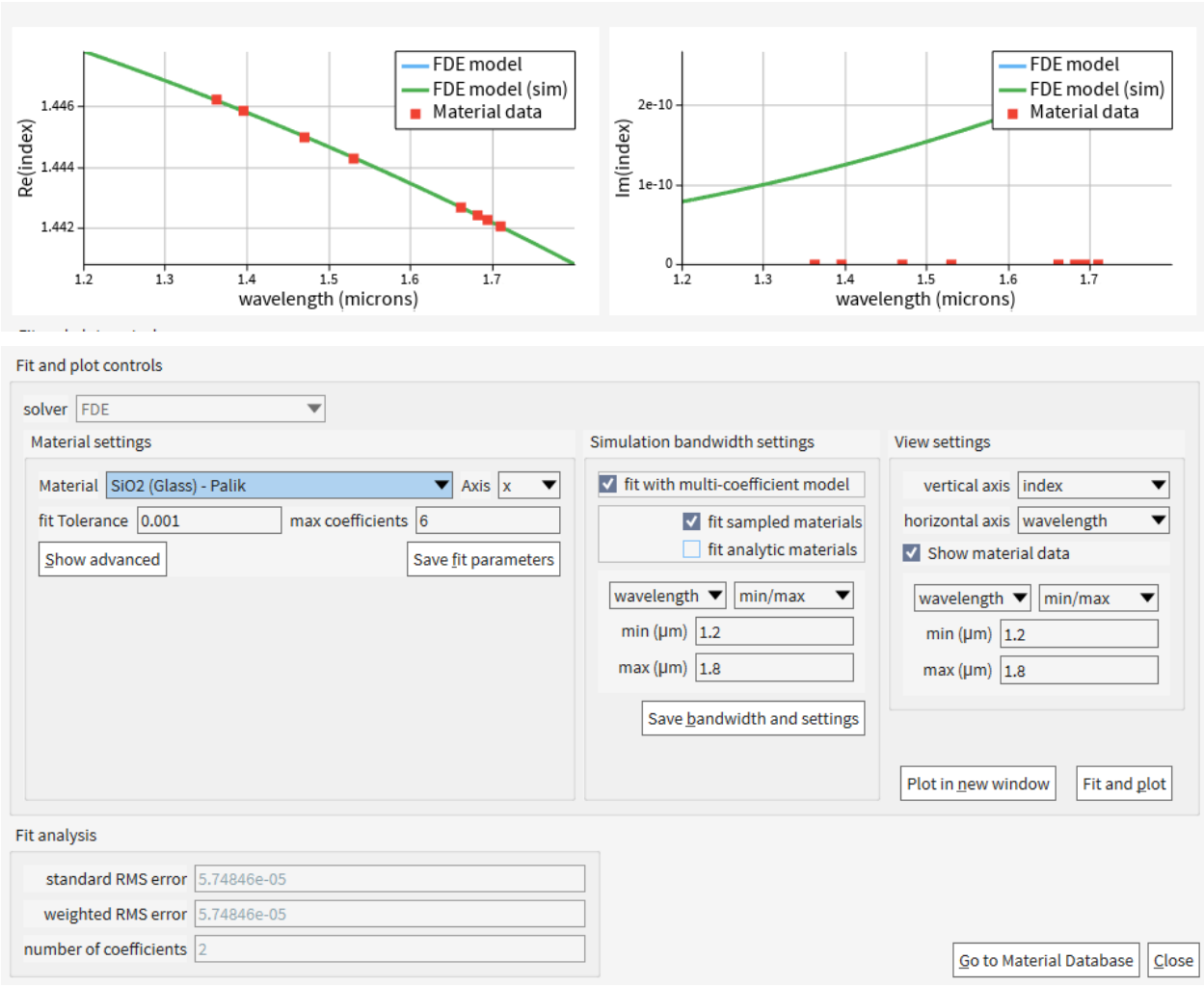
Lumerical Mode Simulations:
Si Waveguide:

Width = 350nm, 220nm thickness

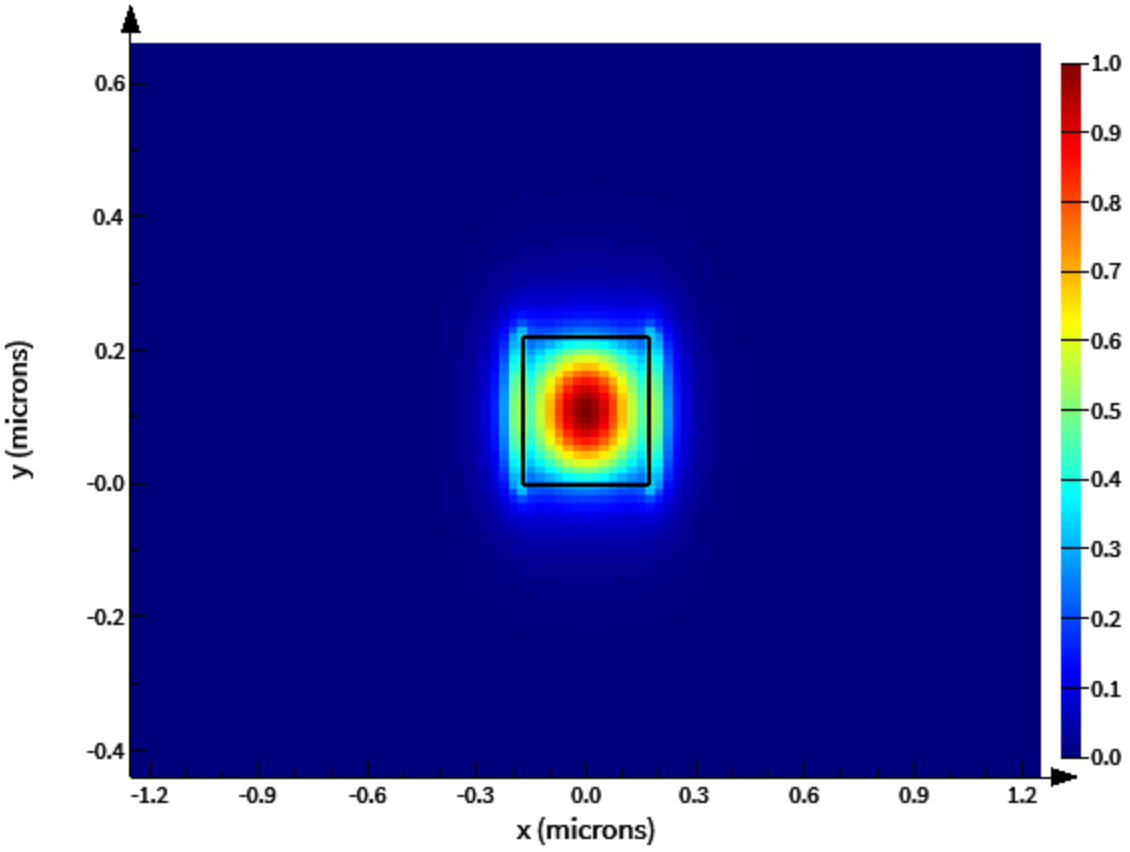
Re Index = 3.5 at wavelength of 1310nm
Im Index = 1.4e-9 at wavelength of 1310nm



SiO2 Material Dispersion Captures
ReIndex = 1.44 at 1310nm
Im Index = 1.025 e-10 at 1310nm

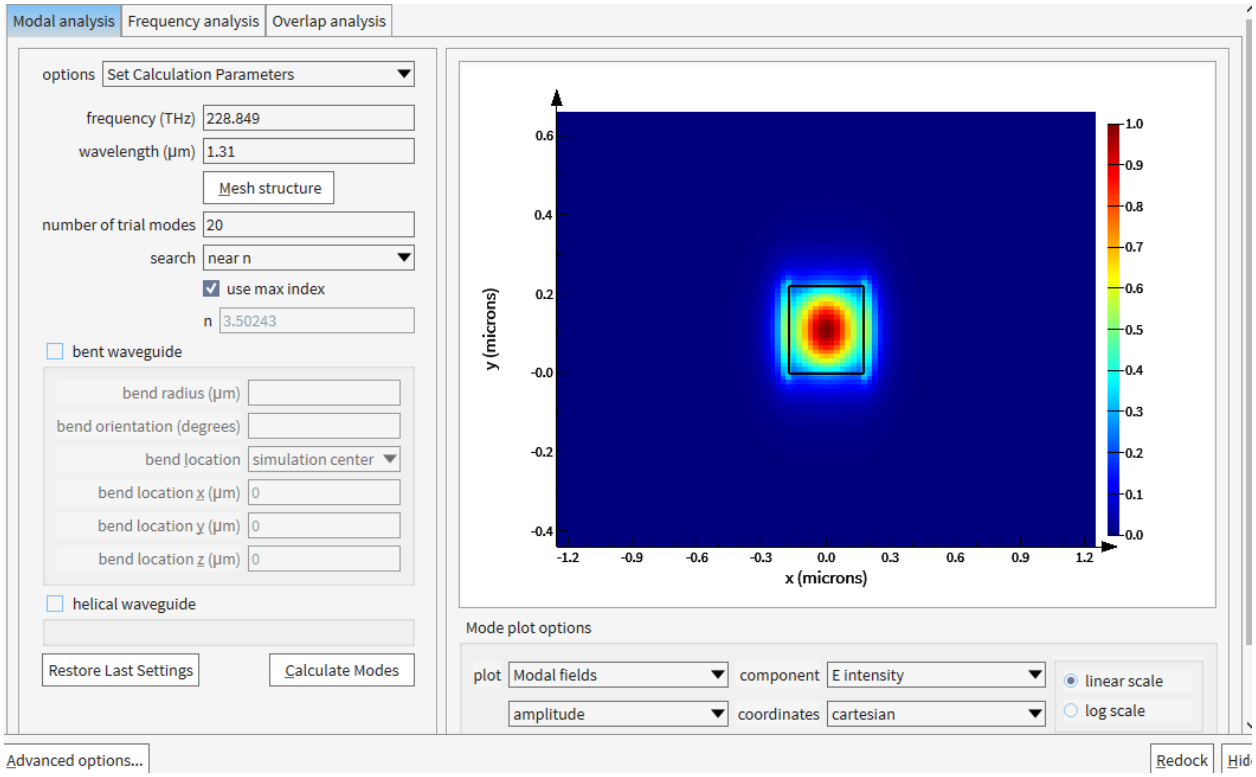


Mode Simulation at 1310nm Linear
Effective Index of first mode is 2.4 and is quasi polarized



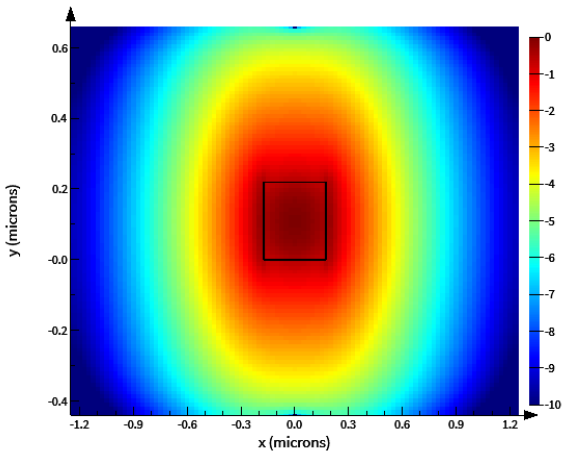
mode #	effective index	wavelength (μm)	loss (dB/cm)	group index	TE polarization fraction (Ex)	waveguide TE/TM fraction (%)
1	2.432751+1.580621e-09i	1.31	0.00065849	4.498554+3.707324e-09i	98	70.24 / 84.02
2	2.011675+1.381512e-09i	1.31	0.00057554	4.593208+5.943398e-09i	5	63.19 / 87.9
3	1.466727+3.669182e-10i	1.31	0.00015286	2.073480+1.757221e-09i	45	92.65 / 98.86
4	1.387351+3.025568e-10i	1.31	0.00012605	2.011487+3.947927e-09i	6	98.98 / 72.66
5	1.338043+2.028817e-10i	1.31	8.4521e-05	1.829420-4.343849e-10i	0	93.85 / 86.67
6	1.297733+1.451085e-10i	1.31	6.0453e-05	1.681700-1.976978e-10i	99	96.16 / 85.37
7	1.296440+1.196355e-10i	1.31	4.9841e-05	1.651038-2.050792e-10i	74	99.41 / 80.2
8	1.219599+1.344275e-10i	1.31	5.6003e-05	1.746593-2.423637e-10i	9	90.36 / 81.61
9	1.216081+2.112087e-10i	1.31	8.7990e-05	1.986581-6.772020e-11i	56	67.71 / 98.57
10	1.186289+7.247230e-10i	1.31	0.00030192	3.213641+2.155017e-09i	30	98.79 / 40.04
11	1.105650+3.560496e-10i	1.31	0.00014833	2.450192-1.634924e-09i	0	74.97 / 82.47
12	1.099572+3.059926e-10i	1.31	0.00012748	2.221451-6.617469e-10i	95	65.86 / 94.27
13	1.071102+1.475465e-10i	1.31	6.1468e-05	2.013558-3.482246e-10i	27	99.06 / 55.07
14	0.9518516+3.335136e-10i	1.31	0.00013894	2.660851-1.099847e-09i	52	99.33 / 37.46
15	0.8344429+1.965319e-10i	1.31	8.1876e-05	2.546078-6.785752e-10i	14	97.93 / 36.21
16	0.7882326+1.994756e-10i	1.31	8.3102e-05	2.685785-7.792908e-10i	96	96.83 / 33.2
17	0.7613070+4.344592e-10i	1.31	0.00018100	3.422520-9.500937e-10i	79	25.8 / 99.3
18	0.7604632+2.901233e-10i	1.31	0.00012087	3.011141-1.326173e-09i	84	99.45 / 26.3
19	0.7016898+2.560345e-10i	1.31	0.00010666	3.089904-1.085257e-09i	9	90.52 / 32.34
20	0.6561016+2.722418e-10i	1.31	0.00011342	3.417327-1.120795e-09i	34	21.32 / 98.02

Setting for plotting:

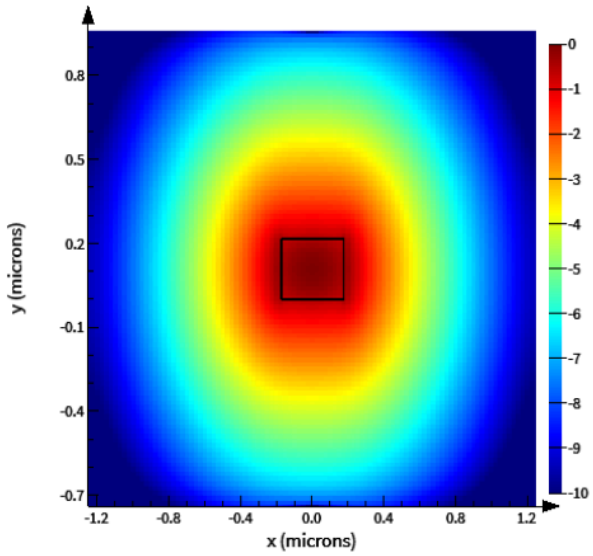


Log Scale Mode

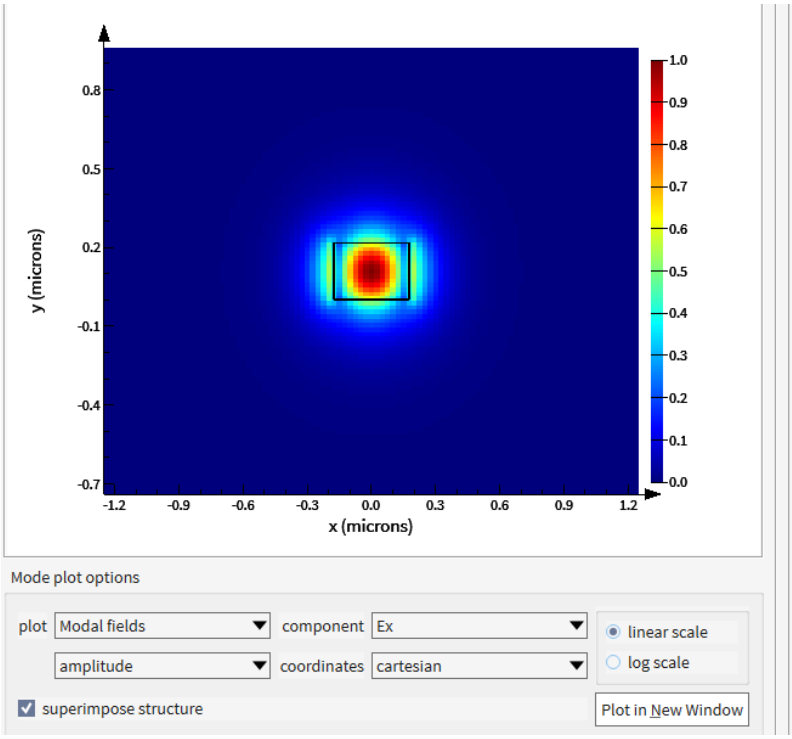
- Field decays in the x direction but not in the y direction

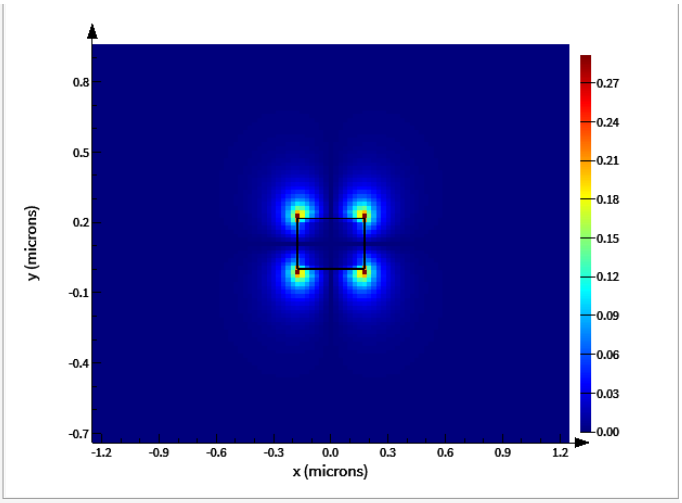


Expanded simulation region by 0.6:
Still see x component decay



Ex Component:



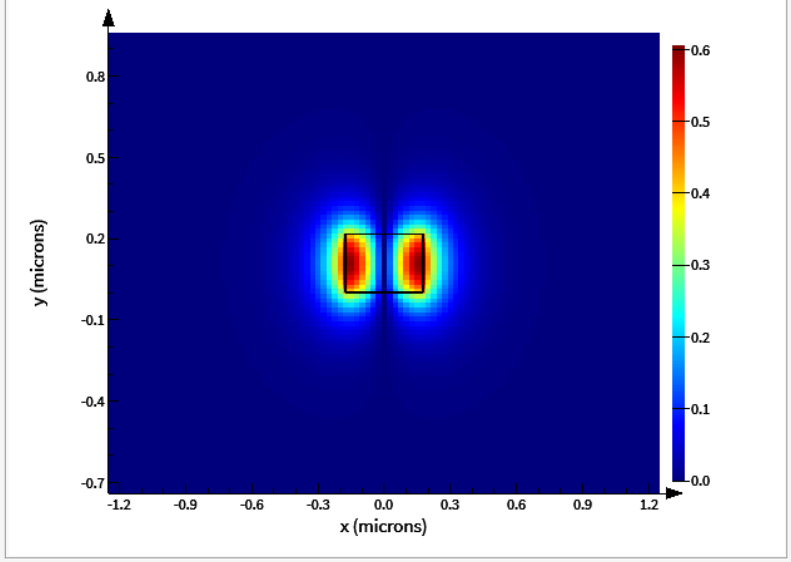


Mode plot options

plot Modal fields component Ey linear scale

amplitude coordinates cartesian log scale

superimpose structure Plot in New Window



Mode plot options

plot Modal fields component Ez linear scale

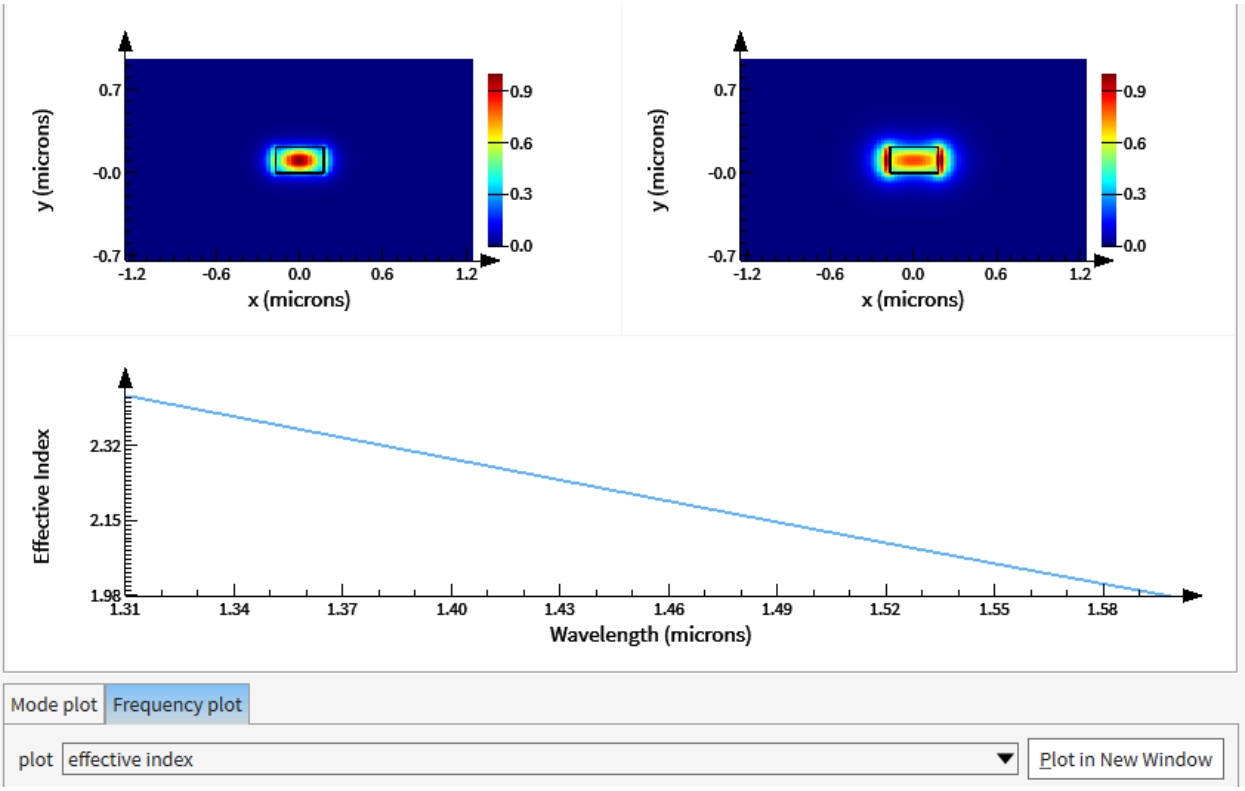
amplitude coordinates cartesian log scale

superimpose structure Plot in New Window

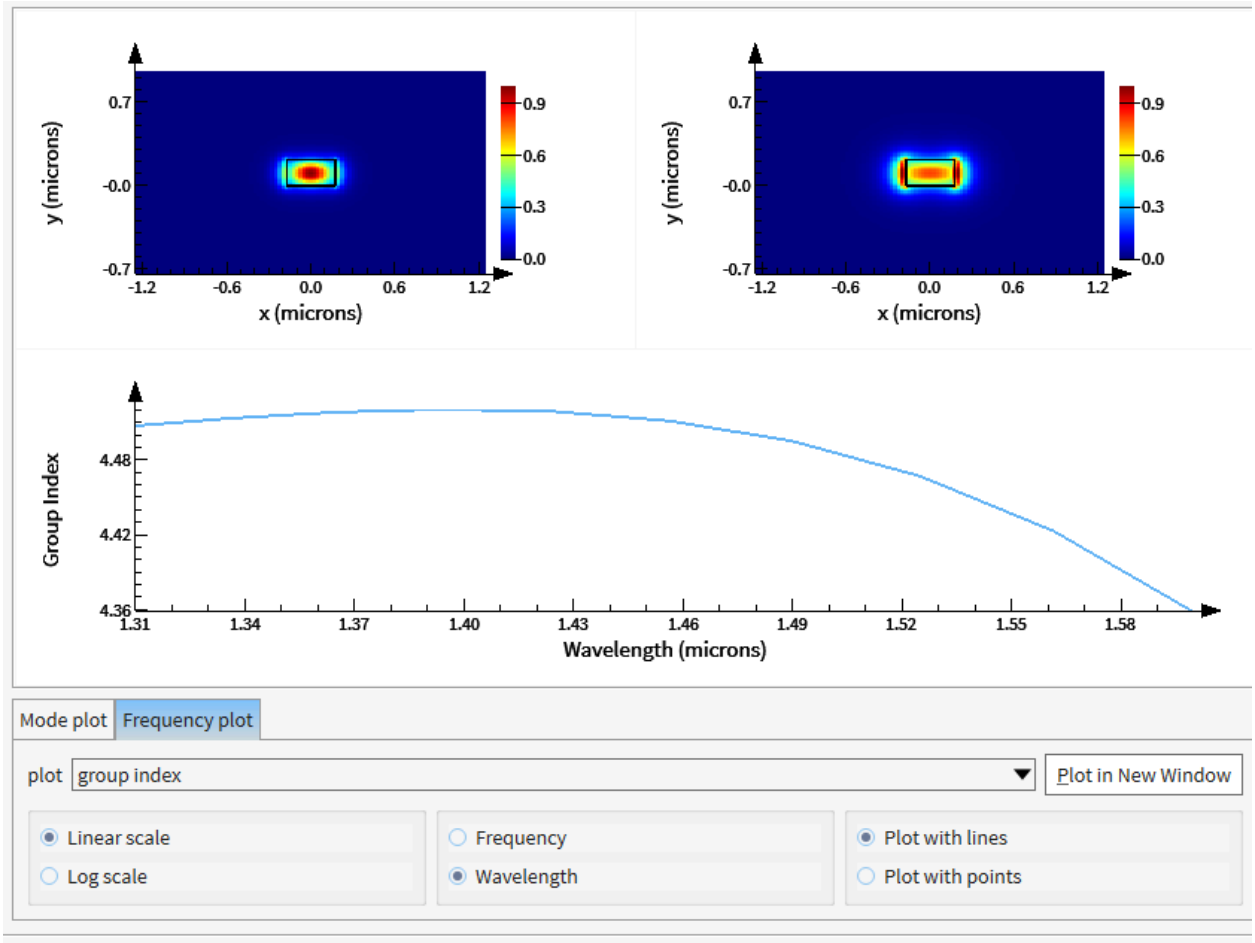
mode #	effective index	wavelength (μm)	loss (dB/cm)	group index	TE polarization fraction (Ex)
1	2.433749+1.583954e-09i	1.31	0.00065988	4.507478+3.727410e-09i	98
2	2.005431+1.390915e-09i	1.31	0.00057946	4.620122+5.835228e-09i	5
3	1.465835+3.335569e-10i	1.31	0.00013896	2.000054+1.951383e-09i	54
4	1.379141+2.991080e-10i	1.31	0.00012461	2.003111+4.601437e-09i	9
5	1.375687+1.638336e-10i	1.31	6.8254e-05	1.685610-4.590318e-10i	0
6	1.374869+1.300521e-10i	1.31	5.4180e-05	1.579365-2.147980e-10i	100
7	1.371596+1.099672e-10i	1.31	4.5813e-05	1.548582-2.115957e-10i	56
8	1.313594+2.166807e-10i	1.31	9.0270e-05	1.874443-3.105320e-10i	60
9	1.294560+1.171199e-10i	1.31	4.8793e-05	1.634981-2.456676e-10i	2
10	1.272512+3.842652e-10i	1.31	0.00016009	2.282432+2.817309e-09i	70

Frequency Sweep Simulations:

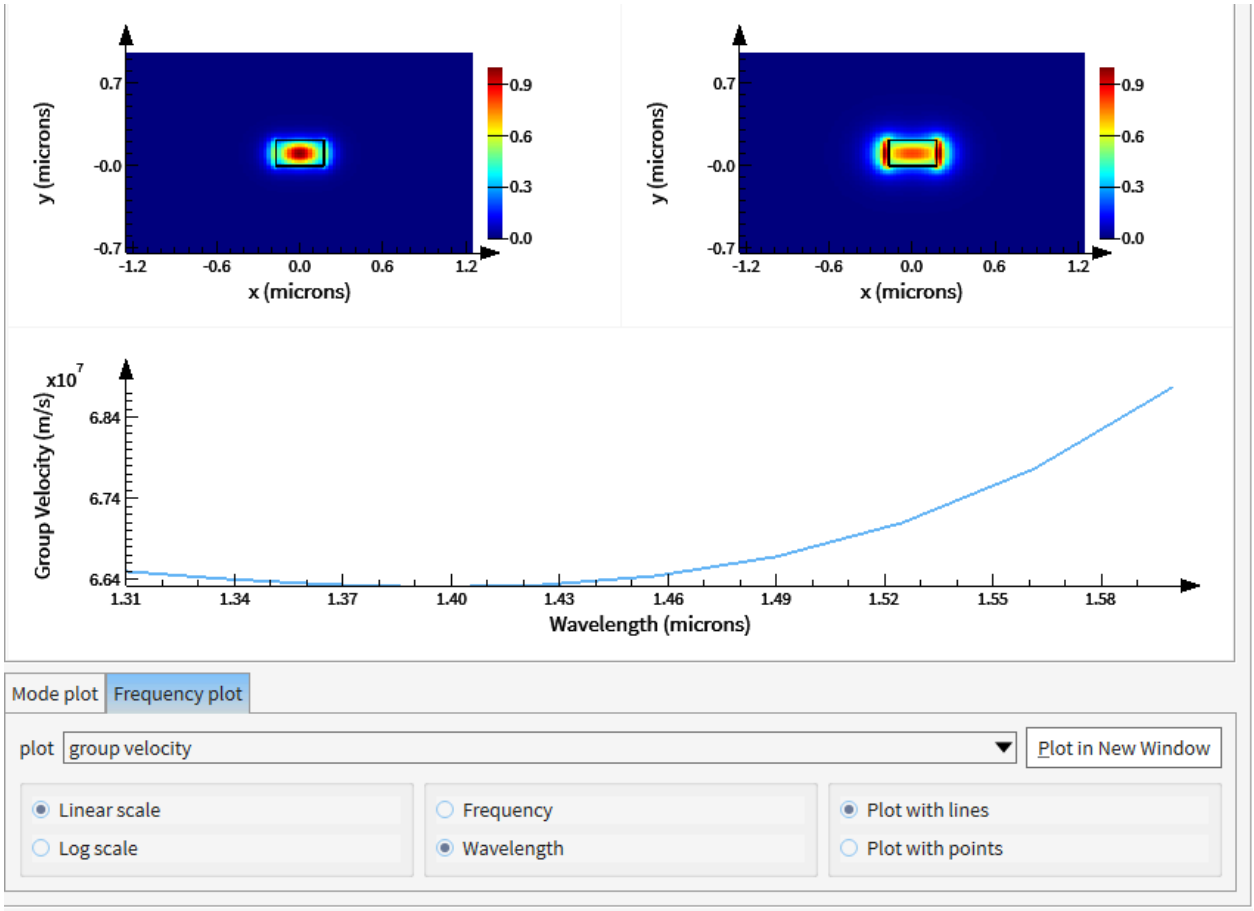
- **Effective index decreases with wavelength**
-



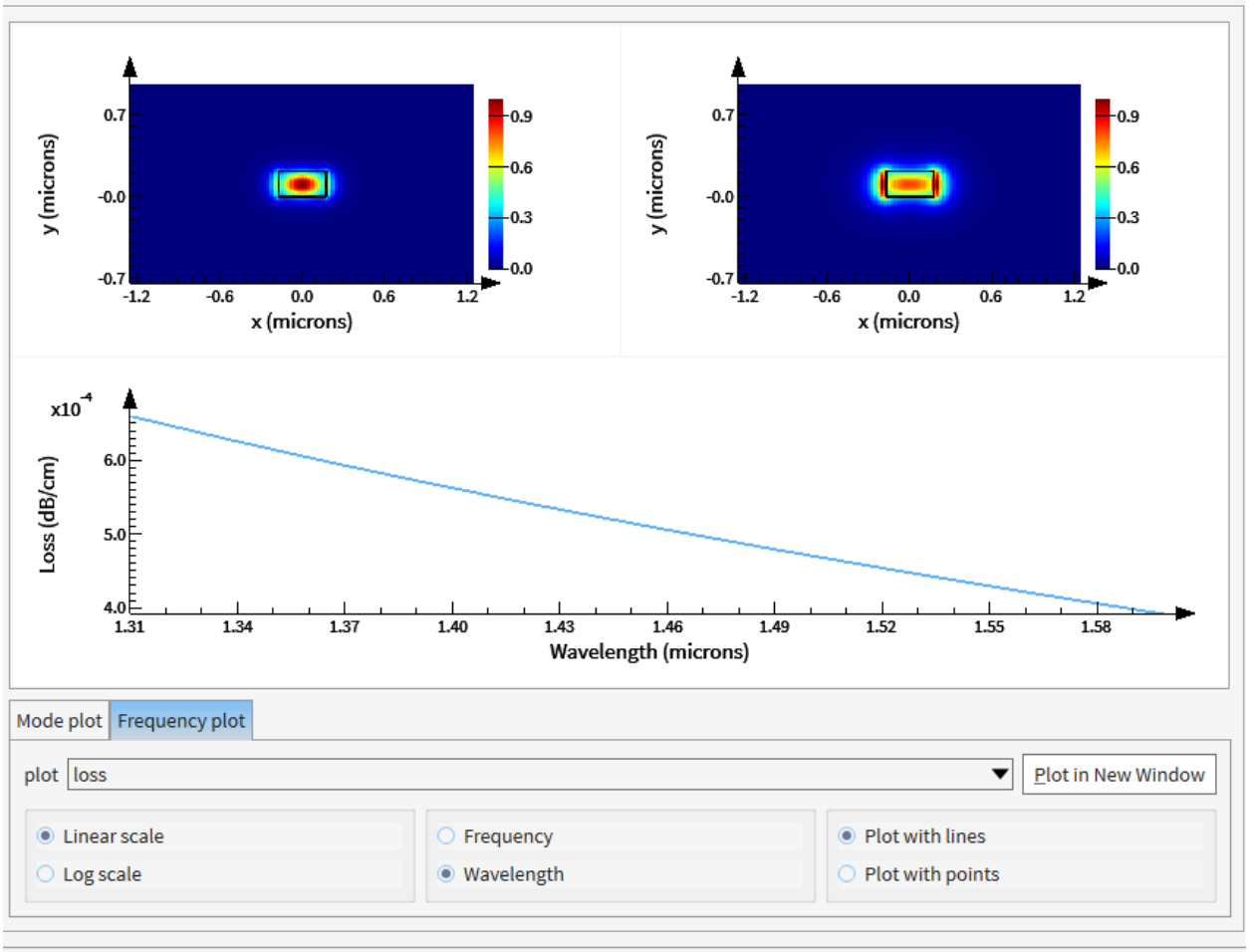
Group Index is decreasing…but according to lecures it should be increasing with wavelength



Group velocity:


y (microns)
0.7
-0.0
-0.7
-1.2
-0.6
0.0
0.6
1.2
x (microns)
0.9
0.6
0.3
0.0
x10^7
Group Velocity (m/s)
6.84
6.74
6.64
1.31
1.34
1.37
1.40
1.43
1.46
1.49
1.52
1.55
1.58
Wavelength (microns)
Mode plot
Frequency plot
plot
group velocity
Plot in New Window
Linear scale
Log scale
Frequency
Wavelength
Plot with lines
Plot with points

Loss:



Waveguide Compact Model

FSR Calculations:

If a desired FSR of 25Ghz is required, then the following length difference is needed using the equations below.

We can convert $\Delta\lambda$ [nm] to $\Delta\nu$ [GHz] by the following,

$$\Delta\nu \approx -\frac{c\Delta\lambda}{\lambda^2} = \frac{c}{\Delta L n_g}$$

$$\mathrm{FSR} = \Delta\lambda = \frac{\lambda^2}{\Delta L\left(n - \lambda\frac{dn}{d\lambda}\right)} = \frac{\lambda^2}{\Delta L n_g}$$

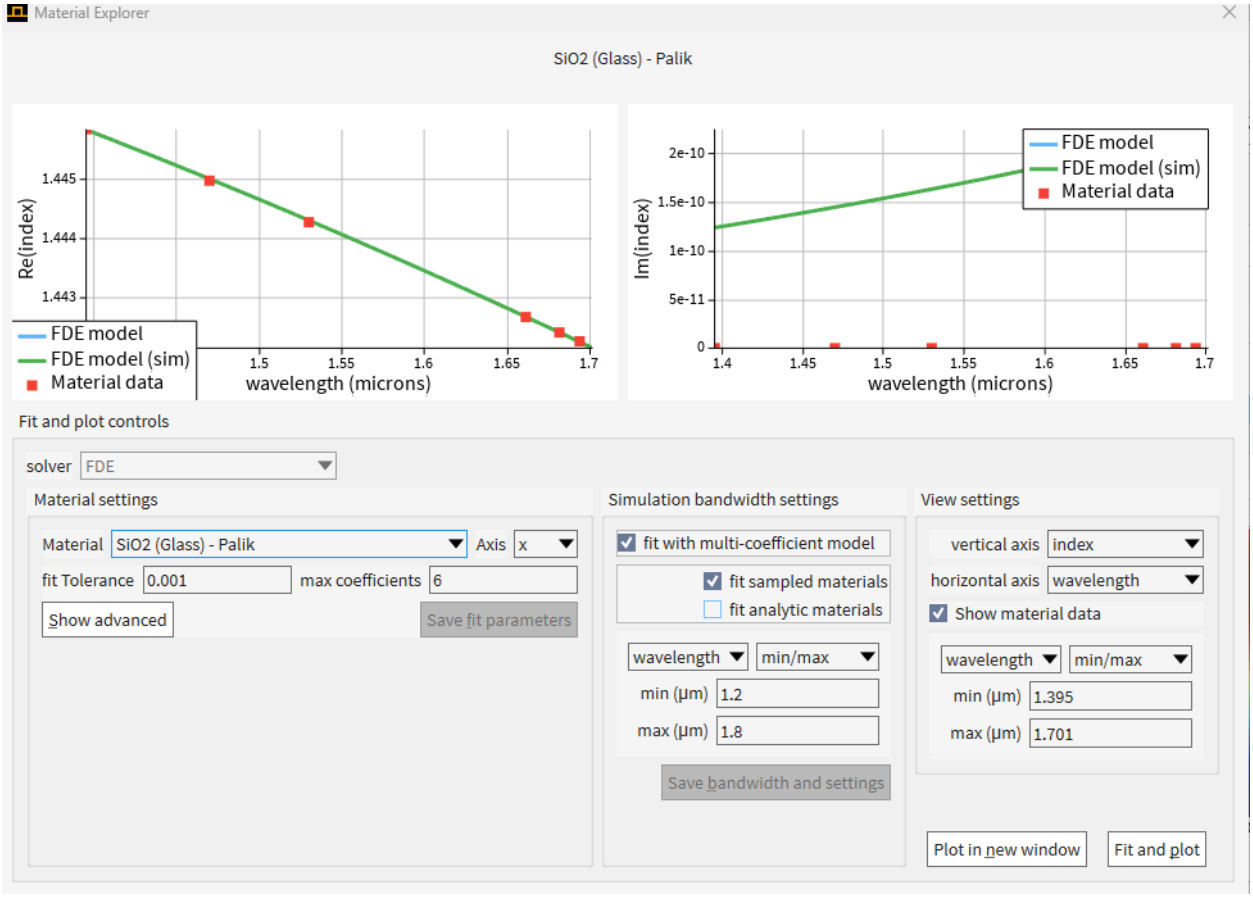
Given the length difference, I'll make 3 designs with slightly different length differences. 2.5mm, 2.66mm 2.7mm and duplicates of these.

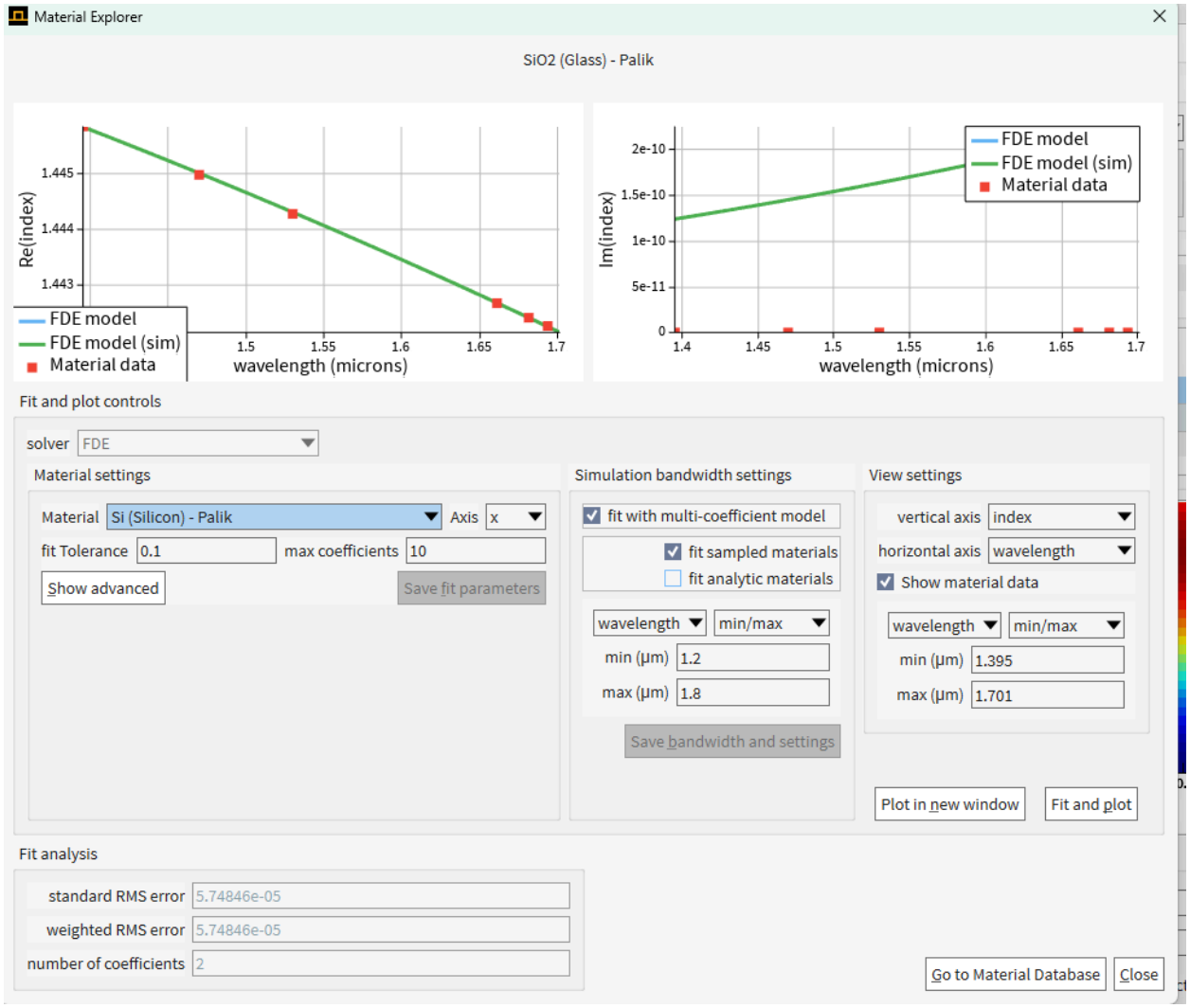
Chip 1 Variations In Designs

To account for manufacturing differences that impact the width of the waveguide, different calculations were performed for varying waveguide widths, the group index was found from simulations in lumericla mode and the target length difference for each was calculated.

Width (nm)	Group Index	FSR	Wavelength (nm)	Target Length Difference (microns)
350		25	1310	2667
335	2630	25	1310	2630
340	4.53	25	1310	2649
360	4.46	25	1310	2690

Chip 2


Material Explorer
SiO2 (Glass) - Palik
Re(index)
1.445
1.444
1.443
1.5
1.55
1.6
1.65
1.7
wavelength (microns)
FDE model
FDE model (sim)
Material data
Im(index)
2e-10
1.5e-10
1e-10
5e-11
0
1.4
1.45
1.5
1.55
1.6
1.65
1.7
wavelength (microns)
FDE model
FDE model (sim)
Material data
Fit and plot controls
solver
FDE
Material settings
Material
SiO2 (Glass) - Palik
Axis
x
fit Tolerance
0.001
max coefficients
6
Show advanced
Save fit parameters
Simulation bandwidth settings
fit with multi-coefficient model
fit sampled materials
fit analytic materials
wavelength
min/max
min (μm)
1.2
max (μm)
1.8
Save bandwidth and settings
View settings
vertical axis
index
horizontal axis
wavelength
Show material data
wavelength
min/max
min (μm)
1.395
max (μm)
1.701
Plot in new window
Fit and plot



Chip 2	
FSR Desired (Ghz)	25
Wavelength (nm)	1310
c (m/s)	300000000
FSR in (nm)	-0.1430083333
nG	4.785922
Length Difference	-2507353.86
Target Length (um)	2507
Length Difference in mm	-2.6