Chip1 Design

Introduction:

To be written later

Calculations and Simulations:

$$FSR(Hz) = \frac{c}{n_g \Delta L}$$

$$\Delta L = \frac{c}{n_g FSR}$$

Fig. x Formula for Delta L and FSR

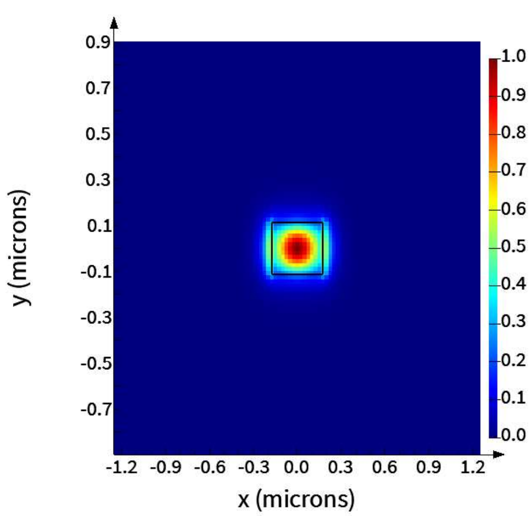
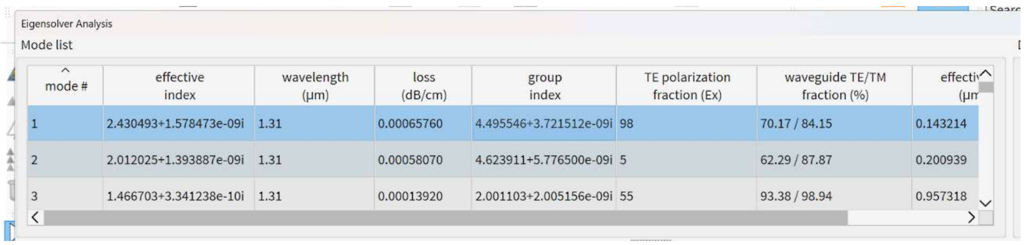


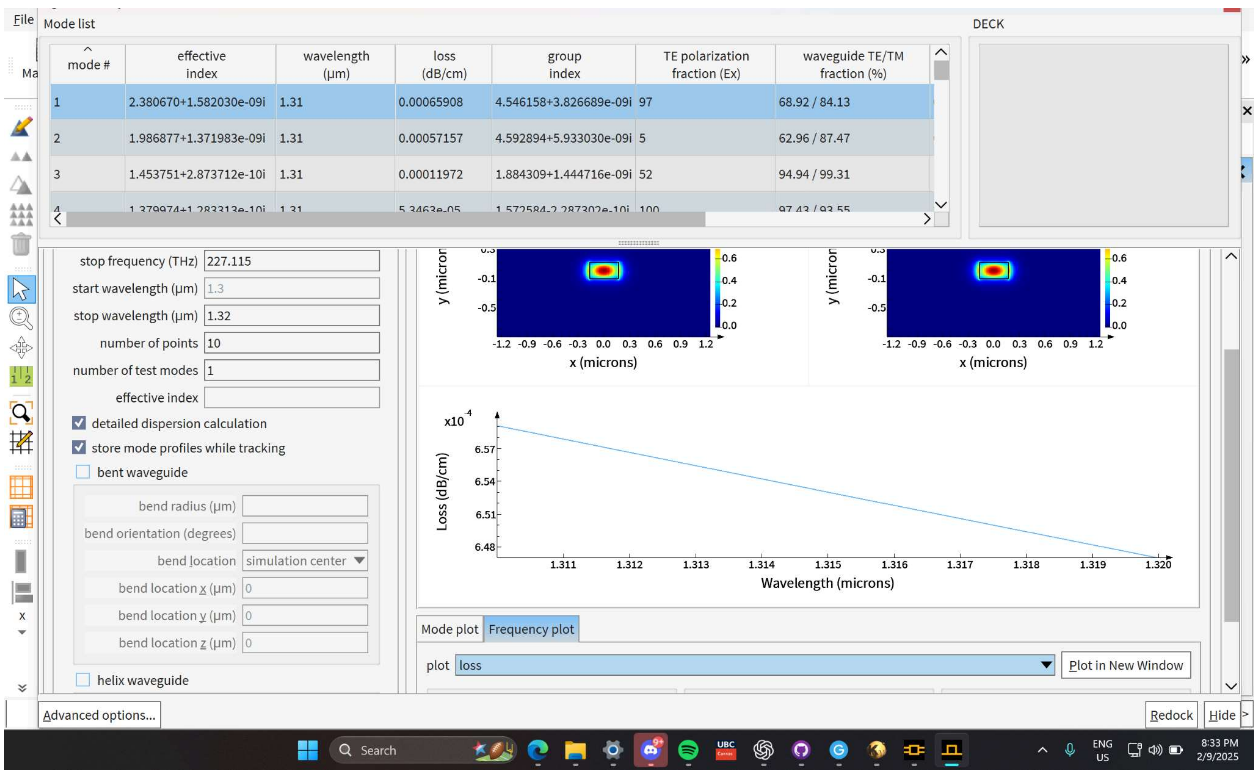
Fig. x E intensity of 350nm x 220nm Si, SiO2 Waveguide at 1310nm Wavelength



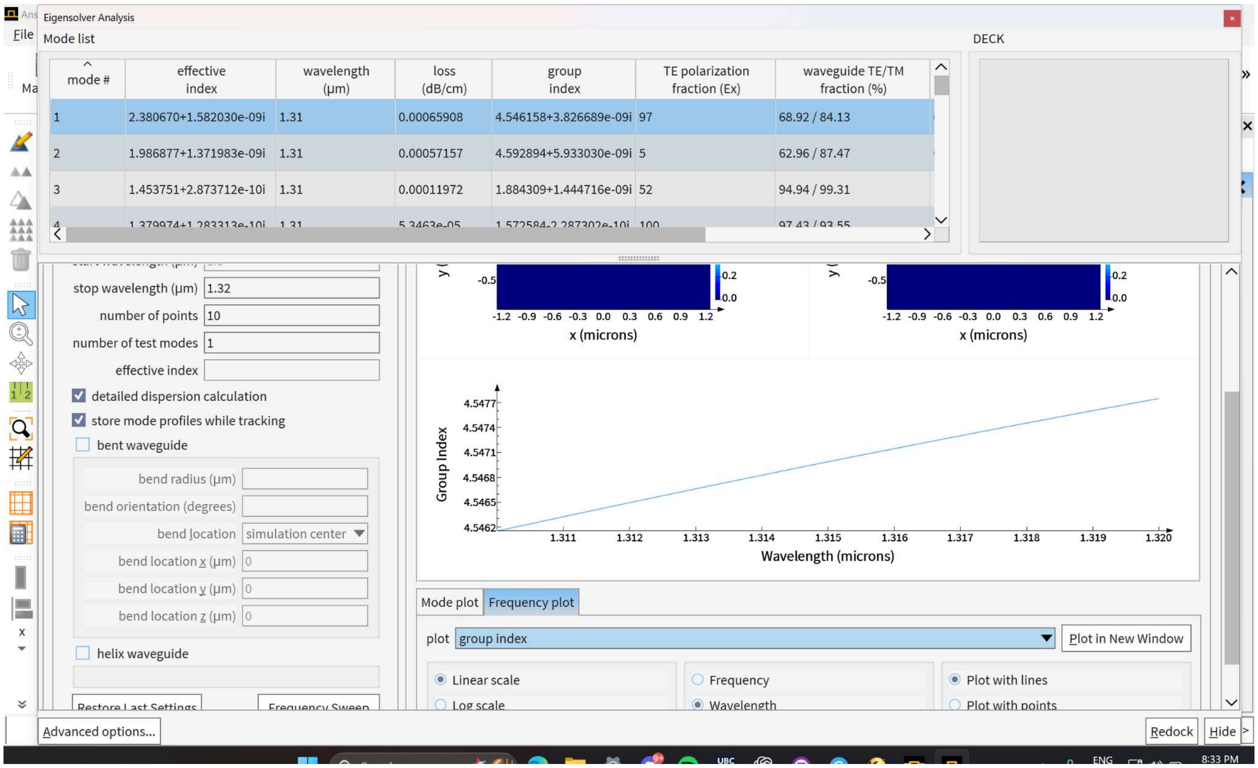
mode #	effective index	wavelength (µm)	loss (dB/cm)	group index	TE polarization fraction (Ex)	waveguide TE/TM fraction (%)	effecti (µm
1	2.430493+1.578473e-09i	1.31	0.00065760	4.495546+3.721512e-09i	98	70.17 / 84.15	0.143214
2	2.012025+1.393887e-09i	1.31	0.00058070	4.623911+5.776500e-09i	5	62.29 / 87.87	0.200939
3	1.466703+3.341238e-10i	1.31	0.00013920	2.001103+2.005156e-09i	55	93.38 / 98.94	0.957318

First Few Modes - Group Index of 4.495546

I ended up redoing my Mode simulations for 335 nm width and designing for that. The group index gained from the simulation was about 4.56158



mode #	effective index	wavelength (µm)	loss (dB/cm)	group index	TE polarization fraction (Ex)	waveguide TE/TM fraction (%)
1	2.380670+1.582030e-09i	1.31	0.00065908	4.546158+3.826689e-09i	97	68.92 / 84.13
2	1.986877+1.371983e-09i	1.31	0.00057157	4.592894+5.933030e-09i	5	62.96 / 87.47
3	1.453751+2.873712e-10i	1.31	0.00011972	1.884309+1.444716e-09i	52	94.94 / 99.31
4	1.379974+1.283313e-10i	1.31	5.3463e-05	1.572584-2.287302e-10i	100	97.43 / 93.55



We’re told that the manufacturing process has like +-10nm error on width/height. I simulated their group indices in MODE and calculated the expected FSR for a delta L that was designed to work with 335x220 nm waveguide. There is honestly not that much variation (WORST case is like 0.7GHz)

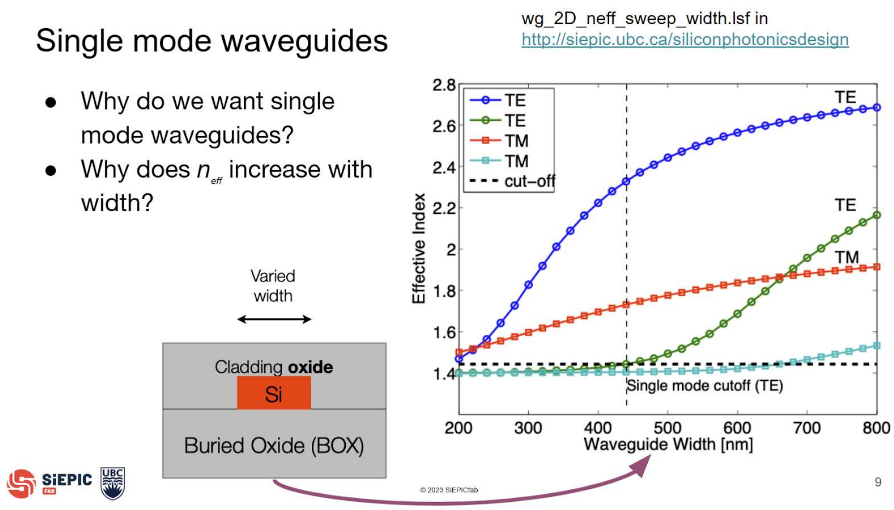
Width (nm)	Height (nm)	Value	Temperature (K)	Wavelength (nm)	FSR (GHz)	Note		Range	0.7082649648
350	220	4.499503	300	1310	25.34491032				
335	220	4.56158	300	1310	25				
340	220	4.531555	300	1310	25.16564402				
320	220	4.591867	300	1310	24.8351052				
360	220	4.467205	300	1310	25.52815463				
350	230	4.50285	300	1310	25.32607127				
350	210	4.486381	300	1310	25.41904042				
360	210	4.464544	300	1310	25.54337016				
335	230	4.550814	300	1310	25.05914327				
350	220	4.499503	293.15	1310	25.34491032				

Q: I need to find the group index to calculate the FSR. Would the group index be that of the first mode? the second? Should I look at the first **TE polarized** or TM polarized mode? does it matter?

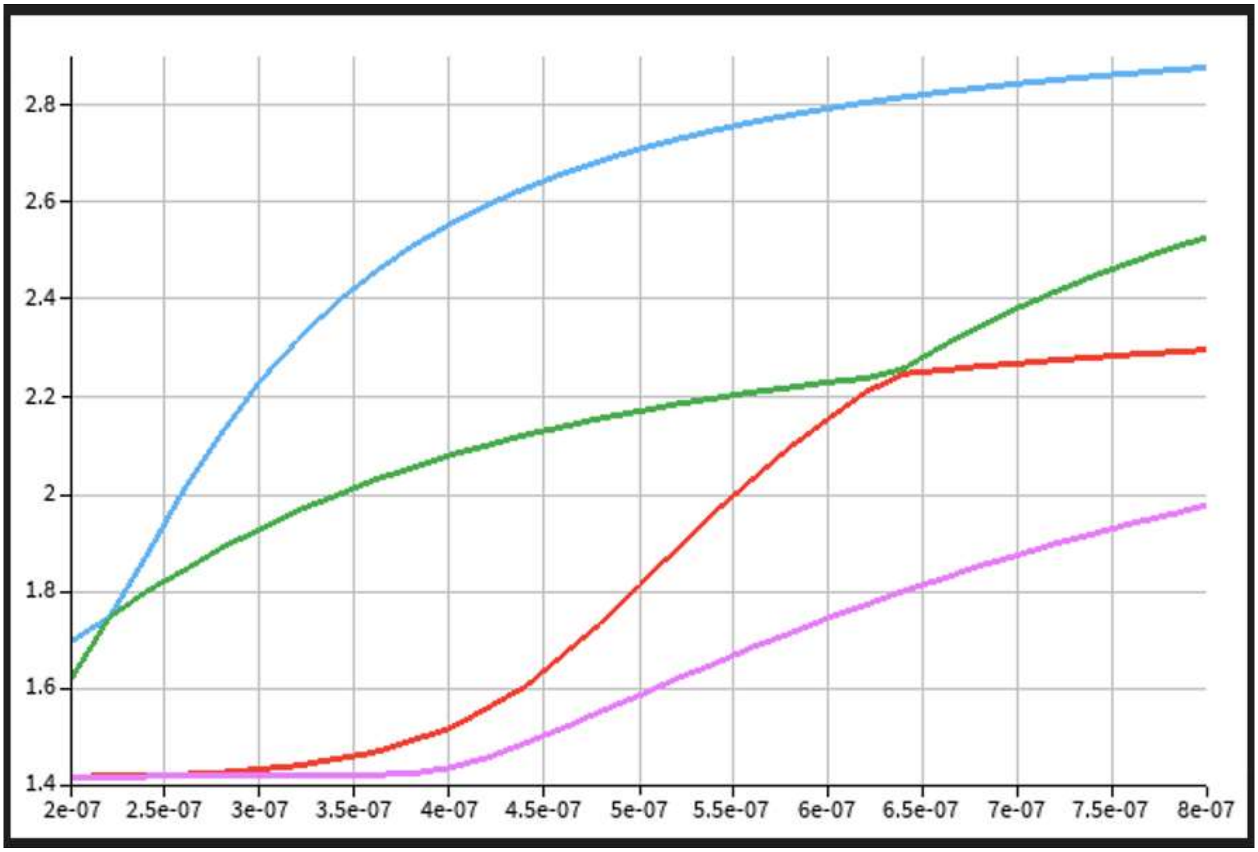
- …. hints the most SIP waveguides are designed for TE modes due to lower propagation loss and better confinement in high-contrast waveguides
- **TE polarized** because lasers normally do that yeah

Q: How do I determine if my waveguide only supports one mode?

- My guess is that we can look at the lecture slide for waveguides. We see that below a waveguide width of about 420nm, our waveguide only supports one mode.
- You need to run his script again at 1310nm because it assumes 1550nm
- We don't really have to resweep because this is common
- Whichever index the effective index is closer to means it spends more time there
    - Like since the center is higher index, higher index means more confined because its more similar to the core
- Multiple nodes is similar to noise in that now your light splits into multiple kinds of waves
- Small bends let the higher order



Regenerated the plot for 1310nm



Sweep for 1310 nm Waveguide (not sure which mode is which exactly but likely similar to above. Red and green seem to swap places at the end, look more into it later. Need to figure out what cutoff is but looks like we're mostly supporting only 1 TE and 1 TM Mode

Google sheets to be formatted later

c			
Parameter	**Value**	**Unit**	**Note**
Number of Outputs	2		
Free Spectral Range (FSR)	25	GHz	
Maximum Floorplan Dimensions	605 x 410	µm	
Waveguide Width	350	nm	
Operating Wavelength	1310	nm	
Speed of Light	299792458	m/s	

Fig.x Input Parameters

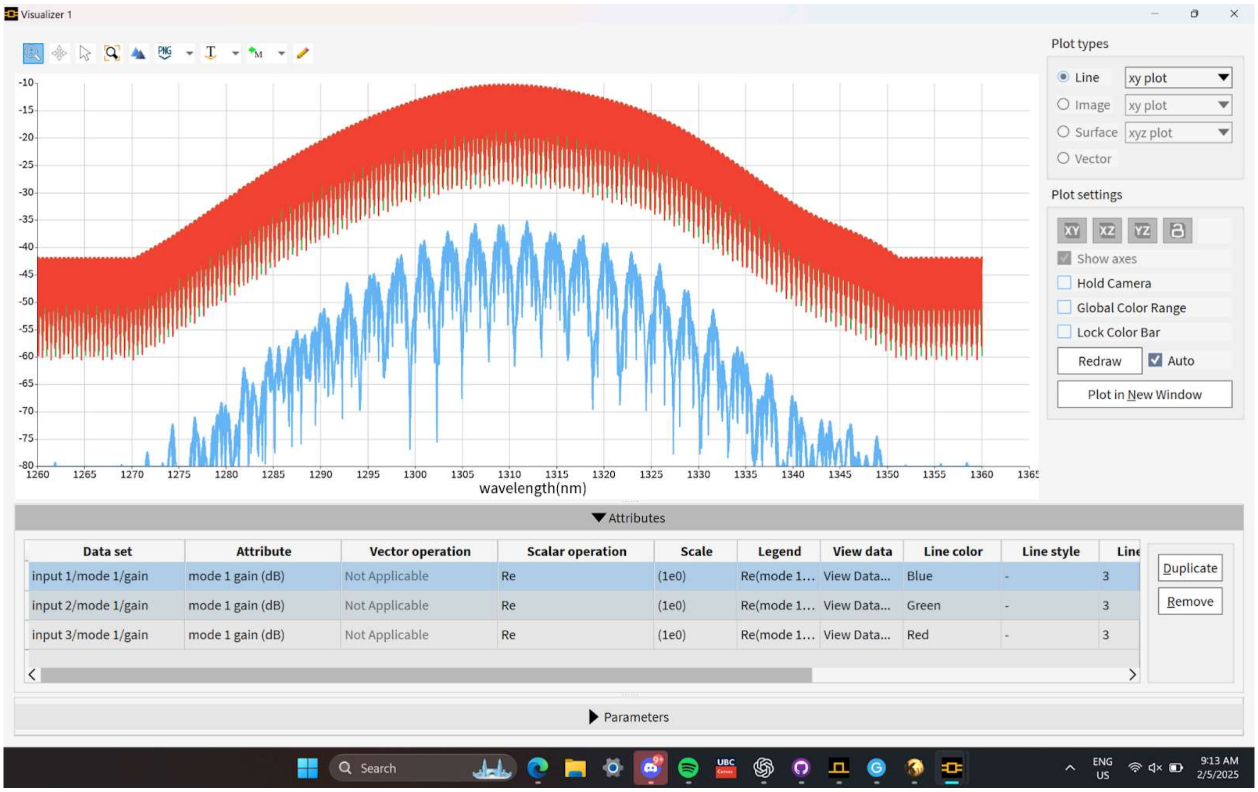
I wanted to vary the design to design from 23 GHz to 26 GHz. Interconnect FSR is the FSR given to me by interconnect simulation. Calculated FSR is based on the equations given at the start of the report.

Calculated Values			
Parameter	**Value**	**Unit**	**Note**
Waveguide neff			MODE Simulation
Waveguide neg1	4.499503		Assumes 350 nm
Waveguide neg2	**4.56158**		**Assumes 335 nm**
Waveguide Loss Sraight			
Waveguide Loss Bend			
Target Delta L	2628.847531	µm	Assumes 335 nm and 25GHz
Target Delta L	2.628847531	mm	Assumes 335 nm and 25GHz
Design 1			
Target FSR	**23**	GHz	
Target Delta L	2857.442968	um	
MZI Length 1	16.789	µm	
Target MZI Length 2	2874.231968	µm	
Segment 1	66.961	µm	
Segment 2	2605.47	µm	
Segment 3	**201.8**	**µm**	
Actual MZ Length 2	2874.231	µm	
Difference From Target	0.000968368893	µm	
Acutal Delta L	2857.442	µm	
Calculated FSR1	23.31732539	GHz	Assumes 350 nm
Calculated FSR2	**23.00000779**	**GHz**	**Assumes 335 nm**
Interconnect FSR	23.46	GHz	
Design 2			
Target FSR	**23**	GHz	
Target Delta L	2857.442968	um	
MZI Length 1	16.789	µm	
Target MZI Length 2	2874.231968	µm	
Segment 1	66.961	µm	
Segment 2	2605.47	µm	
Segment 3	**201.8**	**µm**	
Actual MZ Length 2	2874.231	µm	
Difference From Target	0.000968368893	µm	
Acutal Delta L	2857.442	µm	
Calculated FSR1	23.31732539	GHz	Assumes 350 nm
Calculated FSR2	23.00000779	GHz	Assumes 335 nm
Interconnect FSR	23.3	GHz	
Design 3			
Target FSR	**24**	GHz	
Target Delta L	2738.382845	um	
MZI Length 1	16.789	µm	
Target MZI Length 2	2755.171845	µm	
Segment 1	68.661	µm	
Segment 2	2489.87	µm	
Segment 3	**196.642**	**µm**	
Actual MZ Length 2	2755.173	µm	
Difference From Target	-0.00115531314	µm	
Acutal Delta L	2738.384	µm	
Calculated FSR1	24.33110364	GHz	Assumes 350 nm
Calculated FSR2	23.99998987	GHz	Assumes 335 nm

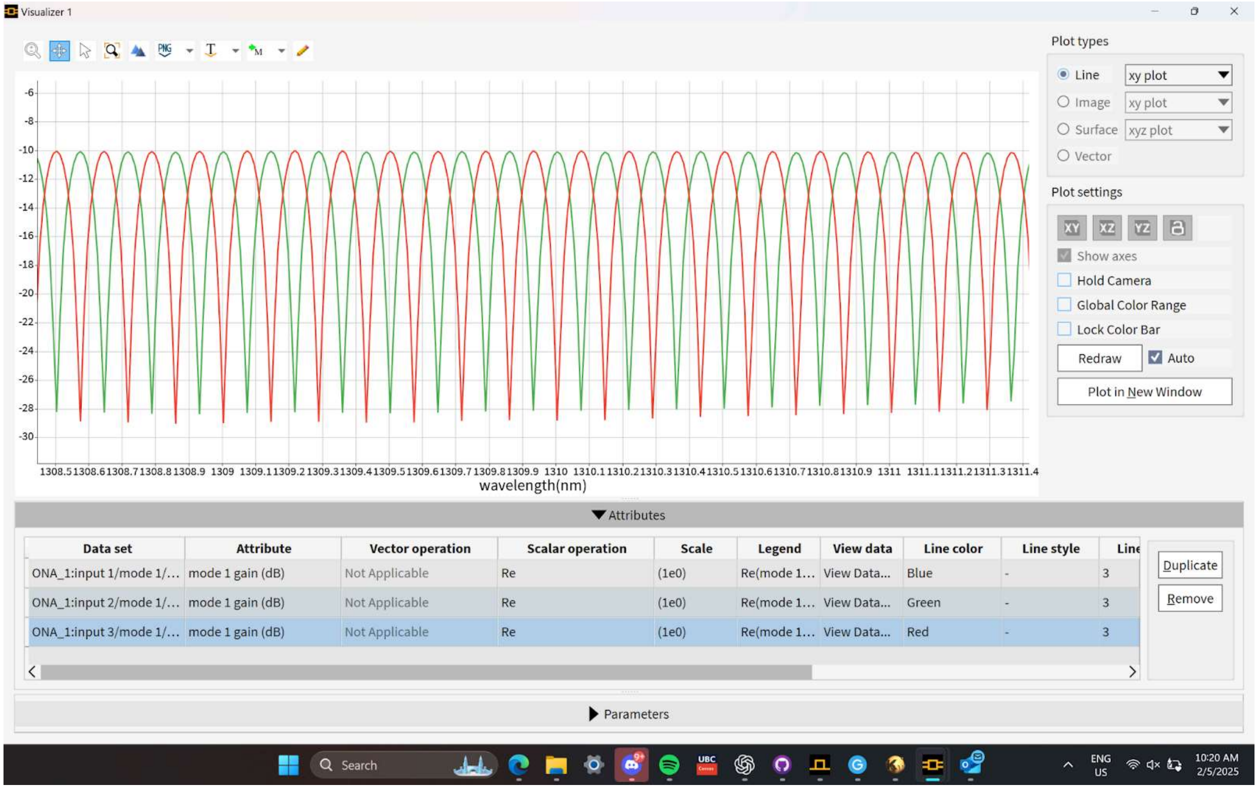
	Design 4		
Target FSR	**24**	GHz	
Target Delta L	2738.382845	um	
MZI Length 1	16.789	µm	
Target MZI Length 2	2755.171845	µm	
Segment 1	68.661	µm	
Segment 2	2489.87	µm	
Segment 3	**196.642**	**µm**	
Actual MZ Length 2	2755.173	µm	
Difference From Target	-0.00115531314	µm	
Acutal Delta L	2738.384	µm	
Calculated FSR1	24.33110364	GHz	Assumes 350 nm
Calculated FSR2	23.99998987	GHz	Assumes 335 nm
Interconnect FSR	24.46	GHz	
	Design 5		
Target FSR	**25**	GHz	
Target Delta L	2628.847531	um	
MZI Length 1	16.789	µm	
Target MZI Length 2	2645.636531	µm	
Segment 1	70.211	µm	
Segment 2	2384.47	µm	
Segment 3	**190.956**	**µm**	
Actual MZ Length 2	2645.637	µm	
Difference From Target	-0.00046910061	µm	
Acutal Delta L	2628.848	µm	
Calculated FSR1	25.34490579	GHz	Assumes 350 nm
Calculated FSR2	24.99999554	GHz	Assumes 335 nm
Interconnect FSR	25.46	GHz	
	Design 6		
Target FSR	**25**	GHz	
Target Delta L	2628.847531	um	
MZI Length 1	16.789	µm	
Target MZI Length 2	2645.636531	µm	
Segment 1	70.211	µm	
Segment 2	2384.47	µm	
Segment 3	**190.956**	**µm**	
Actual MZ Length 2	2645.637	µm	
Difference From Target	-0.00046910061	µm	
Acutal Delta L	2628.848	µm	
Calculated FSR1	25.34490579	GHz	Assumes 350 nm
Calculated FSR2	24.99999554	GHz	Assumes 335 nm
Interconnect FSR	25.46	GHz	

Design 7			
Target FSR	**26**	GHz	
Target Delta L	2527.73801	um	
MZI Length 1	16.789	µm	
Target MZI Length 2	2544.52701	µm	
Segment 1	70.881	µm	
Segment 2	2338.91	µm	
Segment 3	**134.736**	**µm**	
Actual MZ Length 2	2544.527	µm	
Difference From Target	0.000010480174	µm	
Acutal Delta L	2527.738	µm	
Calculated FSR1	26.35870684	GHz	Assumes 350 nm
Calculated FSR2	26.00000011	GHz	Assumes 335 nm
Interconnect FSR	26.46	GHz	
Design 8			
Target FSR	**26**	GHz	
Target Delta L	2527.73801	um	
MZI Length 1	16.789	µm	
Target MZI Length 2	2544.52701	µm	
Segment 1	70.881	µm	
Segment 2	2338.91	µm	
Segment 3	**134.736**	**µm**	
Actual MZ Length 2	2544.527	µm	
Difference From Target	0.000010480174	µm	
Acutal Delta L	2527.738	µm	
Calculated FSR1	26.35870684	GHz	Assumes 350 nm
Calculated FSR2	26.00000011	GHz	Assumes 335 nm
Interconnect FSR	26.46	GHz	

Here is the interconnect simulation for chip 1. (this was before I changed my design but the design is nearly identical, this one I think was designed for 25GHz)

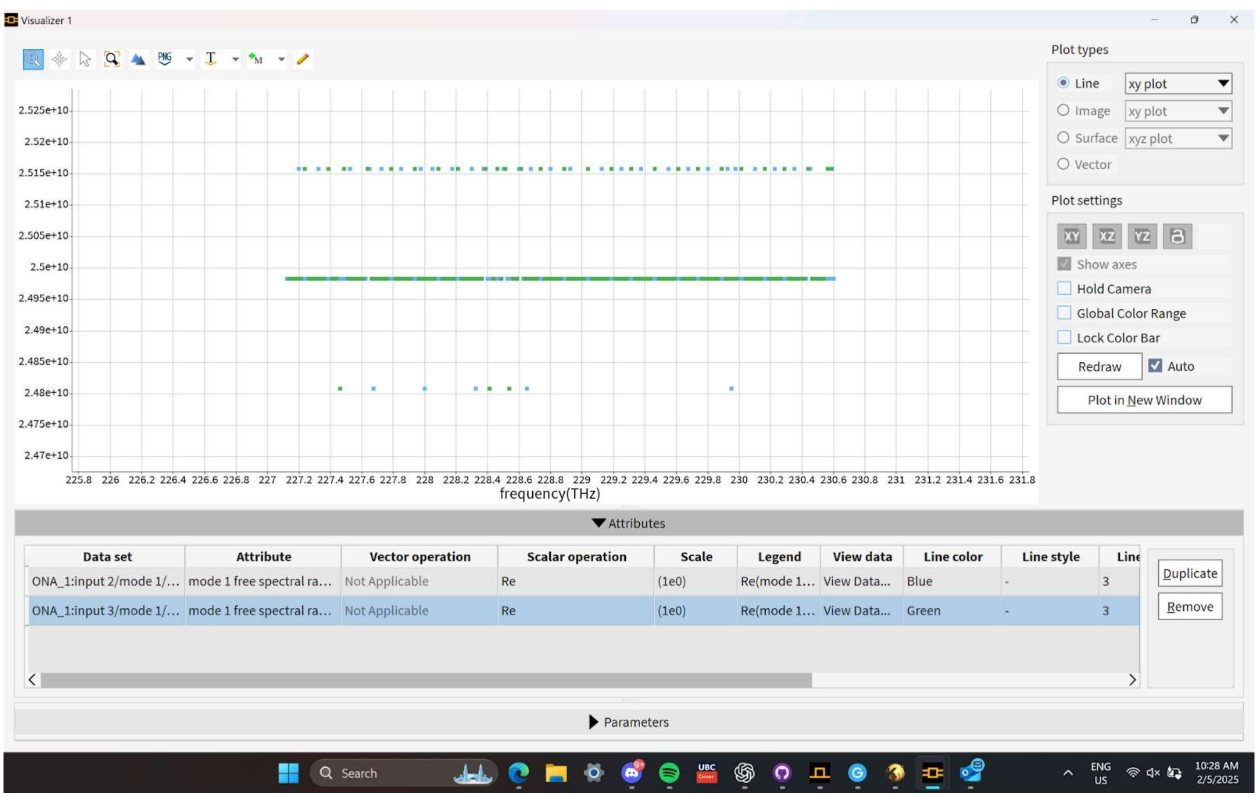


Simulation of MZI 25GHz



Simulation of MZI 25GHz (Gain Plot)

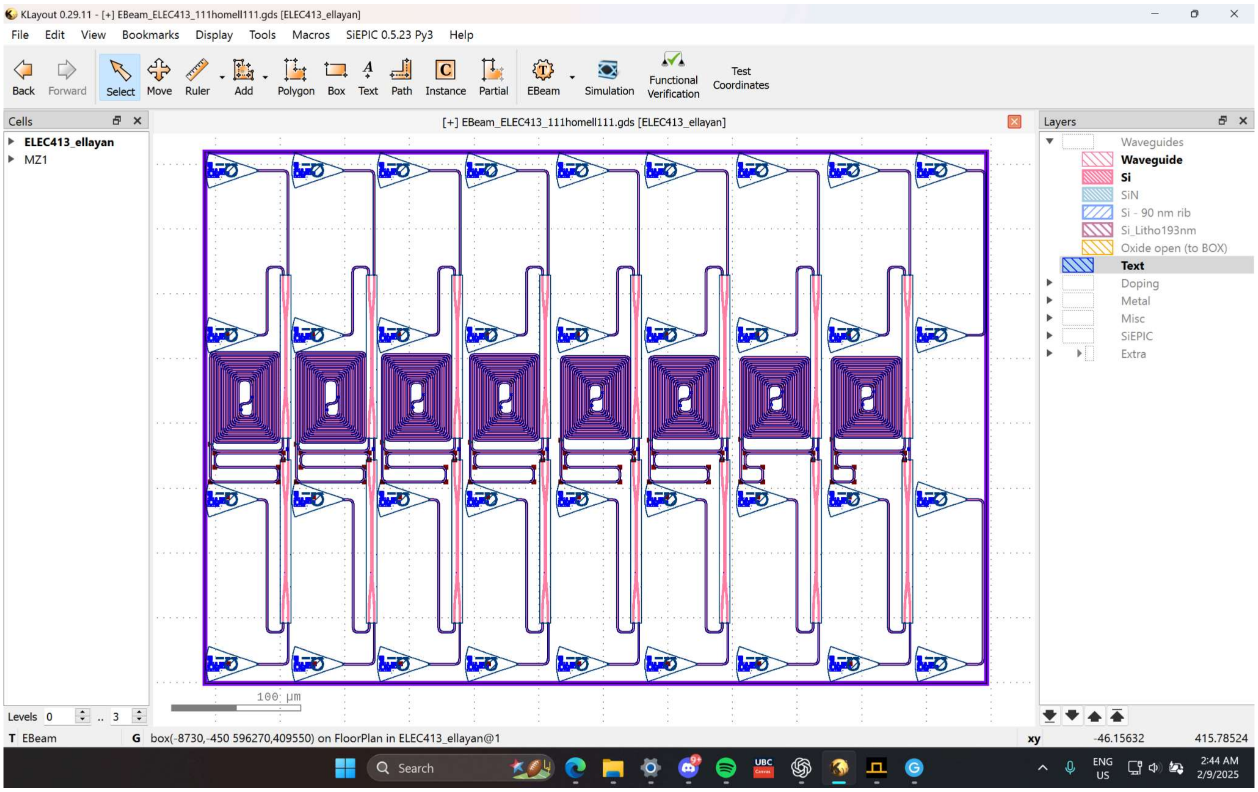
- Zoomed in (INPUT 1 is other input, INPUT2, INPUT3 are actual outputs of MZI)



Simulation of Interferometer 25Ghz, FSR

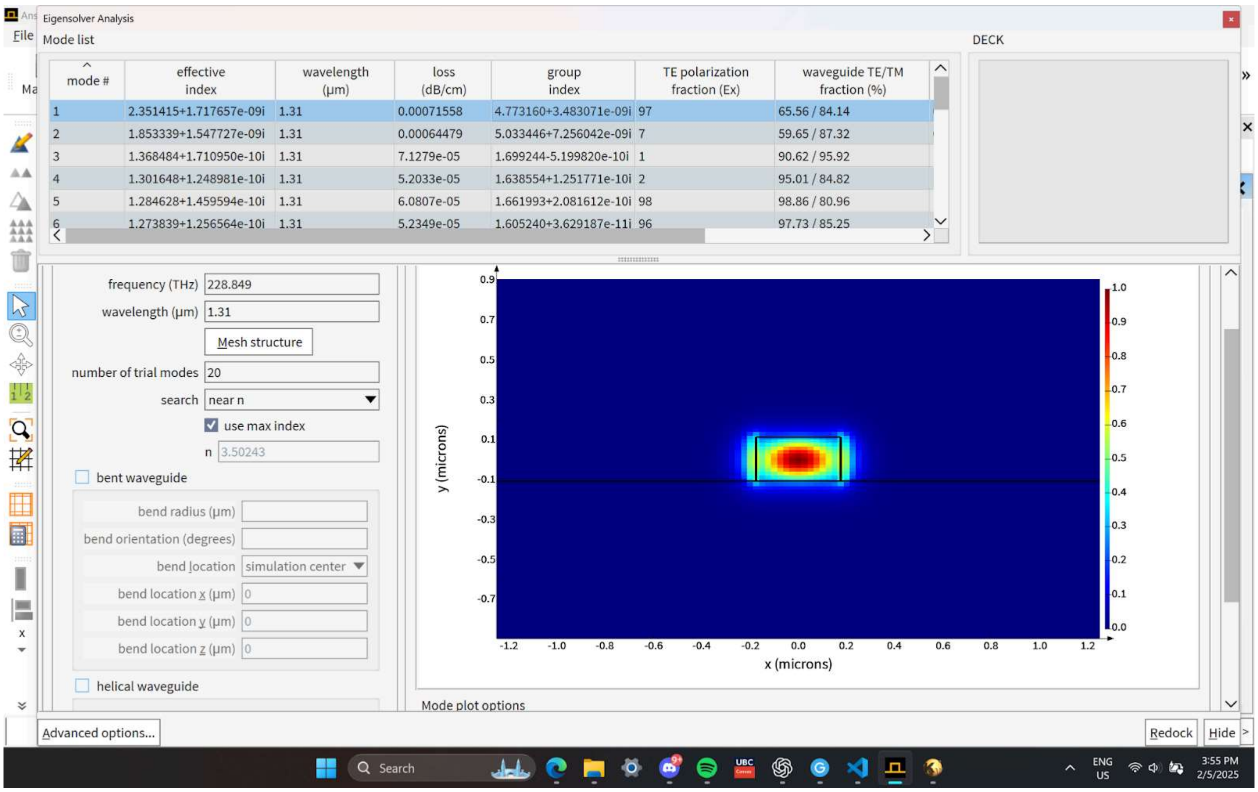
I repeated these interconnect simulations for every single MZI to verify they all had the expected output FSR (I think the FSRs I got were typically a bit higher than expected when simulating in interconnect as u can see in the spreadsheet... I wonder why that is...)

I also added a section to measure insertion loss. Here is the final design



Chip 2

Calculations and Simulation



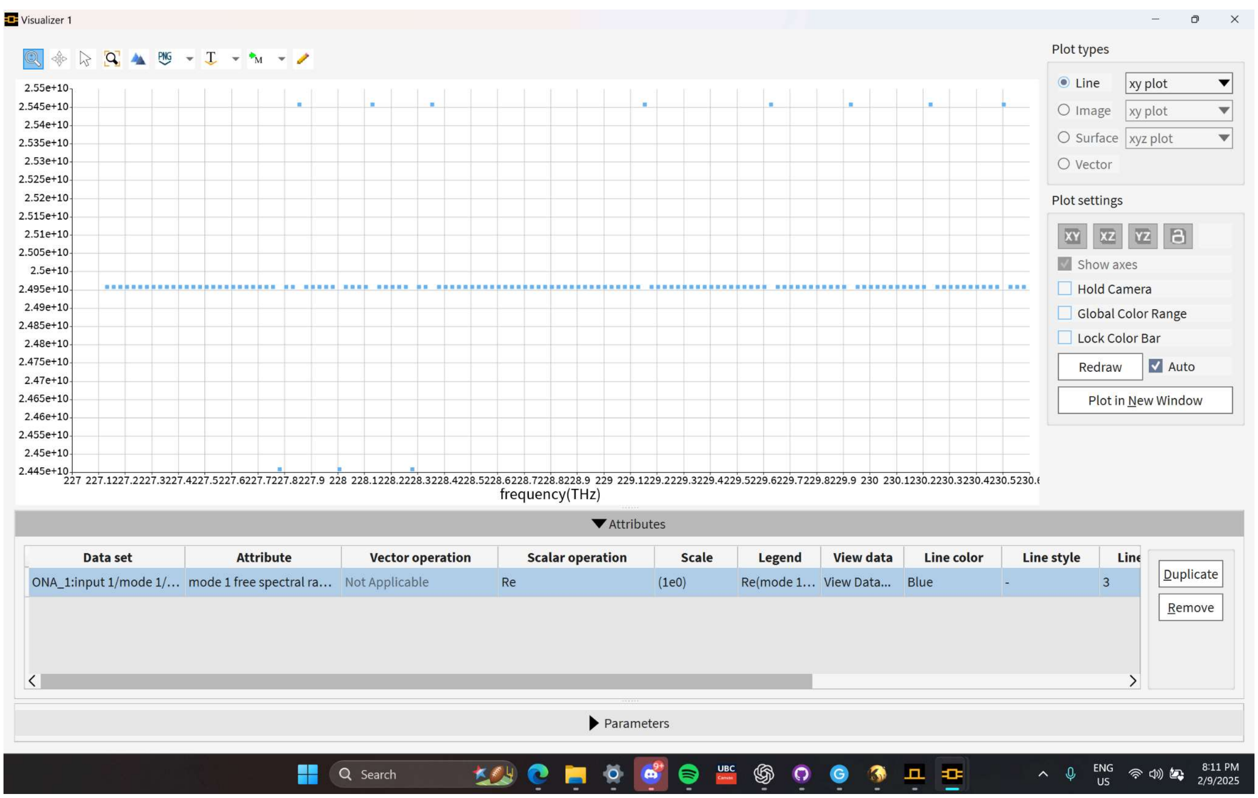
Mode Simulation, top is air (index 1.0), bottom is SiO2

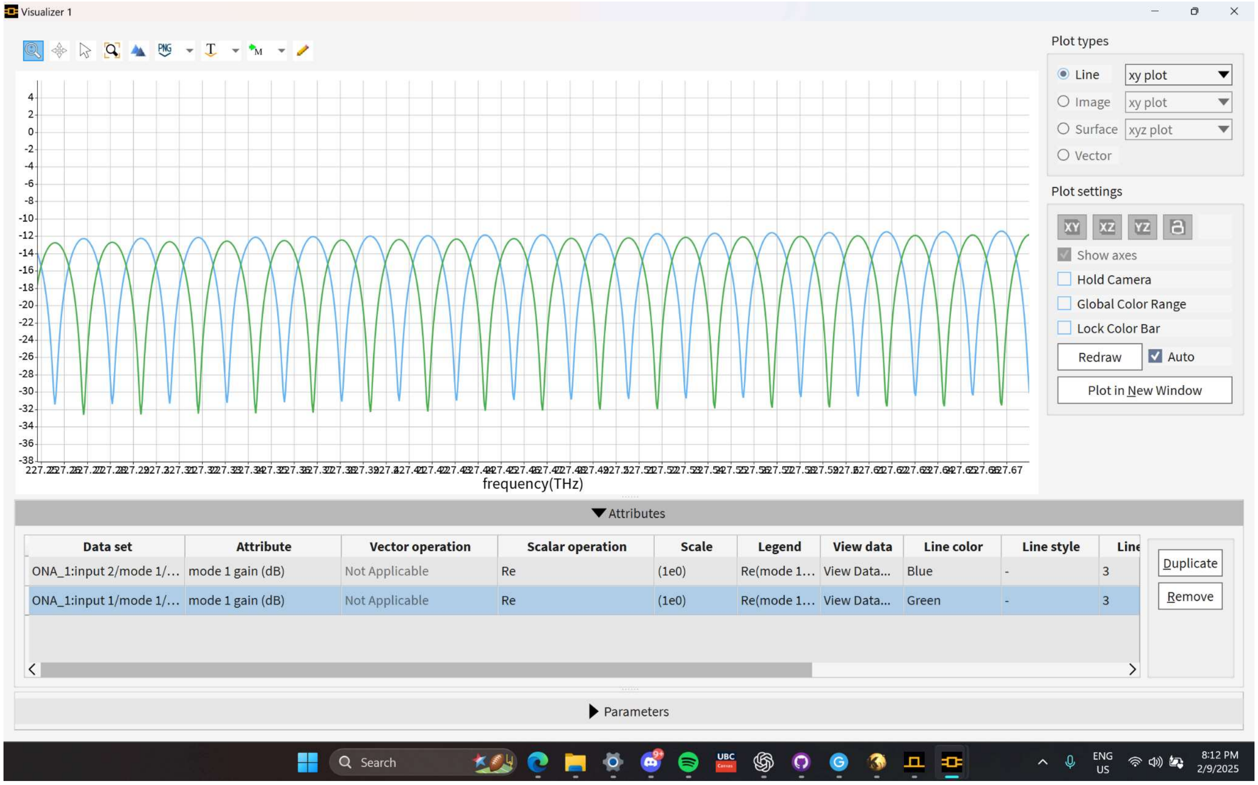
I believe I updated my simulation recently, so the numbers in my spreadsheet might be ever so slightly different. (I think I added more meshes, or changed the sim area)

Parameter	Value	Unit	Note
Calculated Values			
Waveguide neff			MODE Simulation
Waveguide neg	4.785922		Assumed Vacuum figured it was close enough (only changes FSR by like 0.001
Waveguide loss			
Target Delta L	2505.619256	µm	
Target Delta L	2.505619256	mm	
Design 1			
MZI Length 1	43.851	µm	
Target MZI Length 2	**2549.470256**	µm	
Segment 1	221.099	µm	
Segment 2	2100.35	µm	
Segment 3	228.021	µm	
Actual MZ Length 2	2549.47	µm	
Difference From Target	0.000255809015	µm	
Acutal Delta L	2505.619	µm	
Real FSR	25.00000255	GHz	
Distance Straight			
Number of Bends			

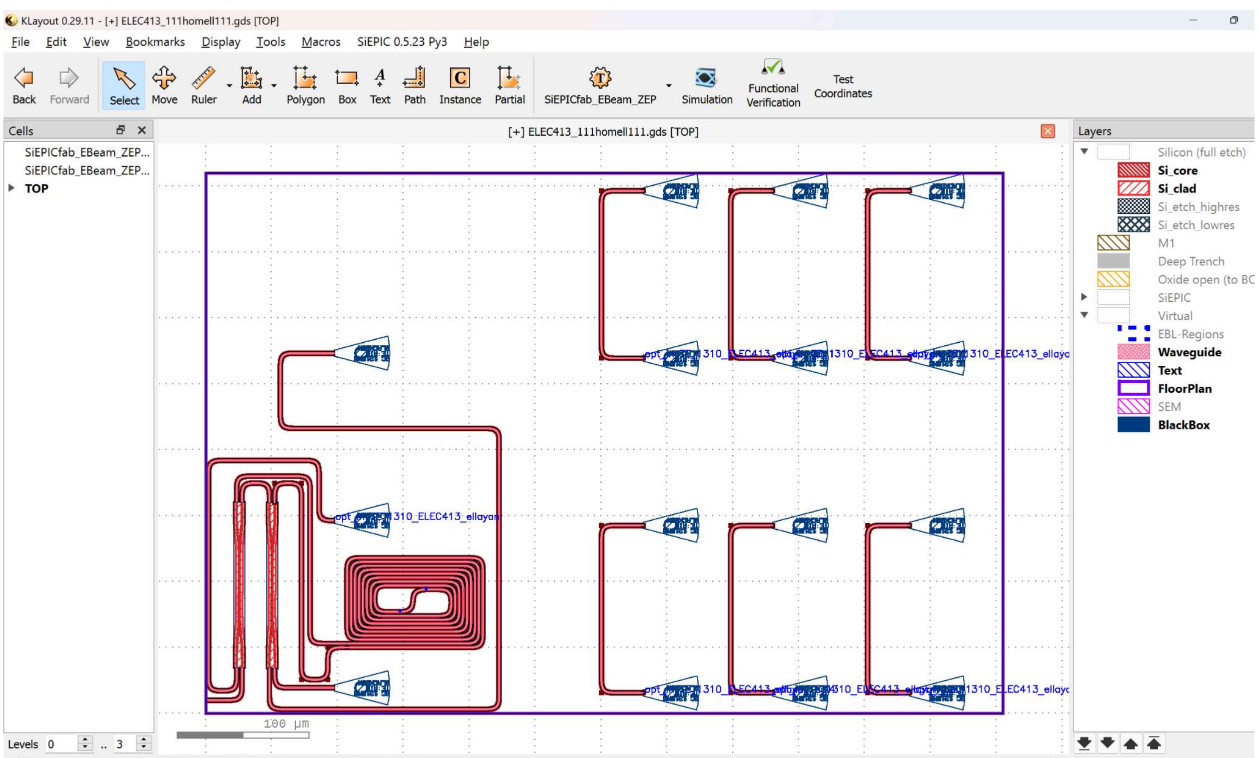
Chip 2 Calcuations

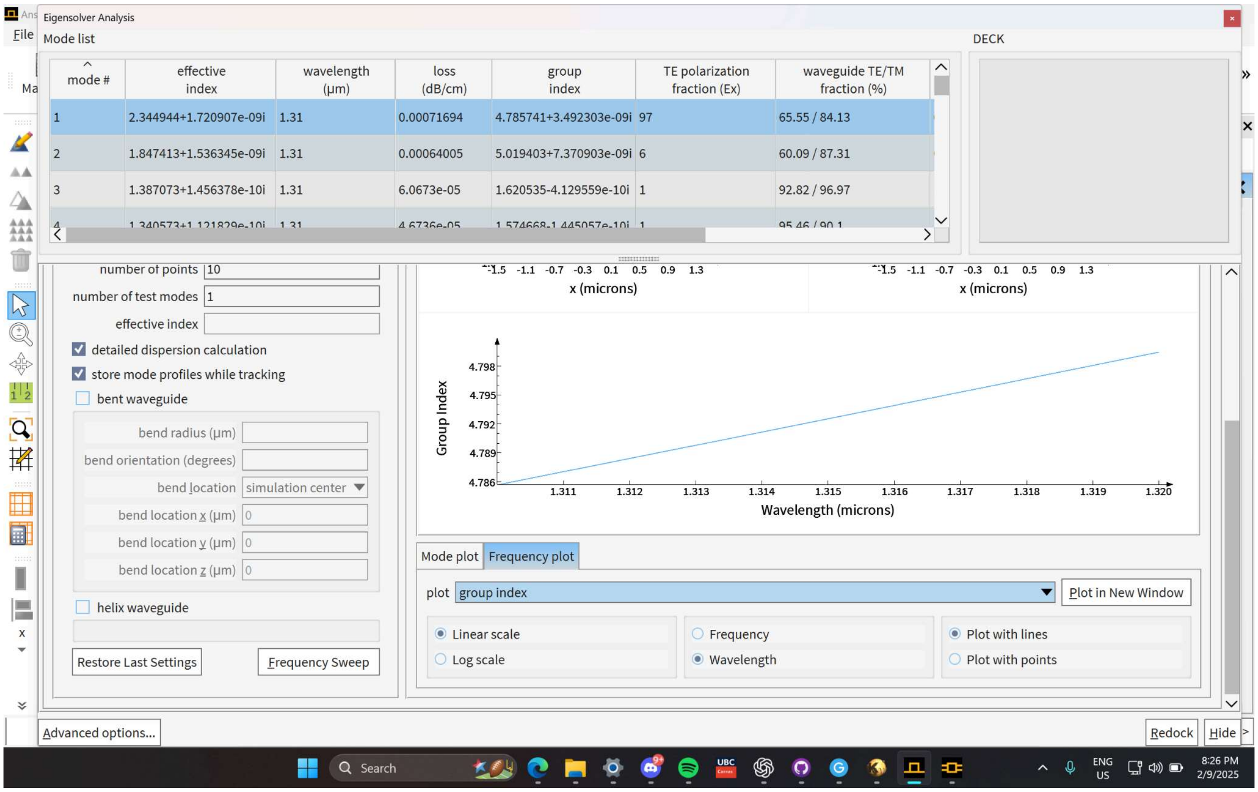
Here is the interconnect simulation

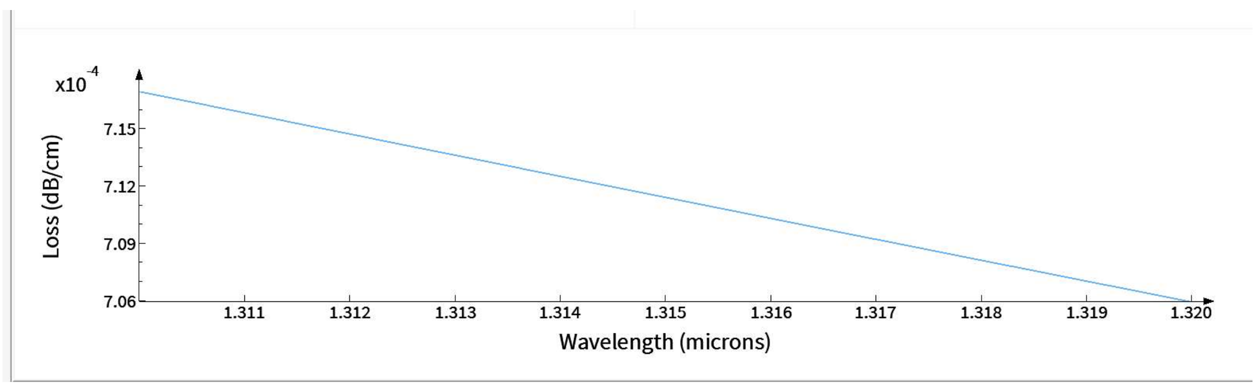




Here is my final design







Frequency sweep data