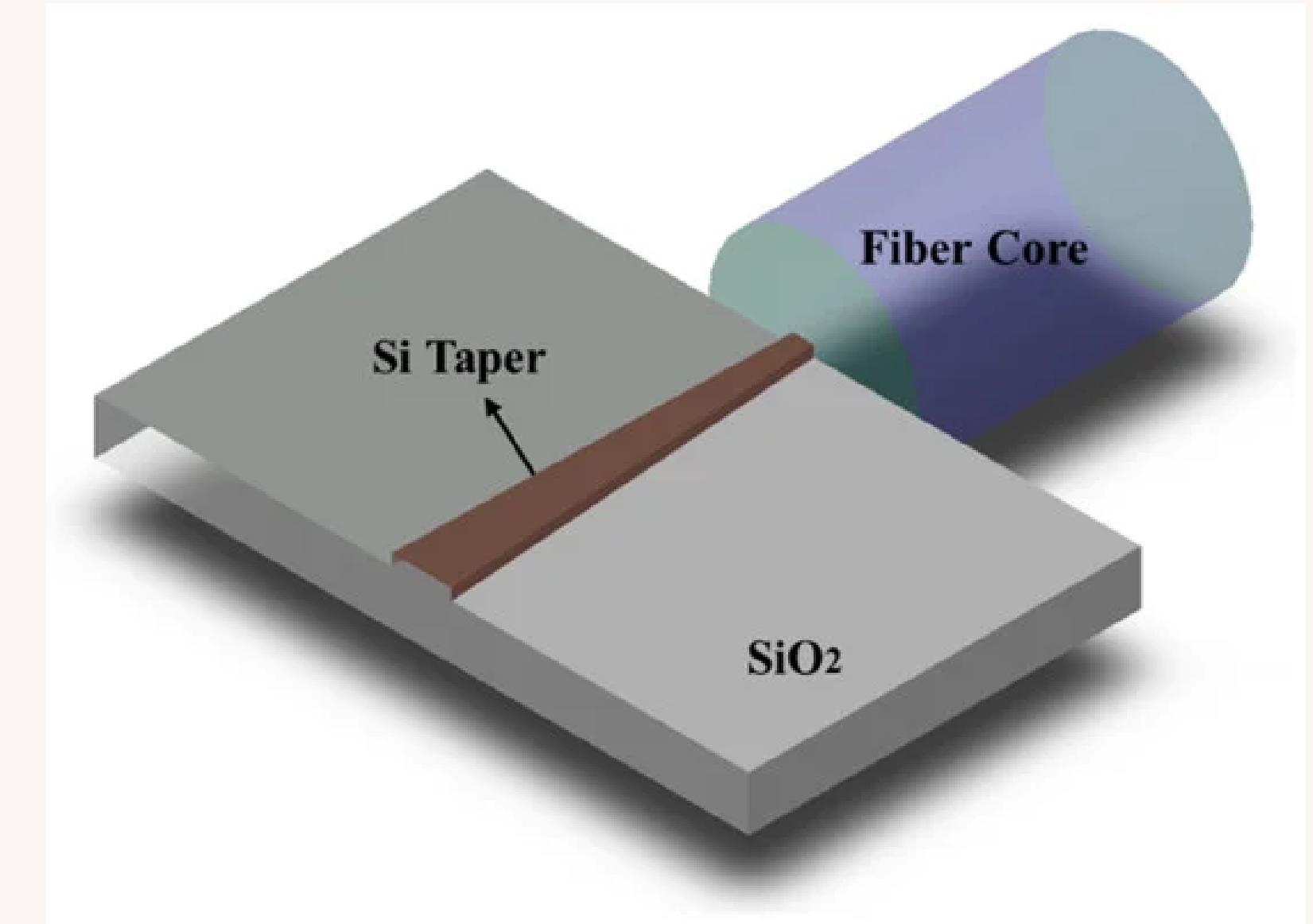


EDGE COUPLER

Leonardo Pessôa

OBJECTIVE

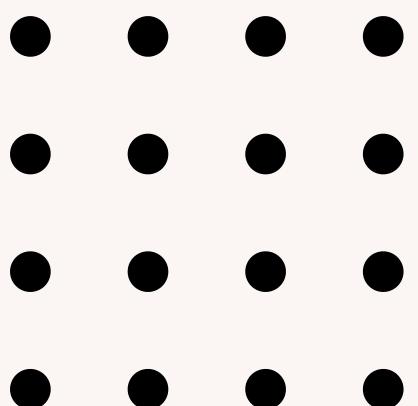
Generate, simulate and optimize an edge multi-modal edge coupler



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DIMENSIONS AND SHAPES

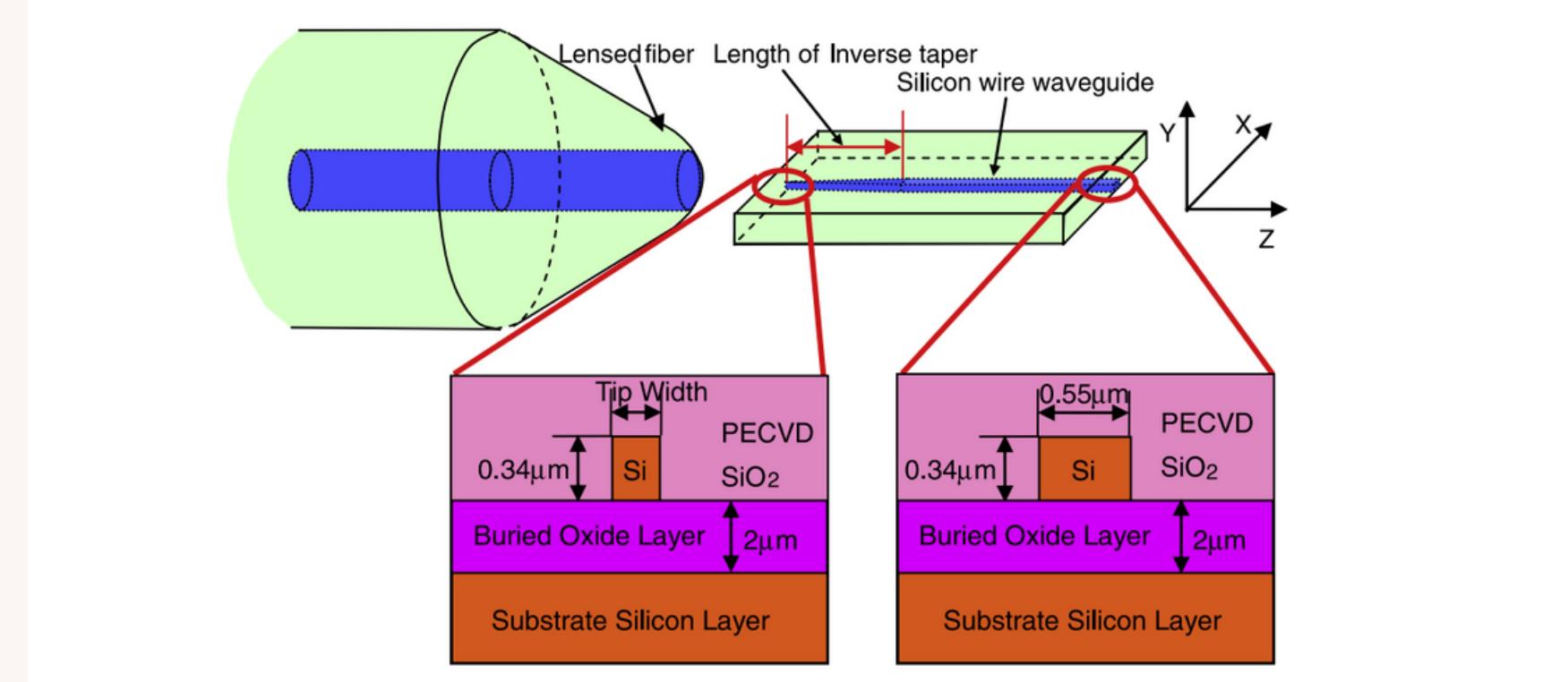
- For this component, the base article [2] graphics will be used as initial parameters and optimized on the latter weeks.
- The shapes to be analized are: linear, exponential and quadratic.
- The dimentions to be first analized are lenght and width.



DIMENSIONS AND SHAPES

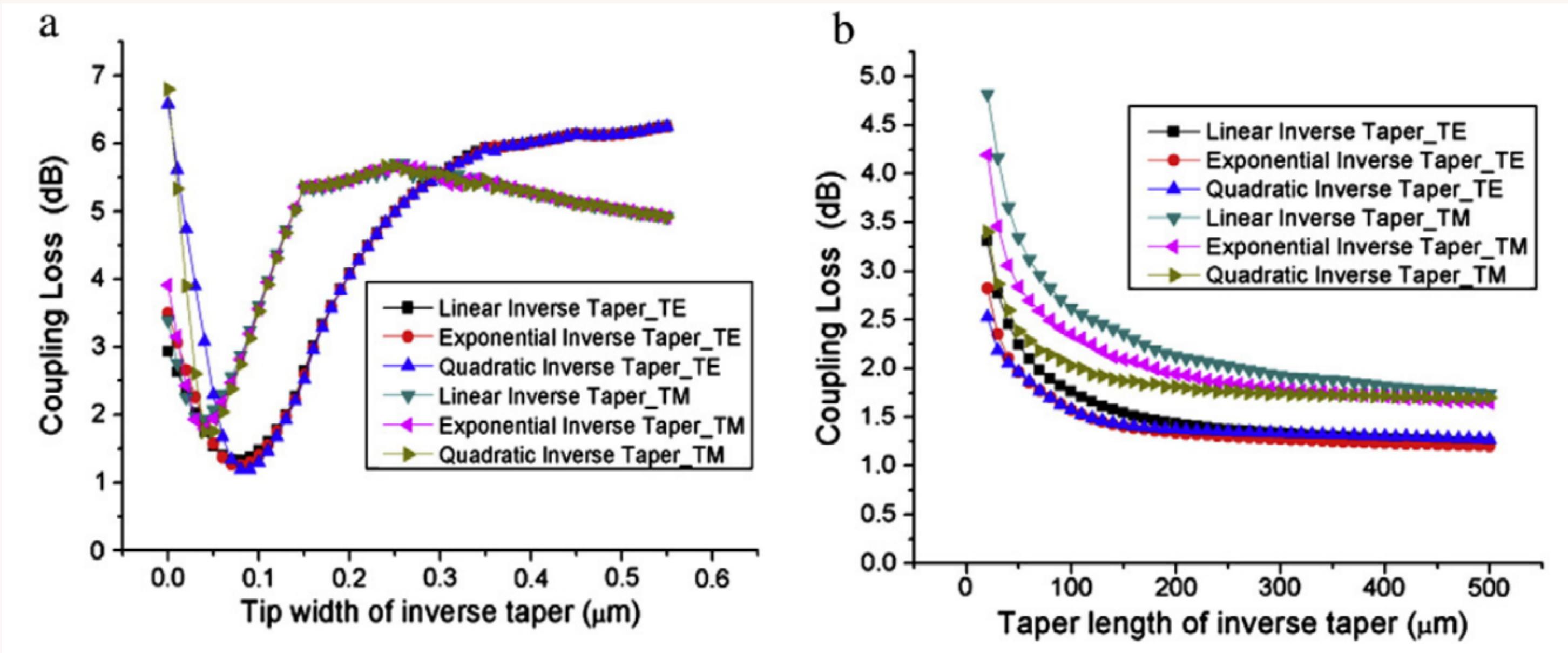


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GENERAL GRAPHICS



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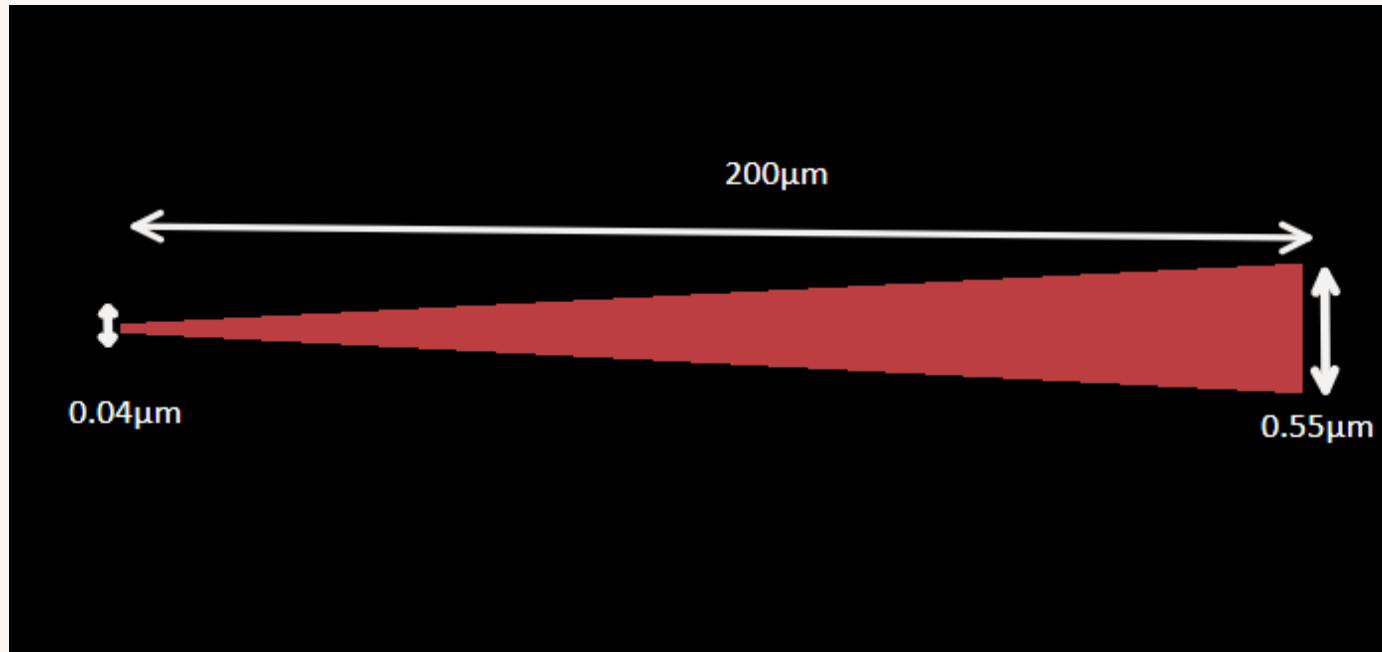
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WEEK 1 OBJECTIVES

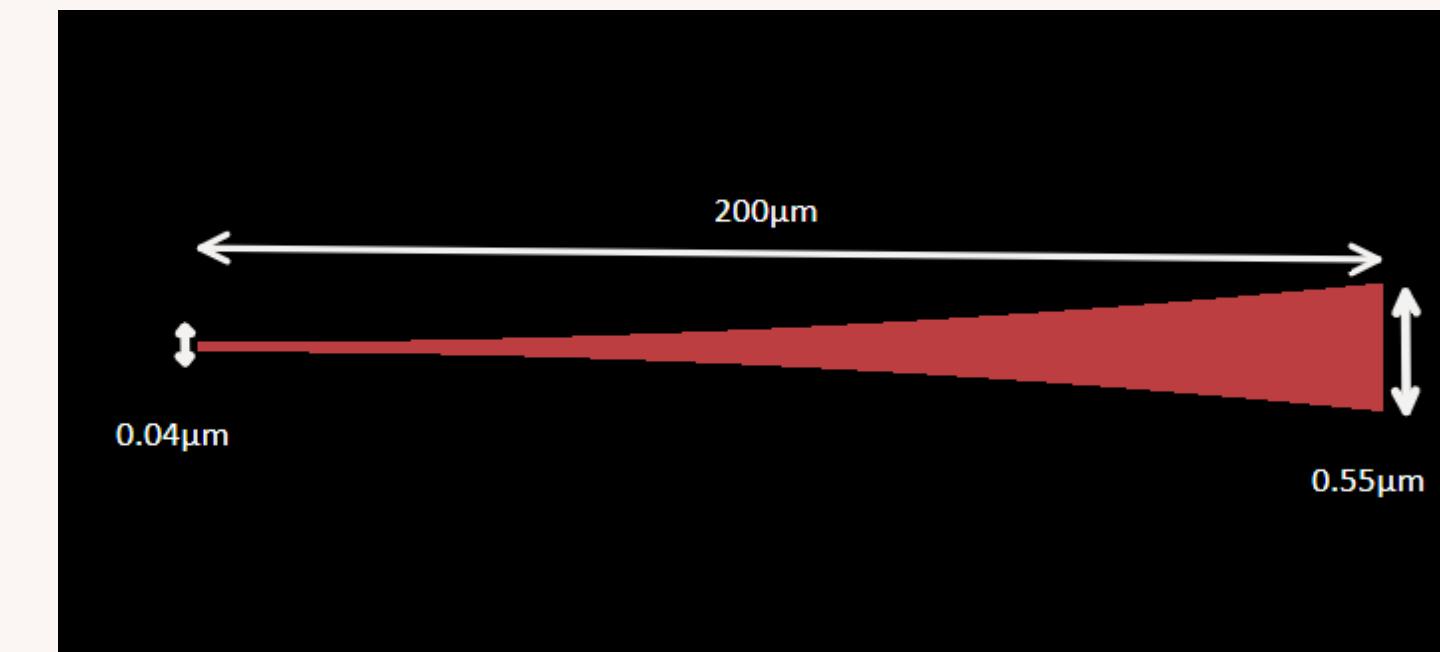
- Generate the taper and start simulations.
- Test the different shapes of the taper.

CORE STRUCTURE

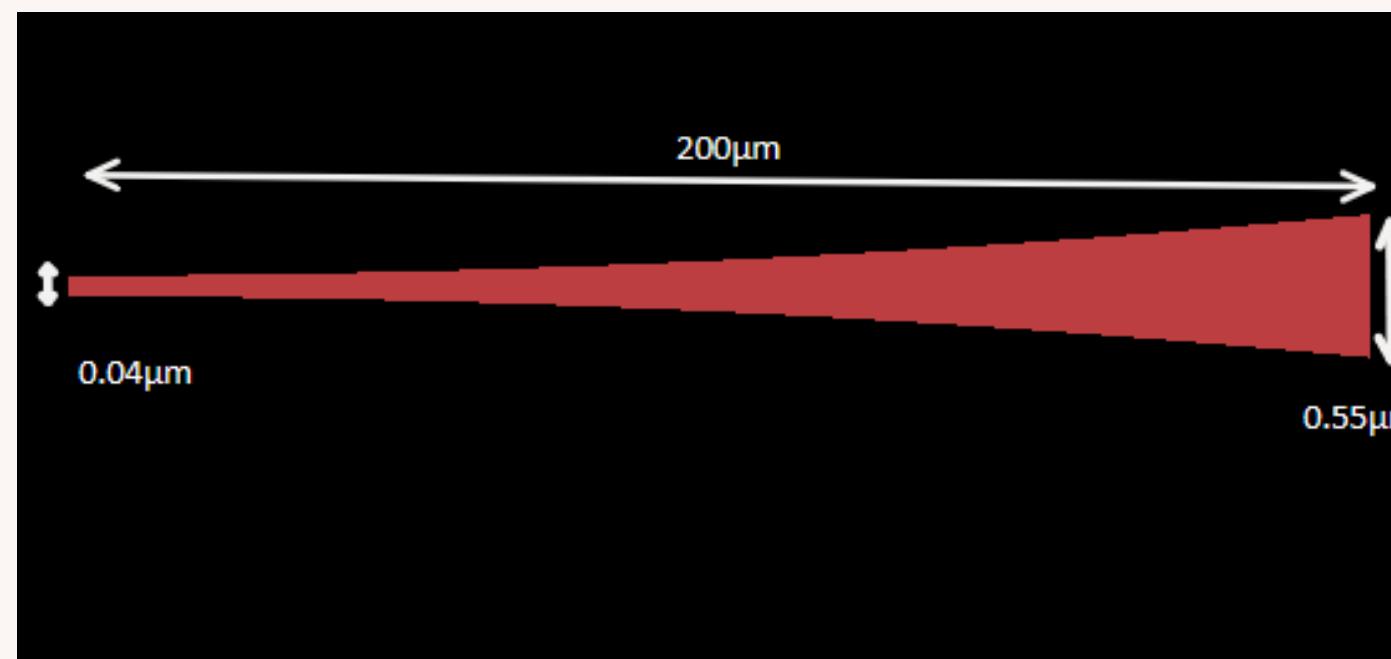
Using 5 μm lenght for an better visualization



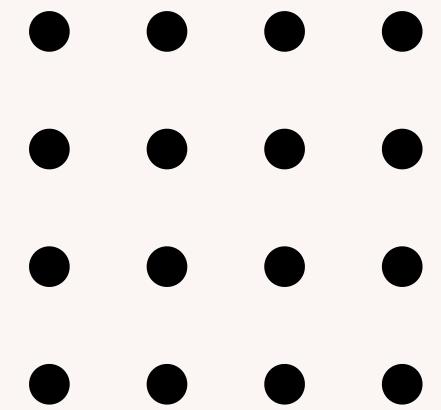
Linear Taper core (XY View)



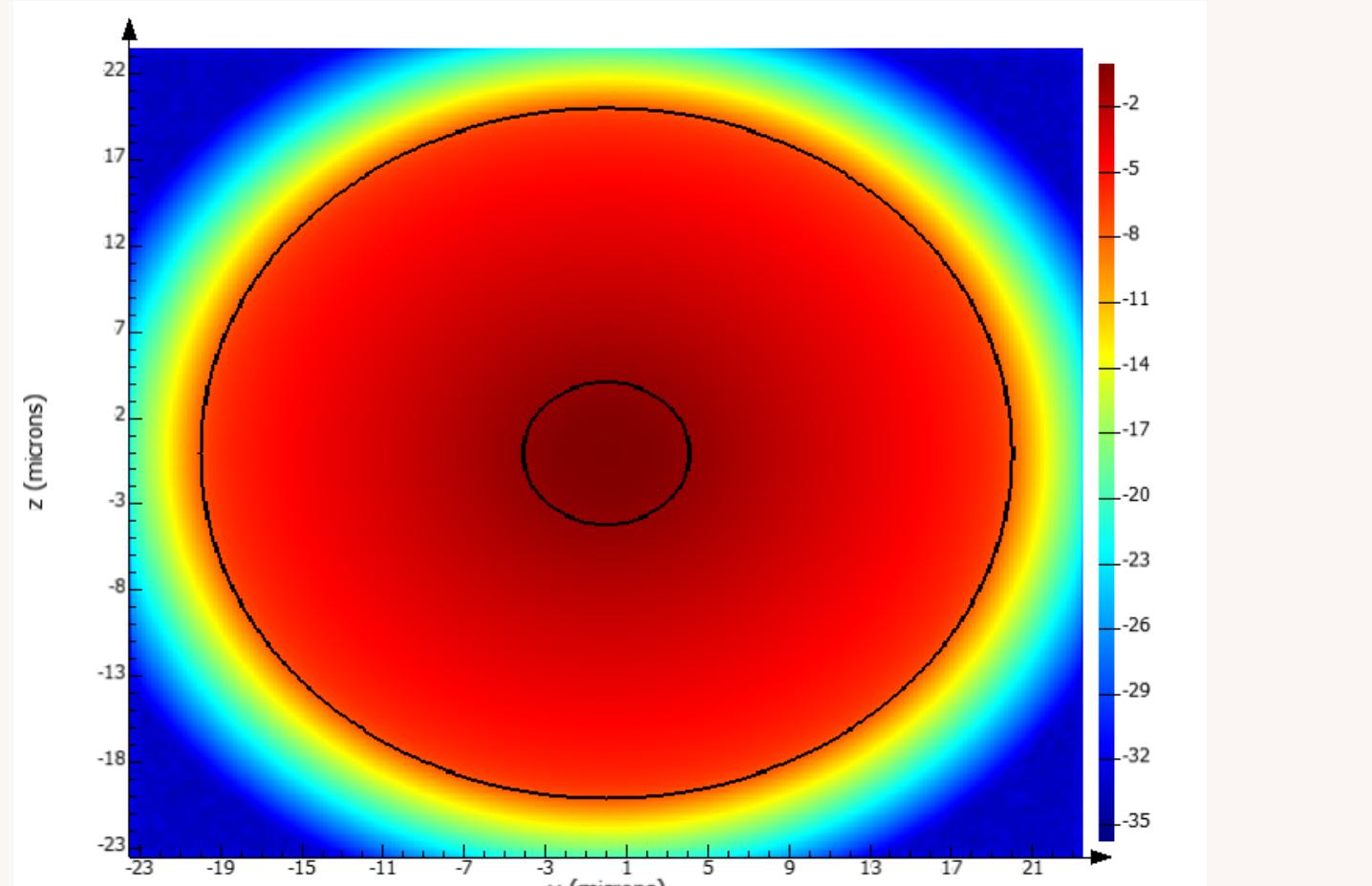
Exponential Taper core (XY View)



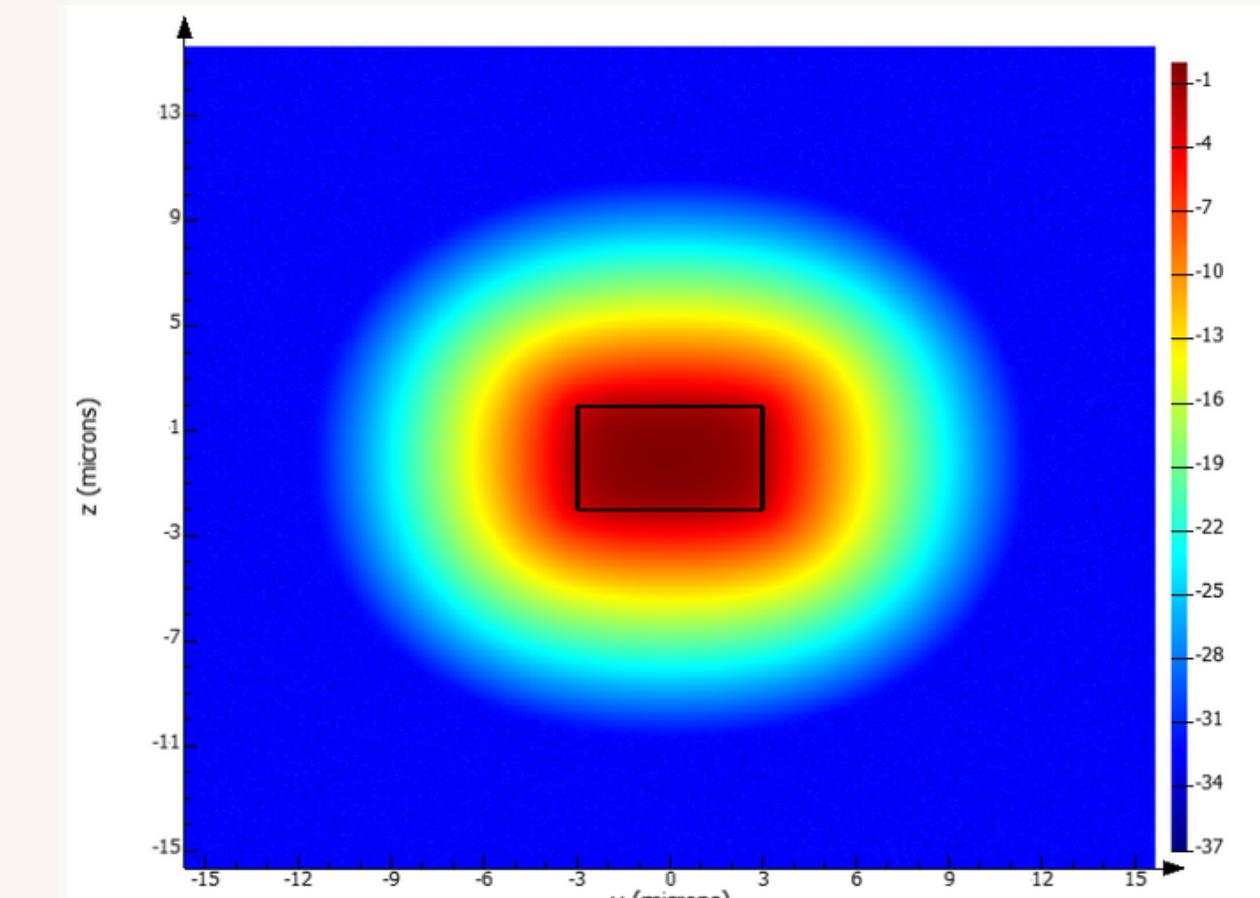
Quadratic Taper core (XY View)



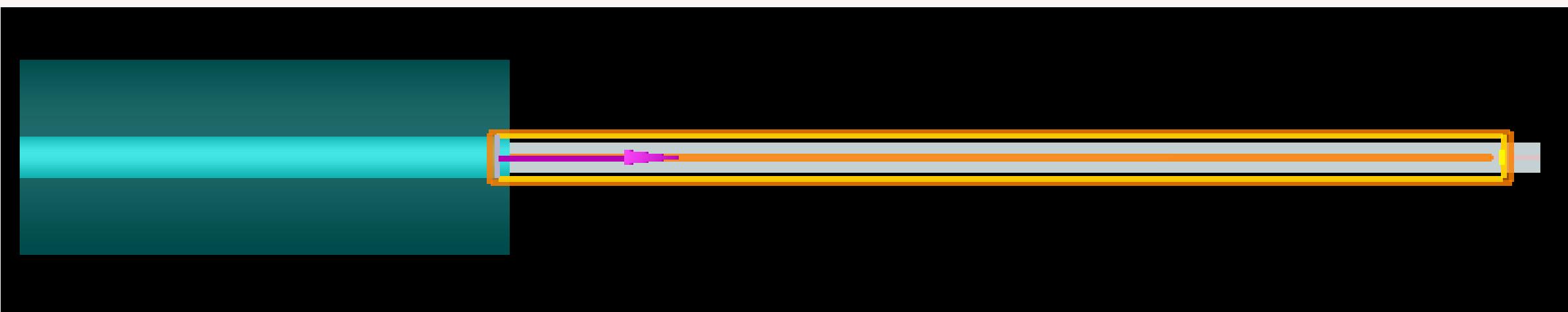
FDTD Guide



Fiber Confinement (Log)

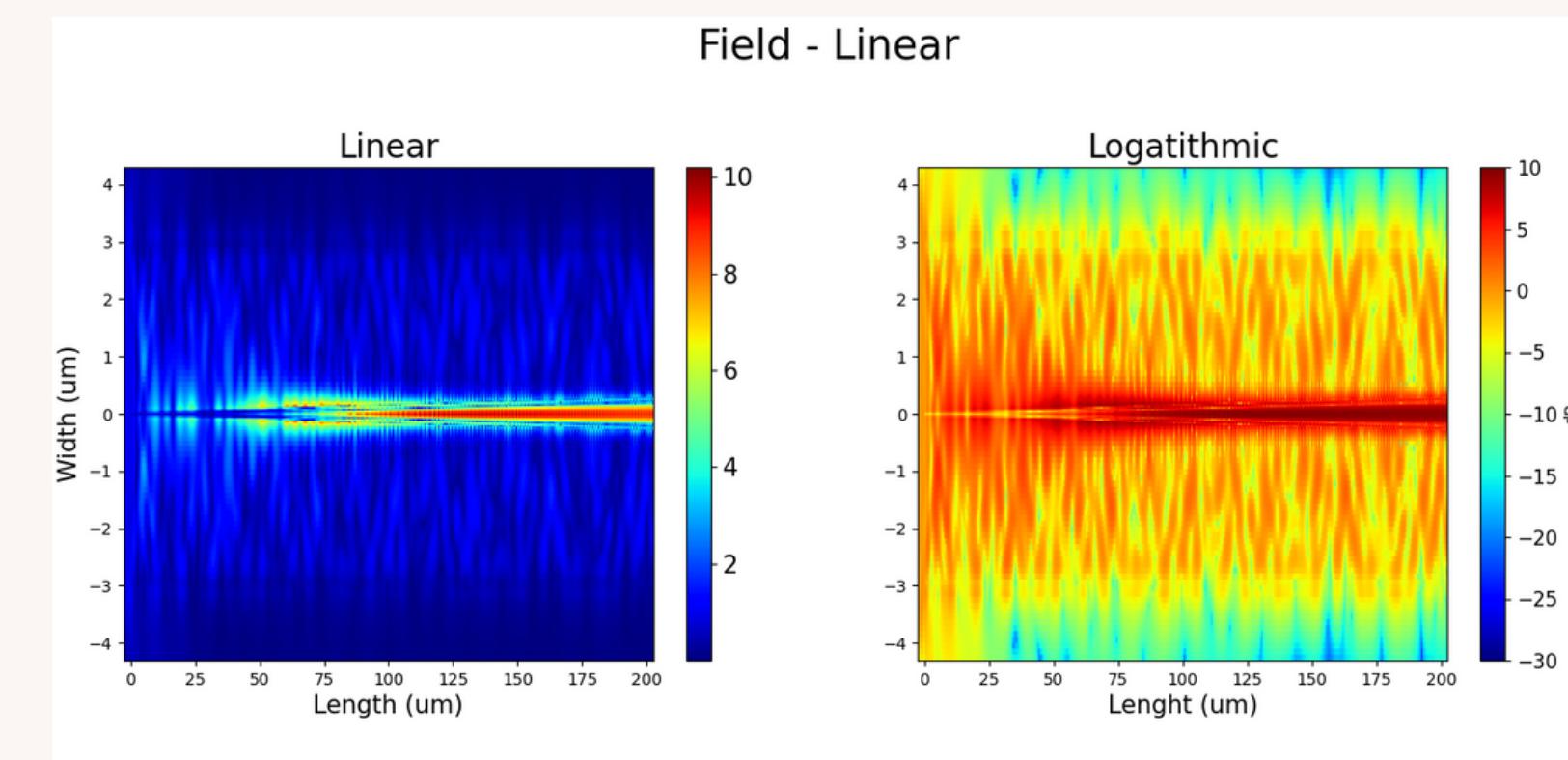


Taper Confinement (Log)



FIELD RESULT

Using FDTD



Mesh accuracy: 2

Monitor frequency points: 200

Simulation time: 5000fs

FDTD dimensions:

y span: 8.5 μ m, z span: 8.5 μ m, x span: 205 μ m

Boundaries: z: Symmetric, x: PML, y: PML

Mode dimensions: z span: 8.5 μ m, y span: 8.5m

Simulation wavelength: 1500nm - 1600nm

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WEEK 2 OBJECTIVES

- Fix the simulation errors obtained on the last week.

FIELD RESULT

Using FDTD

Mesh accuracy: 2

Monitor frequency points: 51

Simulation time: 5000fs

FDTD dimensions:

y span: 8.5 μ m, z span: 8.5 μ m, x span: 205 μ m

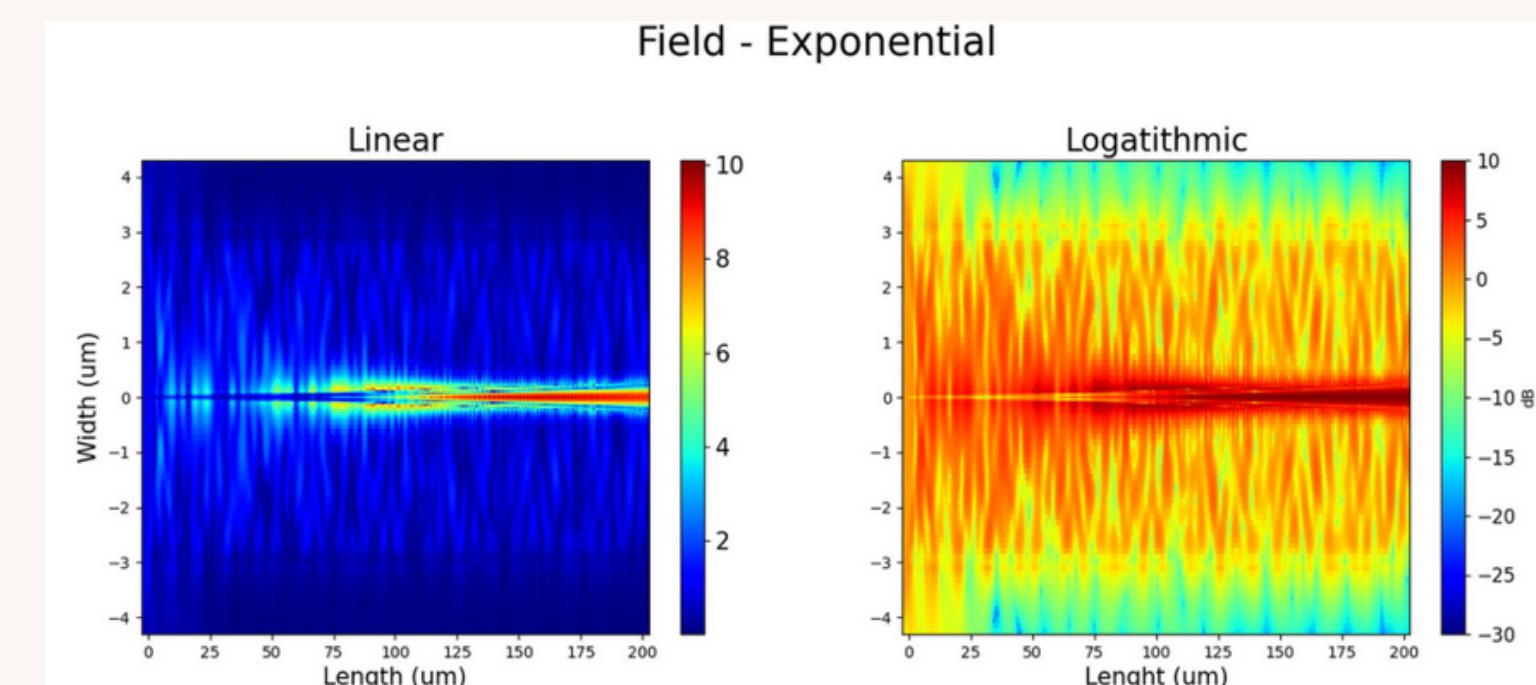
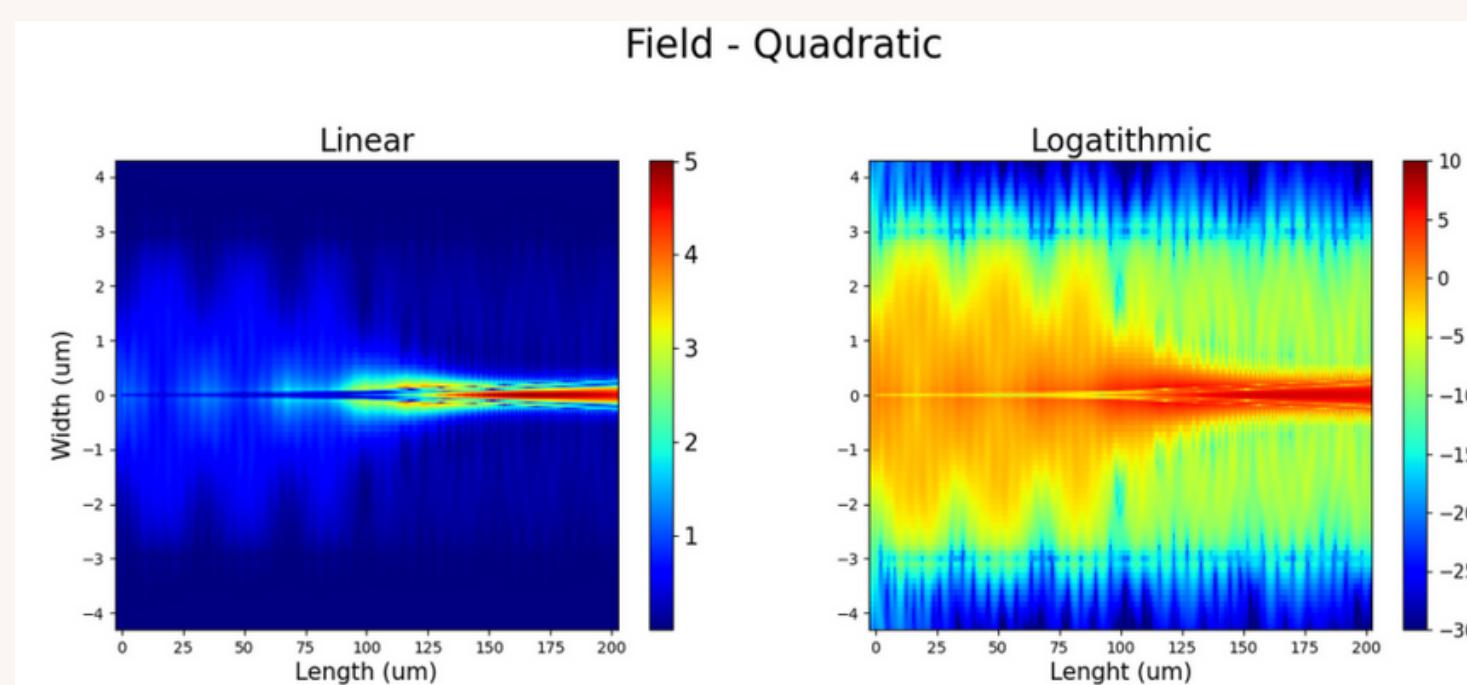
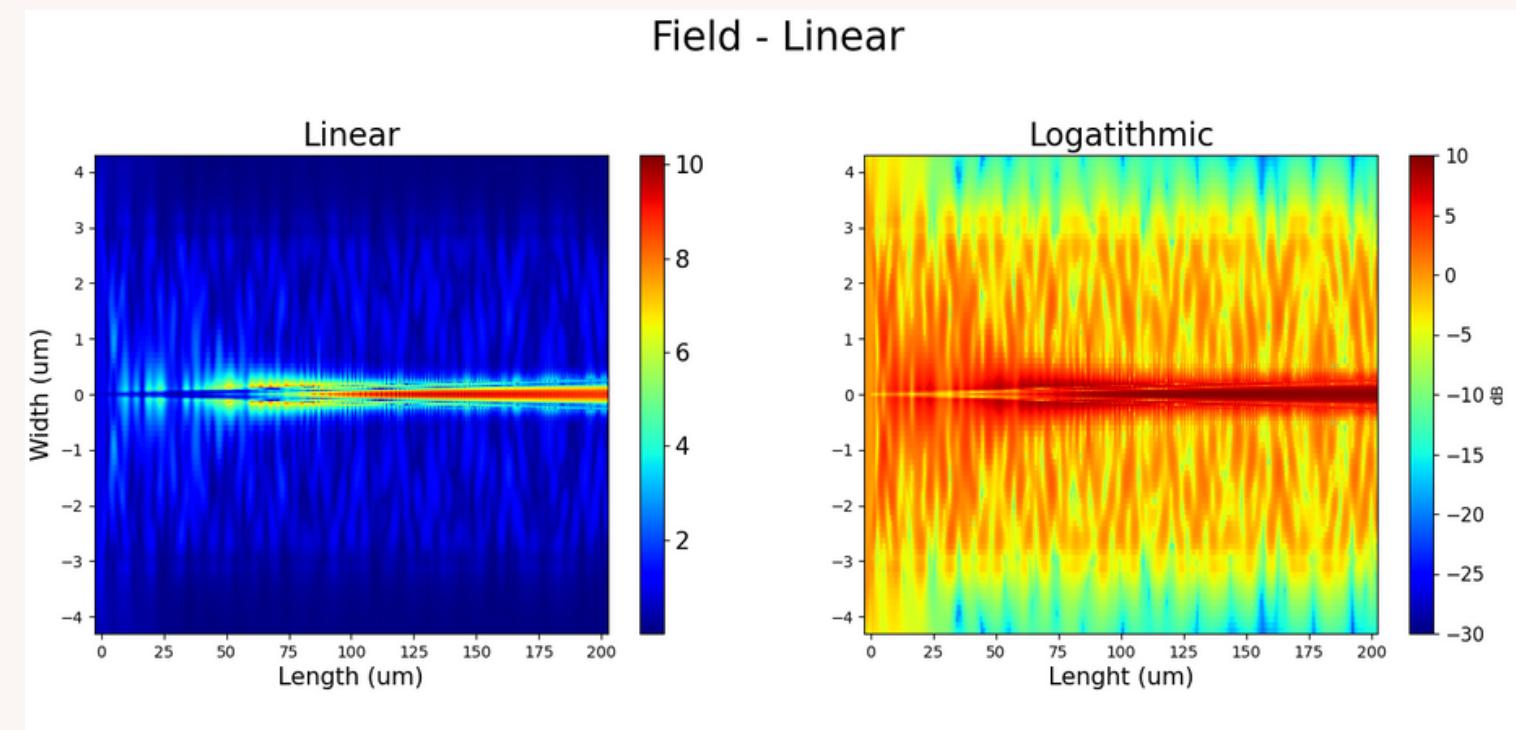
Boundaries: z: Symmetric, x: PML, y: PML

Mode dimensions: z span: 8.5 μ m, y span: 8.5m

Simulation wavelength: 1500nm - 1600nm

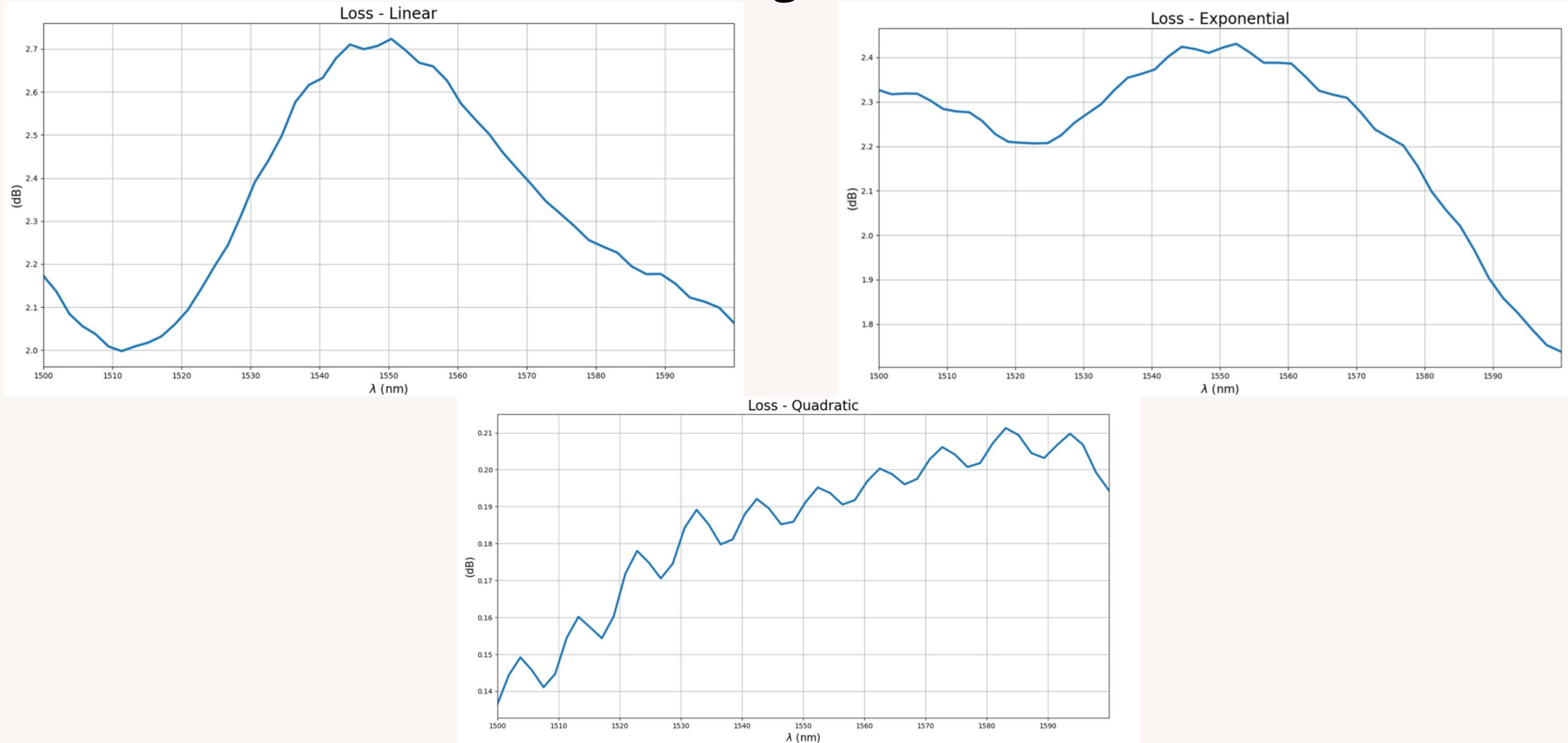
Mesh on the core: equivalent x,y,z index 5

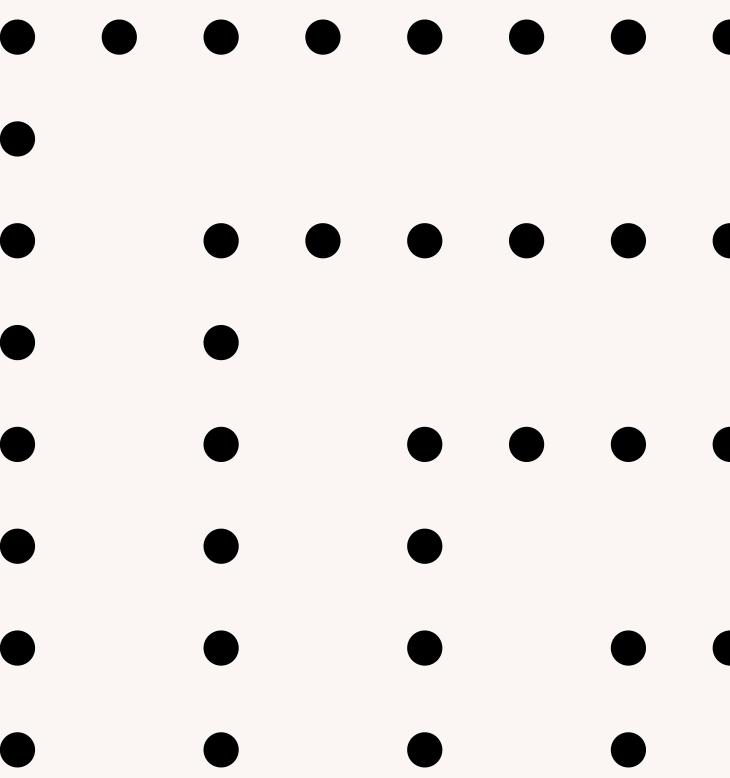
Output monitor dimensions: y span: 3 μ m, zspan: 3 μ m



INSERTION LOSS RESULT

Using FDTD



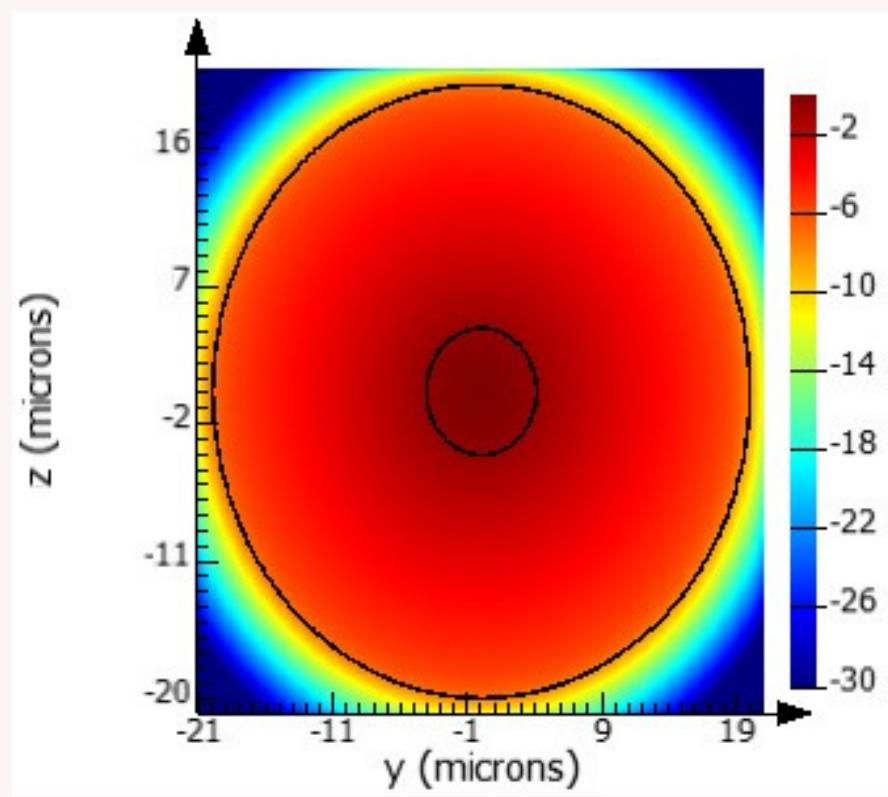


WEEK 3

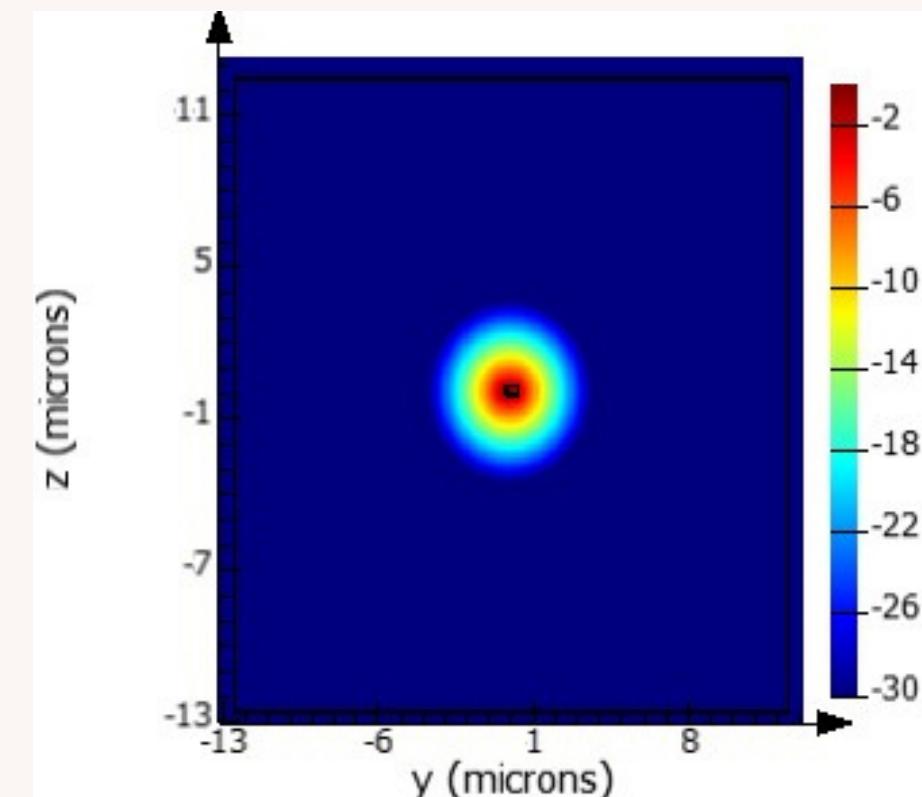
OBJECTIVES

- Use EME simulations to obtain better results.

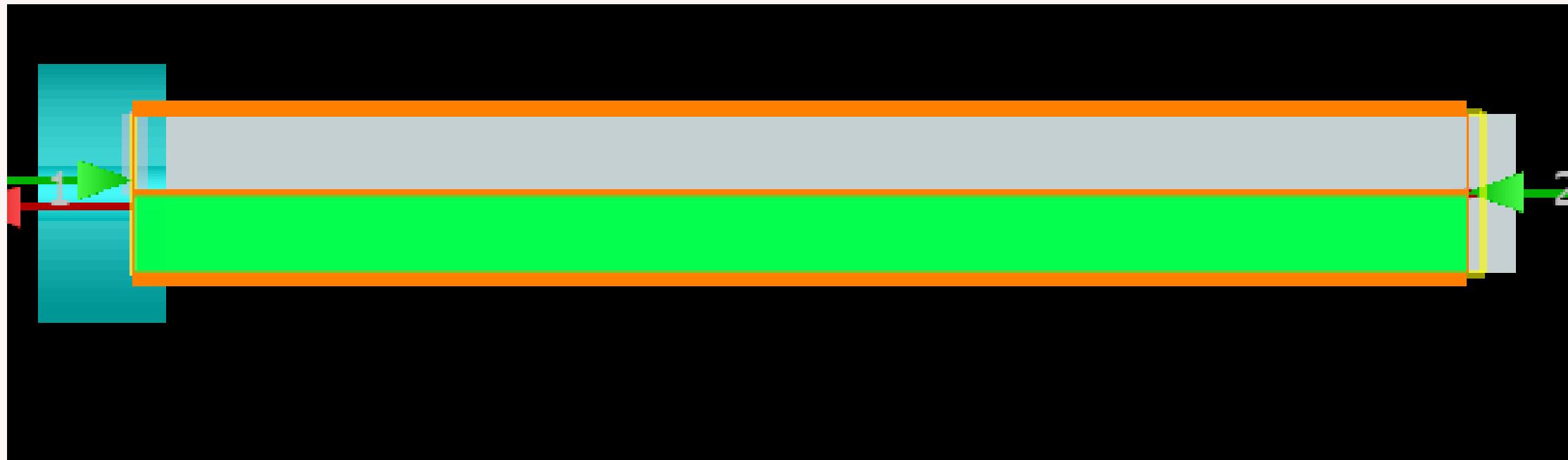
MODE Guide



Fiber Confinement (Log), using FDE

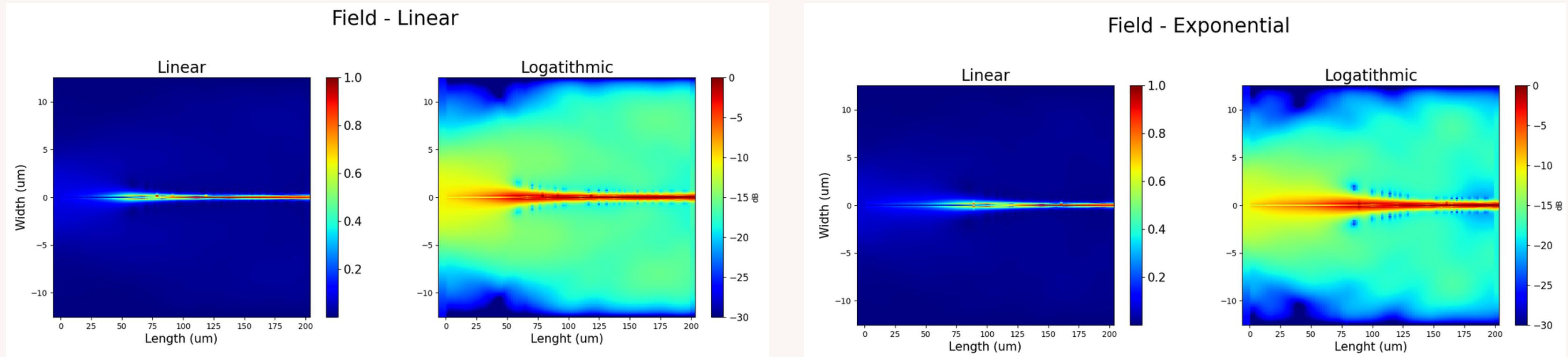


Taper Confinement (Log), using FDE



FIELD RESULT

Using EME



Mesh cells: 250

EME dimensions:

y span: 25 μm, z span: 25 μm, x span: 205 μm

Boundaries: z: Symmetric, y: Anti-symmetric

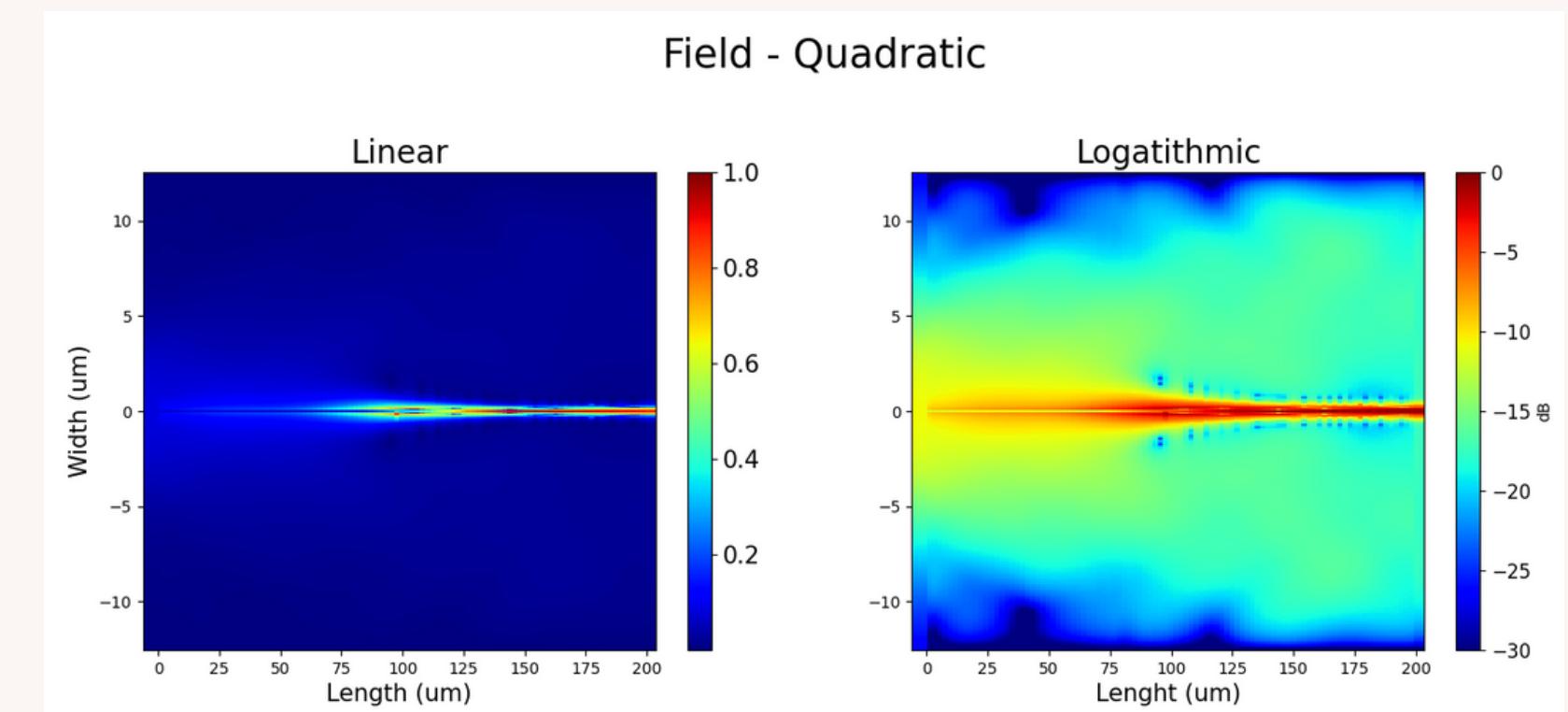
Output: z span: 5 μm, y span: 2 μm

Simulation wavelength: 1550nm

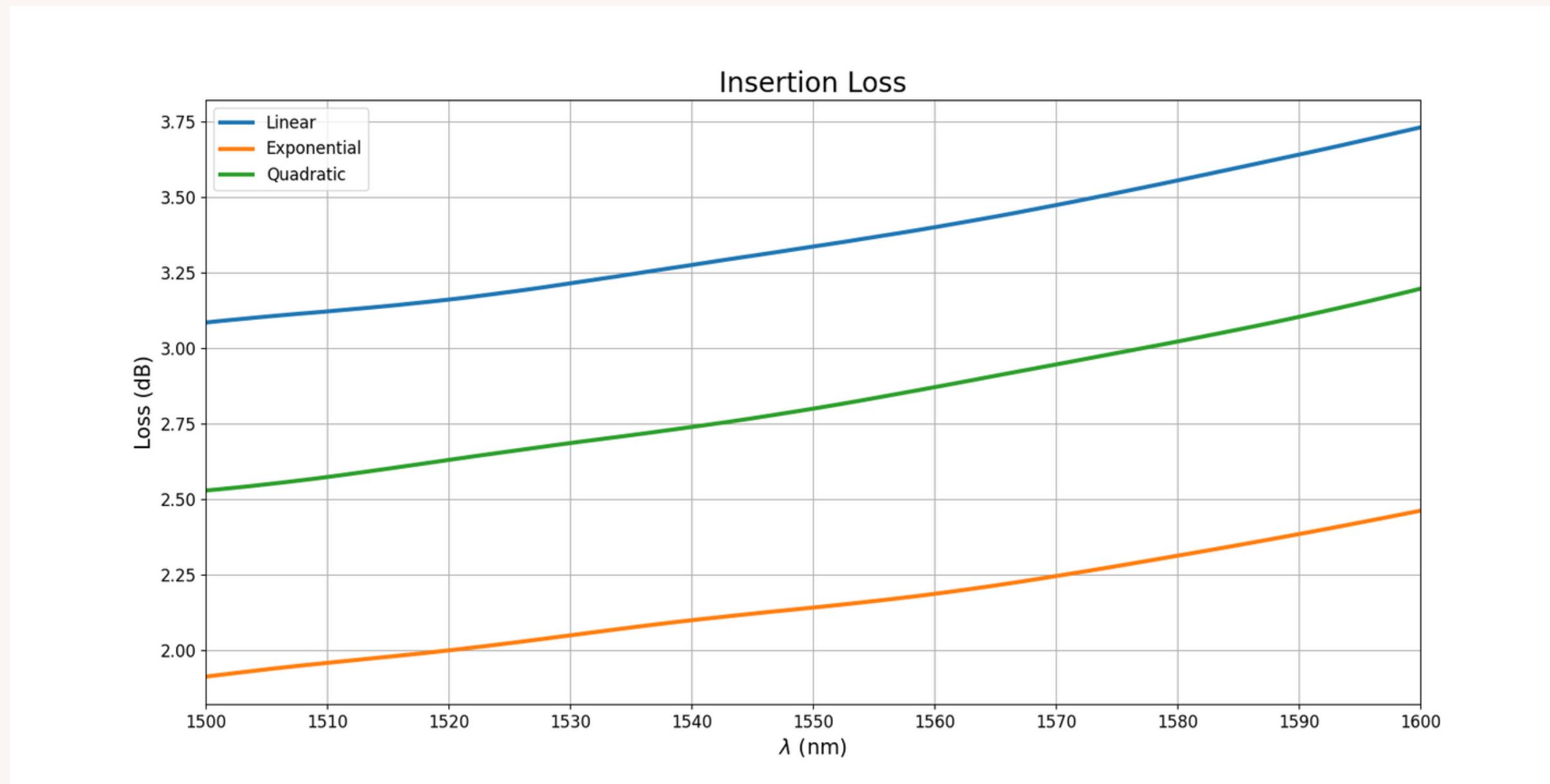
Cells: [1, 60, 1]

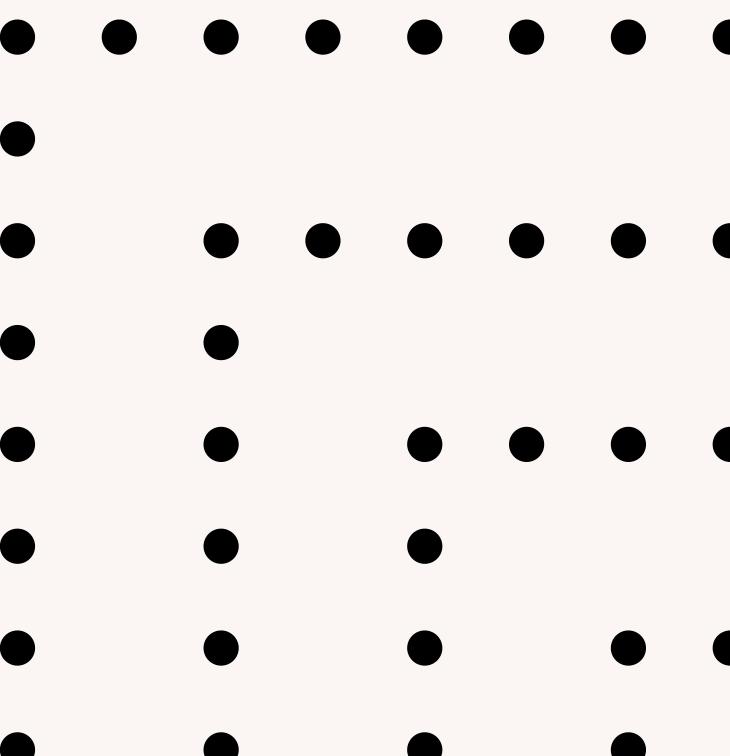
Modes: [5, 45, 5]

Mesh multiplier: y: 3, z: 1.5



Sweep Results



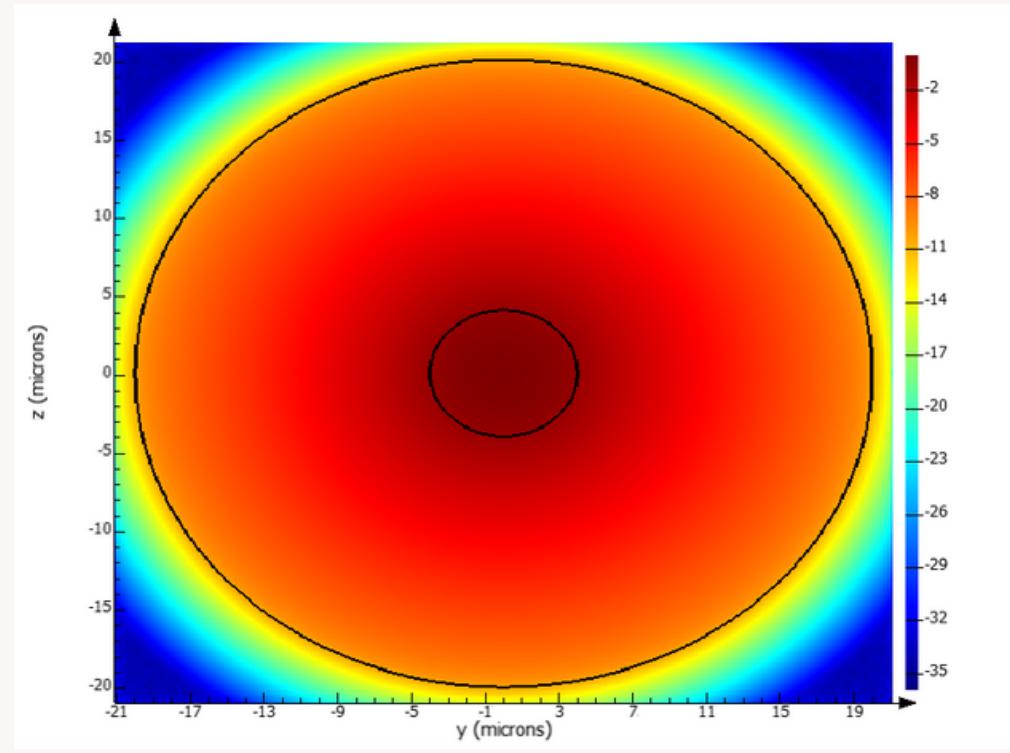


WEEK 4

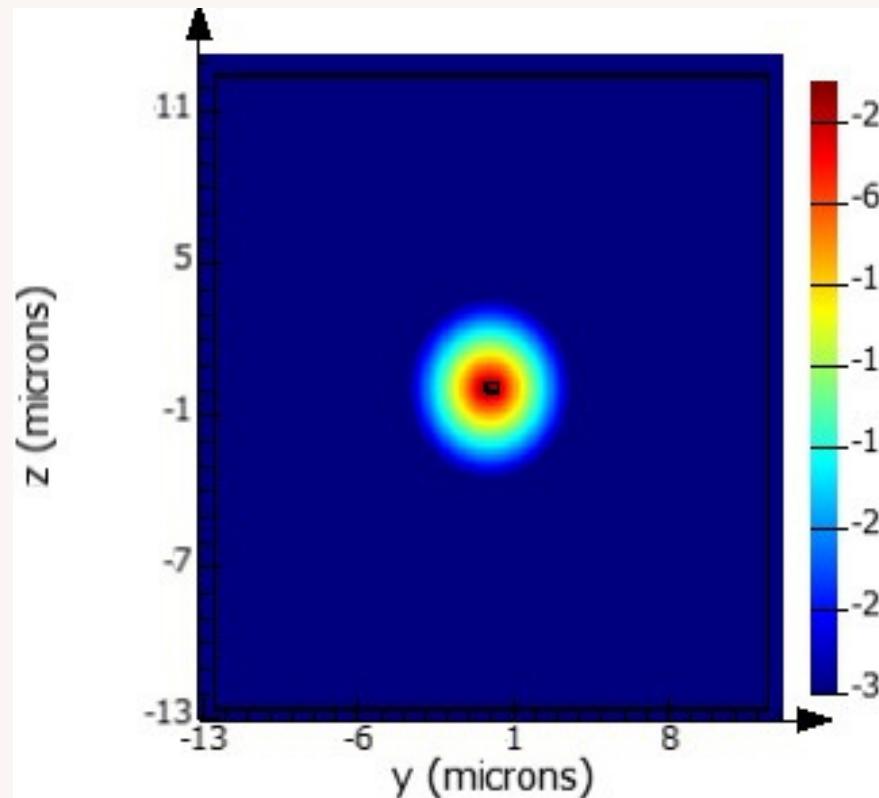
OBJECTIVES

- Use the article fiber and geometry to compare the results

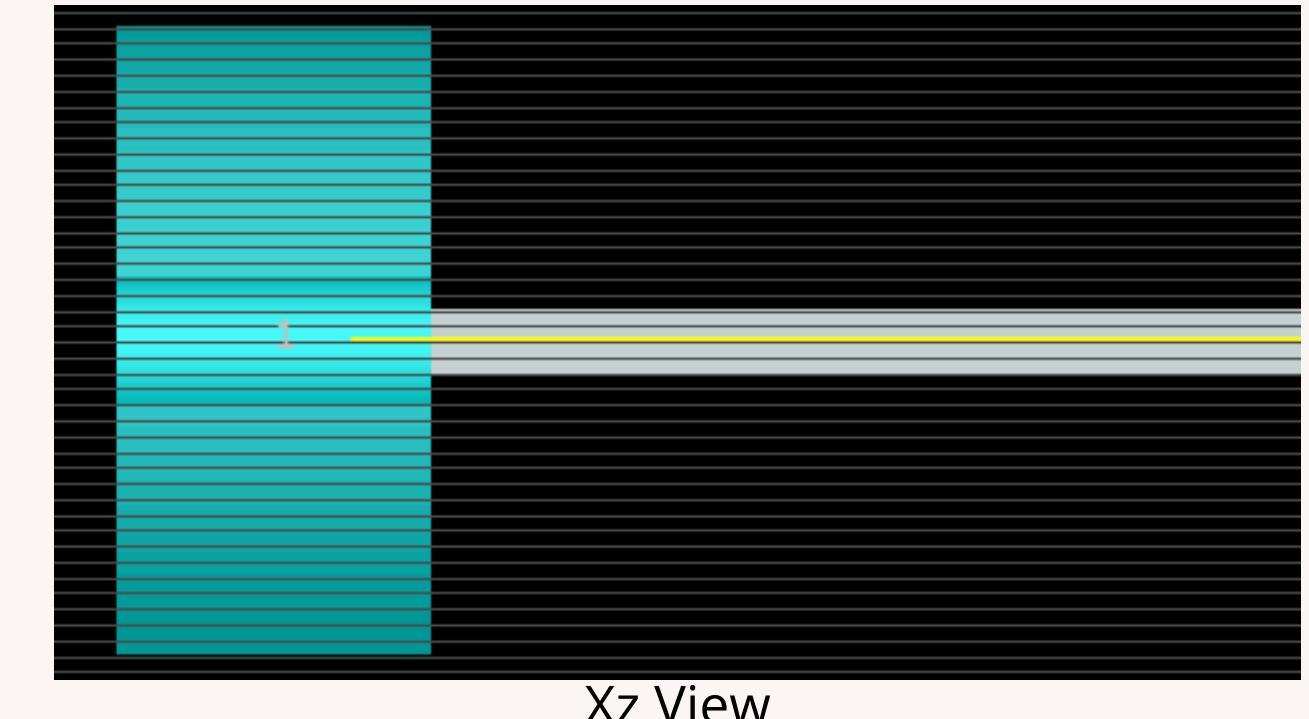
MODE Guide



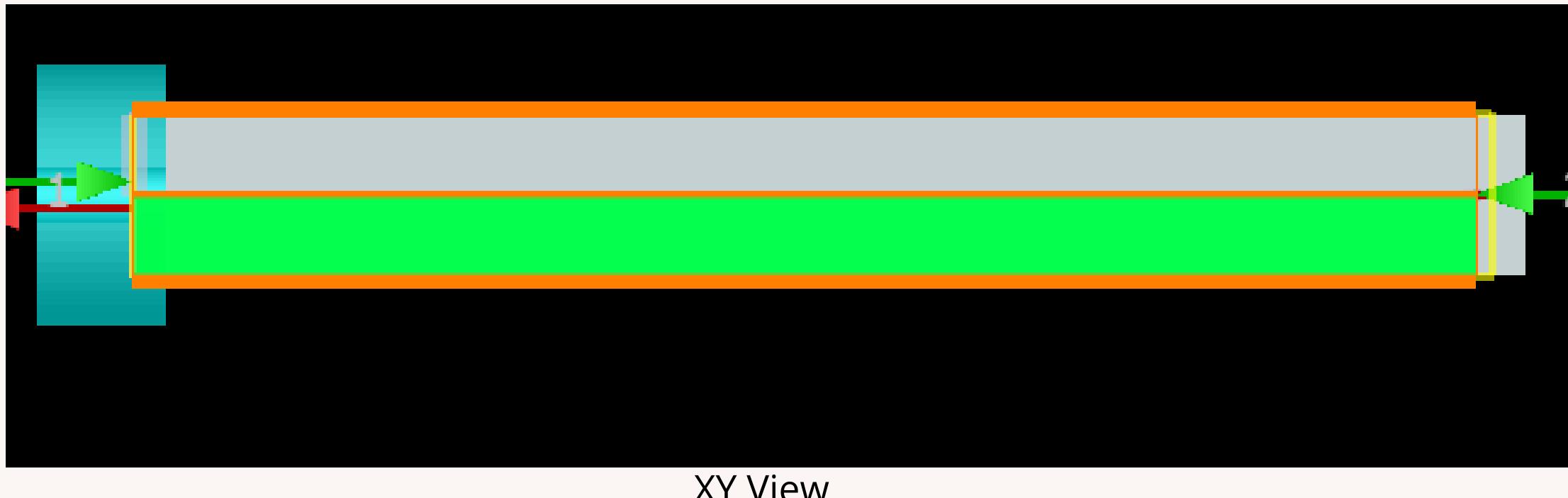
Fiber Confinement (Log), using FDE



Taper Confinement (Log), using FDE



Xz View

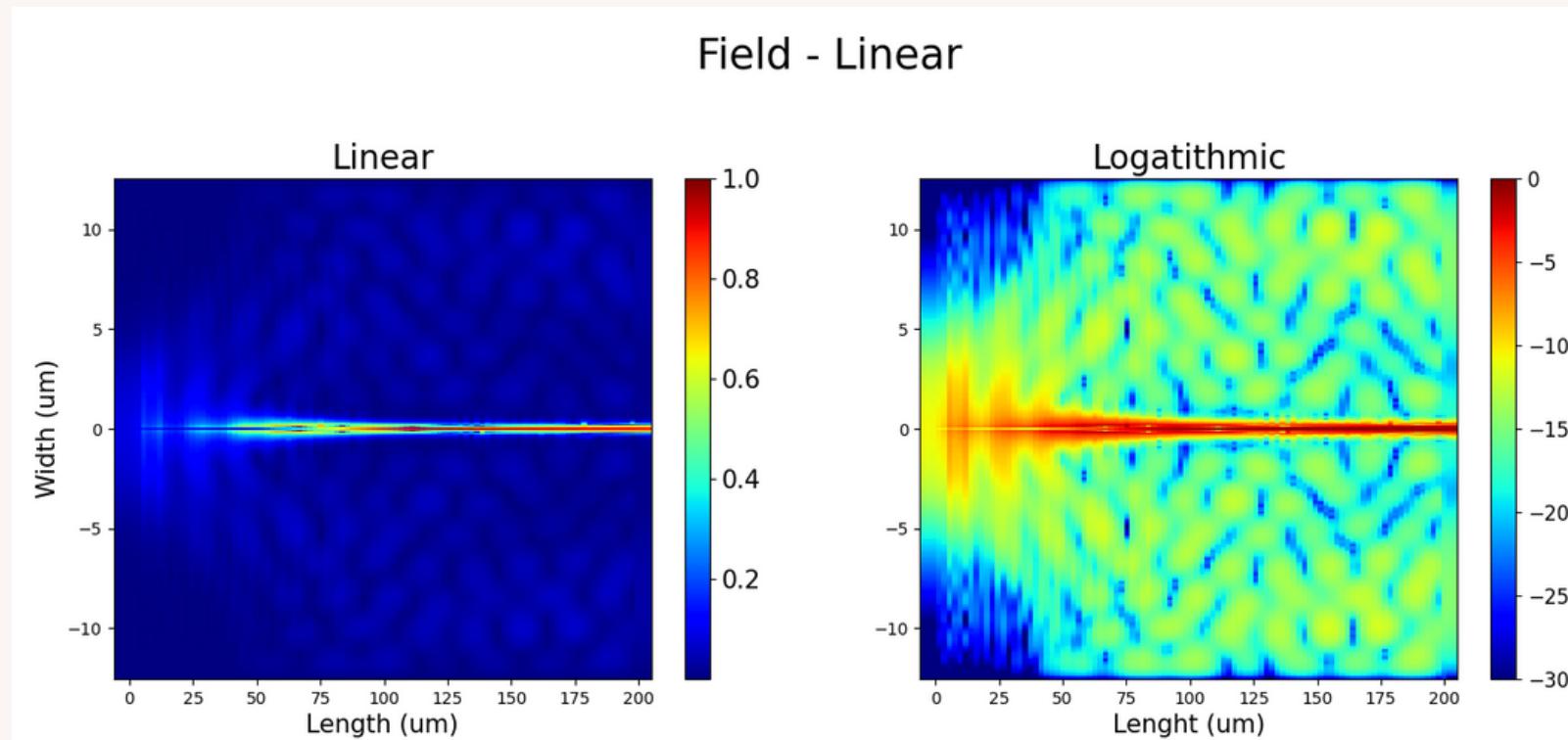


XY View

Fiber Index
1.47 - Core
1.46 - Substract

FIELD RESULT

Using EME



Mesh cells: 250

EME dimensions:

y span: 25 μm , z span: 25 μm , x span: 209 μm

Boundaries: z: Symmetric, y: Anti-symmetric

Output: z span: 5 μm , y span: 2 μm

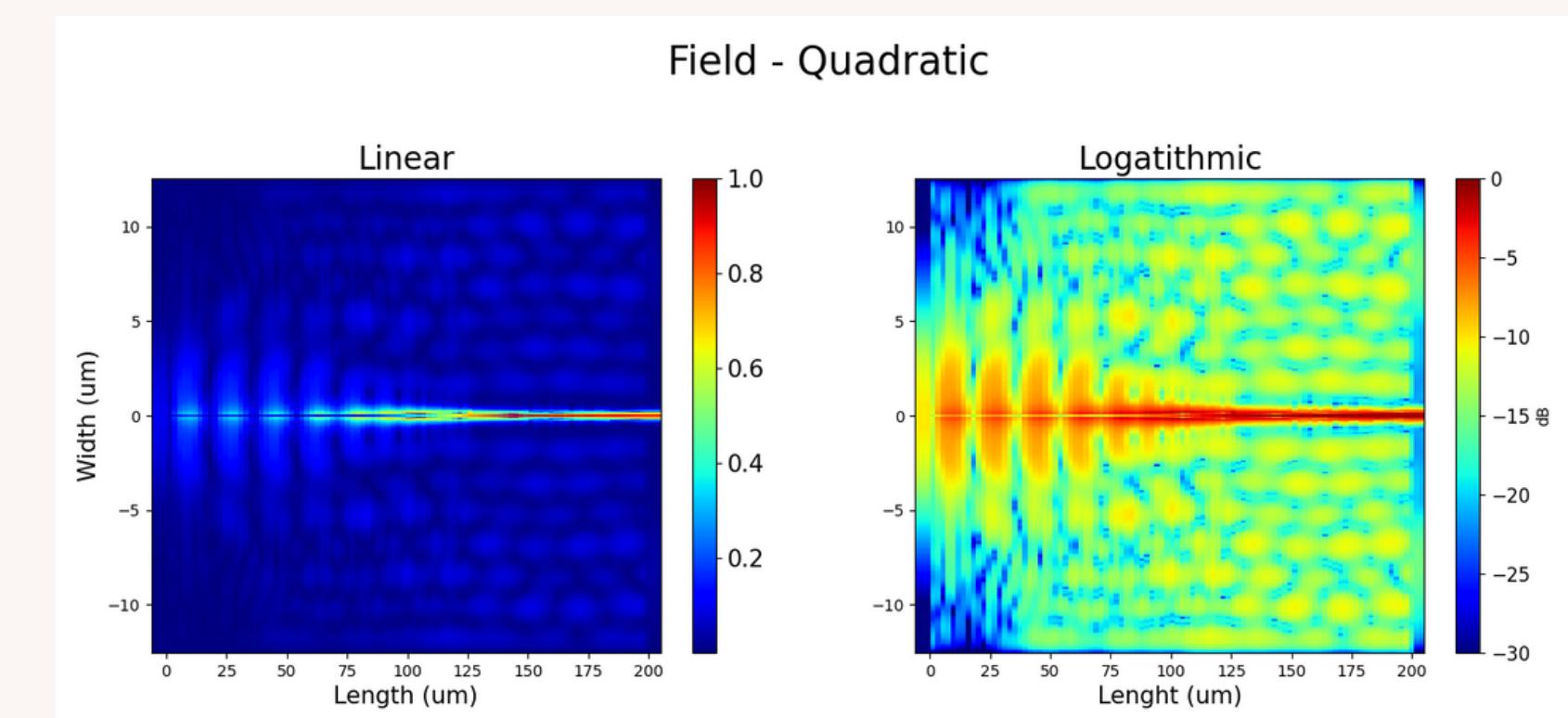
Simulation wavelength: 1550nm

Cells: [1, 80, 1]

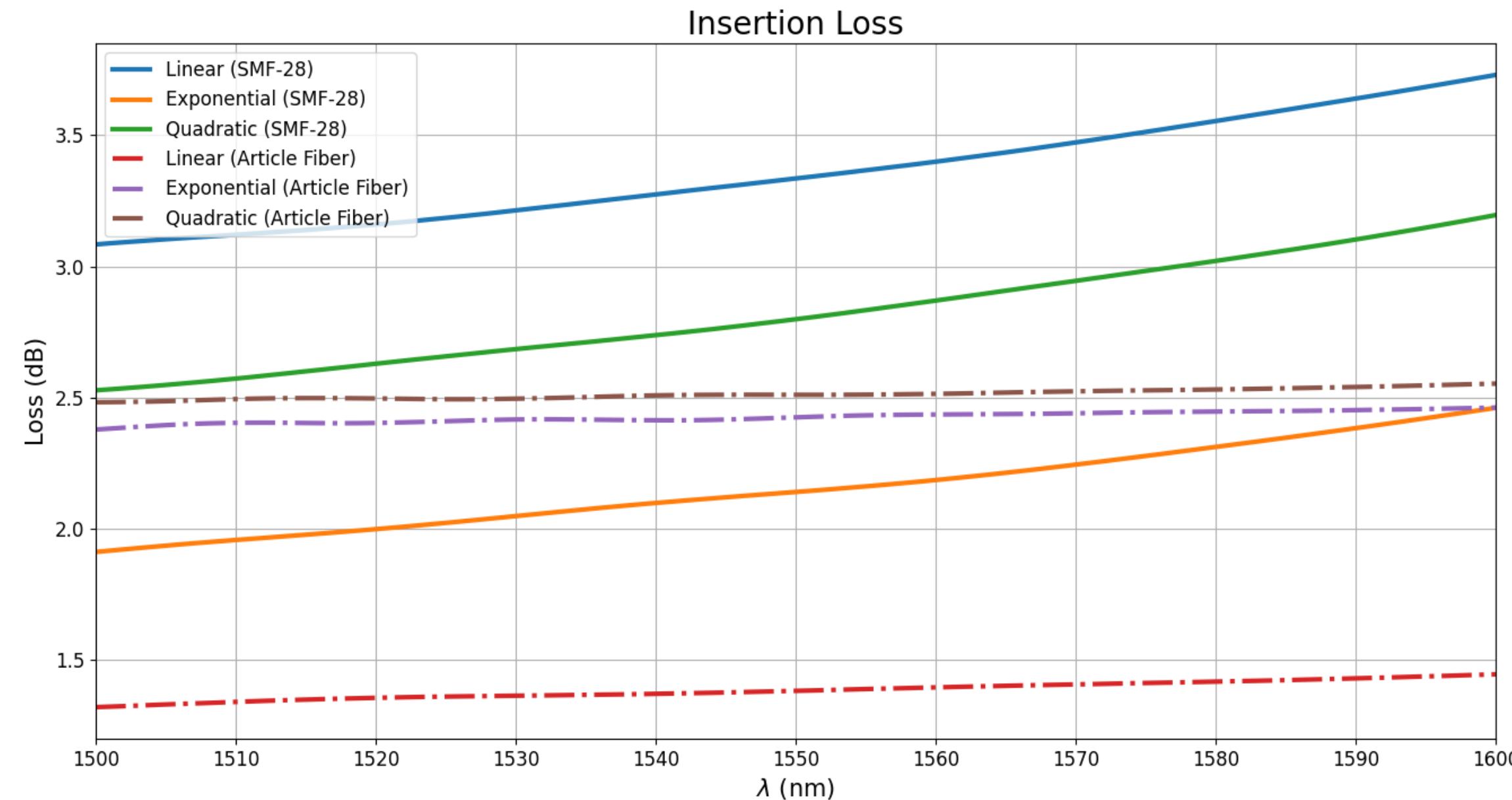
Modes: [4, 32, 4]

Mesh multiplier: y: 3, z: 1.5

High order mesh: dx: 3nm, dy: 3nm, dz: 6nm



Sweep Results



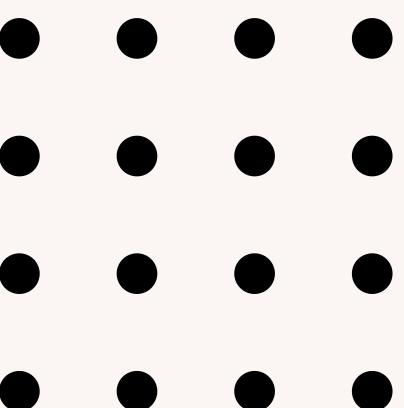
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WEEK 5 OBJECTIVES

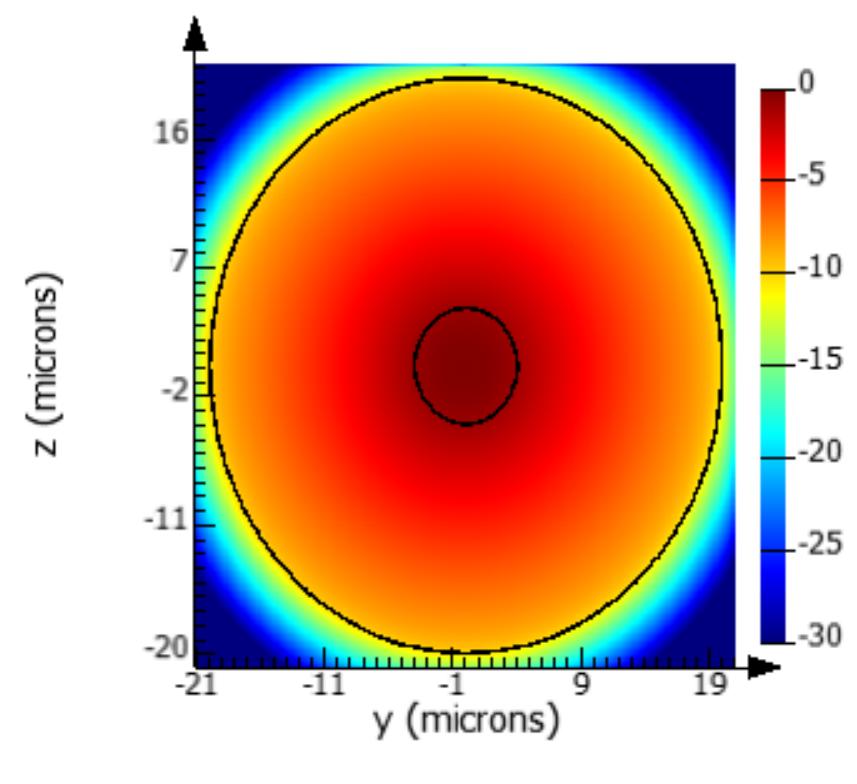
- Recreate the taper loss x wavelength graphic on MODE.

SIMULATION CHANGES

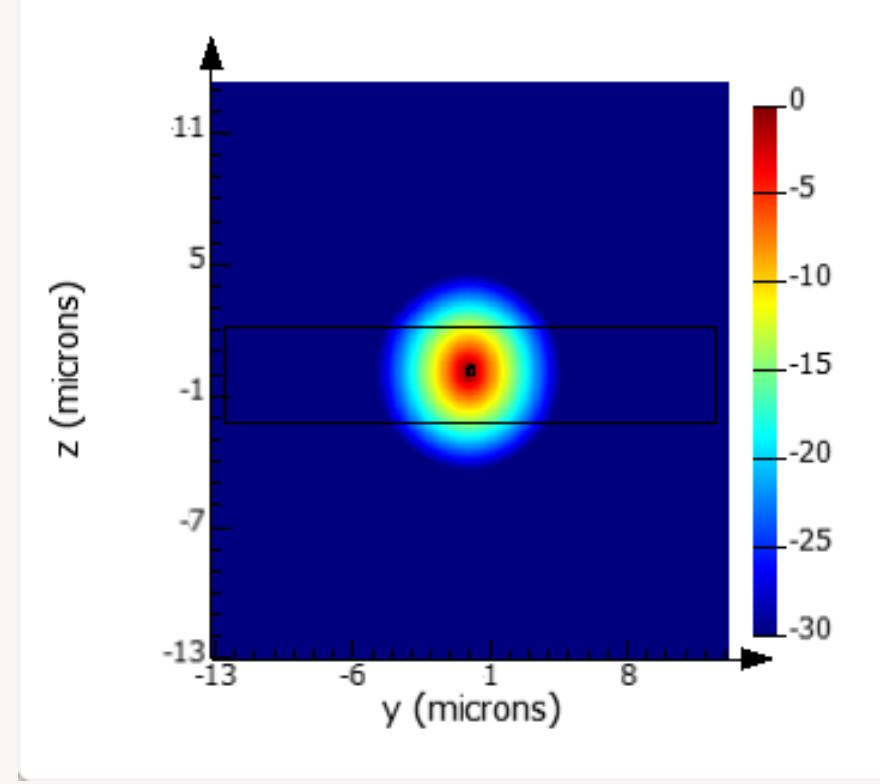
- Increase the mesh on lower width regions (0-50 μ m).
- Test mode convergences and the number of cells needed.



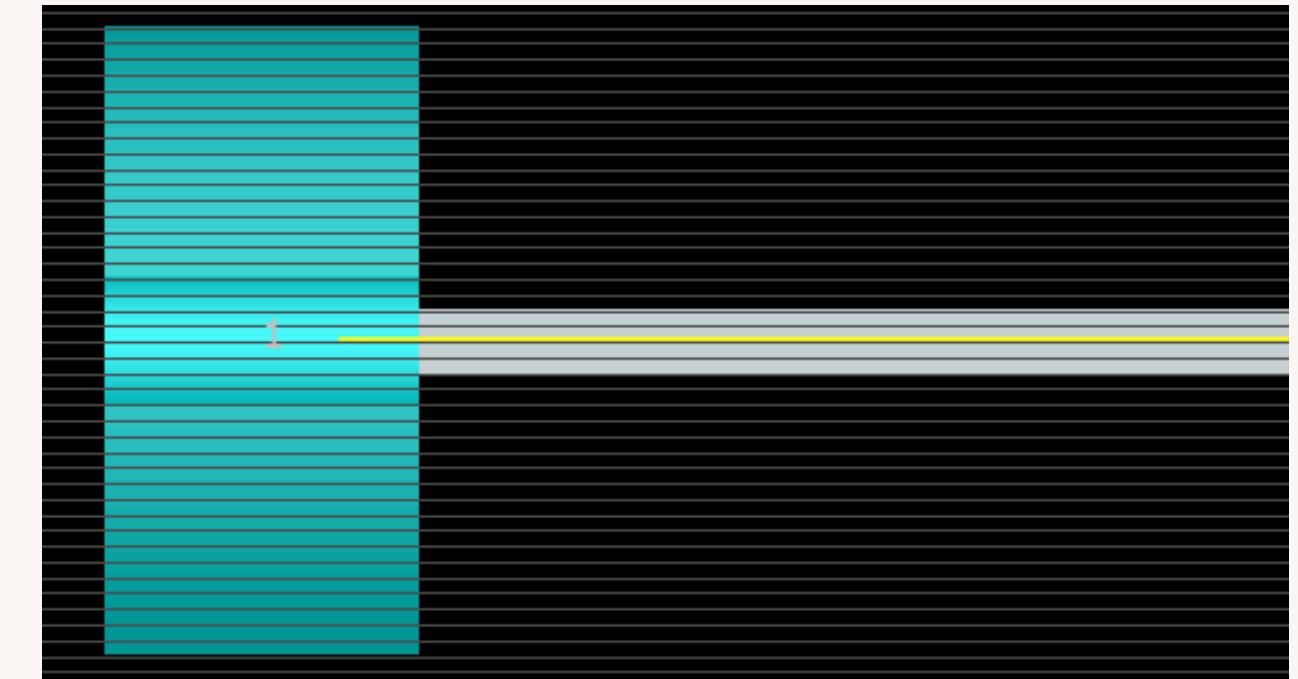
MODE Guide



Fiber Confinement (Log), using FDE



Taper Confinement (Log), using FDE



Xz View

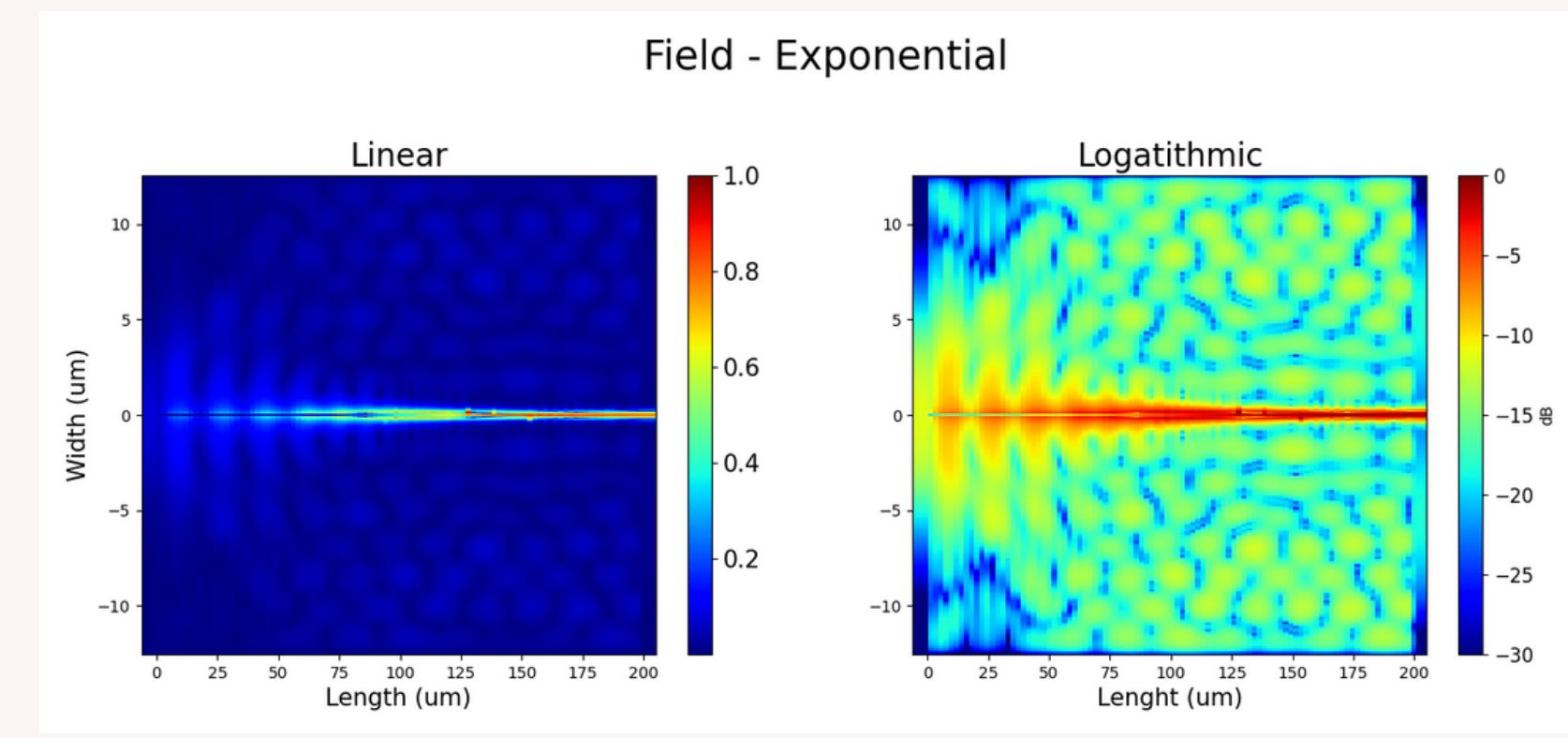
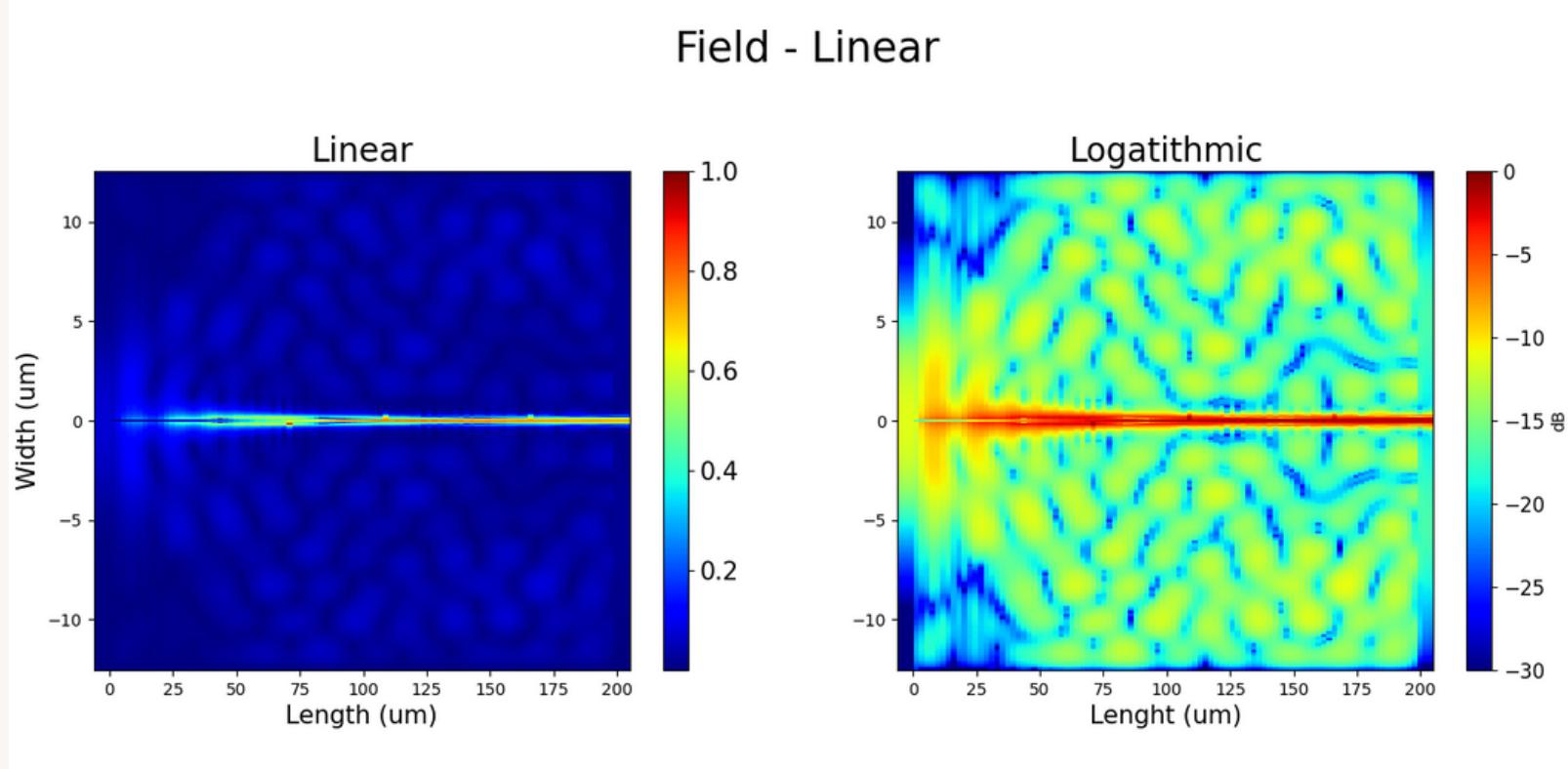


XY View

Fiber Index
1.47 - Core
1.46 - Substrat

FIELD RESULTS

Using EME



Mesh cells: 250

EME dimensions:

y span: 25μm, z span: 25μm, x span: 209μm

Boundaries: z: Symmetric, y: Anti-symmetric

Output: z span: 5μm, y span: 2μm

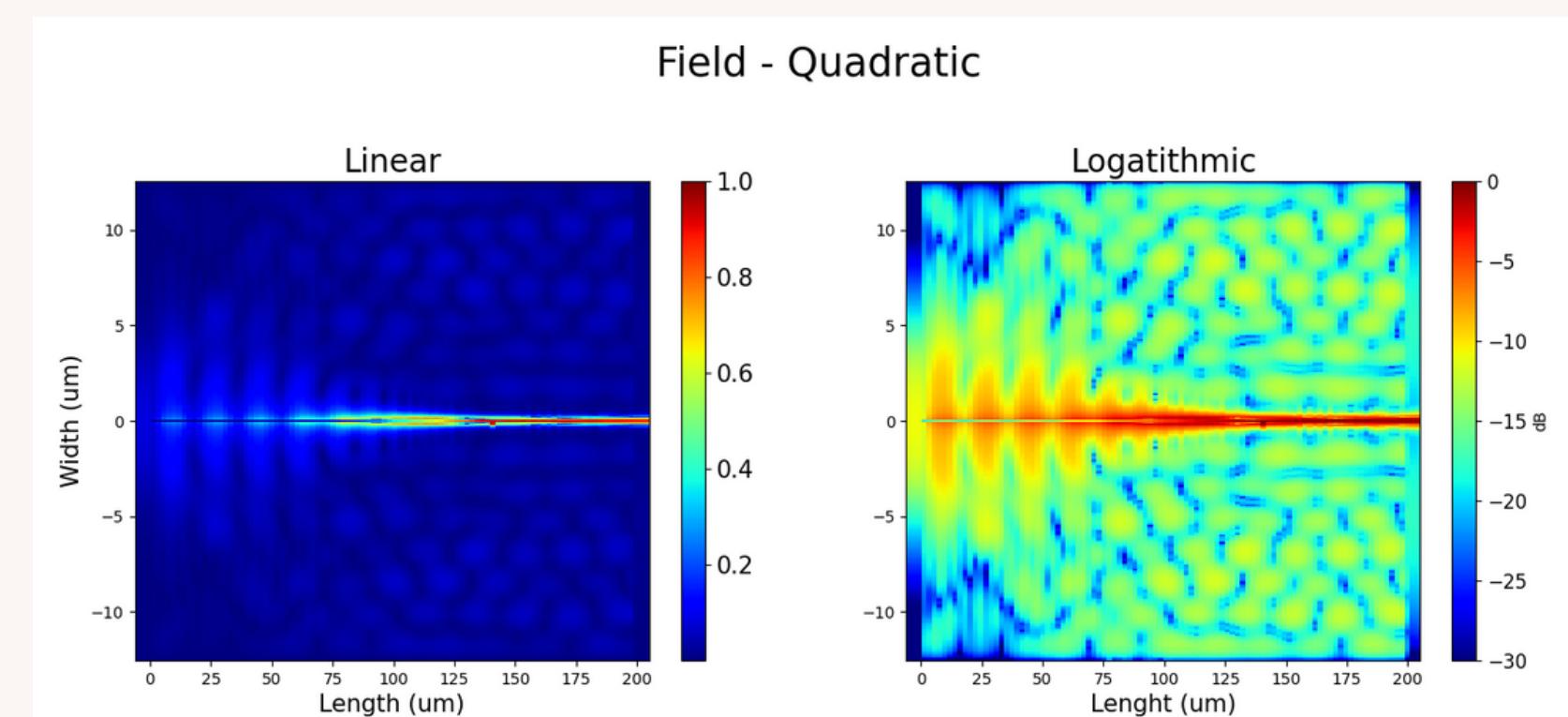
Simulation wavelength: 1550nm

Cells: [1, 80, 1]

Modes: [4, 32, 4]

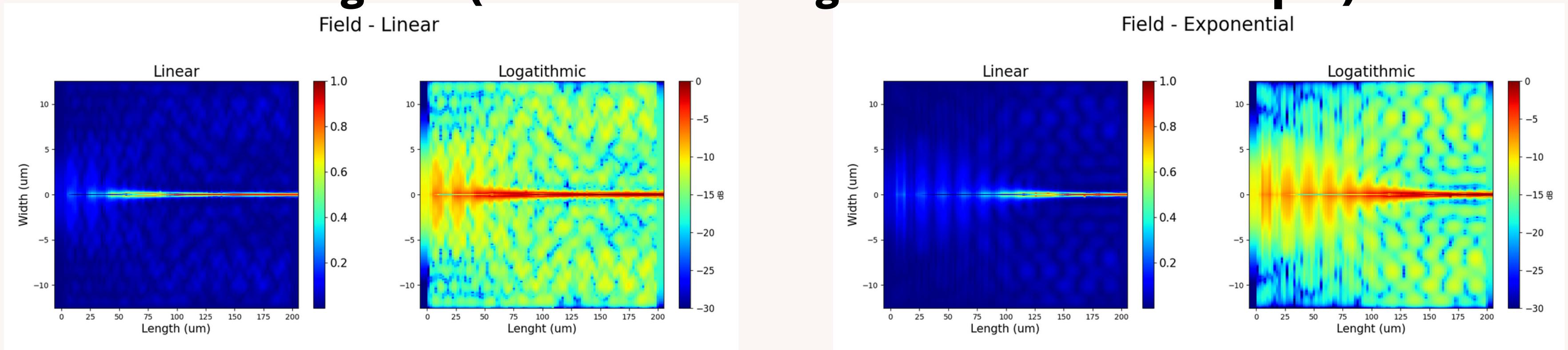
Mesh multiplier: y: 3, z: 1.5

High order mesh: dx: 3nm, dy: 3nm, dz: 6nm



FIELD RESULT TM

Using EME (The same settings used on TE mode taper)



Mesh cells: 250

EME dimensions:

y span: 25 μ m, z span: 25 μ m, x span: 209 μ m

Boundaries: z: Symmetric, y: Anti-symmetric

Output: z span: 5 μ m, y span: 2 μ m

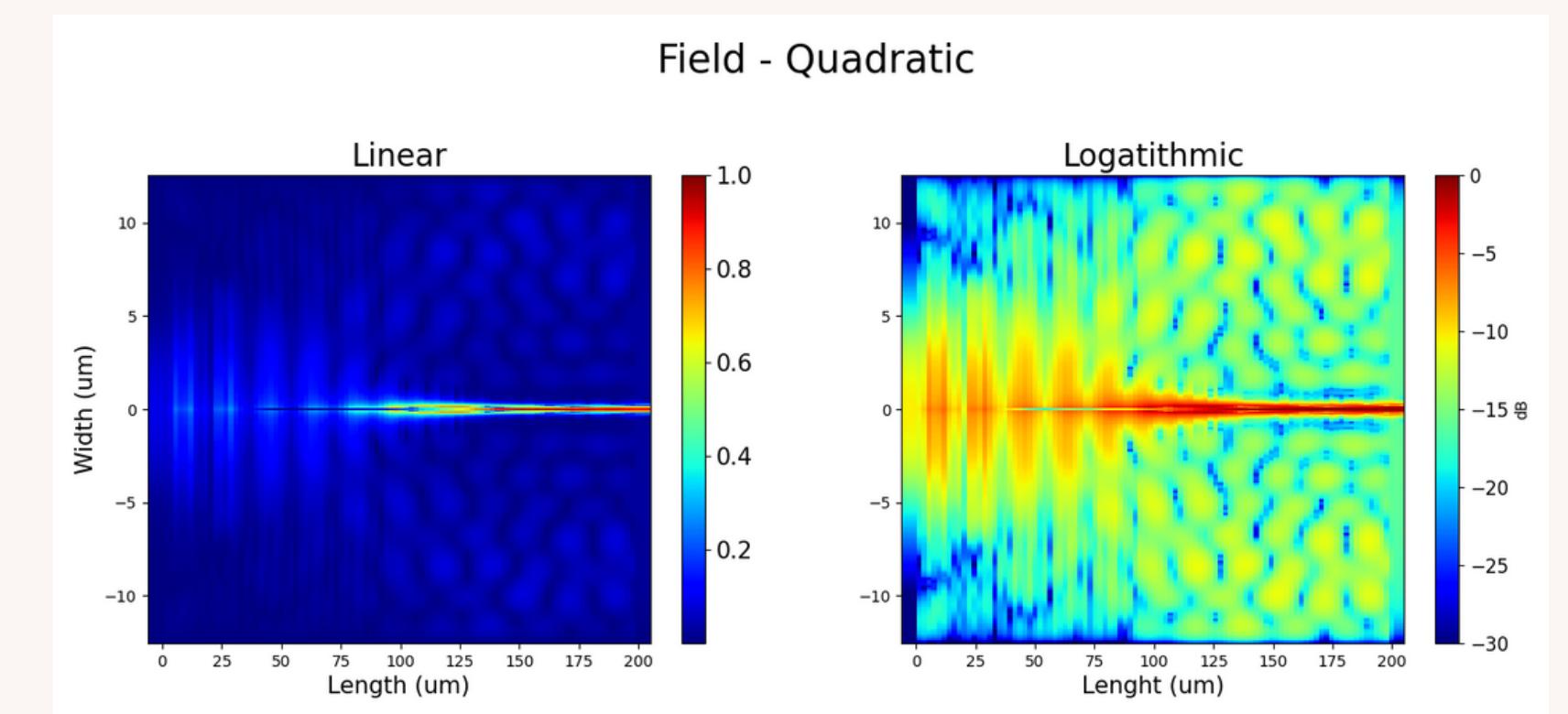
Simulation wavelength: 1550nm

Cells: [1, 80, 1]

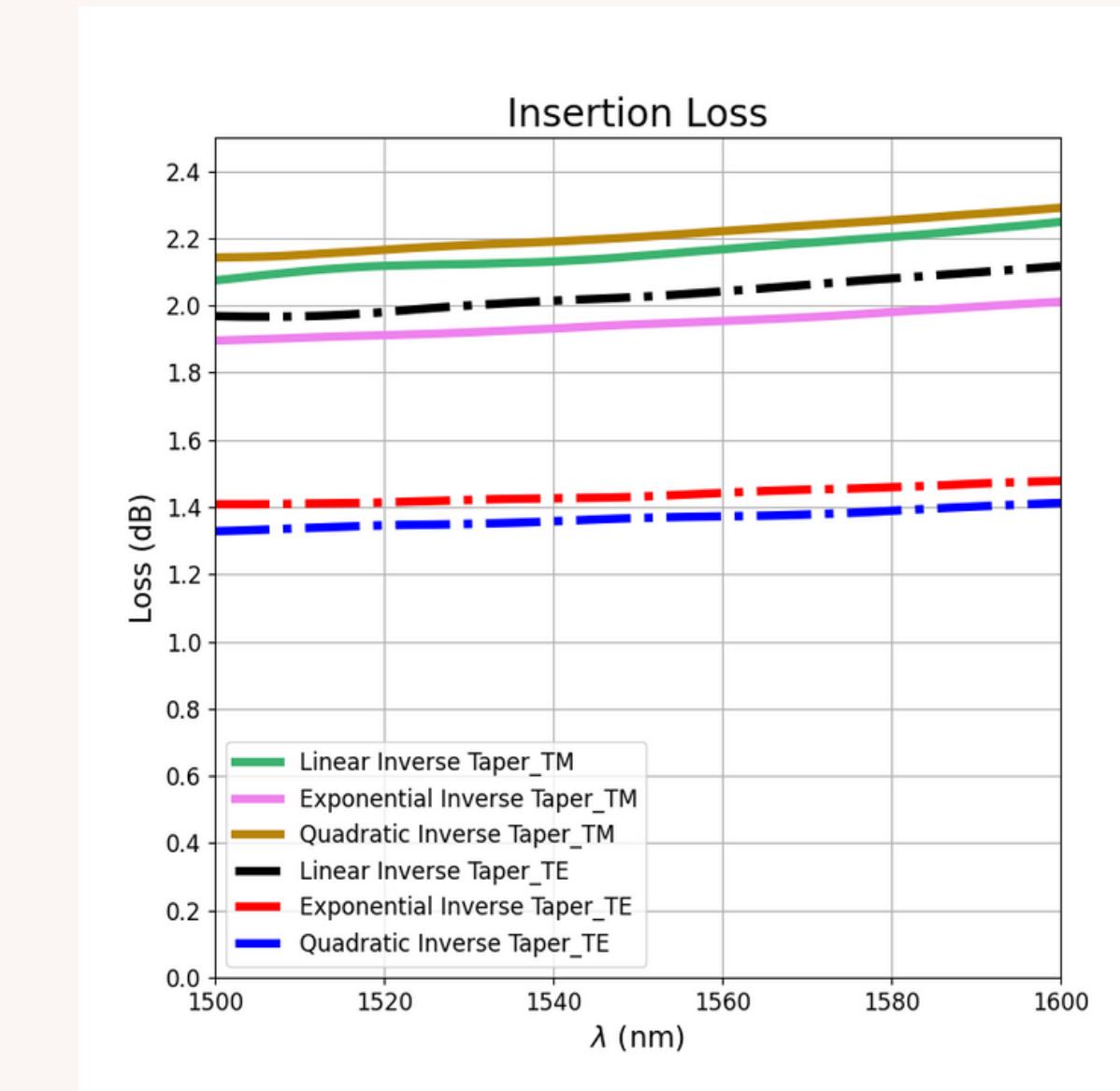
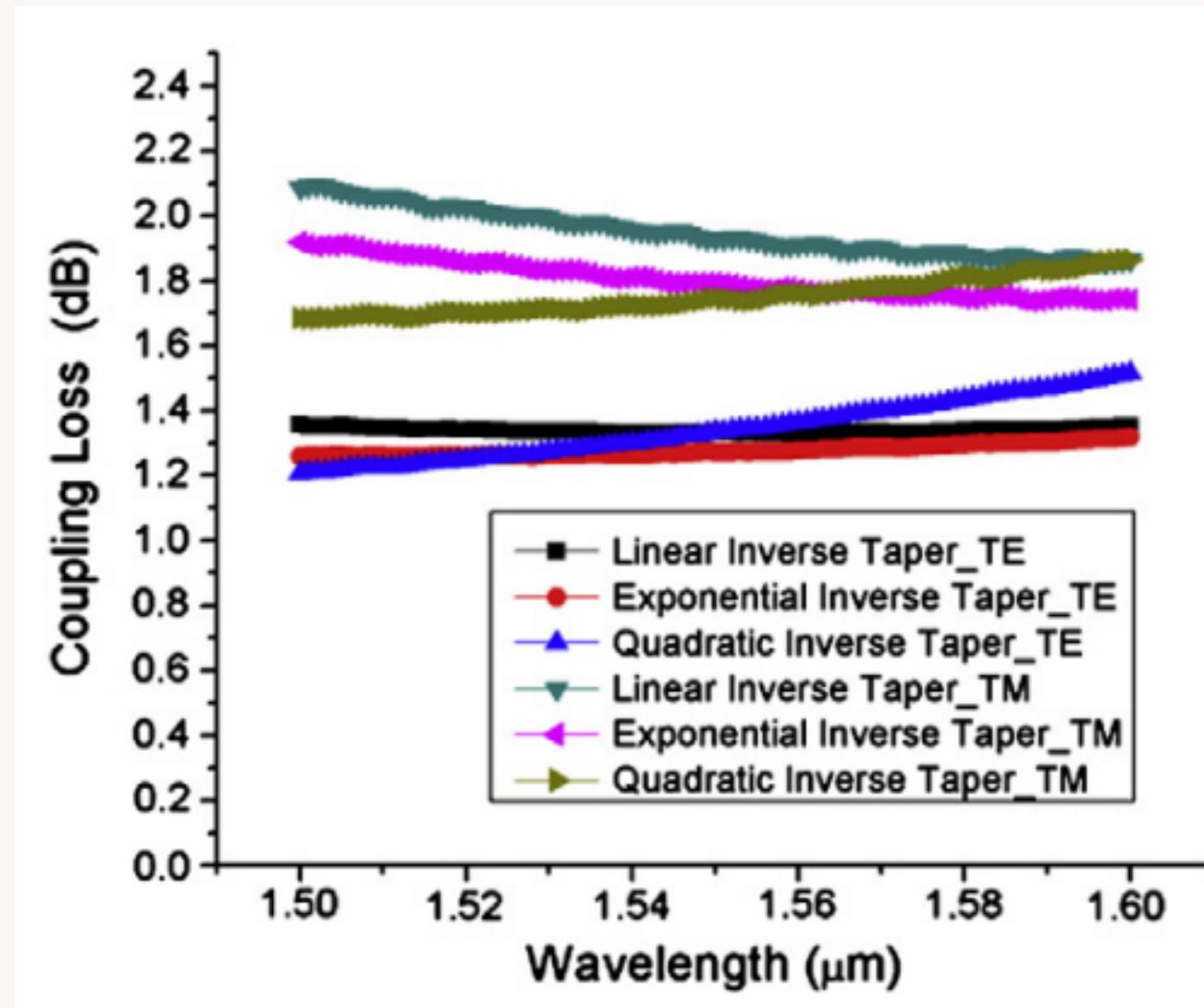
Modes: [4, 32, 4]

Mesh multiplier: y: 3, z: 1.5

High order mesh: dx: 3nm, dy: 3nm, dz: 6nm



Result Comparison



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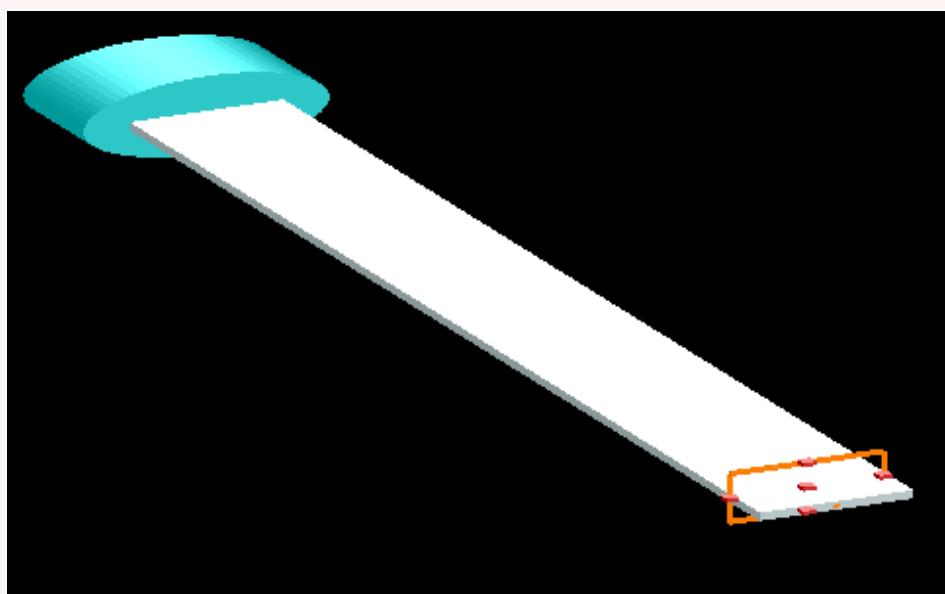
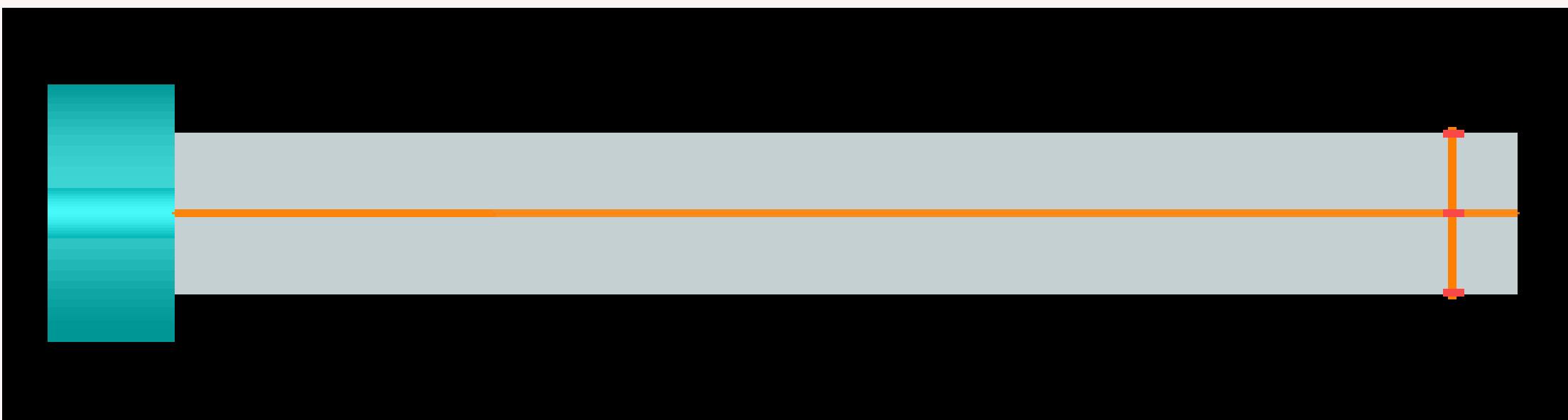
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WEEK 6 OBJECTIVES

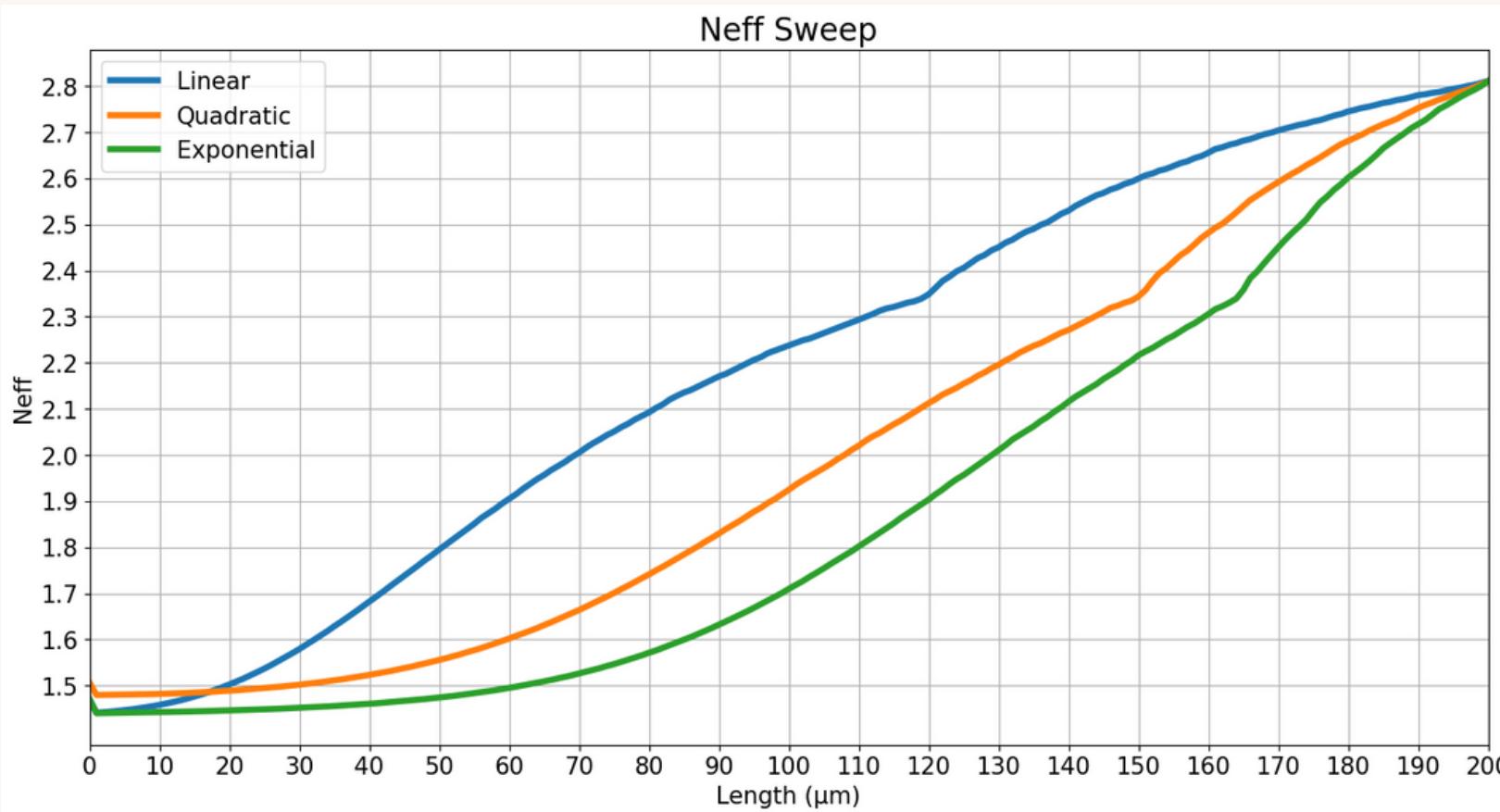
- Use FDE solver to generate an Neff sweep.

FDE SETTINGS



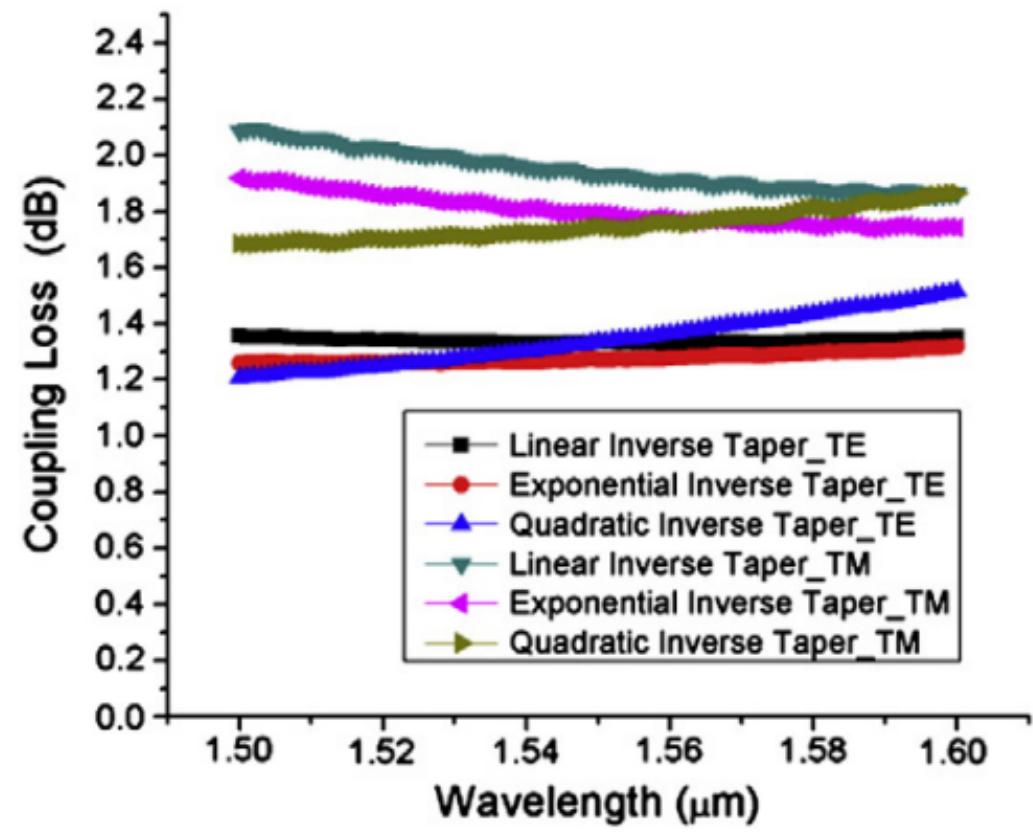
- mesh y & z cells : 300
- Boundaries: PML
- y & zspan: $25\mu\text{m}$
- FDE $\Delta x = 1\mu\text{m}$
- Data obtained using TM taper
($0.04\mu\text{m}$) initial width.

Neff Sweep

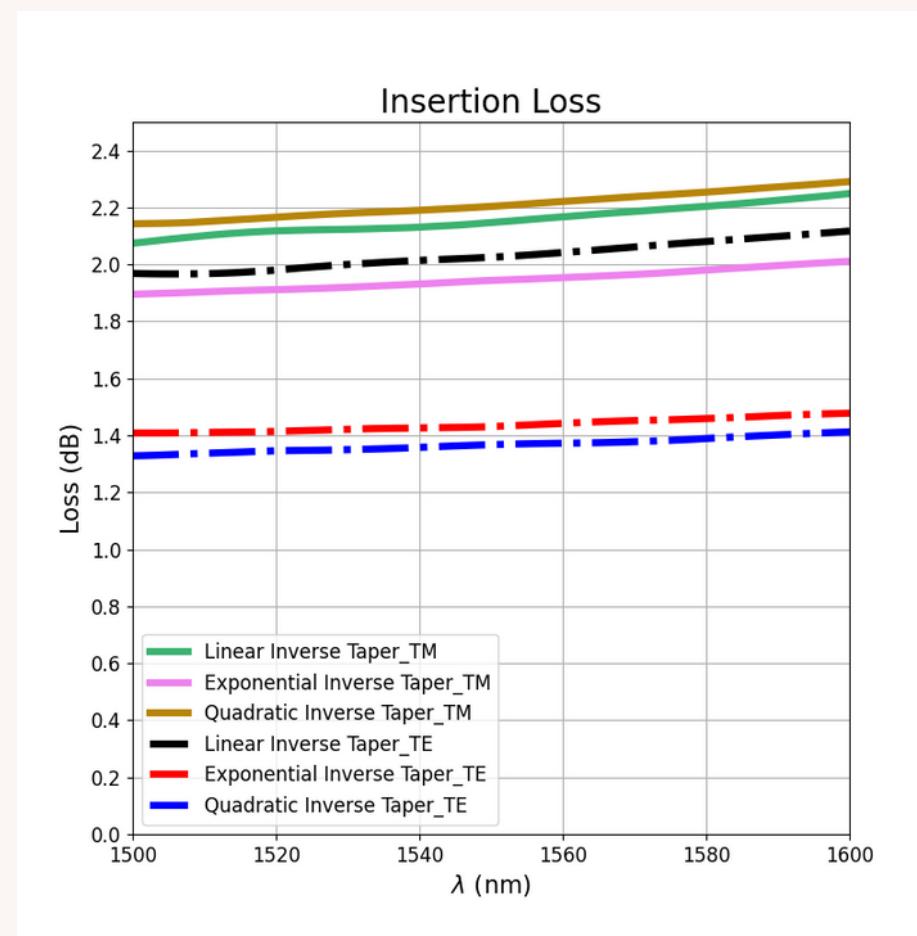


- The Linear taper varies approximately 0.1 Neff for every 10μm. Therefore, using 40 cells should be sufficient.
- The Quadratic Taper varies 0.1 Neff on its firsts 60μm and then increases rapidly, thus using 6 cells on it and 70 cells on the 140μm region should be sufficient.
- The Exponential Taper varies 0.1 Neff on its firsts 80μm and then increases rapidly, thus using 6 cells on it and 70 cells on the 140μm region should be sufficient.

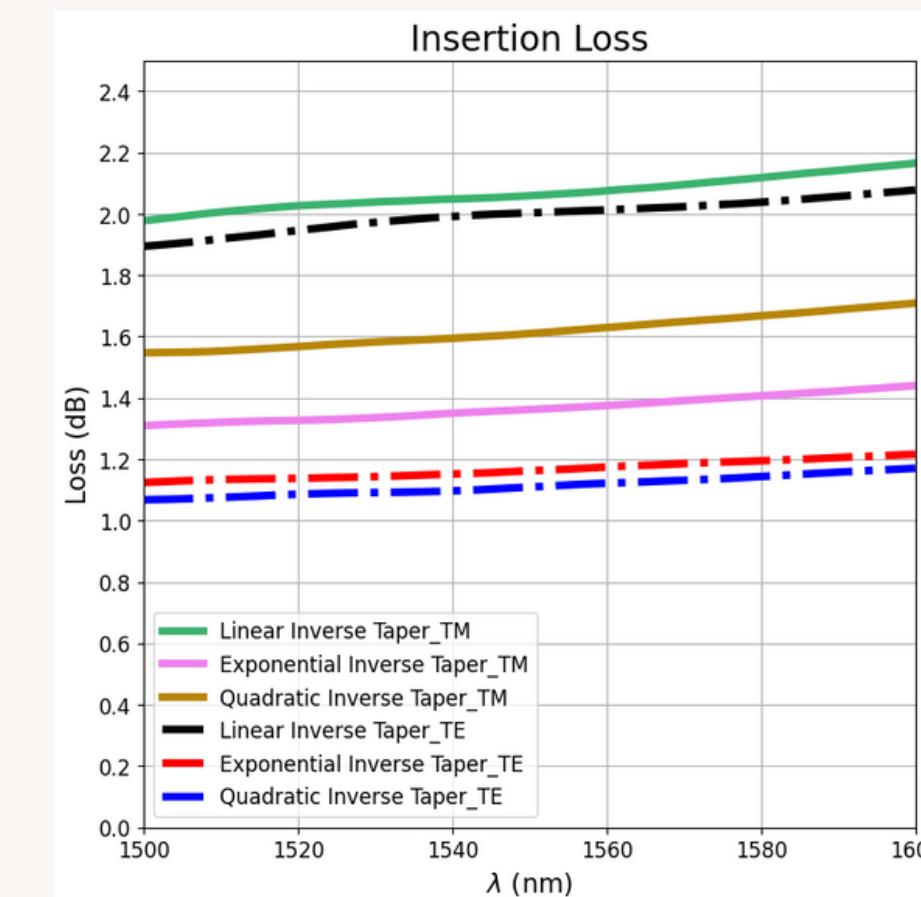
Result Comparison



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Previous Week



This Week

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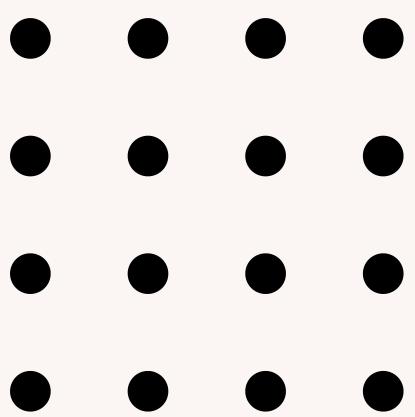
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WEEK 7 OBJECTIVES

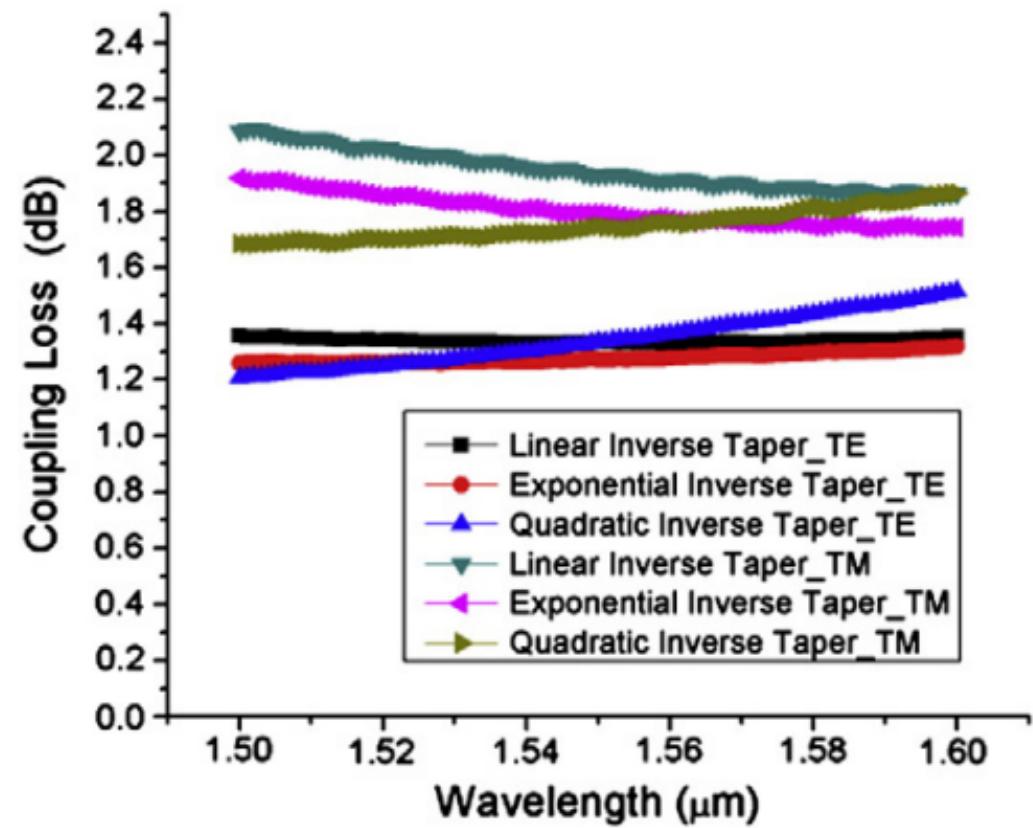
- Return to use single cell groups on the tapers.

SIMULATION CHANGES

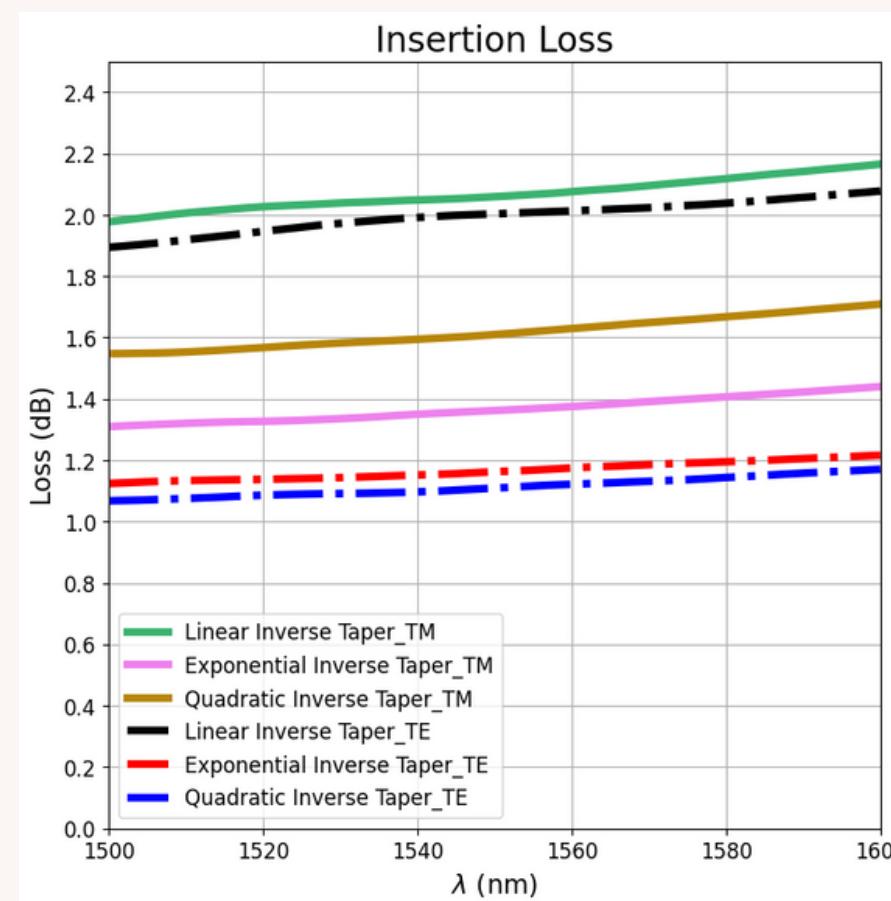
- Use single cell groups on the tapers.
- Use 60 cells on exponential and quadratic tapers.



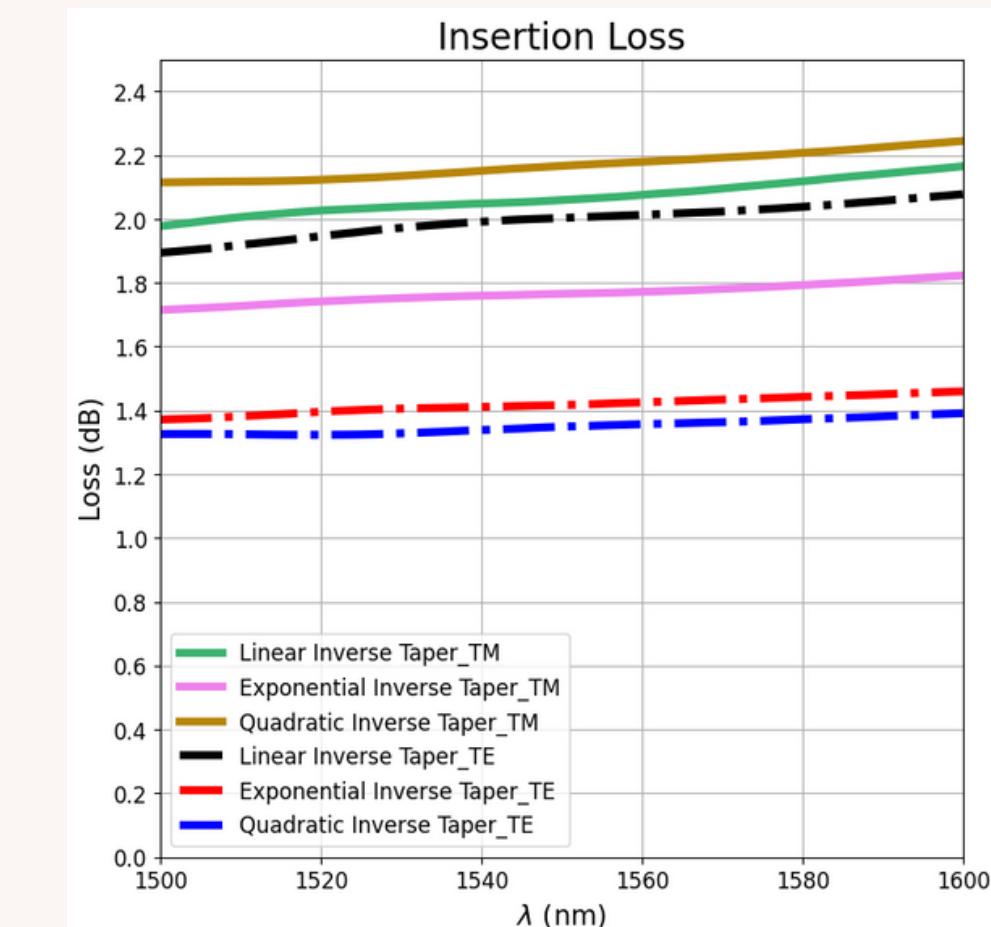
Result Comparison



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Previous Week



This Week

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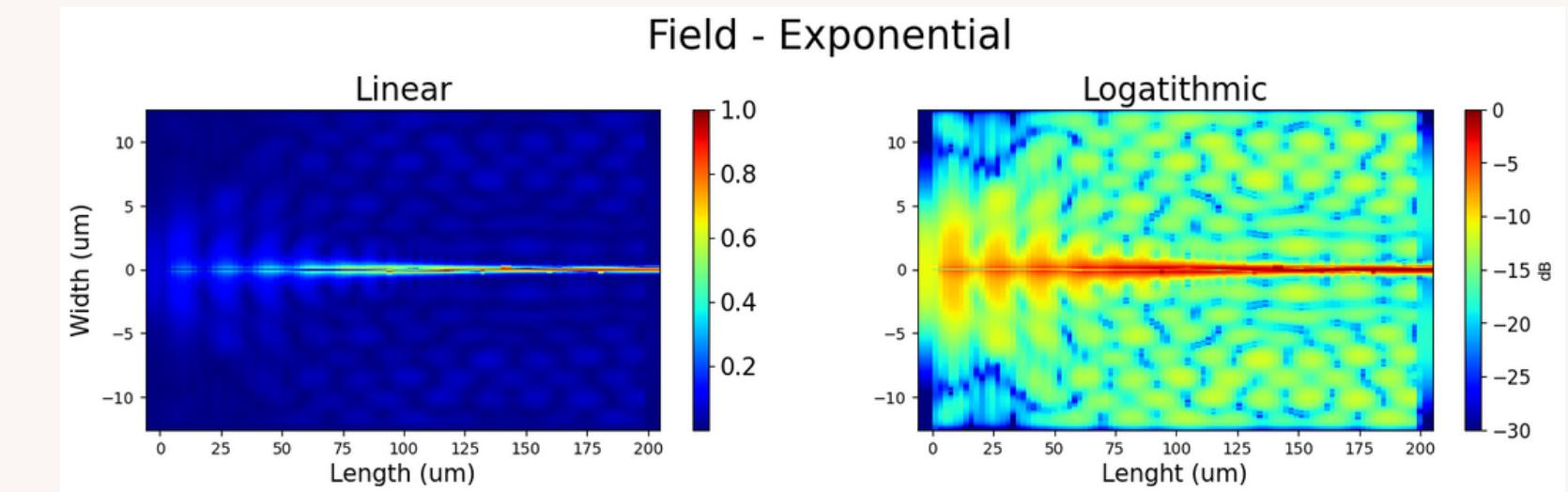
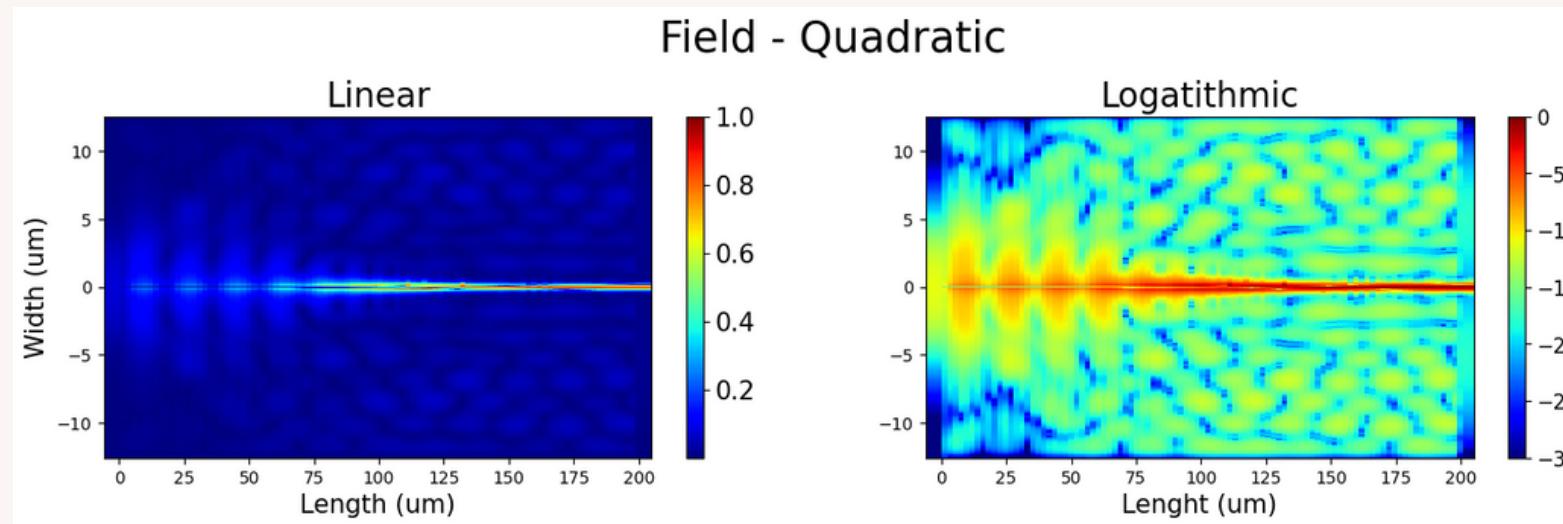
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WEEK 8 OBJECTIVES

- Export last week results to interconnect.
- Obtain field monitor results.

FIELD RESULT TE

Using EME



Mesh cells: 250

EME dimensions:

y span: 25 μm , z span: 25 μm , x span: 209 μm

Boundaries: z: Symmetric, y: Anti-symmetric

Output: z span: 5 μm , y span: 2 μm

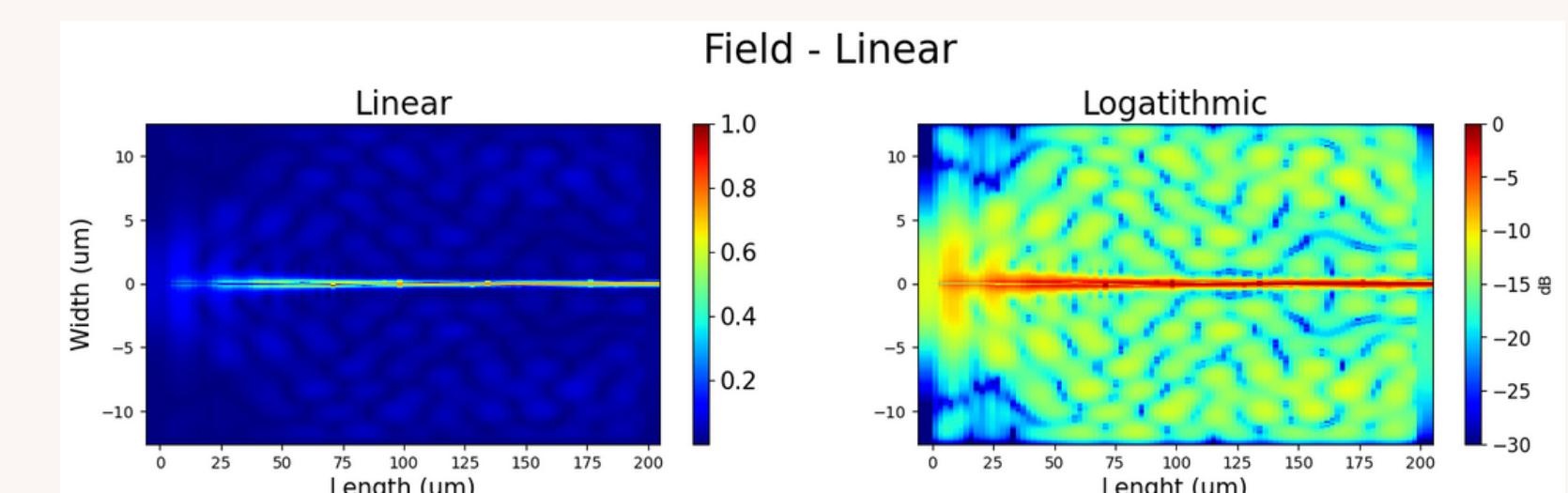
Simulation wavelength: 1550nm

Cells: [1, 40, 1] - Lin / [1, 60, 1] Exp & Qua

Modes: [4, 32, 4]

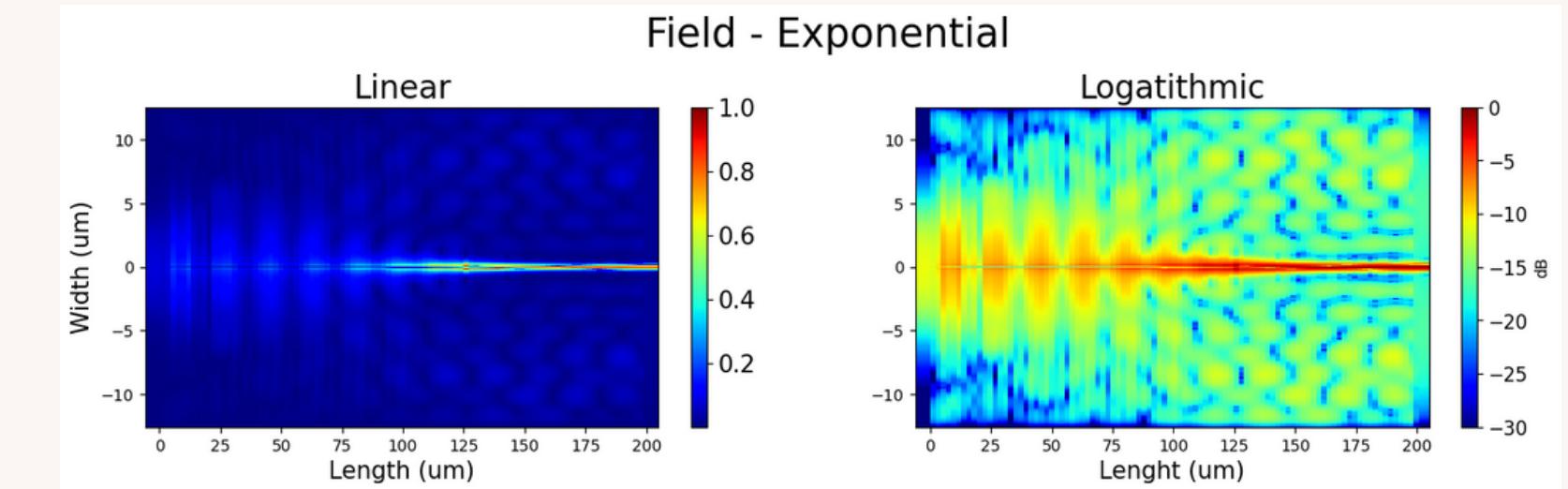
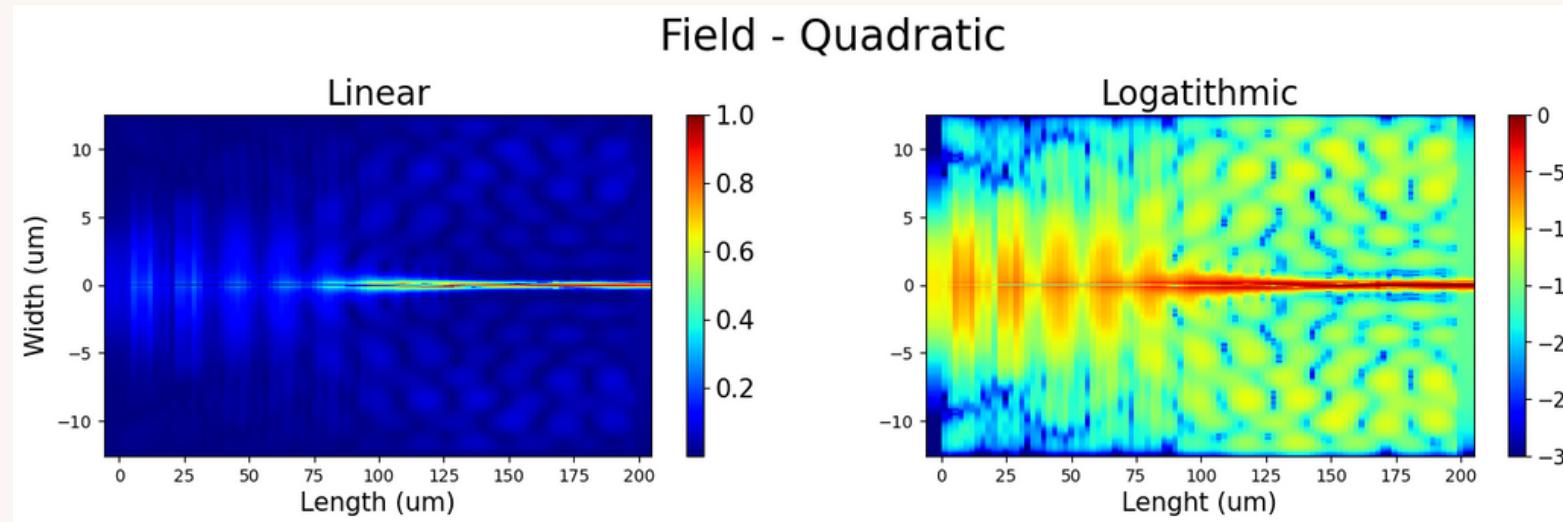
Mesh multiplier: y: 3, z: 1.5

High order mesh: dx: 3nm, dy: 3nm, dz: 6nm



FIELD RESULT TM

Using the same EME settings



Mesh cells: 250

EME dimensions:

y span: 25 μm , z span: 25 μm , x span: 209 μm

Boundaries: z: Symmetric, y: Anti-symmetric

Output: z span: 5 μm , y span: 2 μm

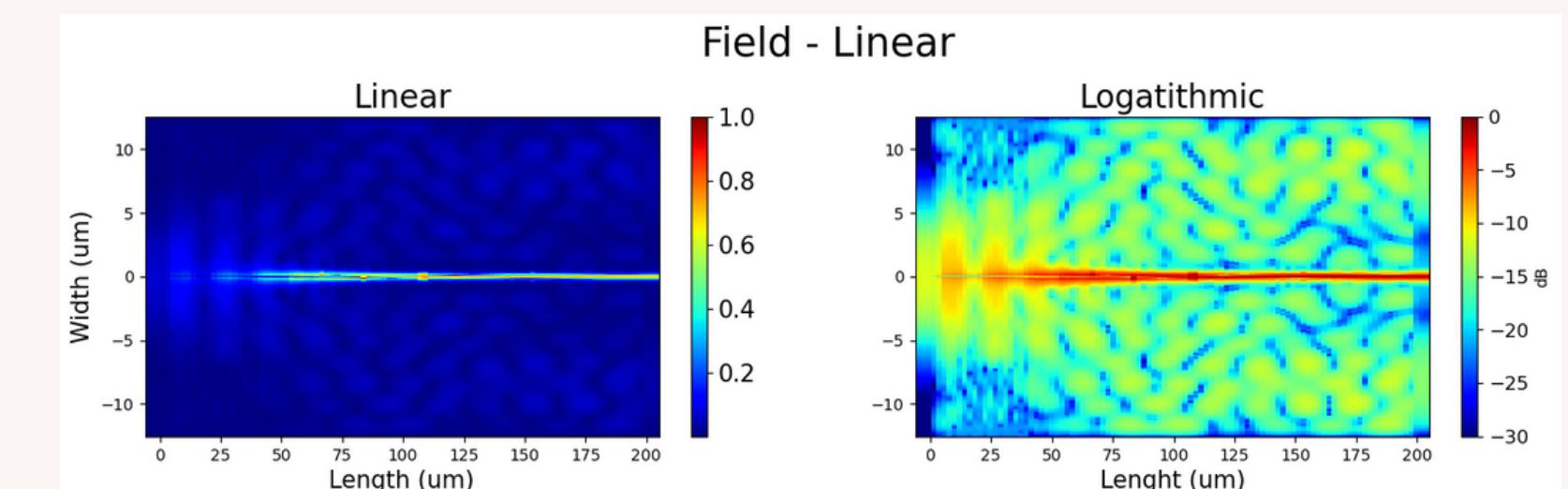
Simulation wavelength: 1550nm

Cells: [1, 40, 1] - Lin / [1, 60, 1] Exp & Qua

Modes: [4, 32, 4]

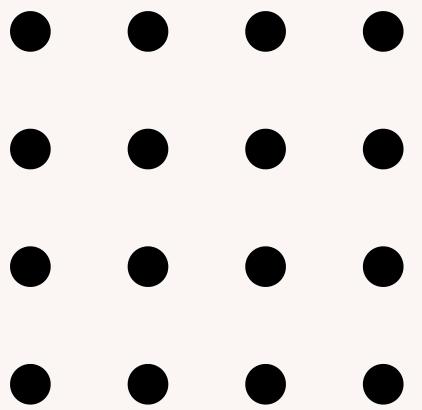
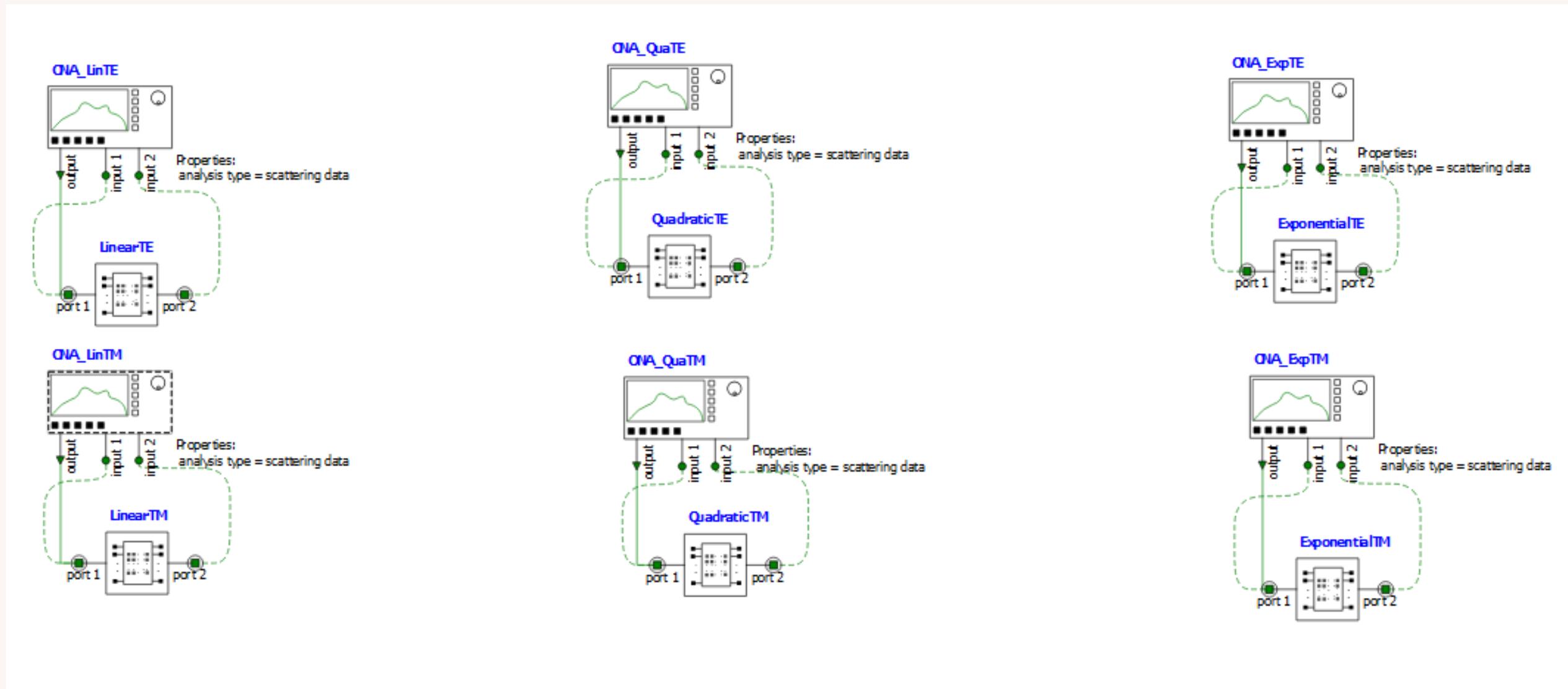
Mesh multiplier: y: 3, z: 1.5

High order mesh: dx: 3nm, dy: 3nm, dz: 6nm

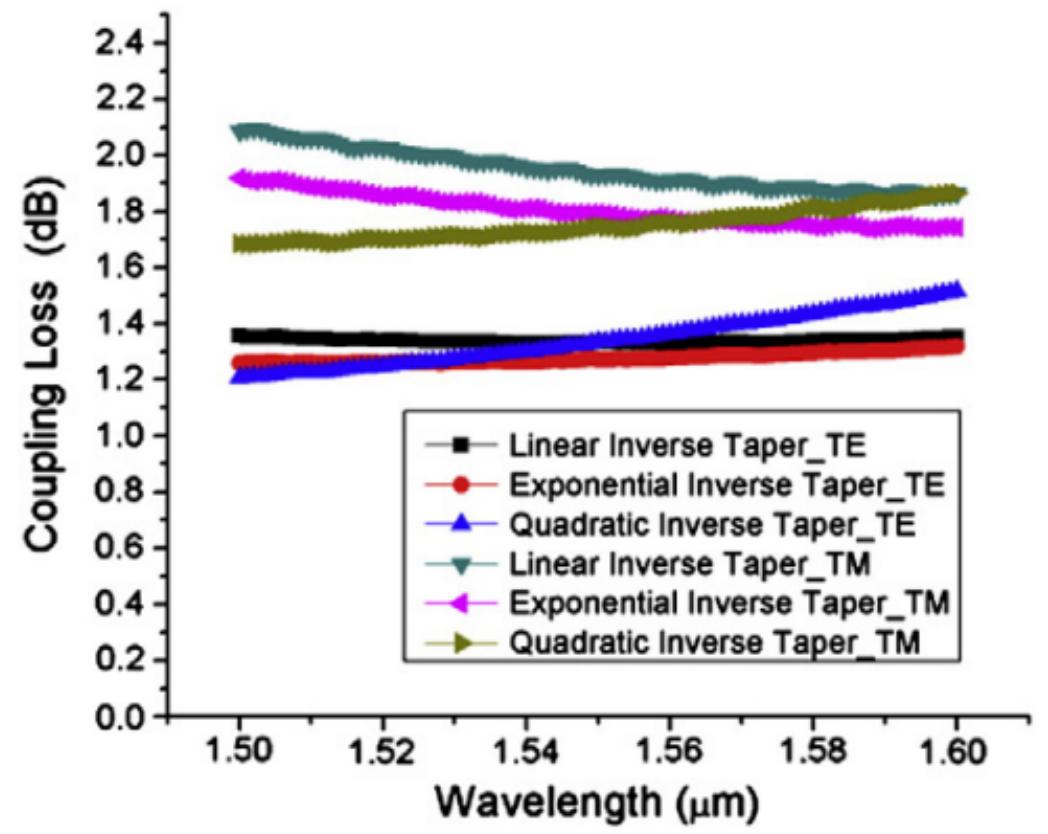


INTECONNECT SETTINGS

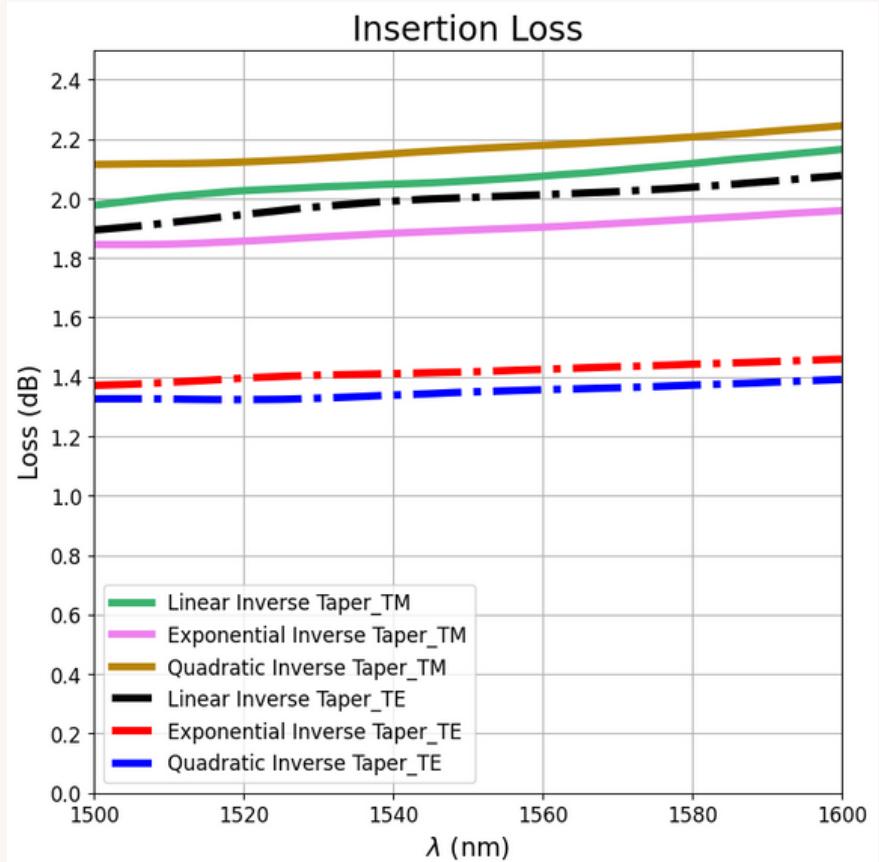
- 10000 Points
- Band: 1500-1600 nm



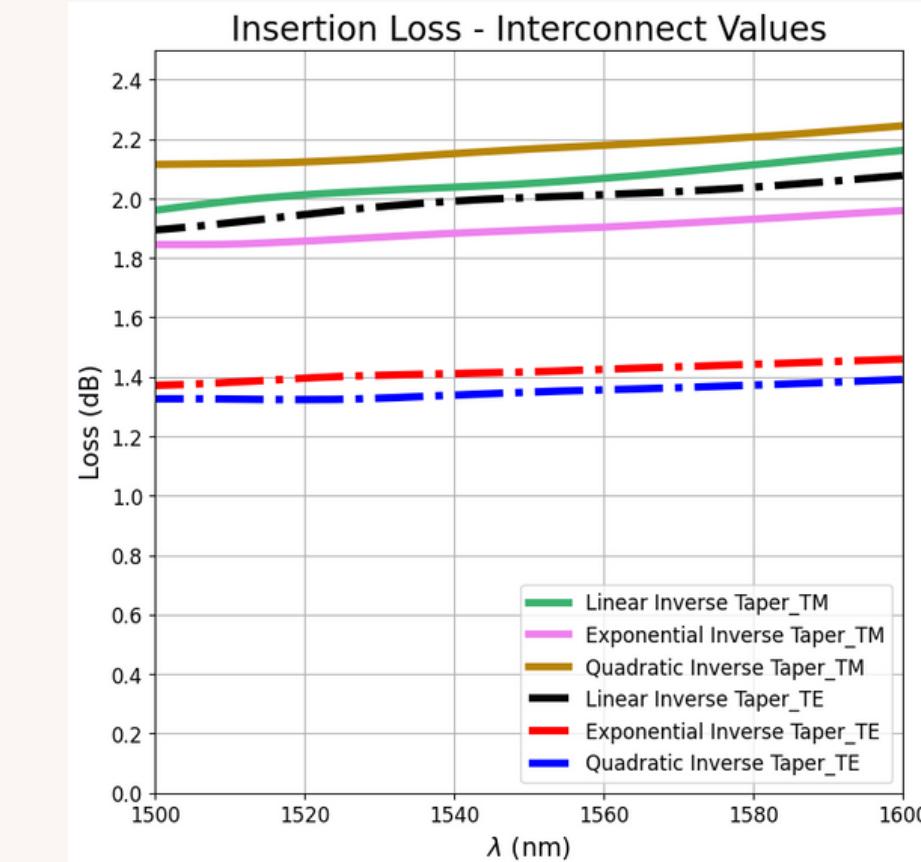
Result Comparison



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EME



INTERCONNECT

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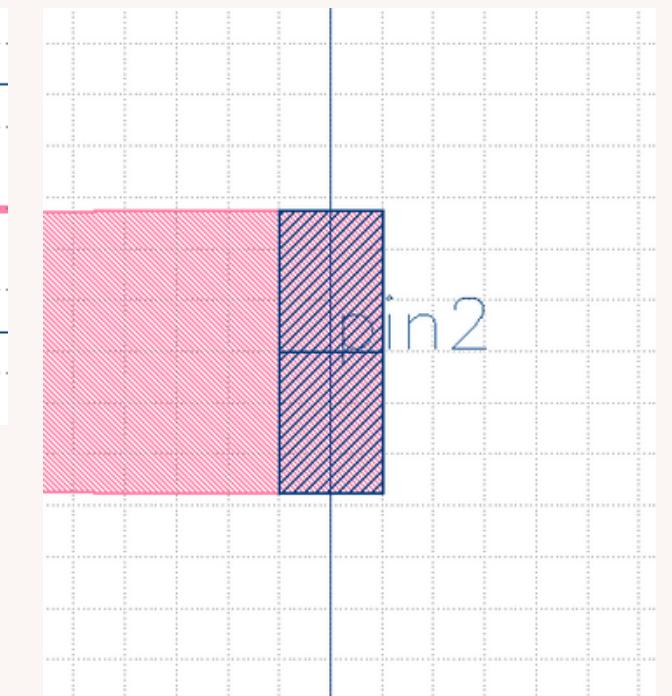
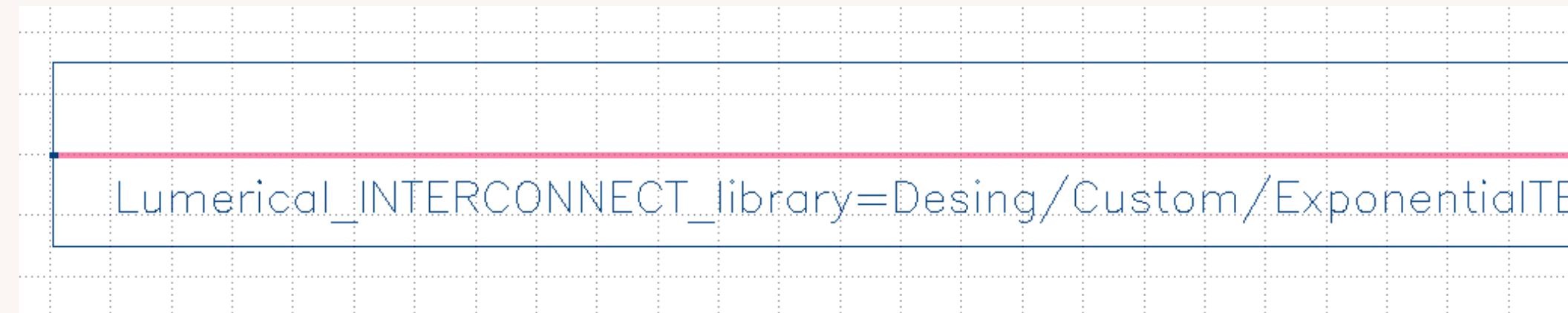
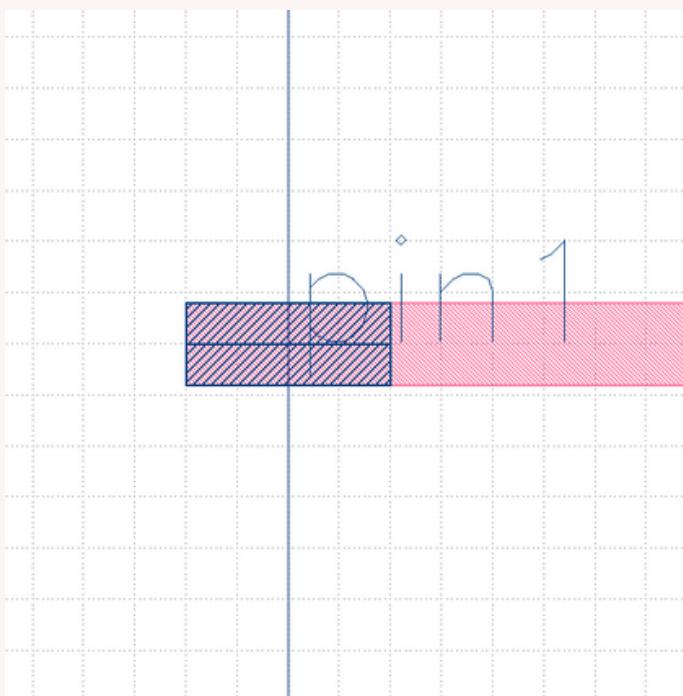
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WEEK 9 OBJECTIVES

- Create GDS file (chip) using Klayout software

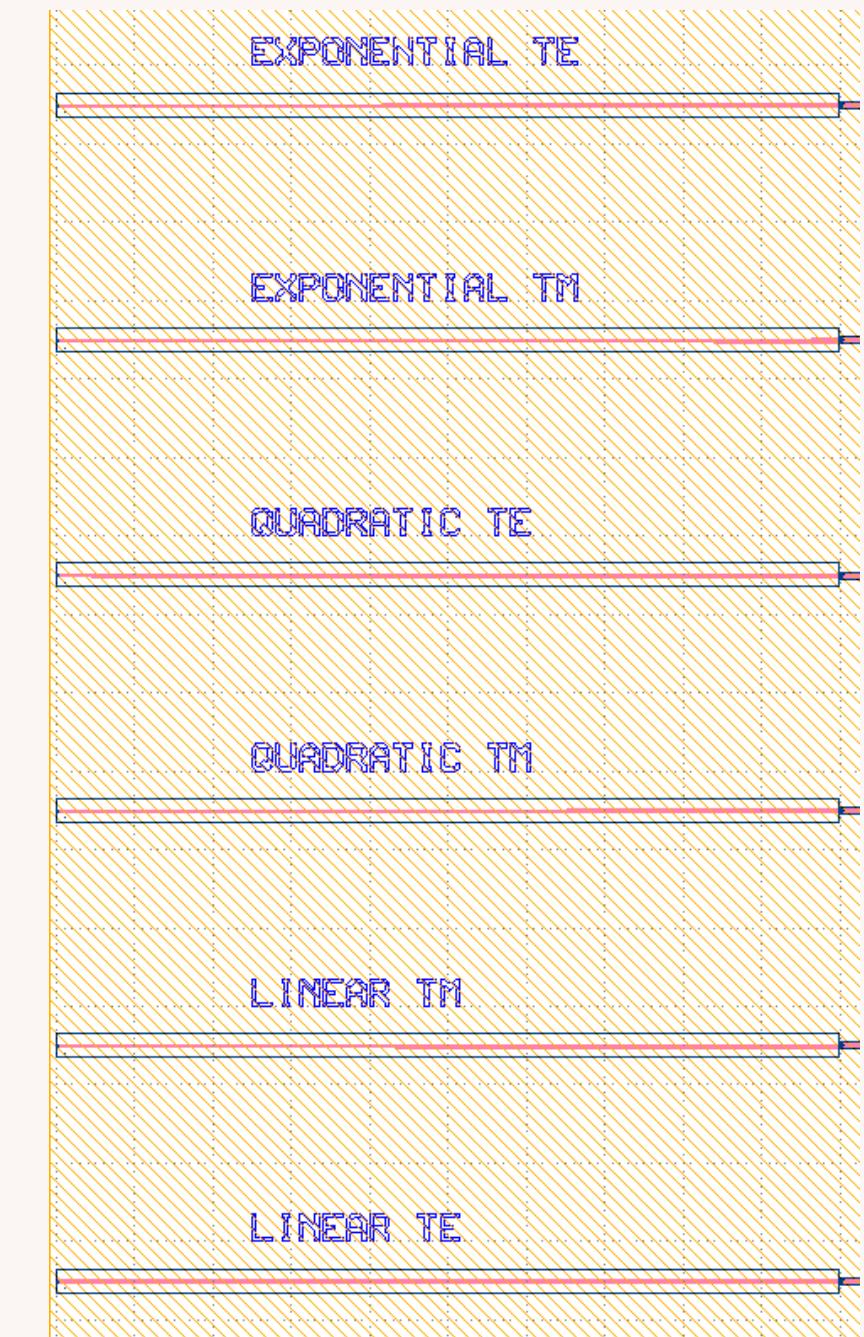
Taper GDS cell

Using Exponential TE as an exemple

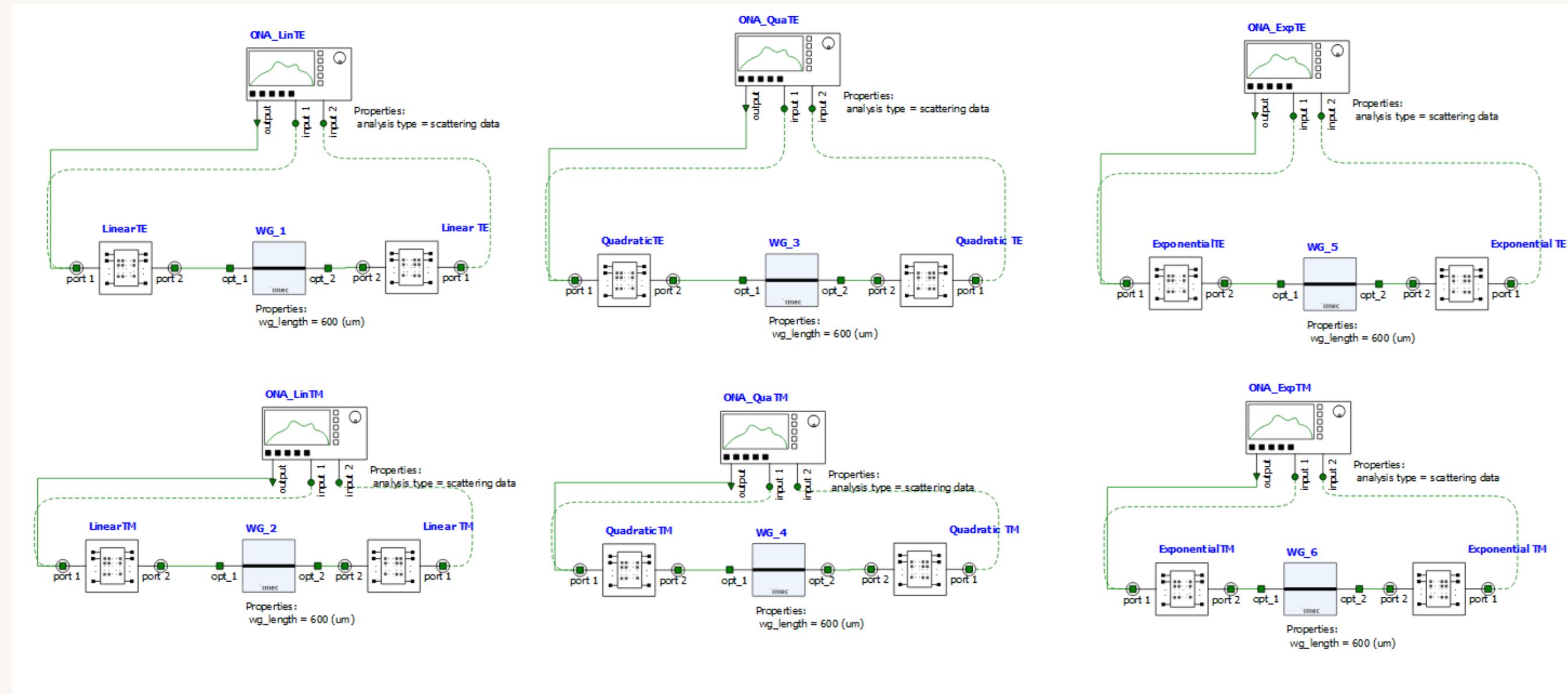


Chip

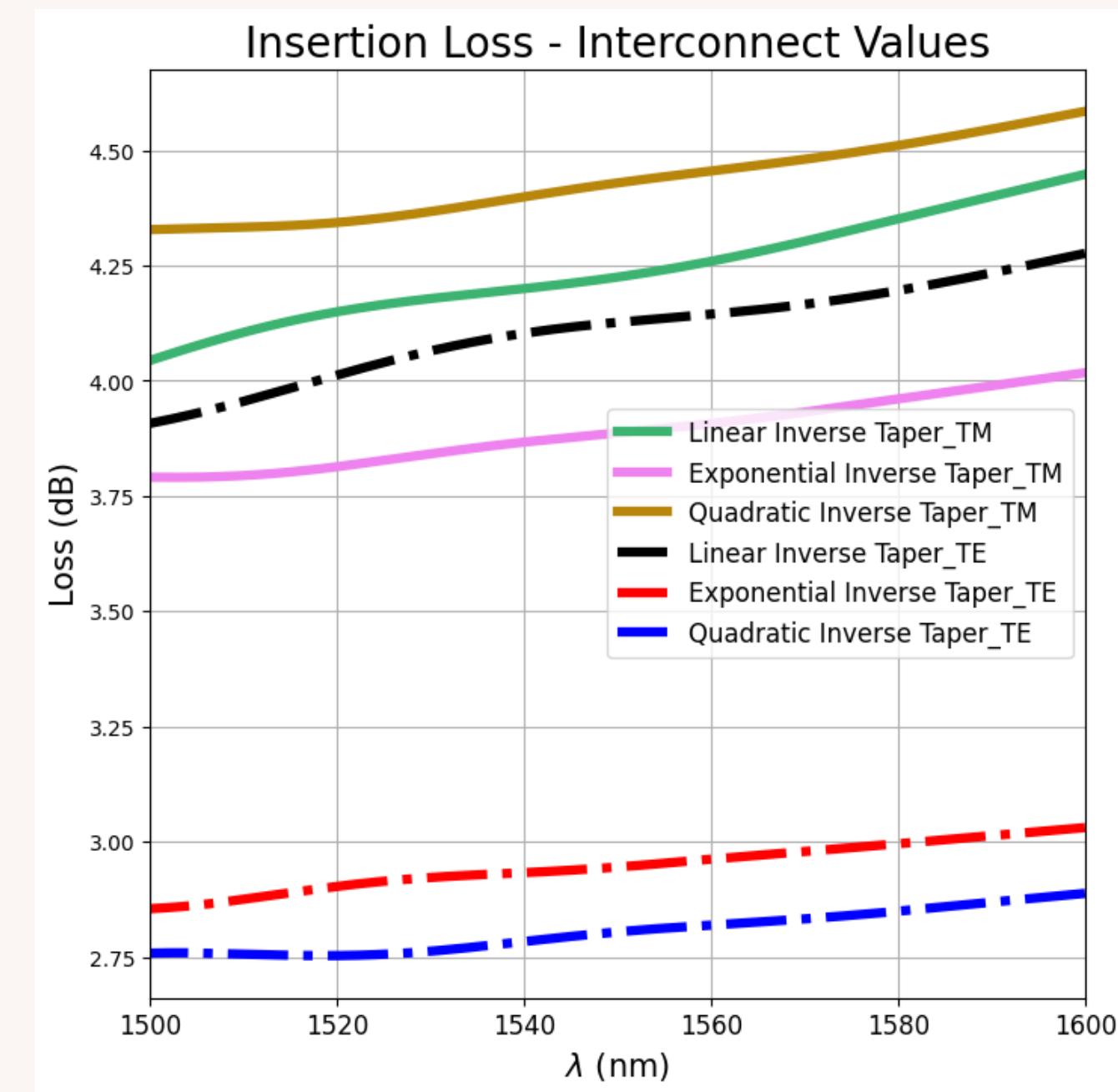
Using two edge couplers, two tapers and one waveguide for each of the tests



Interconnect Test



Interconnect Test



References

- [1] Mu, Xin, et al. "Edge couplers in silicon photonic integrated circuits: A review." *Applied Sciences* 10.4 (2020): 1538.
- [2] Ren, Guanghui, et al. "Study on inverse taper based mode transformer for low loss coupling between silicon wire waveguide and lensed fiber." *Optics Communications* 284.19 (2011): 4782–4788.