# Ring Resonator
# MODE Simulation

High-Speed Circuits & Systems Lab.
Dept. of Electrical and Electronic Engineering
Yonsei University

# Lumerical Solutions

## Our Products

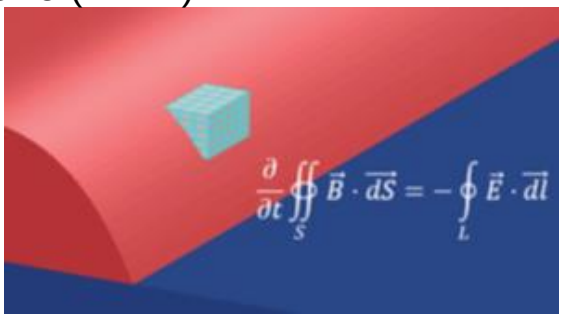
**FDTD Solutions**: Single and multi-processor finite-difference time-domain optical design software.
Product Details | Trial Download

**MODE Solutions**: Waveguide eigenmode solver and omni-directional broadband propagator design software.
Product Details | Trial Download

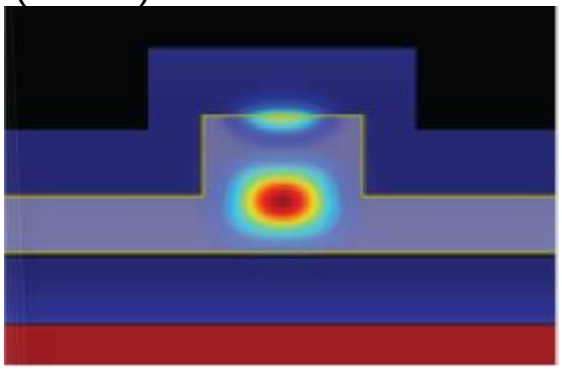
**INTERCONNECT**: Optoelectronic and photonic integrated circuit (PIC) design software package.
Product Details | Trial Download

**DEVICE**: Powerful semiconductor TCAD device simulation software for silicon-based optoelectronic structures.
Product Details | Trial Download

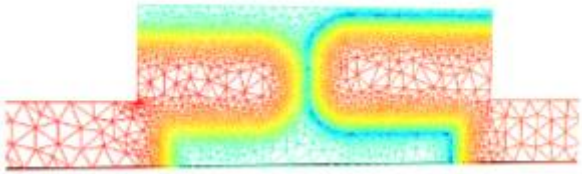
3D Maxwell solver(FDTD)




Modal analysis(MODE)

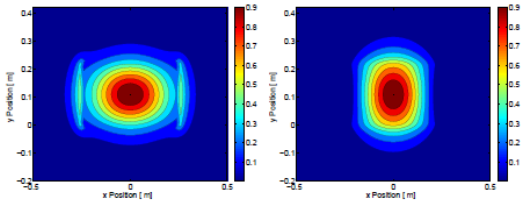


Charge transport & heat transfer(DEVICE)

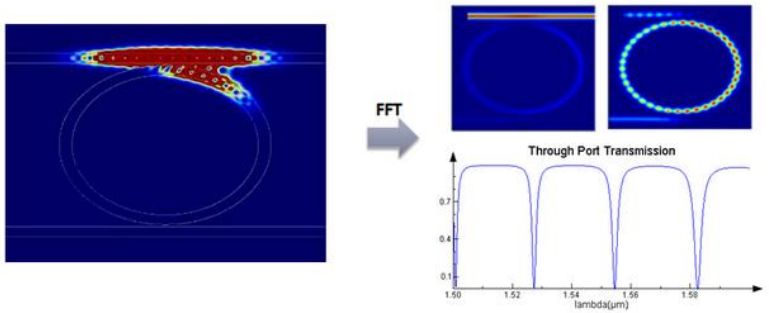


# Lumerical MODE Solution

- **FDE(Finite Difference Eigenmode) solver**
  -Calculate physical properties of **waveguide modes**
  -Solve Maxwell's equations for cross-sectional mesh



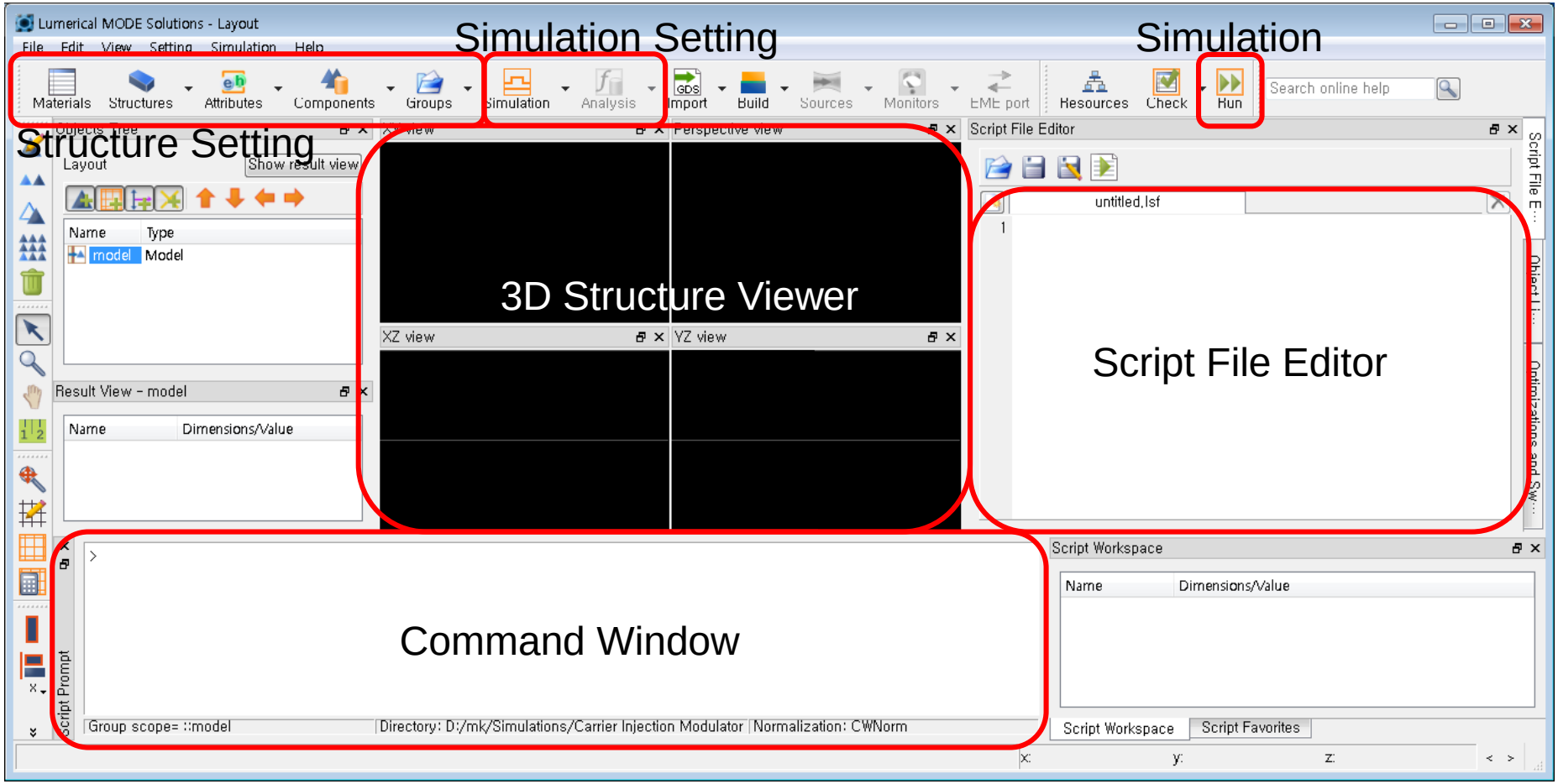
- **2.5D varFDTD(Finite Difference Time Domain)**
  -**Time domain simulation with approximation**
  -2D simulation speed with 3D accuracy



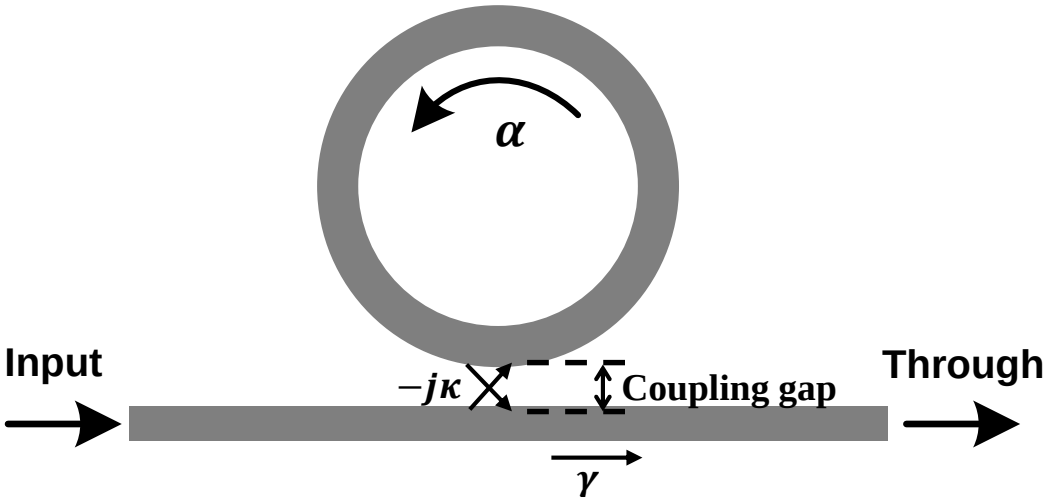

- **EME(Eigenmode Expansion) solver**
  -Frequency domain simulation

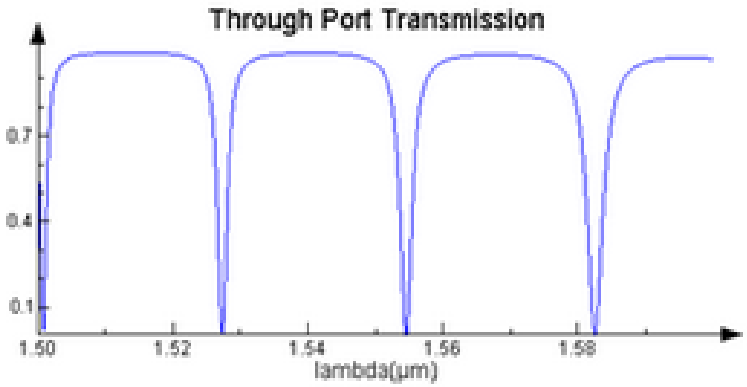
**Most simulations will be held with these solvers**

# MODE Window


Lumerical MODE Solutions - Layout
File Edit View Setting Simulation Help
Simulation Setting
Simulation
Materials Structures Attributes Components Groups Simulation Analysis Import Build Sources Monitors EME port Resources Check Run
Search online help
Structure Setting
Layout
Show result view
Name Type
model Model
Result View – model
Name Dimensions/Value
3D Structure Viewer
XZ view
YZ view
Script File Editor
untitled.lsf
Command Window
Script Prompt
Group scope= ::model
Directory: D:/mk/Simulations/Carrier Injection Modulator
Normalization: CWNorm
Script Workspace
Name Dimensions/Value
Script Workspace
Script Favorites

# Ring Resonator



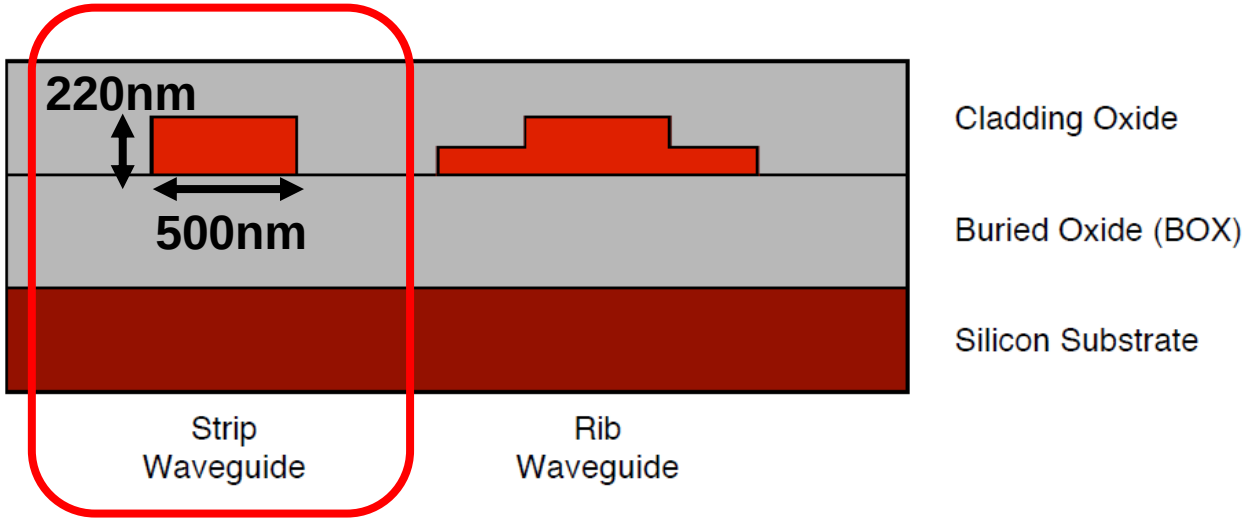

-Resonate on specific wavelength, $\lambda_{res}$
& Out of phase at through port
➔ Large interference at $\lambda_{res}$

-Used in many applications
:Filters, E/O modulators, sensors, RF photonics, etc.

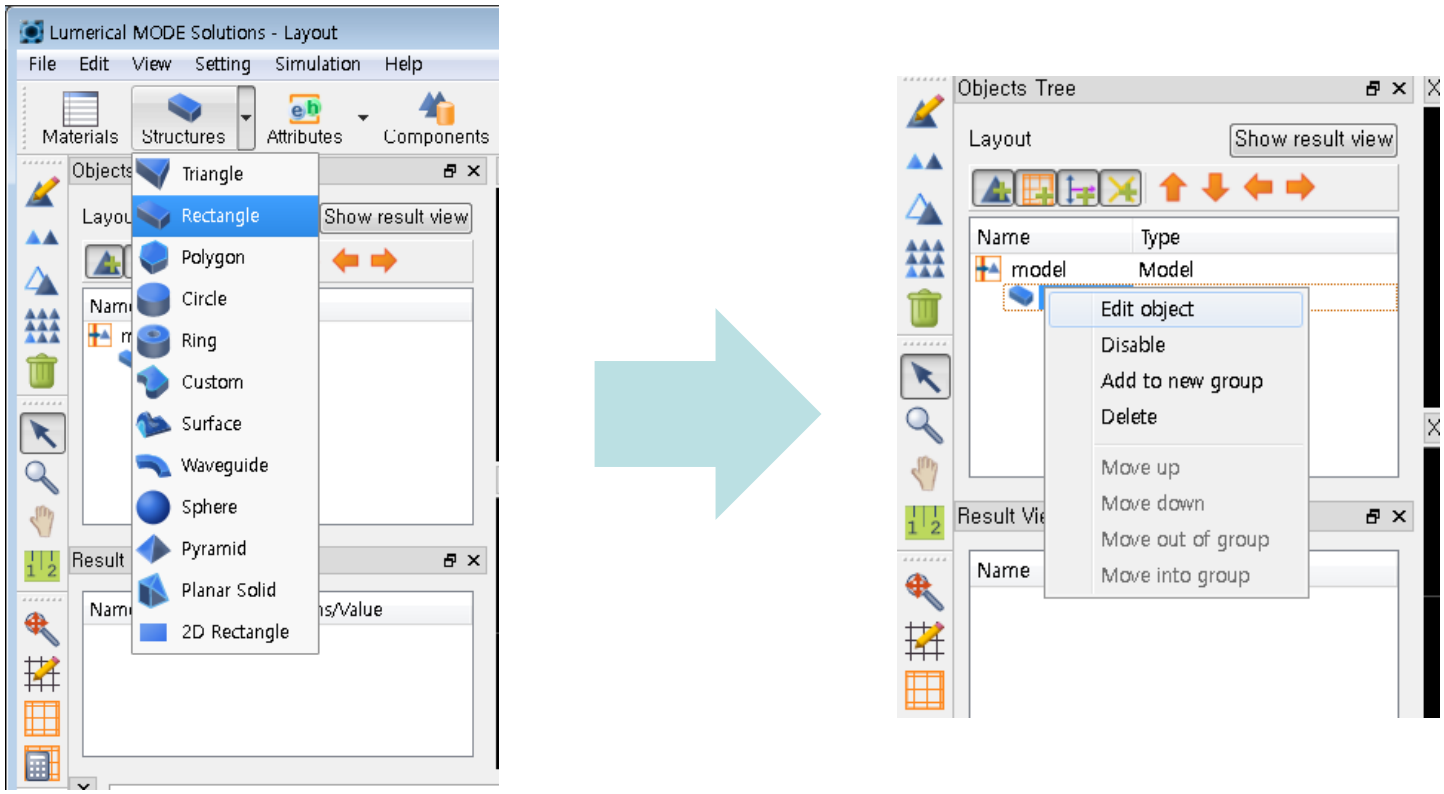
-Waveguide property analysis is necessary

# Waveguide Structure

- **Drawing structure**
  - Example) Make strip waveguide
  - Height: 220 nm
  - Width: 500 nm
  - Length: 30 μm
  - Core material: Si
  - Cladding material: $SiO_2$

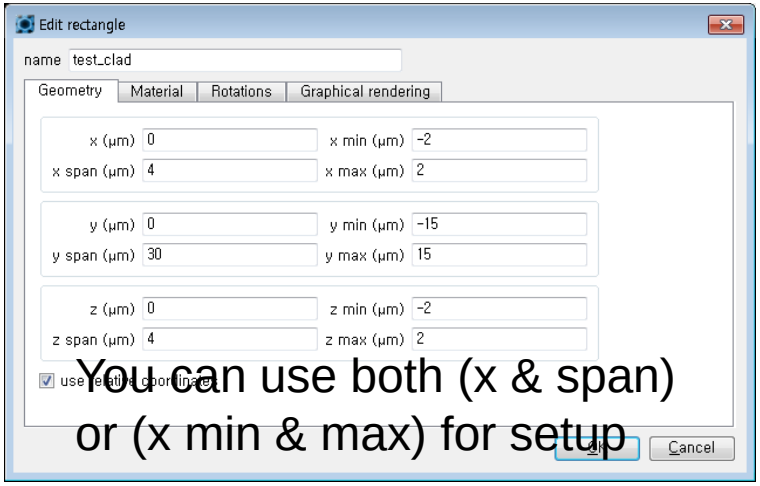


# Structure Build(GUI)

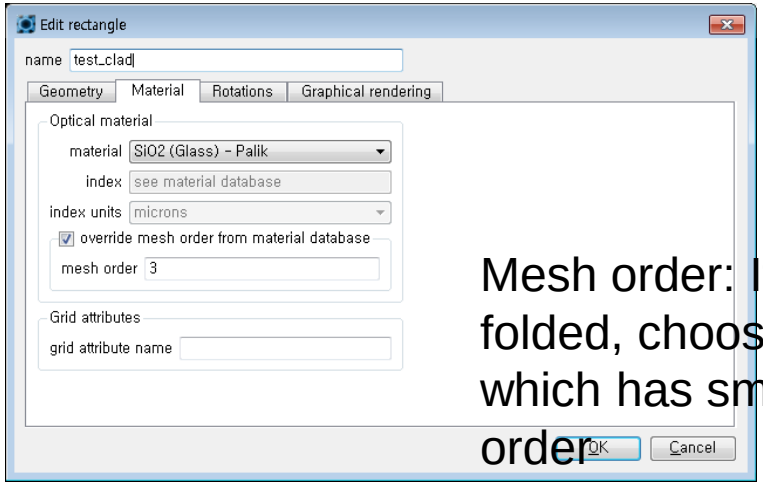


# Structure Build(GUI)

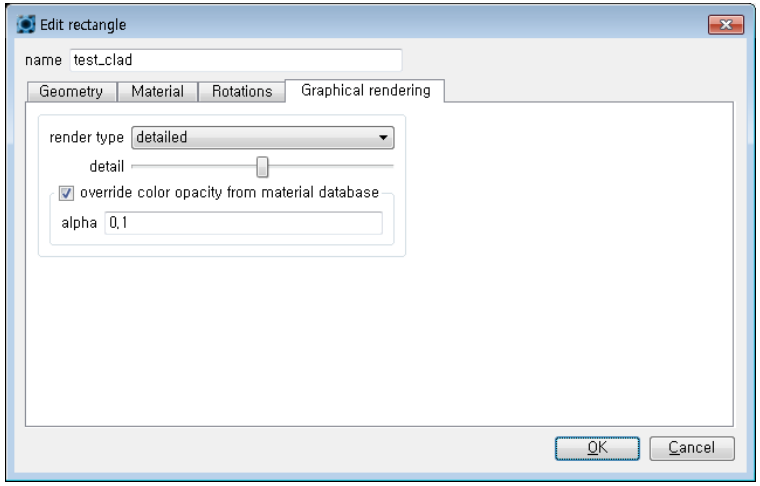
- **Cladding**




You can use both (x & span) or (x min & max) for setup

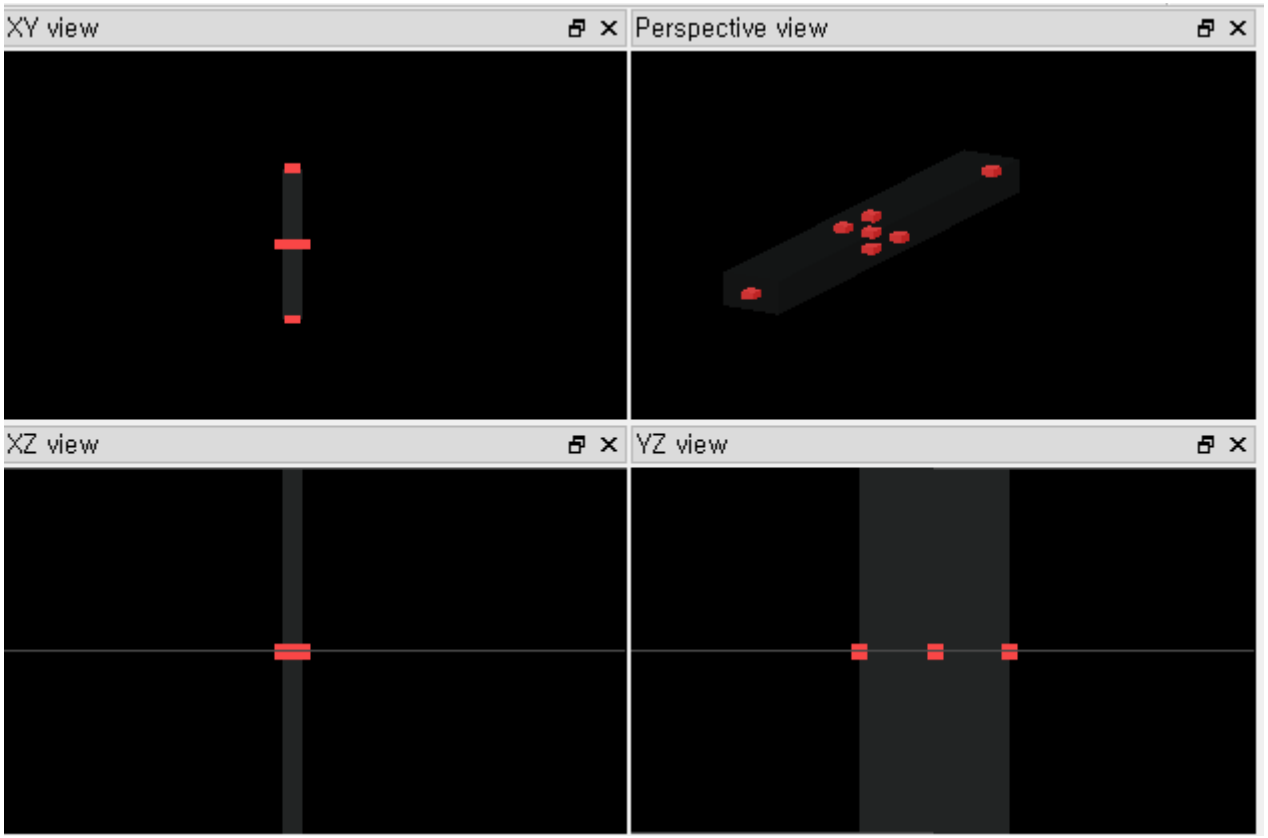



Mesh order: If materi
folded, choose mater
which has smaller me
order



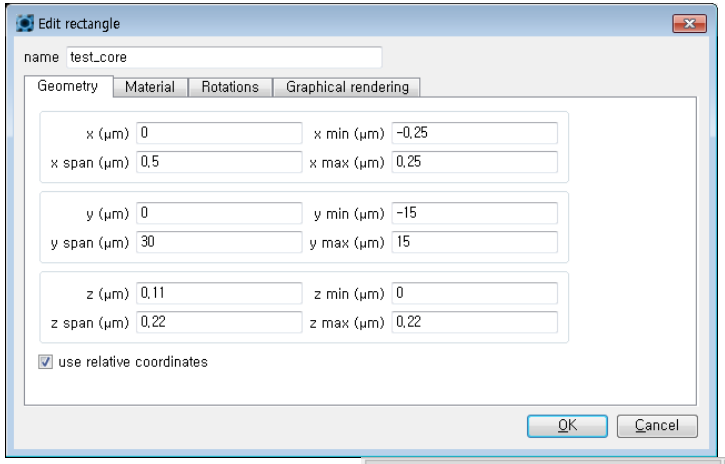
# Structure Build(GUI)

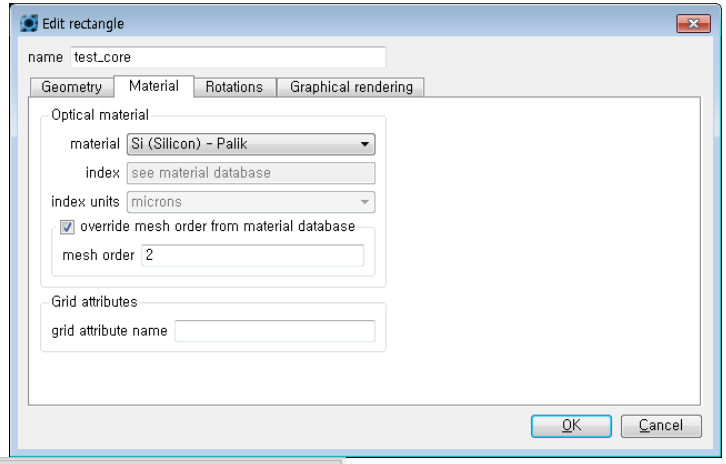
- **Cladding**

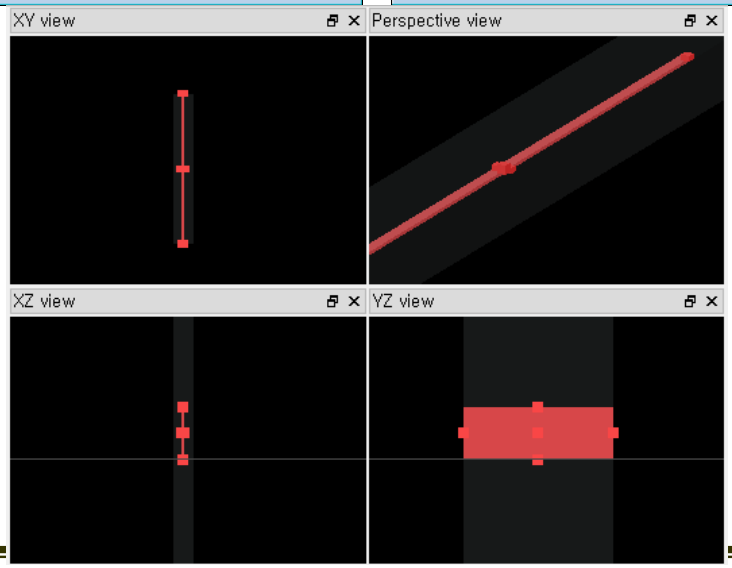


# Structure Build(GUI)

- Core

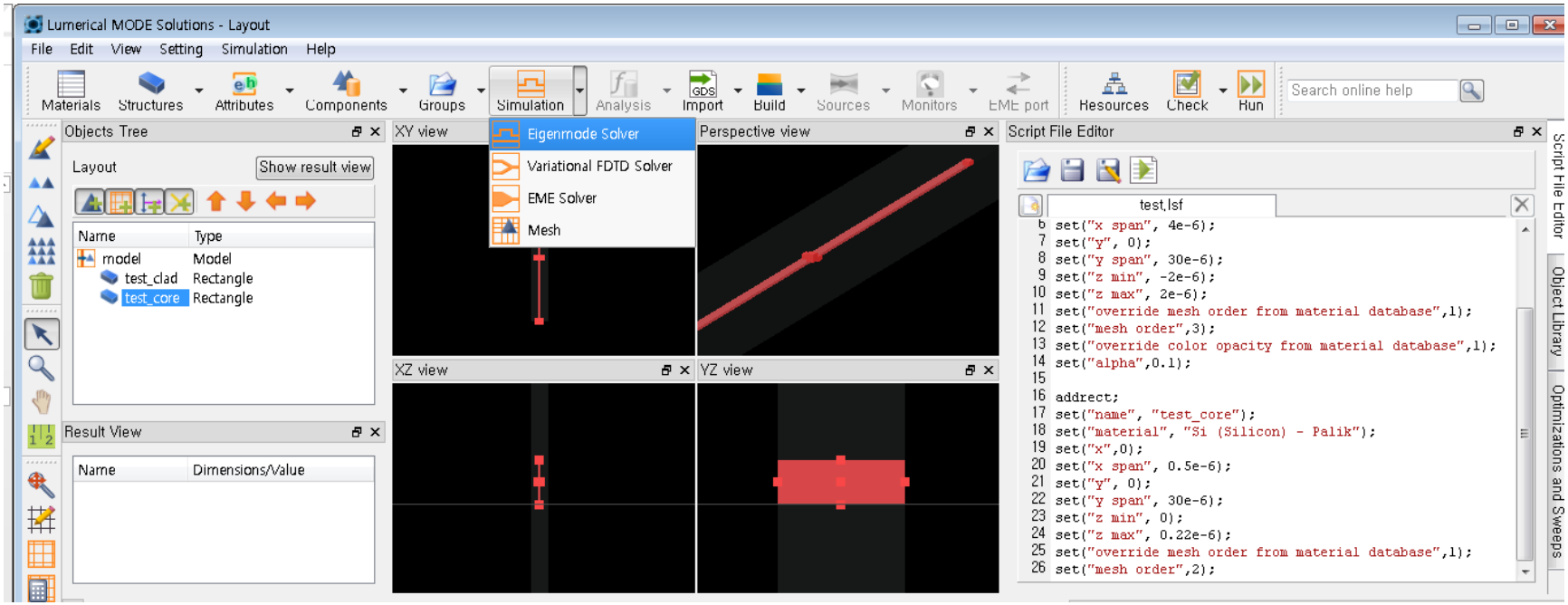


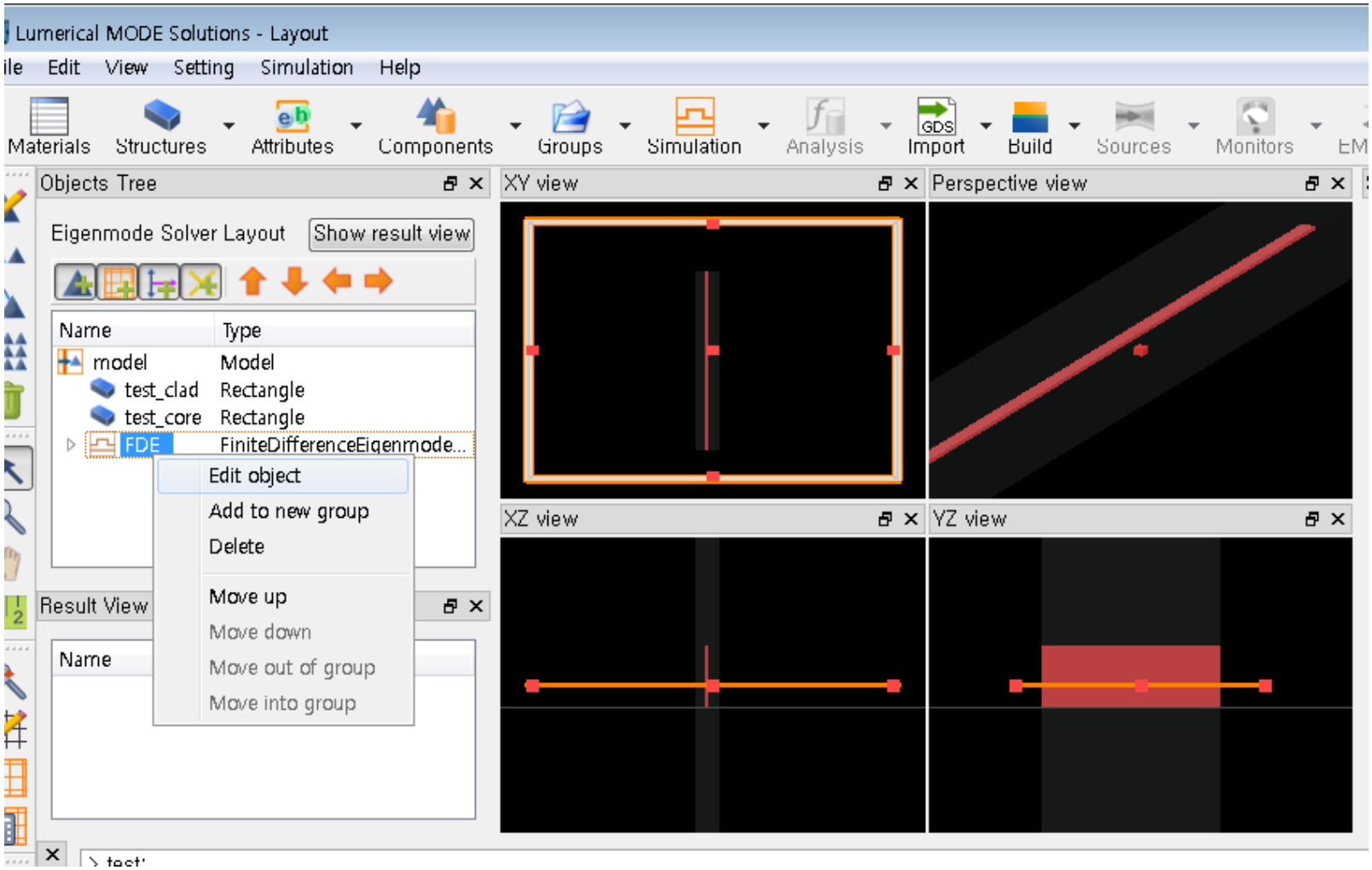



# Simulation Setup(GUI)

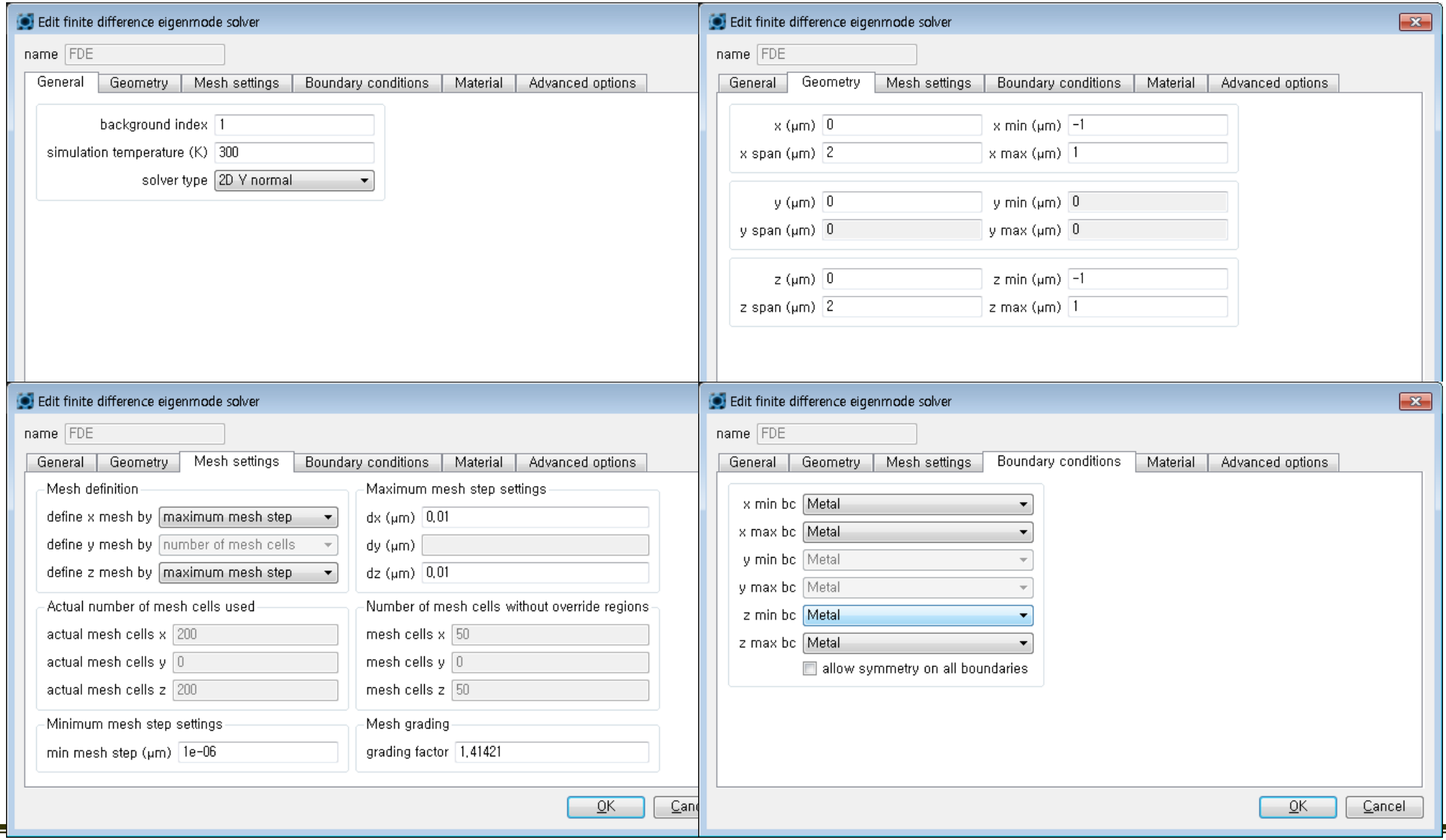
- **Eigenmode Solver**



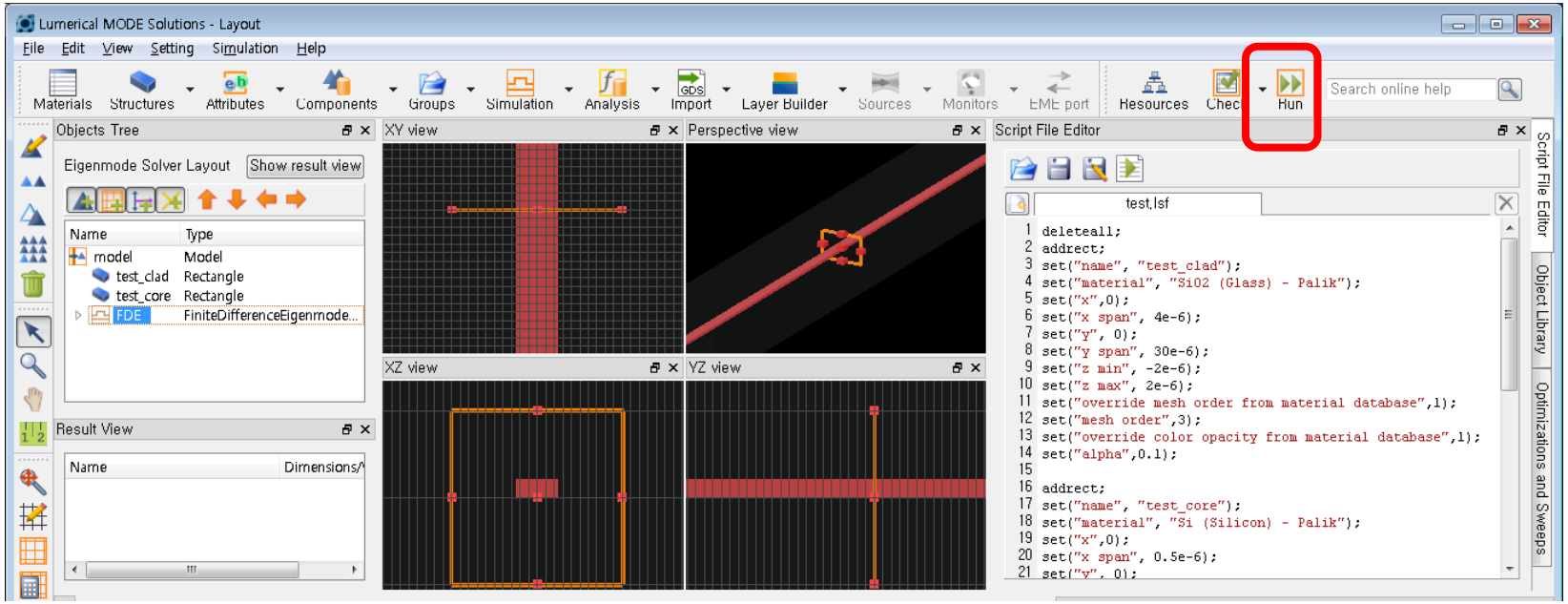
# Simulation Setup(GUI)



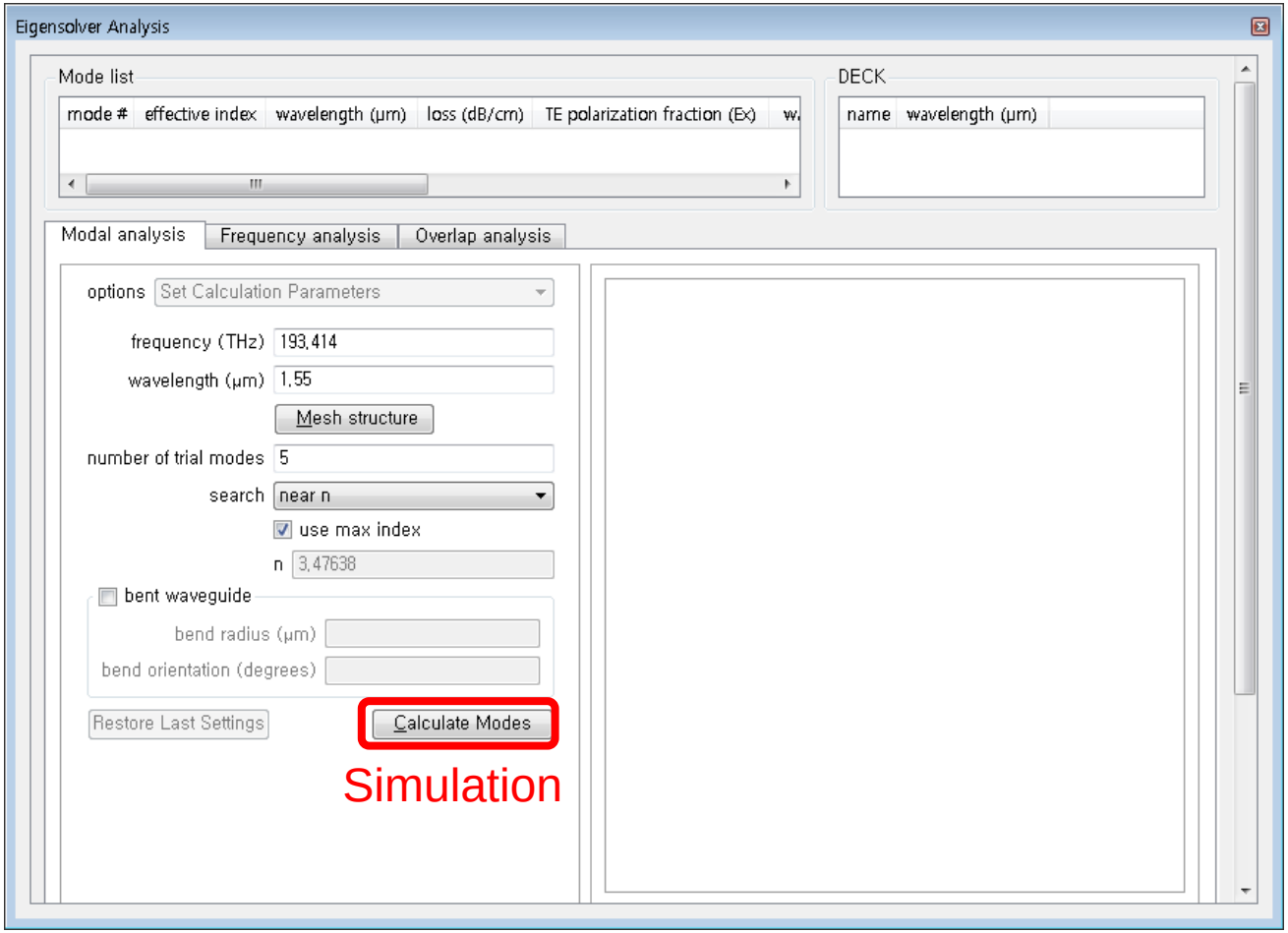
# Simulation Setup(GUI)



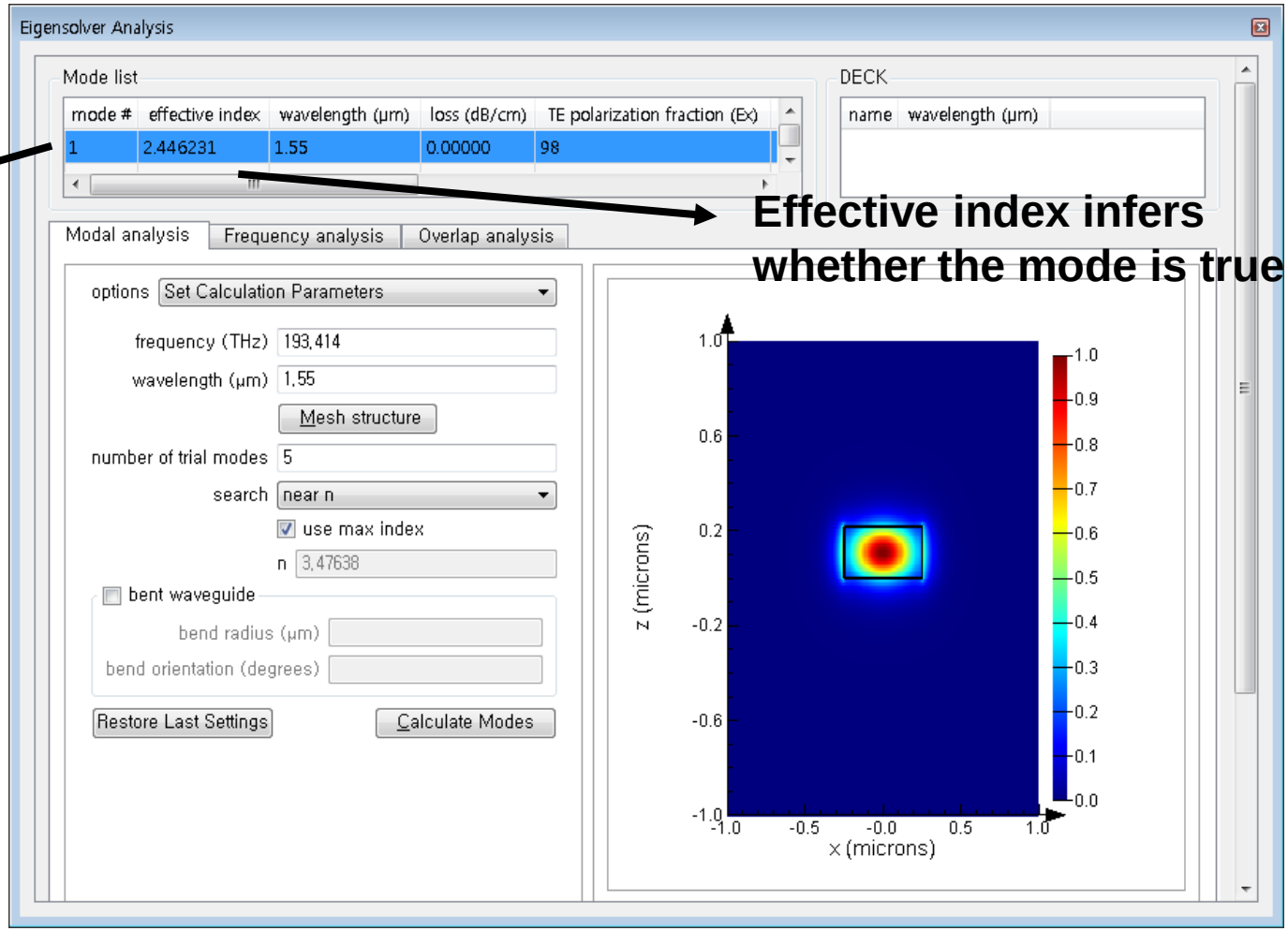
# Simulation Setup(GUI)



# Simulation Setup(GUI)



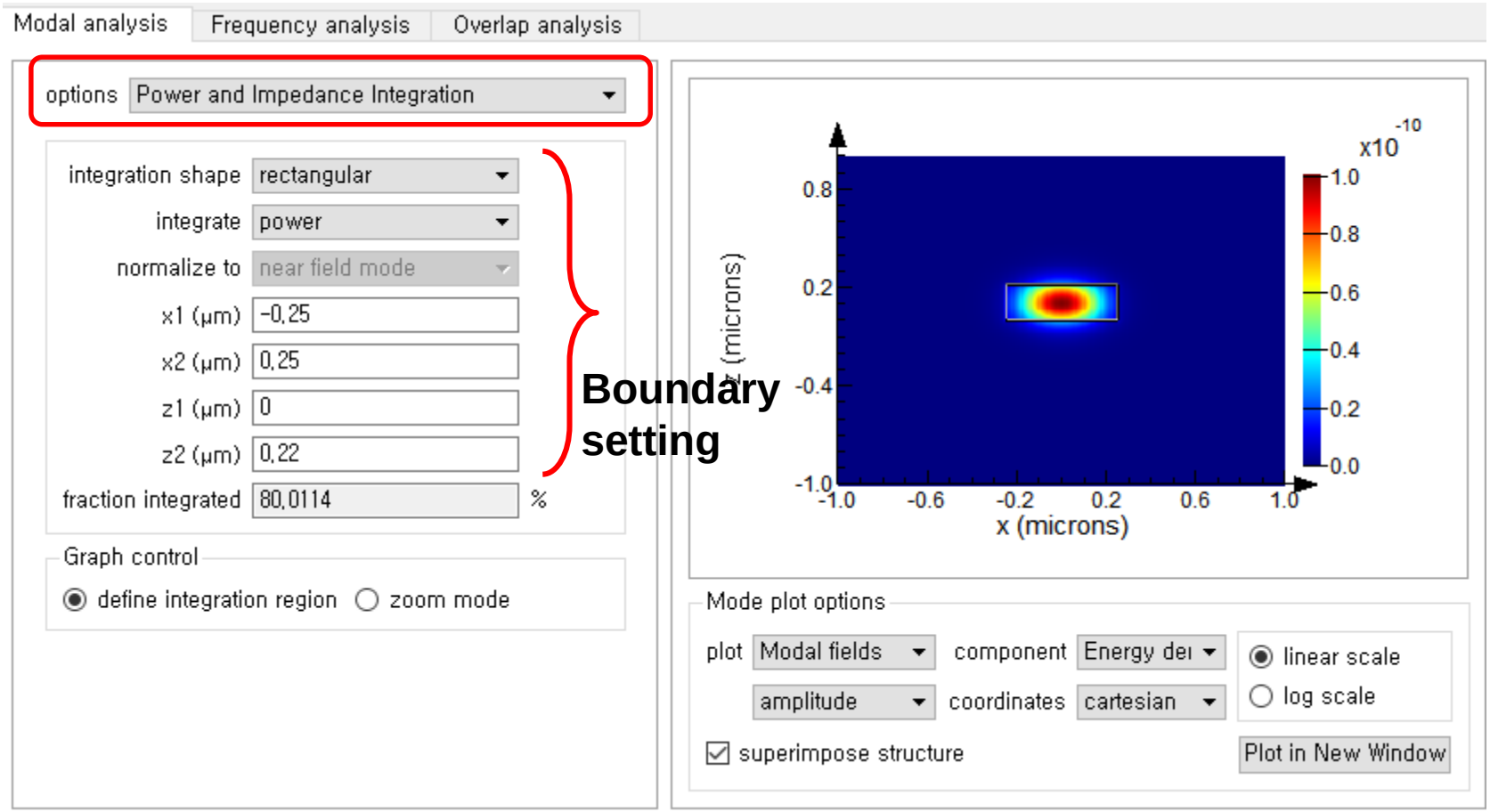
# MODE Solutions



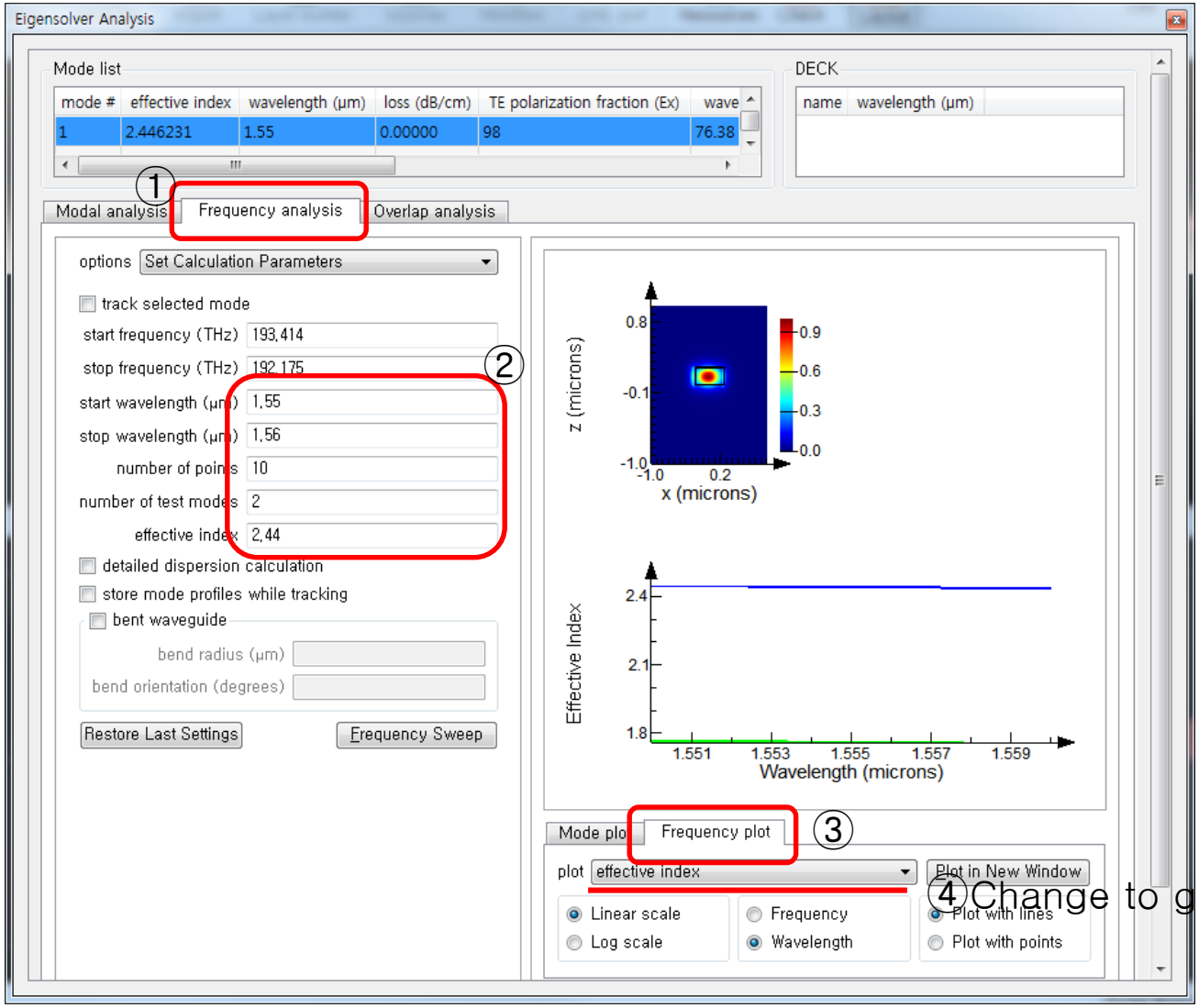

**Calculated modes**

**Effective index infers whether the mode is true or not**

# Confinement Factor

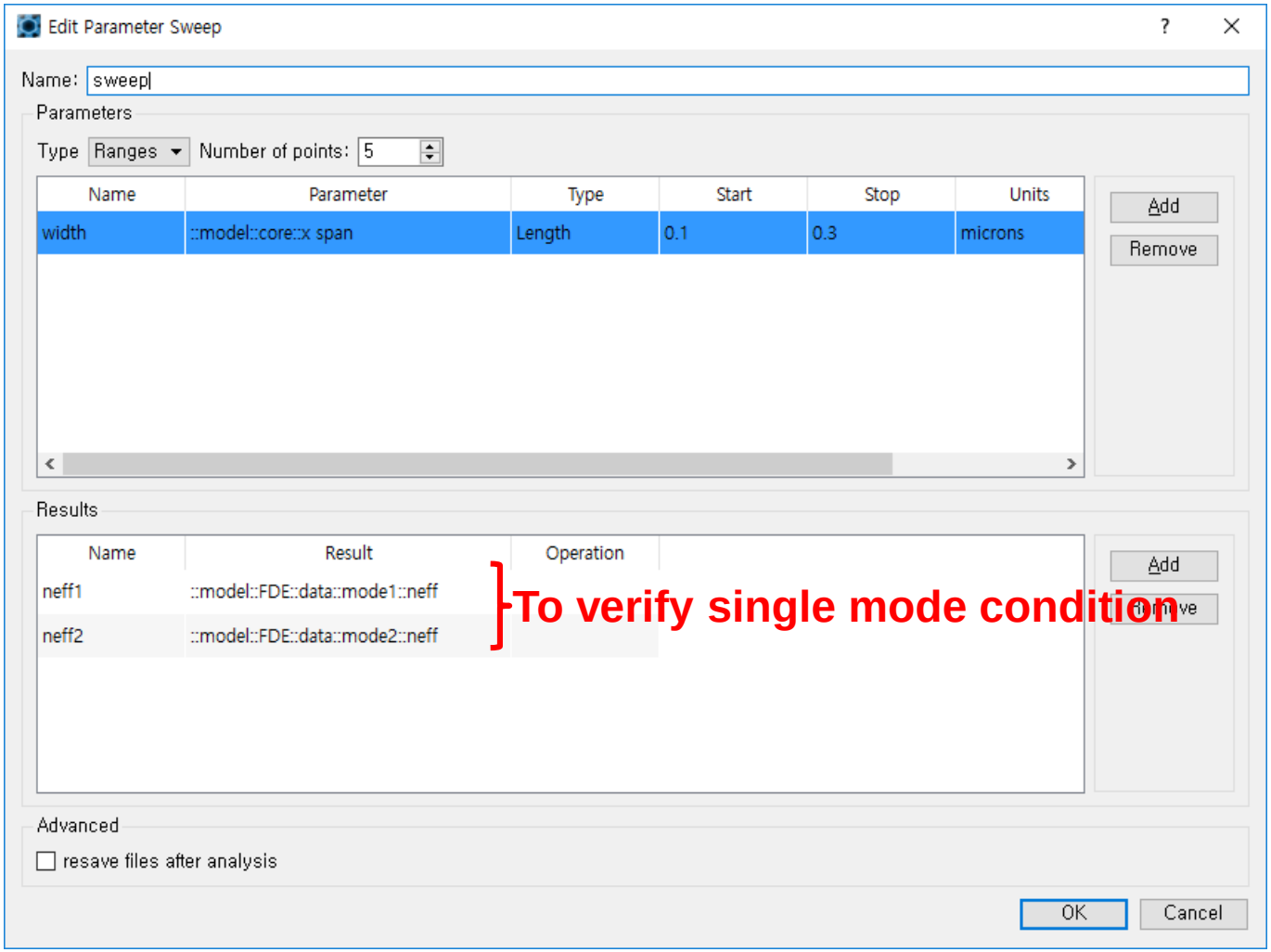


# Group Index($n_g$)

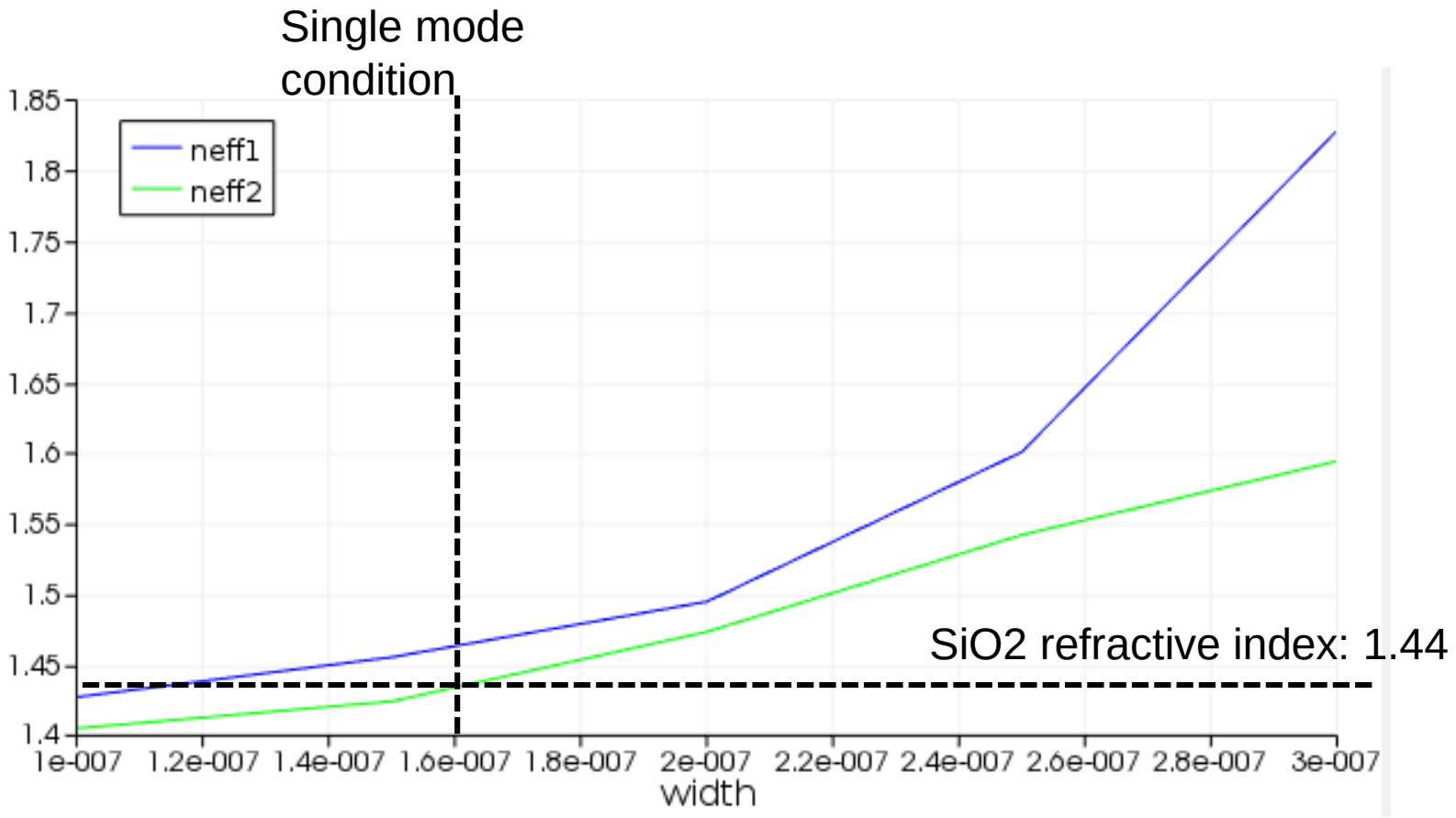


# Sweep Width

**Sweep waveguide width from 100nm to 300nm with 50nm step**



# Sweep Results

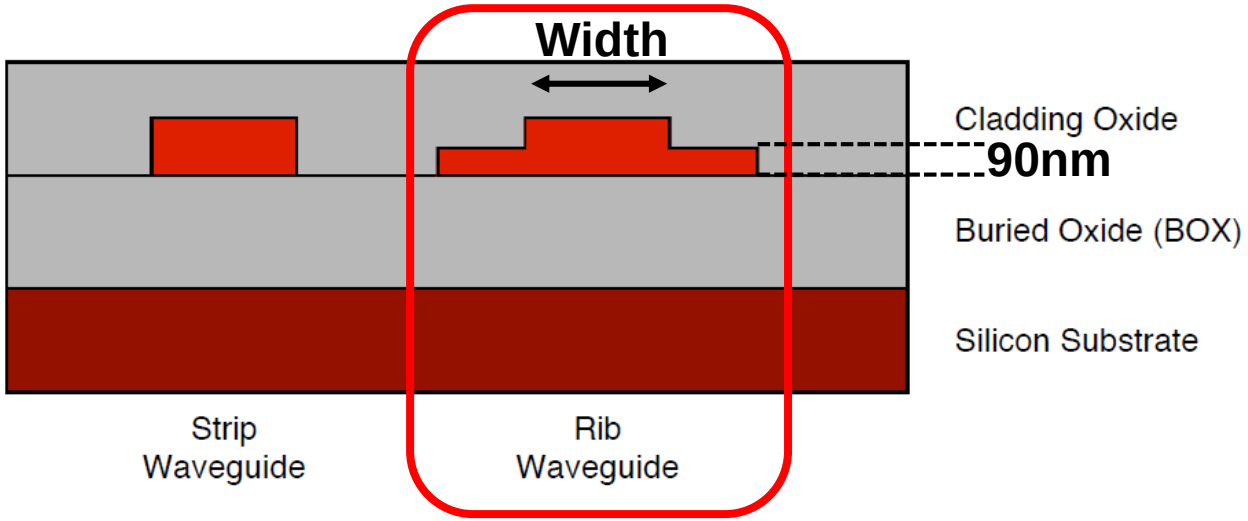


# Design Exercise 2-1

**What is the single-mode condition for the given thickness of rib waveguide? Also, calculate group index($n_g$) for the single-mode rib waveguide.**

-220nm thick & 90nm slab at 1550nm

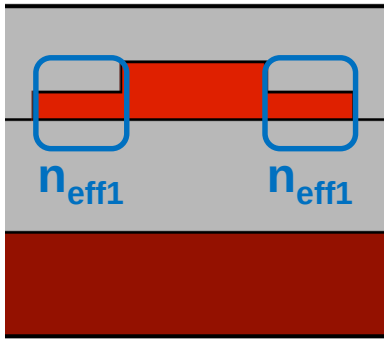
**Due: 30 Nov. in class**



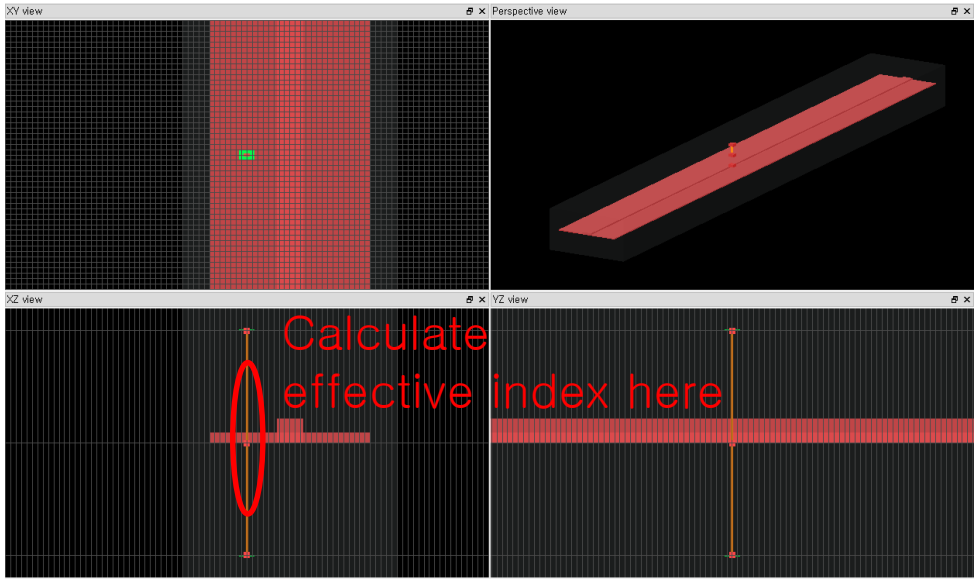
# Design Exercise 2-1

- **Condition for guidance of rib waveguide**
  **:$n_{eff\_total} > n_{eff1}$**
  **:Making same environment as strip waveguide**

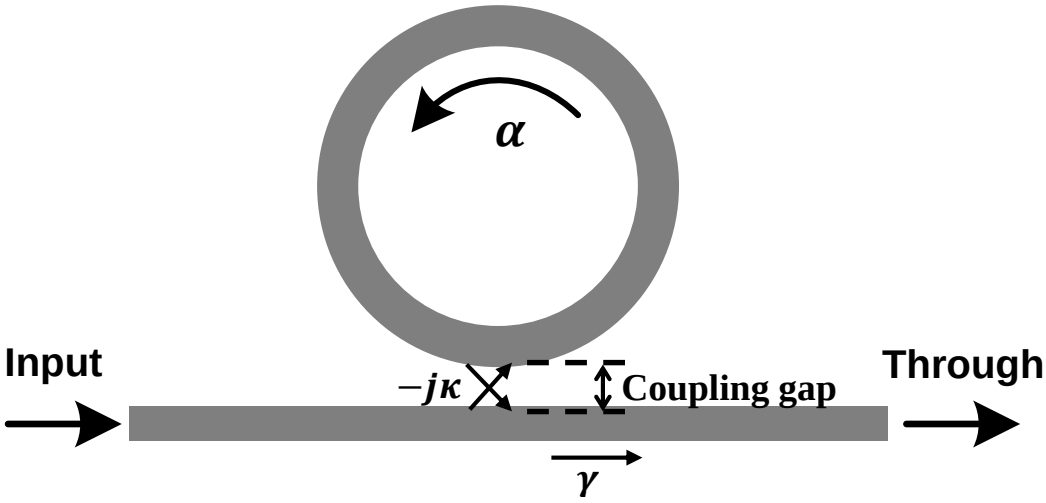
- **How to get $n_{eff1}$**
  **:Use 1-D Z:X prop simulation in FDE solver**

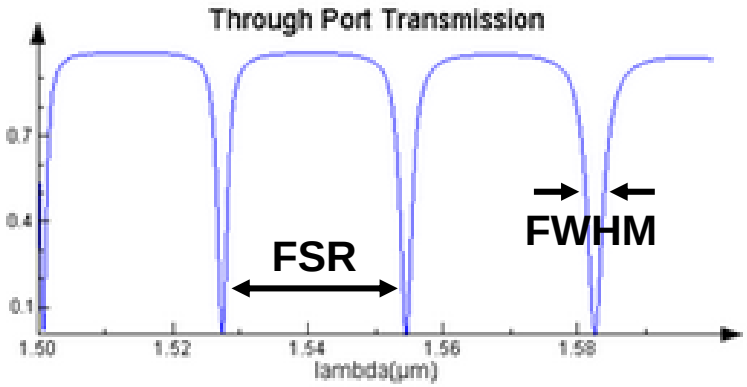



Rib
Waveguide



# Ring Resonator




-Resonate on specific wavelength, $\lambda_{res}$

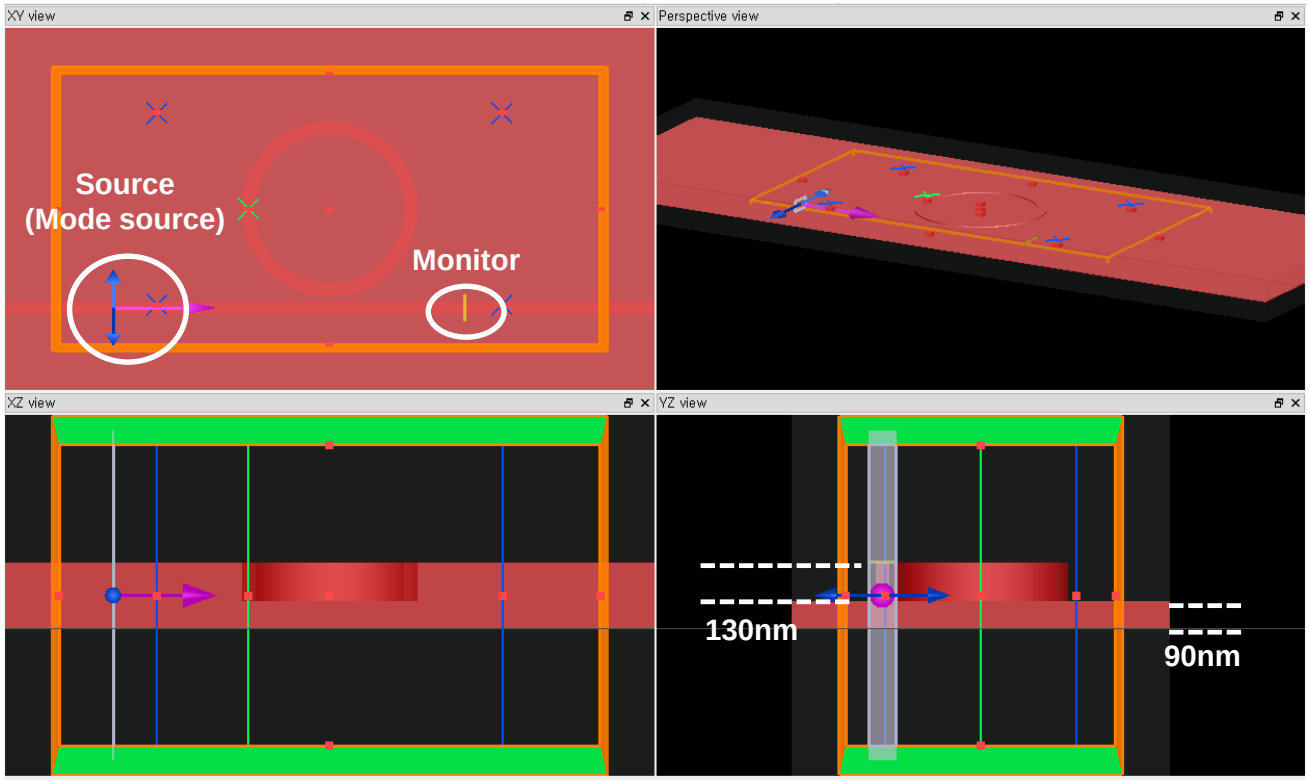
-Key parameters : $\alpha, \gamma, \kappa$ and assume $|\gamma|^2 + |\kappa|^2 = 1$

-$FSR = \frac{\lambda_{res}^2}{n_g L}$ , $FWHM = \frac{(1-\alpha\gamma)\lambda_{res}^2}{\pi n_{eff} L \sqrt{\alpha\gamma}}$

-$\alpha, \gamma, n_{eff}, n_g$ are determined by simulation

➔ FSR, FWHM(Full-Width Half Maximum) can be calculated

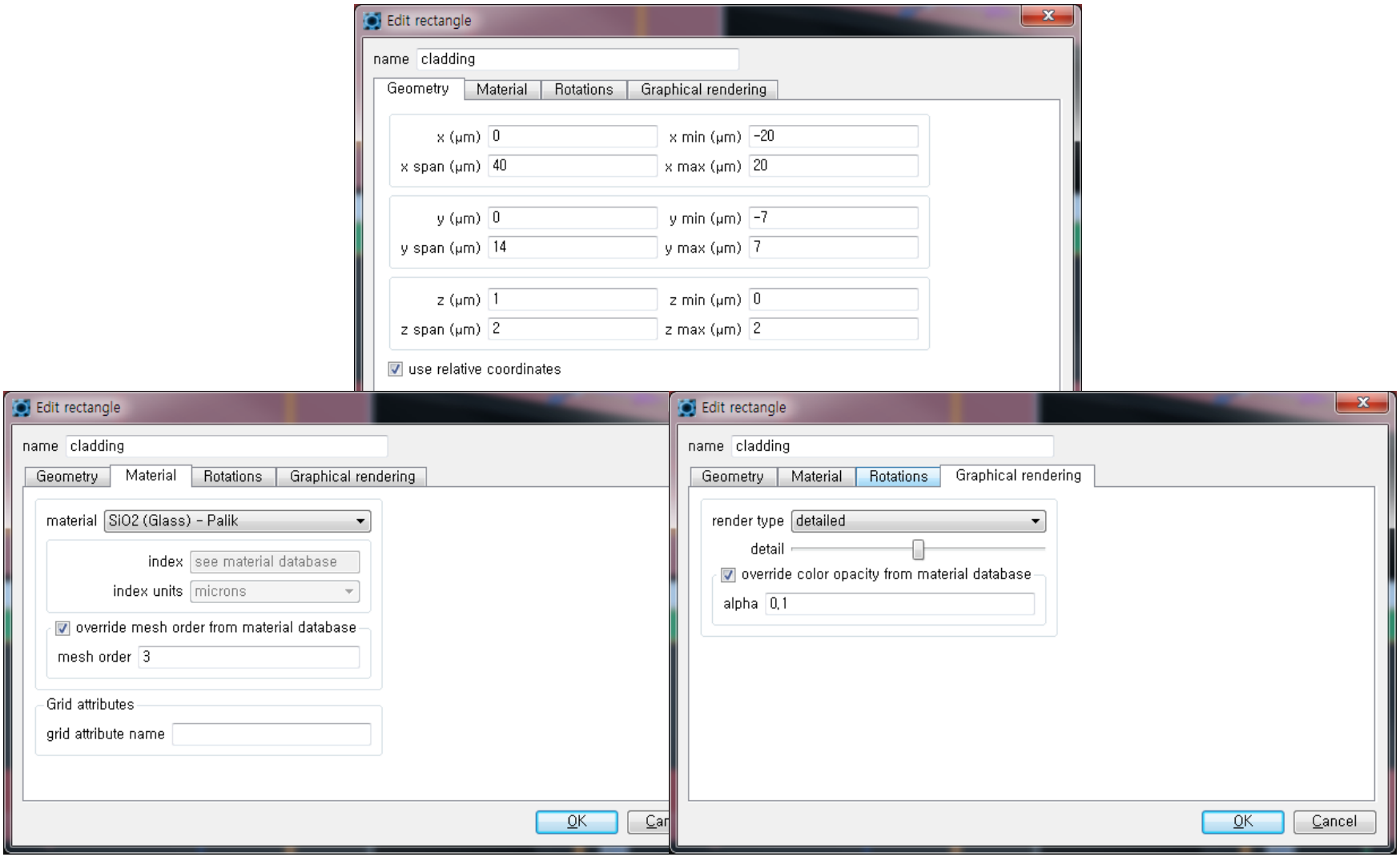
# Structure



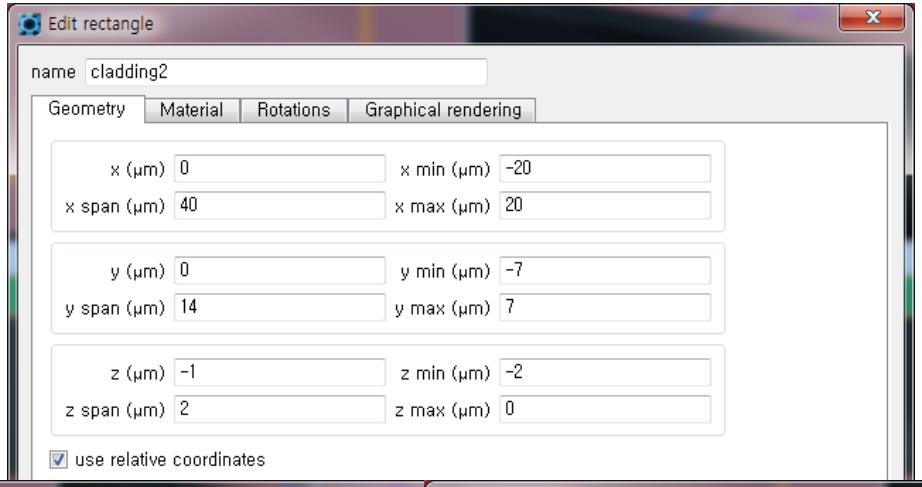

- Rib waveguide
  -Width : 500nm
  -Thick : 220nm
  -Slab : 90nm

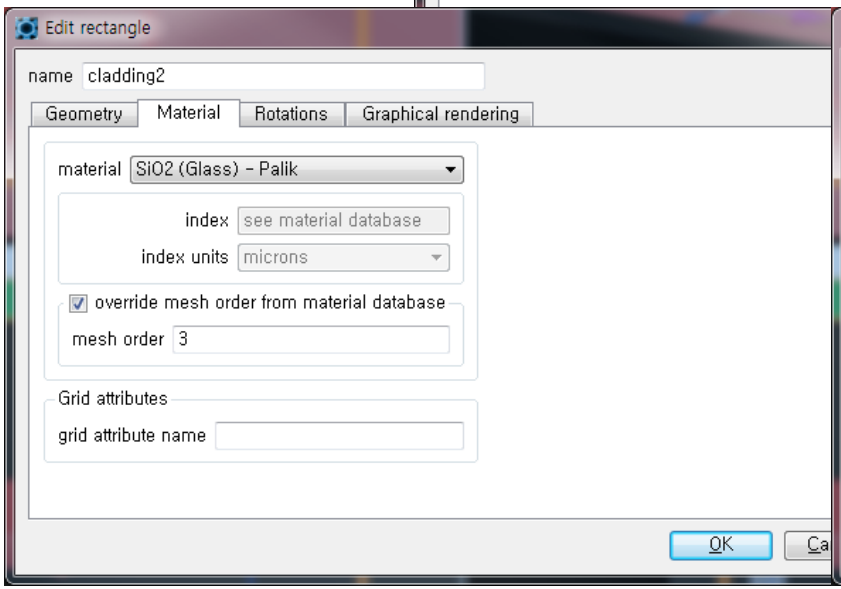
- Resonator
  -gap : 150nm
  -radius : 3um

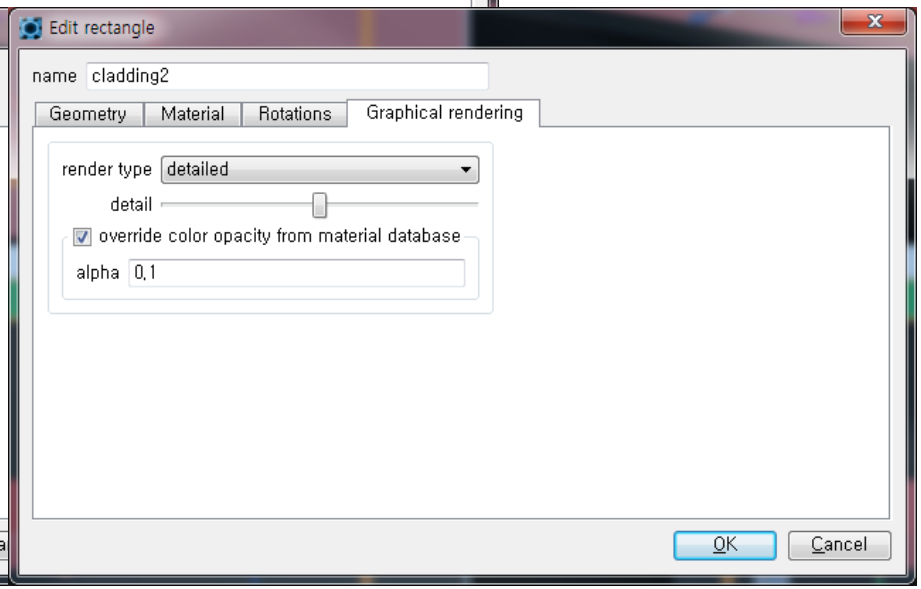
# Structure(Cladding)



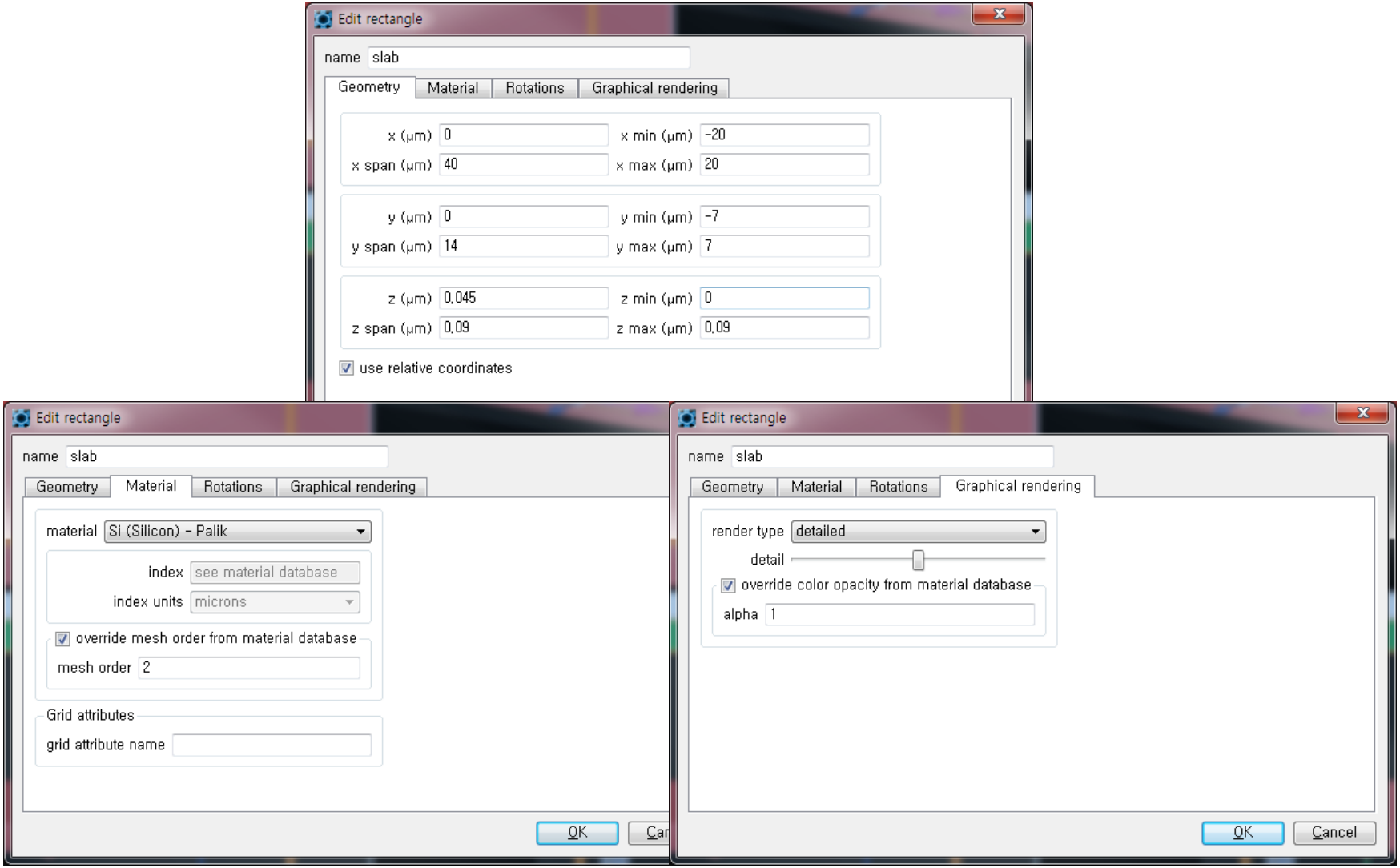
# Structure(Cladding2)



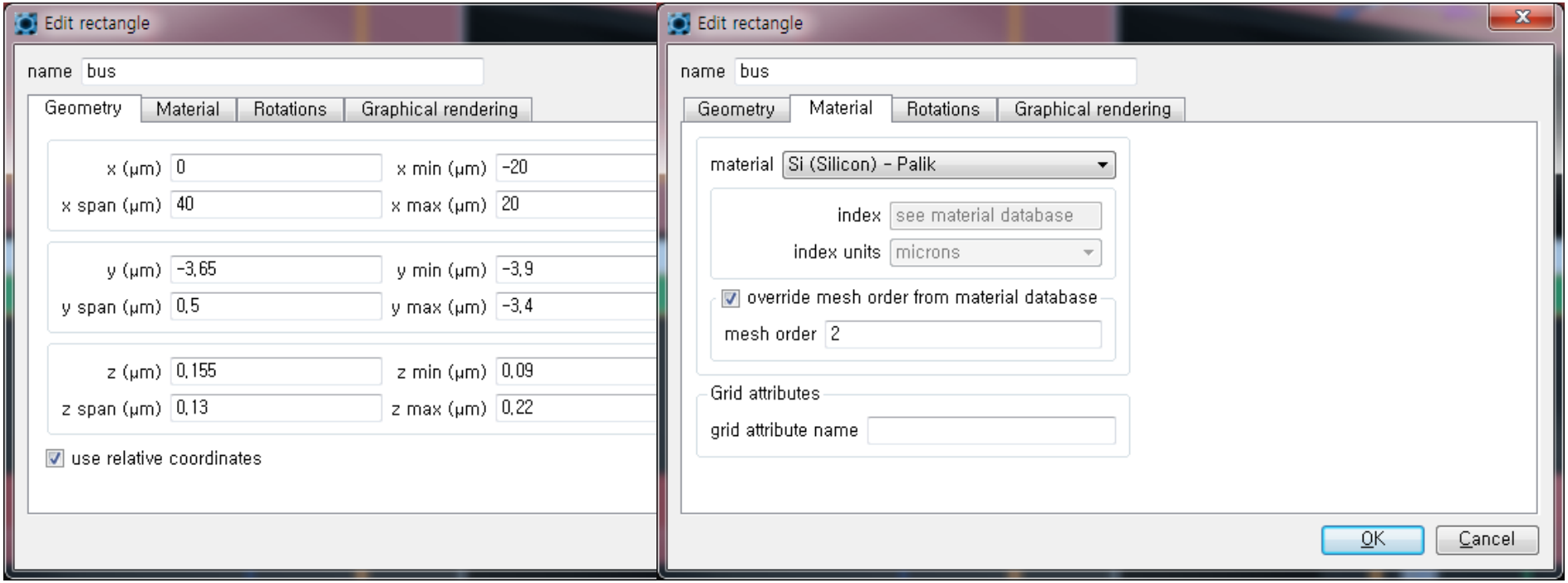



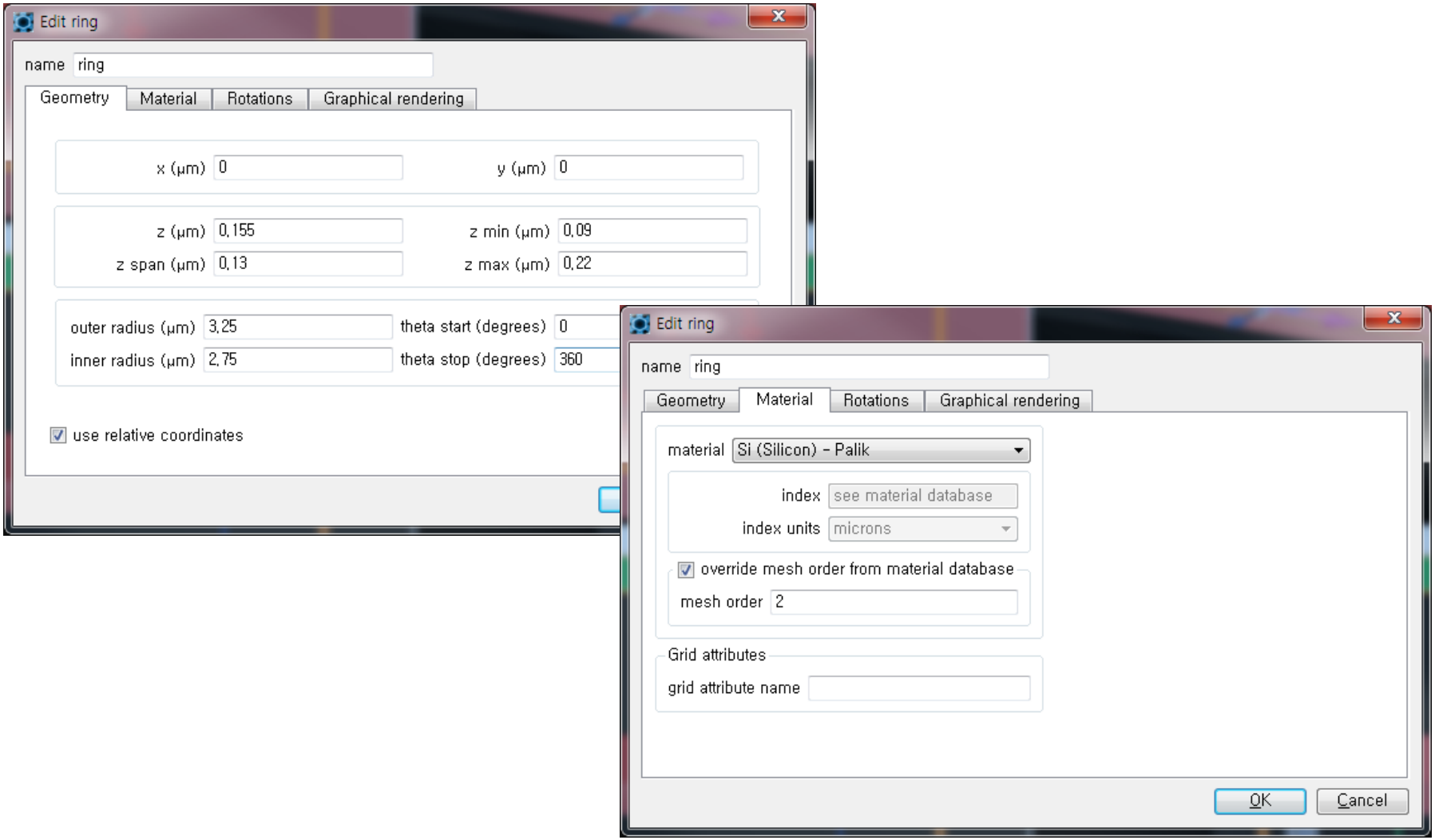
# Structure(Slab)



# Structure(Bus Waveguides)

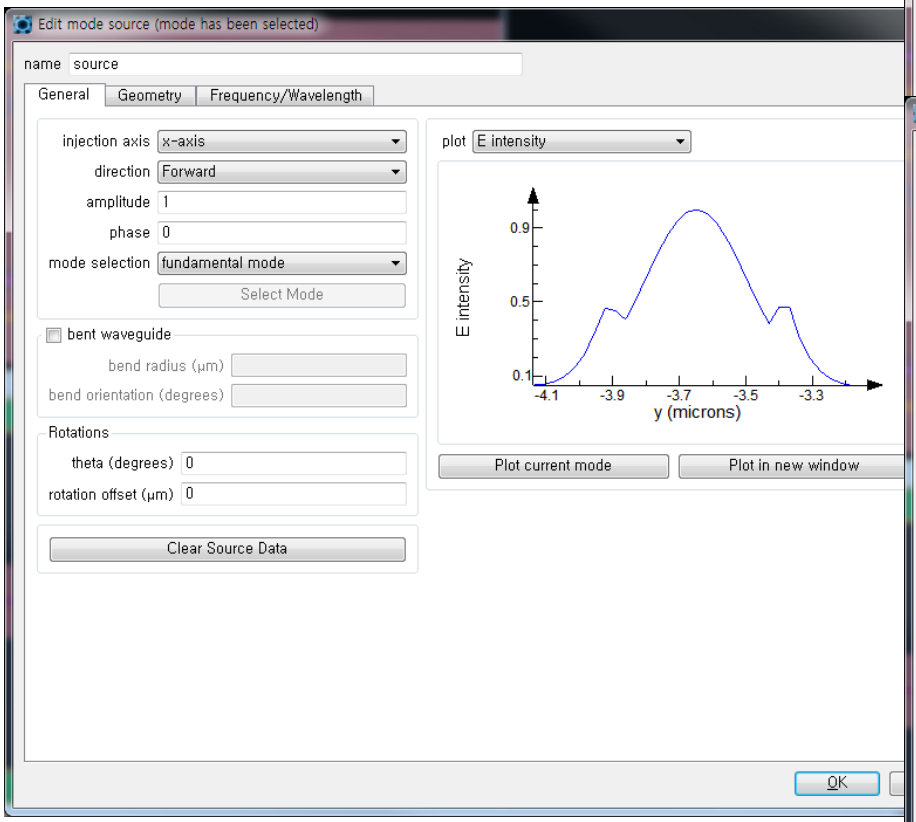


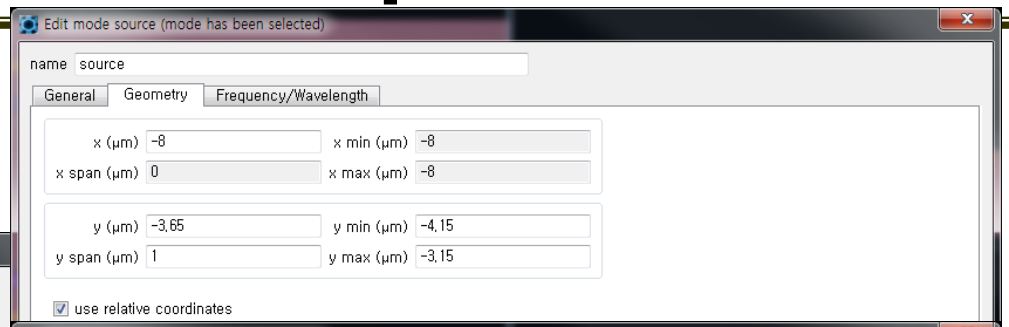
# Structure(Ring)

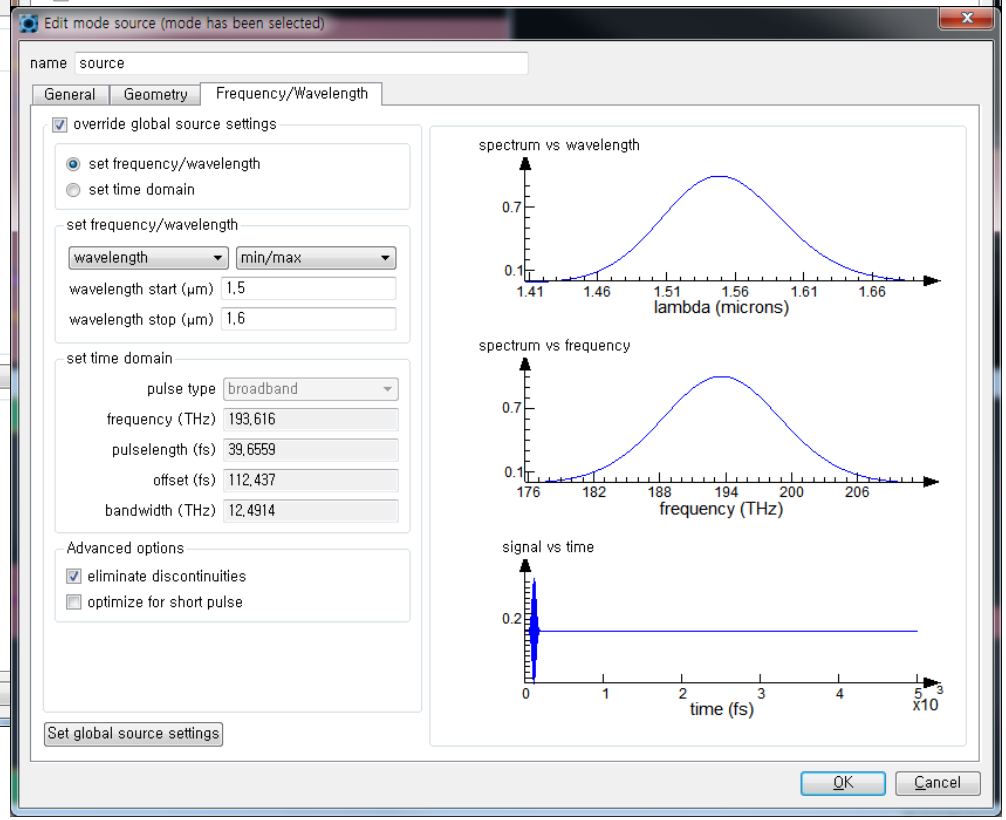


# Simulation setup

- **Source Setting (MODE source)**

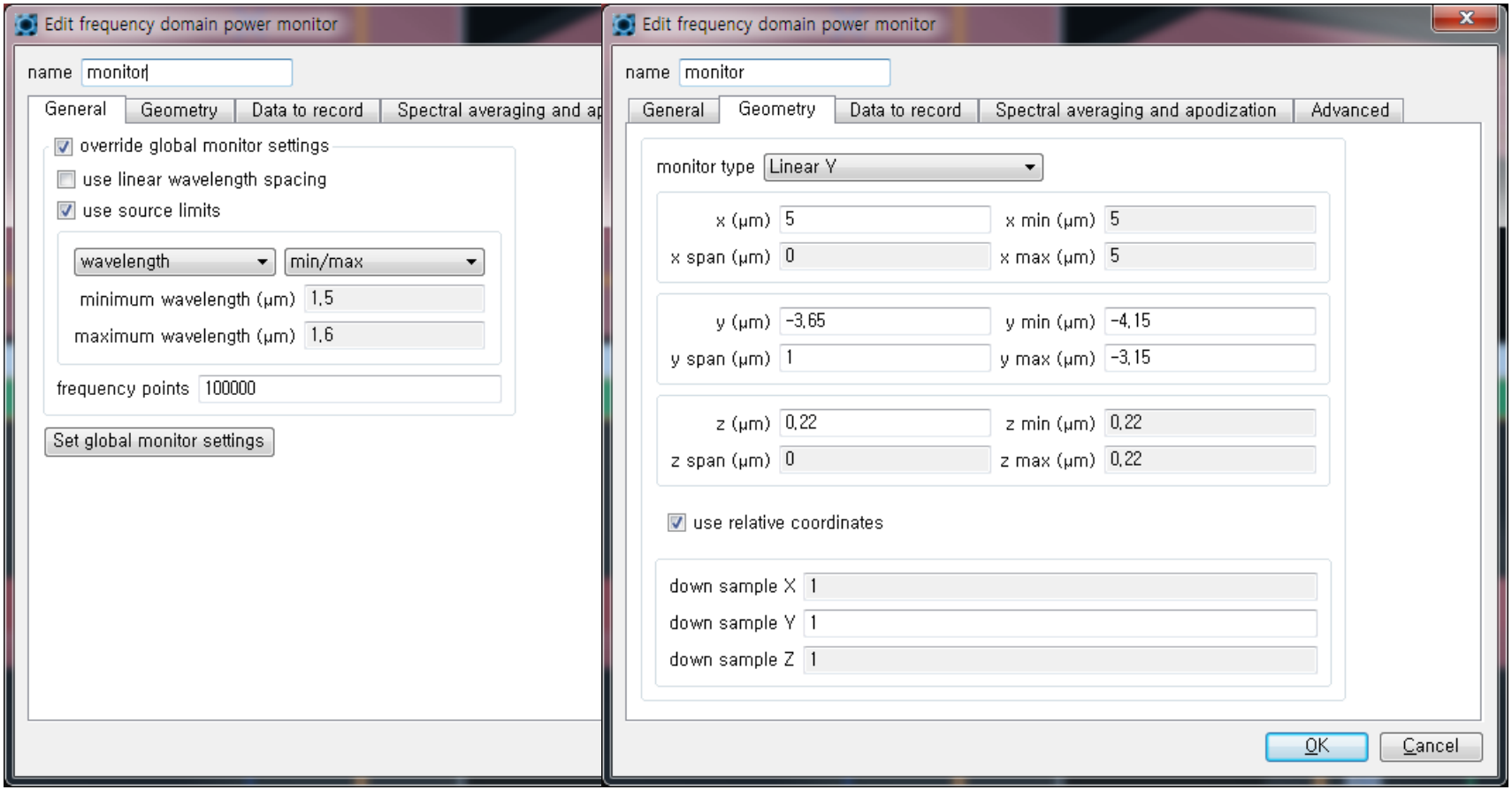


# Simulation Setup

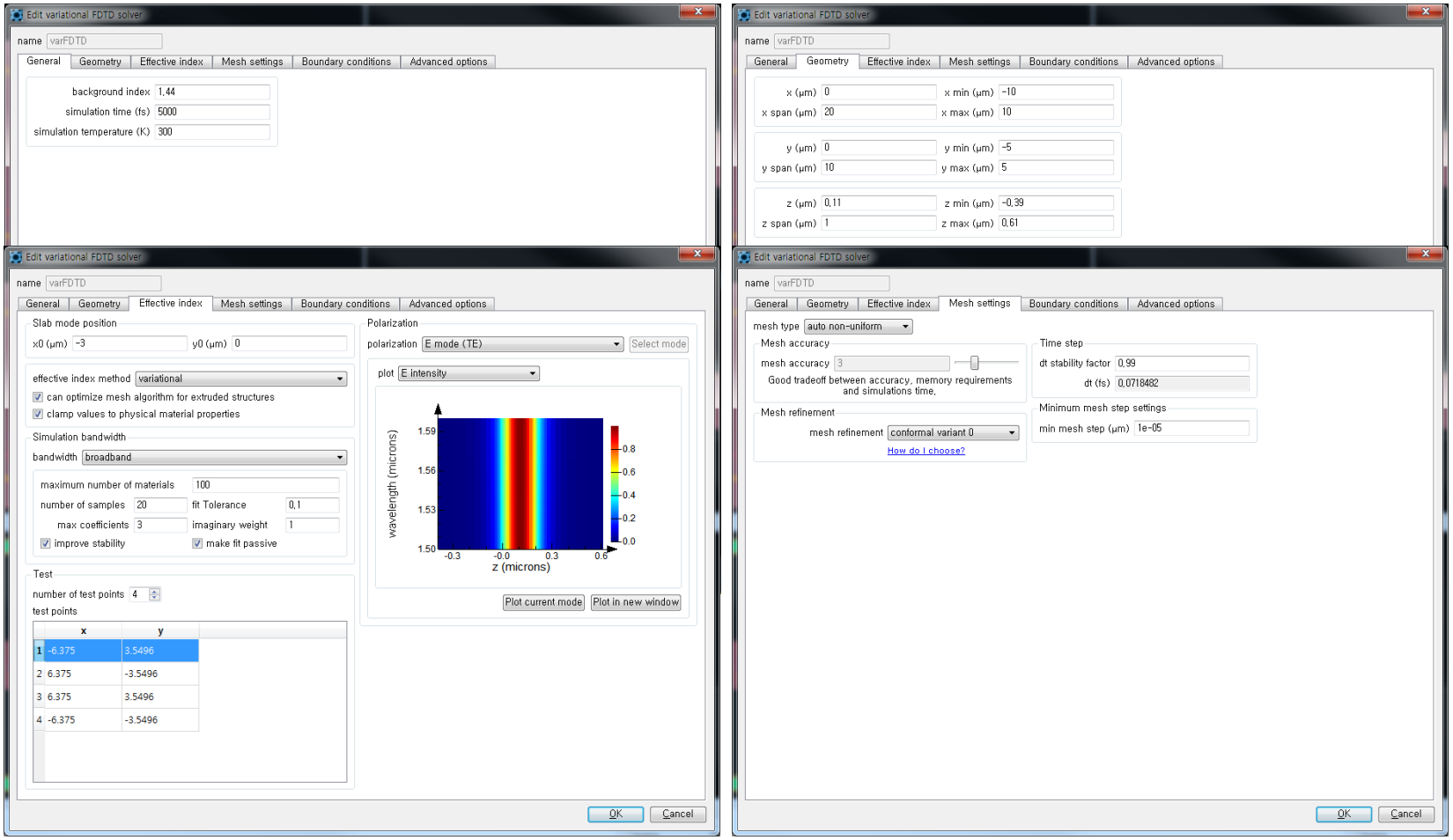
- **Monitor Setting(Frequency domain field and power)**




-Frequency point should be large enough

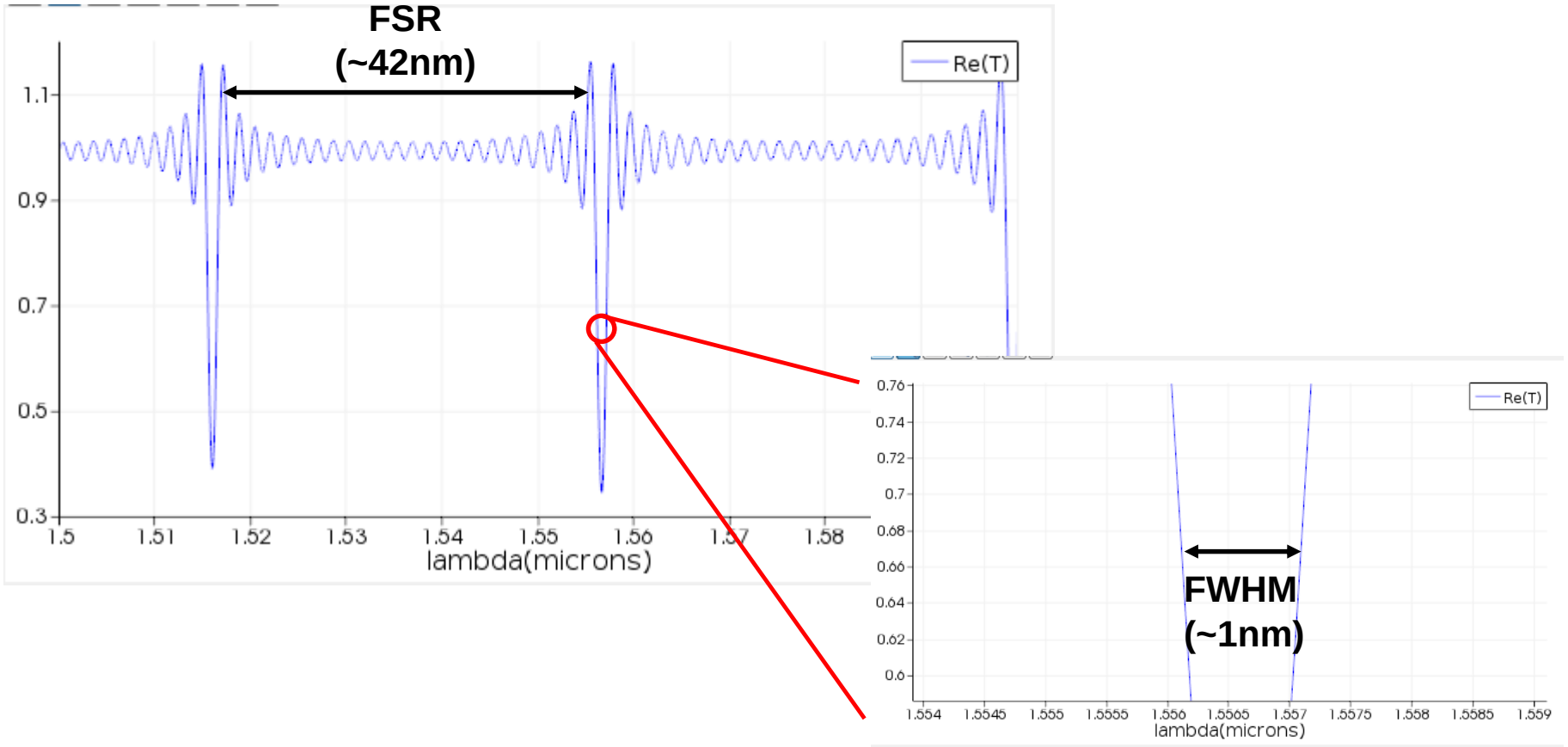
# Simulation Setup

- **2.5D FDTD Solver Setting(Variational FDTD Solver)**



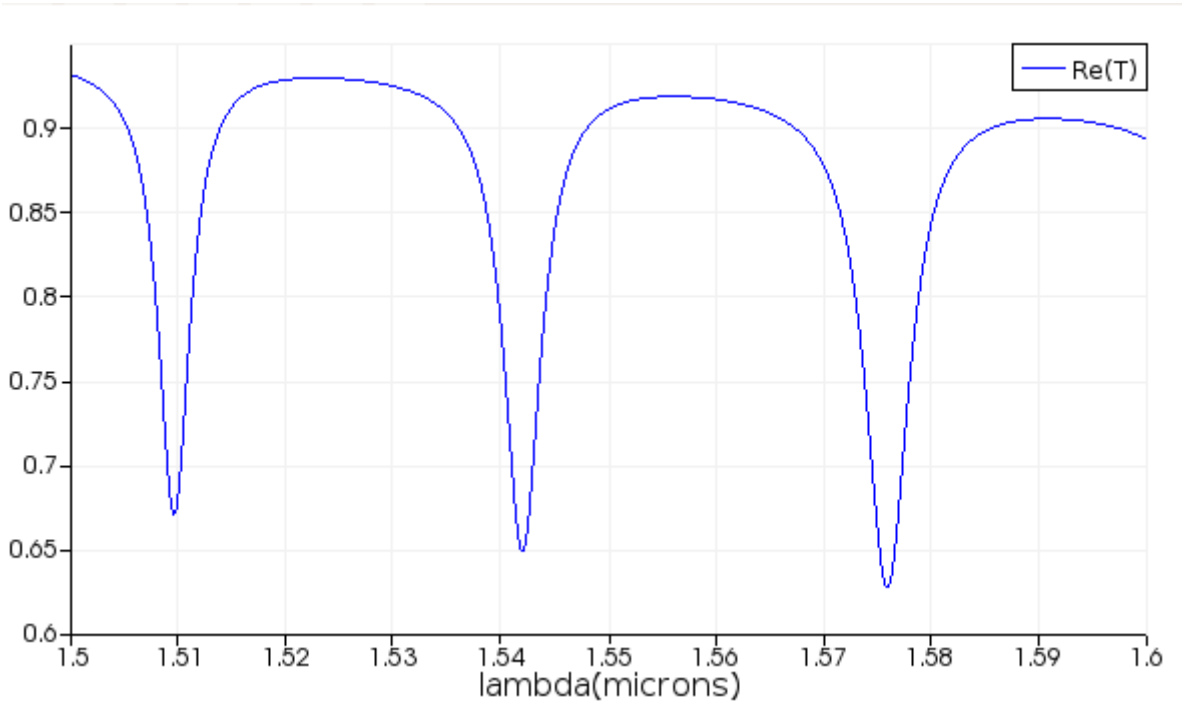
# Transmission Curve

- **Simulation Result**



# FDTD Simulation Comparison

- Same simulation condition
- Source: z span 500nm, z center 110nm
- Monitor: 2D X-normal monitor, z span 500nm, z center 110nm
- Simulation: 3D, 5000fs simulation time



# Design Exercise 2-2

**Use the rib waveguide designed in Design Exercise 2-1, and design & analyze ring resonator with MODE to satisfy specification below. Also, compare & analyze the result with FDTD simulation.**

$$FSR > 40nm$$
$$FWHM < 0.8nm$$
$$1.55\mu m\ wavelength$$

**Due: 30 Nov. in class**