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Nano-lens and pixel simulations using OptiFDTD

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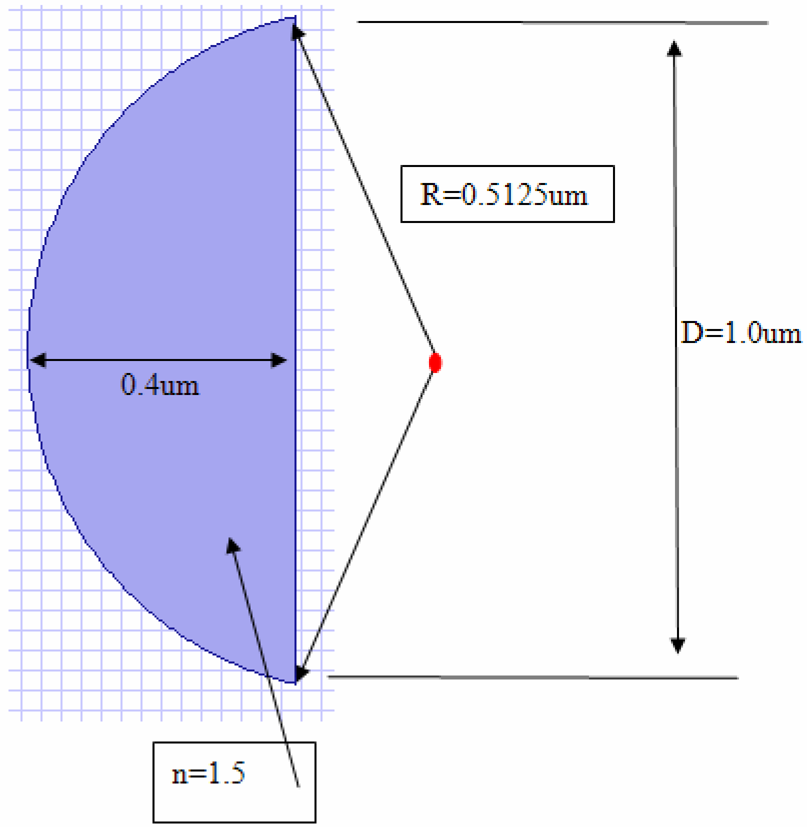
Micro Optical Lens and pixel simulations using OptiFDTD

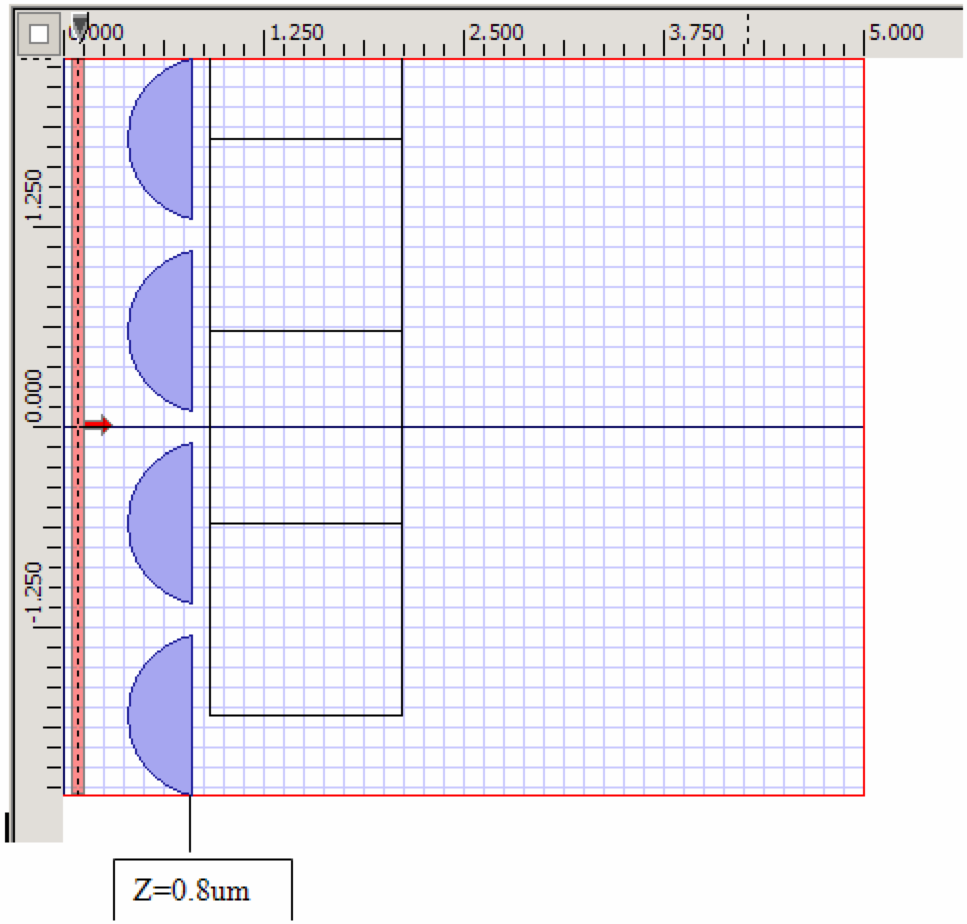
- **Micro-lens with dimension compatible with working wavelength is not suitable using the Ray-tracing method.**
- **Micro-Lens in Pixel layout and image application can be simulated using OptiFDTD.**
- **Layout sweep simulation can scan the Lens' parameters.**
- **Tools in OptiFDTD can measure the focusing distance, focusing spot size, transmission and more.**
- **This presentation will explore the extensive simulation and post processing tools included with OptiFDTD.**

(1) Example1---4*4 Lens array

Lens dimension

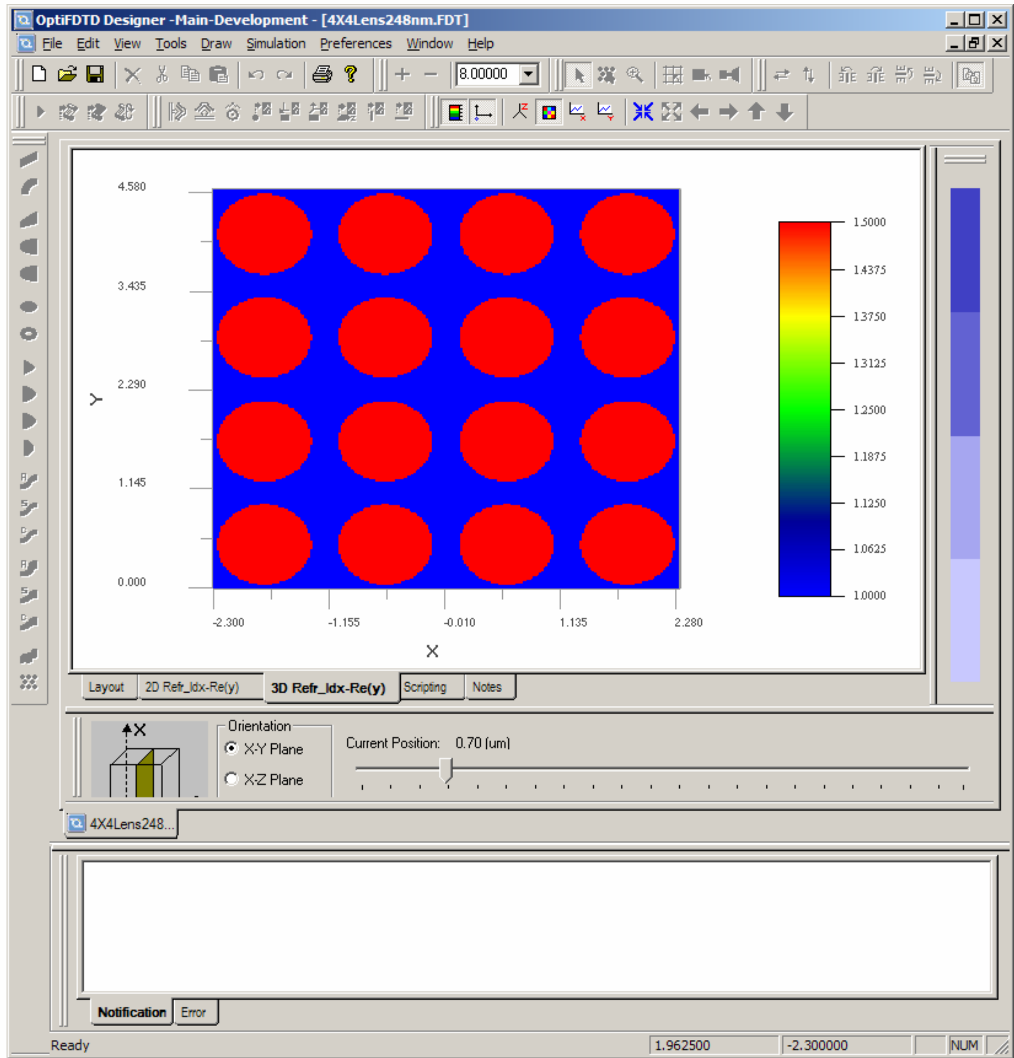


Example1---4*4 Lens array in OptiFDTD



Example1---4*4 Lens array in OptiFDTD

(3) XY plane at z=0.7



Simulation domain

4.6um*4.6*5.0um

X: -2.3---2.3um

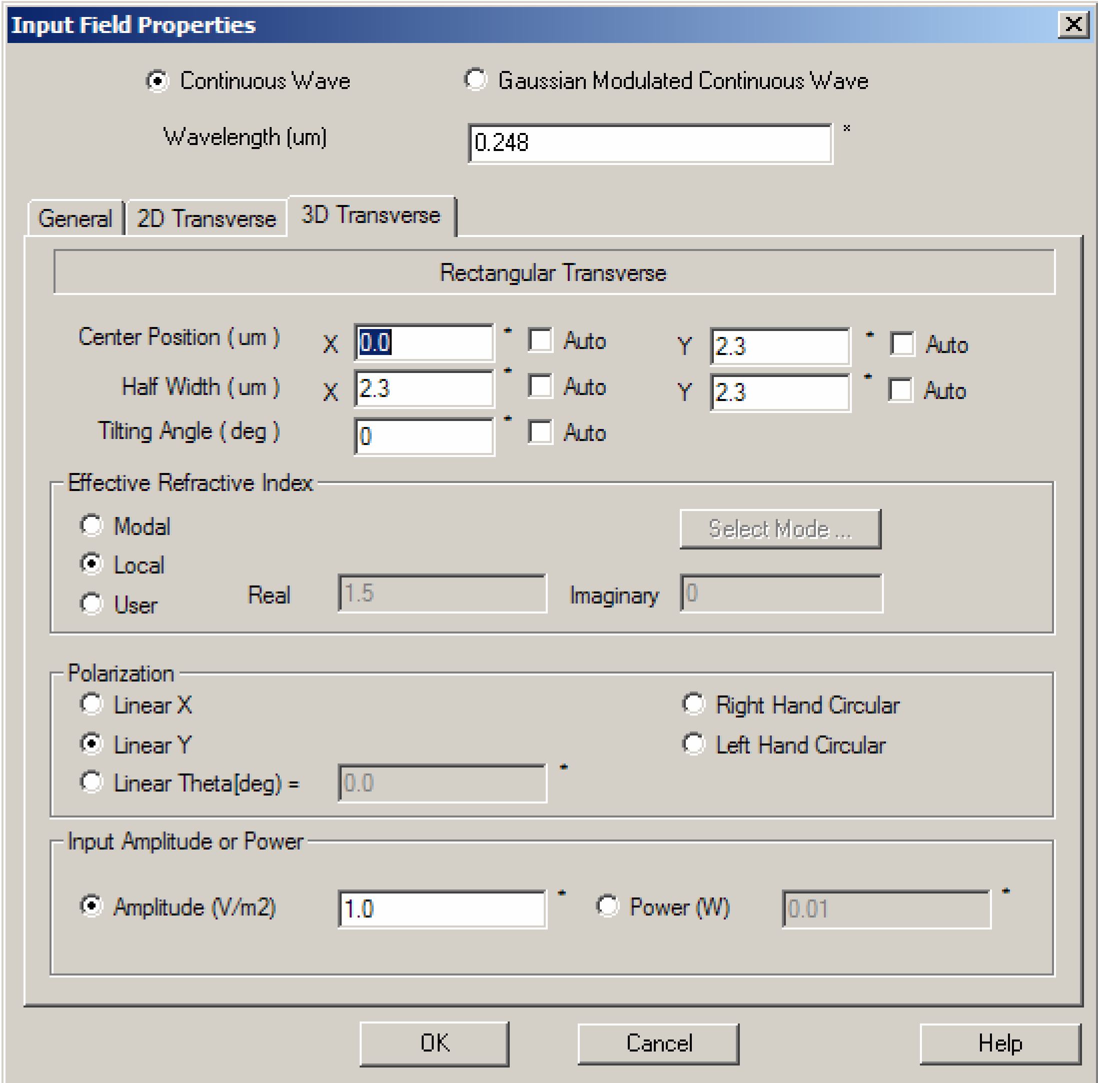
Y: 0.0--- 4.6um

Z: 0.0---5.0um

Example1---4*4 Lens array---input wave

(a) Input transverse is set as y-polarized plane wave in the whole xy plane. Boundary condition makes the plane wave straight forward propagate to the lens.

(b) Select from a variety of input transverse beam formats: Modal, Gaussian, or user defined.



Example1---4*4 Lens array---Simulation parameters

(5) Simulation Parameters

(a) Mesh size

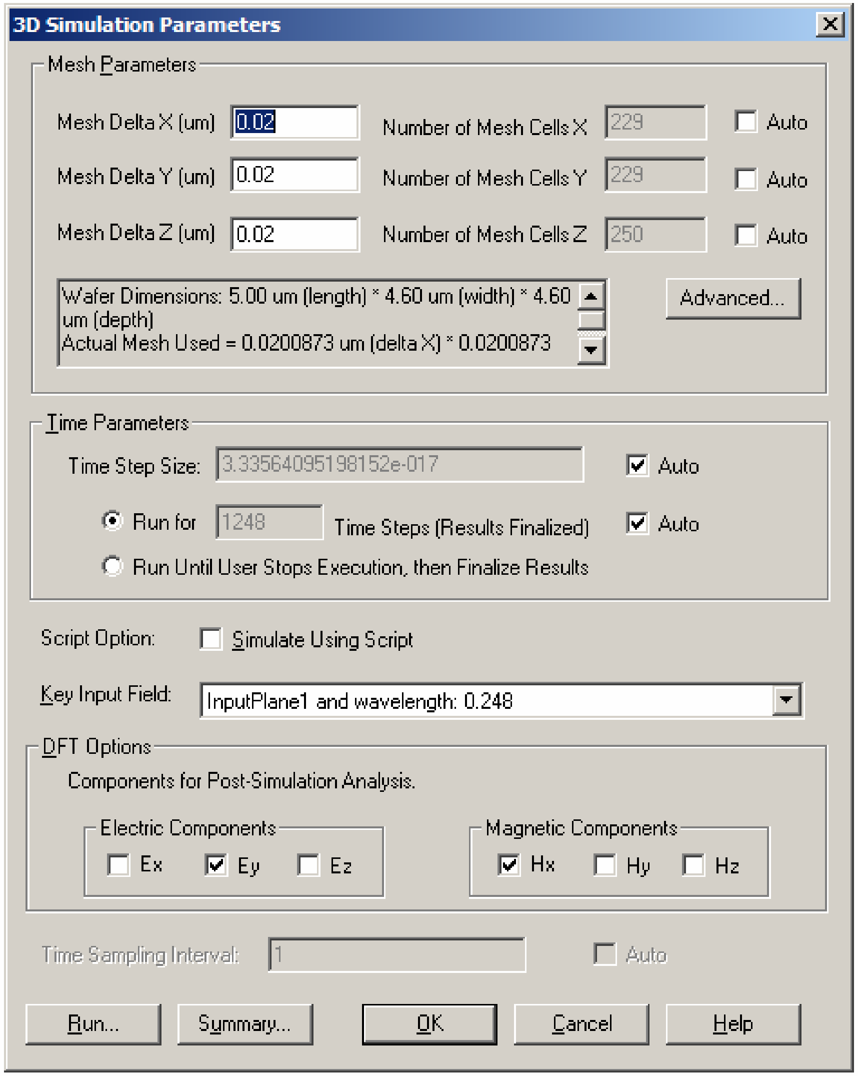
0.02um*0.02um*0.02um

(b) Run for 1248 time step +

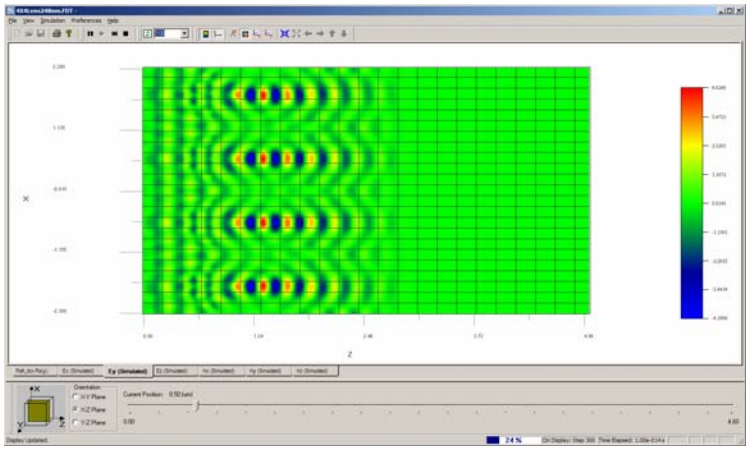
10 additional cycle to get the steady state field

(c) Calculate steady state field for Ey and Hx (Disretized Fourier transform)

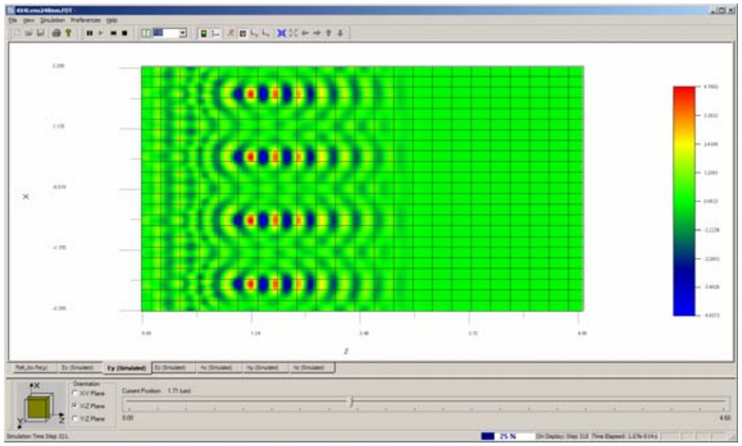
(d) x-y boundary use the upper-lower symmetric boundary condition. Z-direction user the APML as the boundary condition



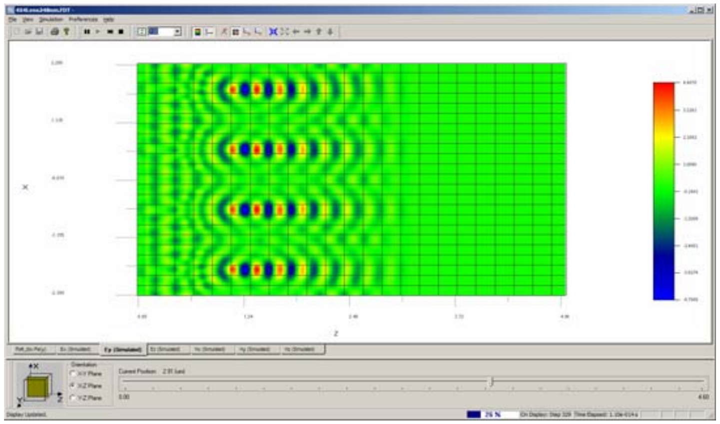
Simulation ---Observe the time domain response (time step around 310)



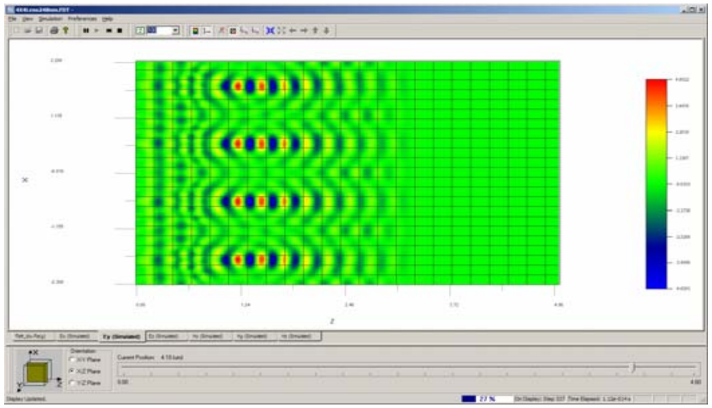
Ey at xz plane at y=0.5 (the center of first row)



Ey at xz plane at y=1.7 (the center of second row)

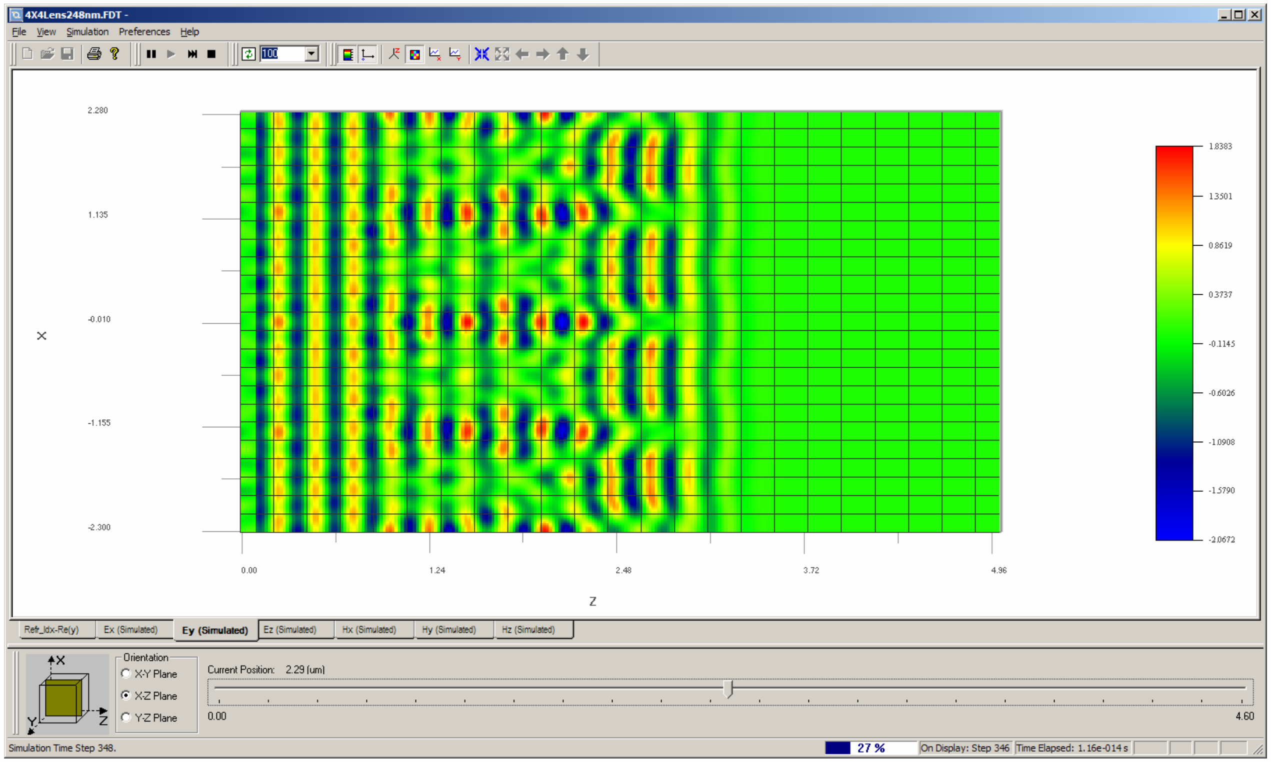


Ey at xz plane at y=2.9 (the center of third row)



Ey at xz plane at y=4.1 (the center of third row)

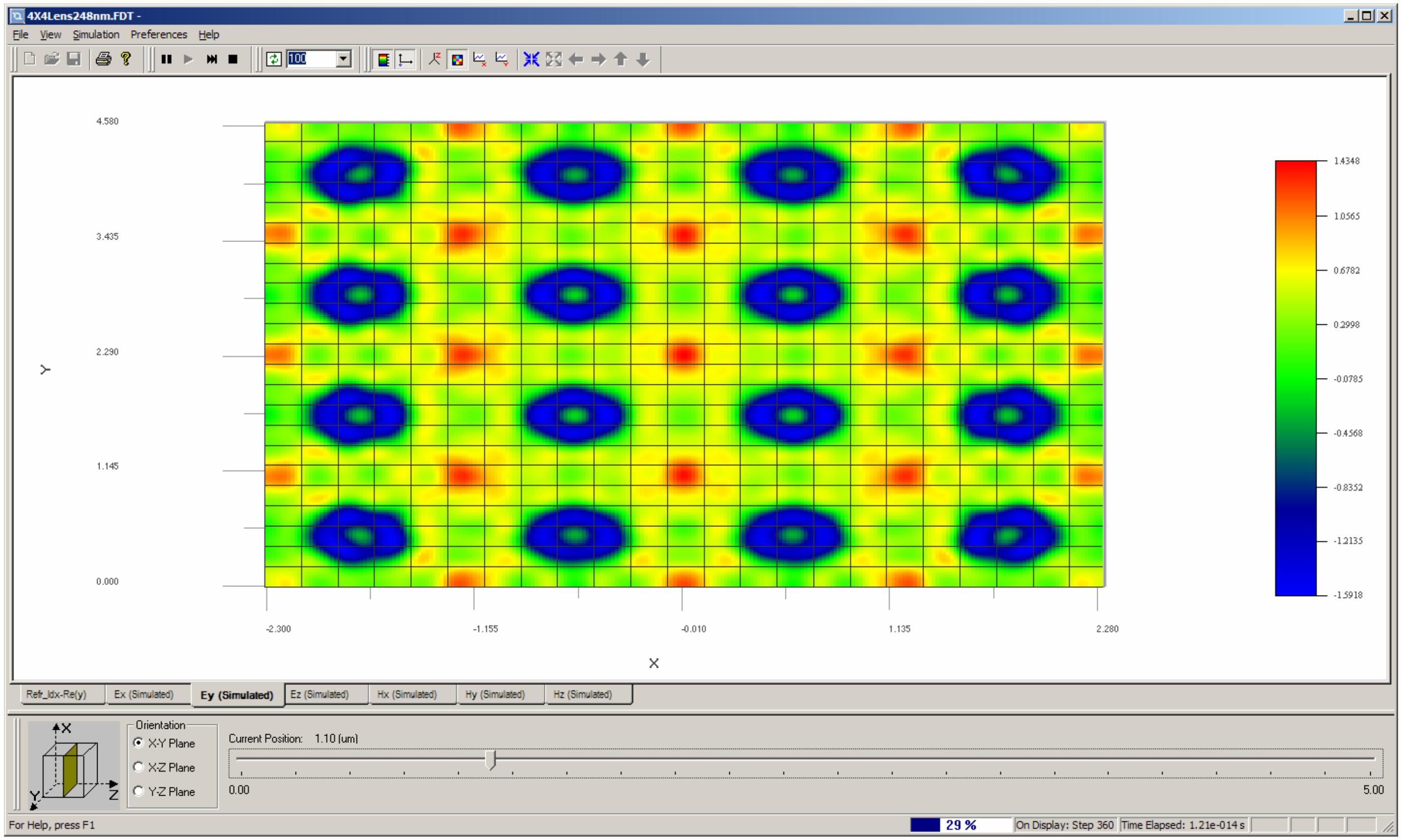
Simulation ---Observe the time domain response (time step around 310)



Ey at xz plane at y=1.8 (the center of domain)

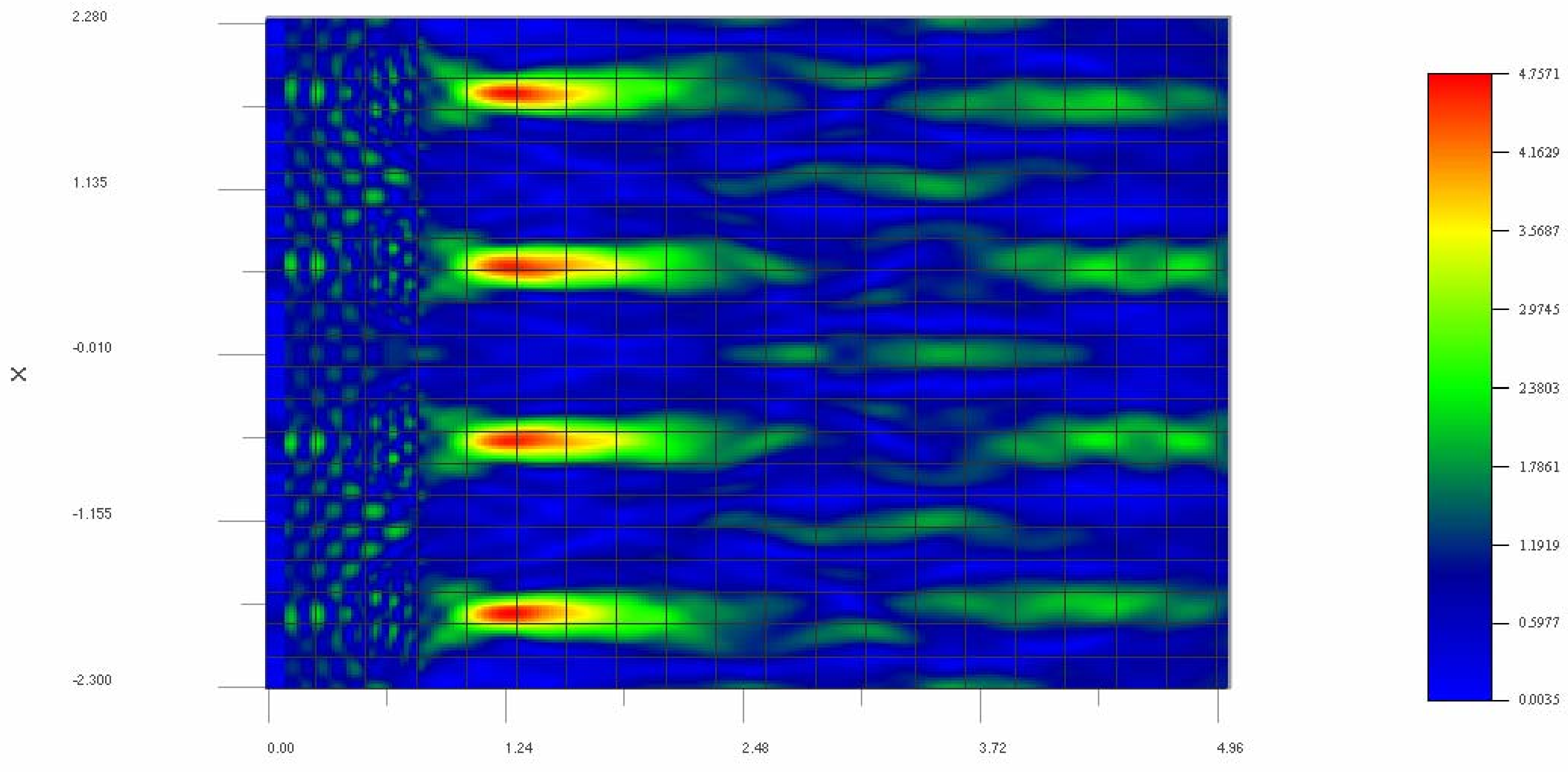
Simulation uses 761.58MB RAM and CPU time 1:33:49

Simulation ---Observe the time domain response (time step 360)



Ey at xy plane at z=1.1 (300nm from lens edge z=0.8um)

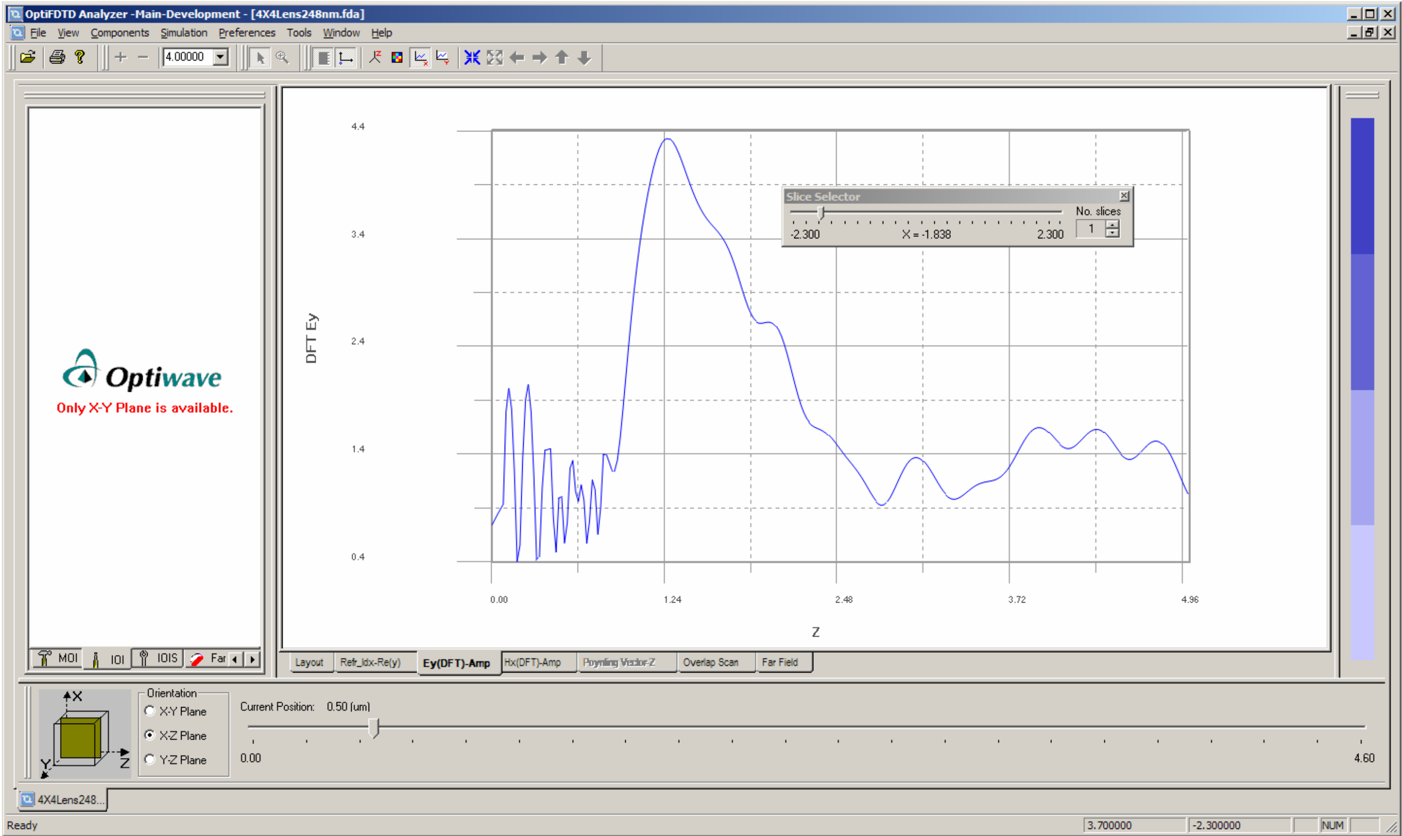
Analyzer ---Observe the steady state response



Ey at xz plane at y=0.5 (the center of first row)

*steady state response can be observed in any xy, yz, zx slice

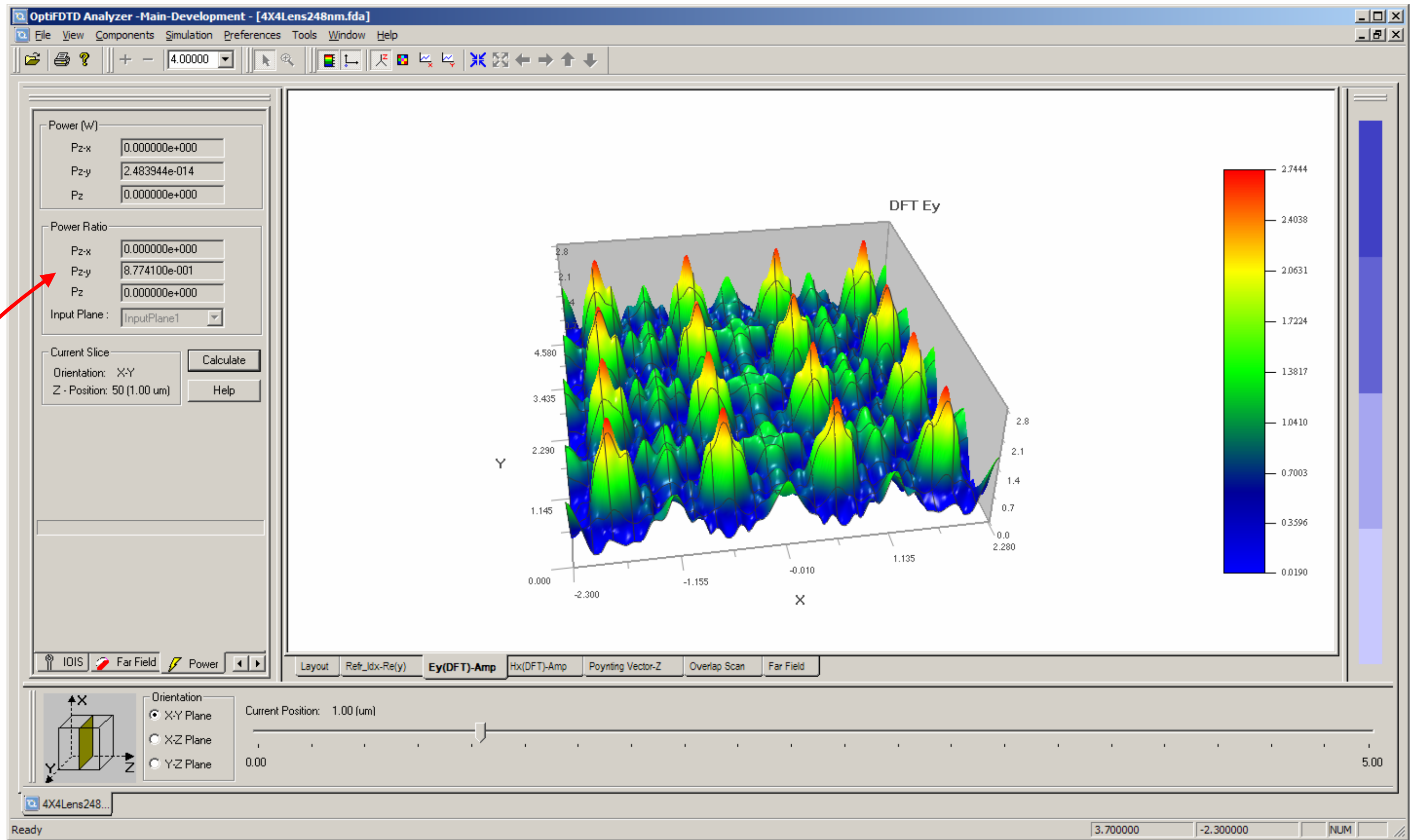
Analyzer ---Observe the steady state response



Ey along z direction at x=-1.8, y=0.5

It can be read that ach lens focus at z=1.26, focus distance 1.26-0.8=0.46um

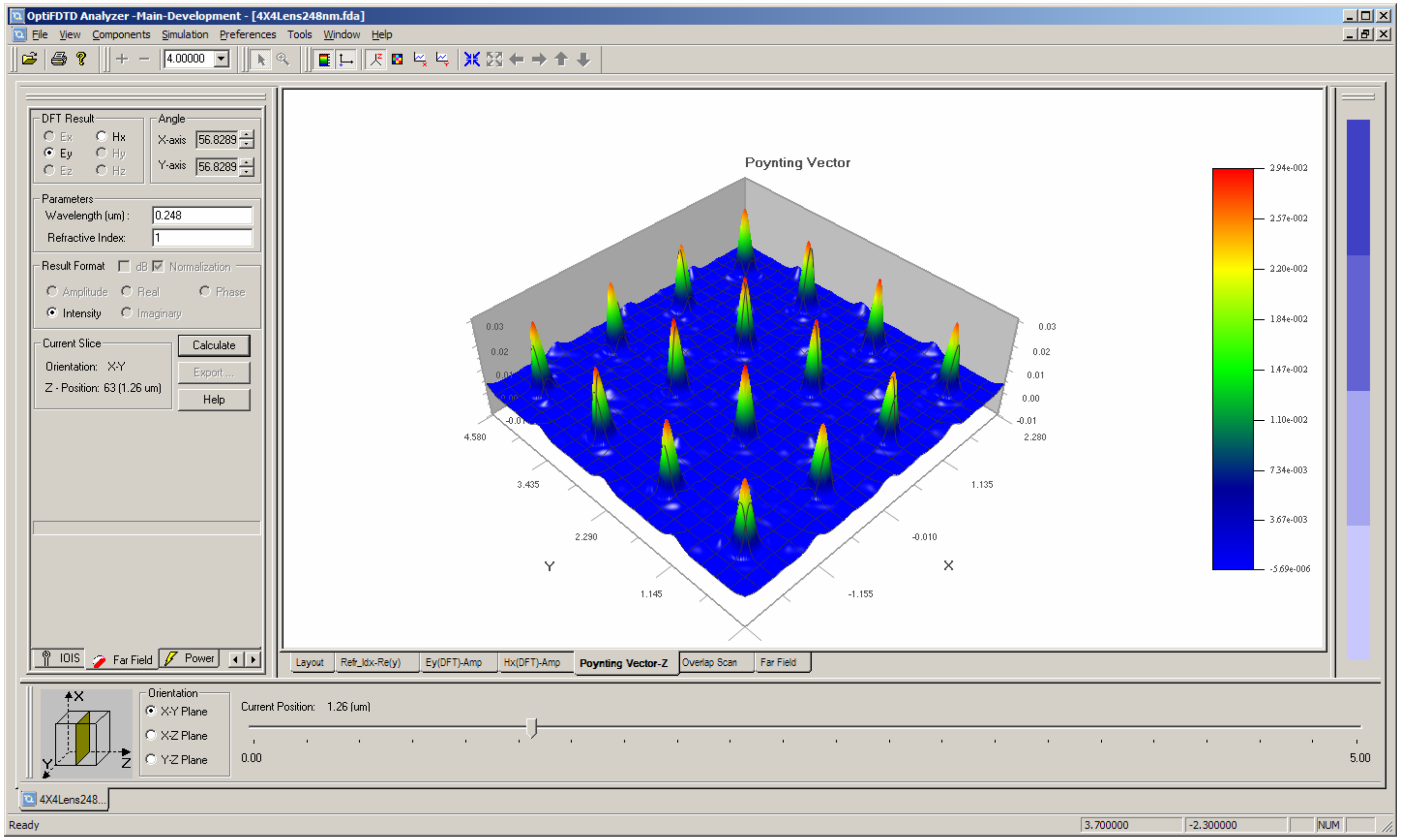
Analyzer ---Observe the steady state response



Ey at xy plane z=1.0um

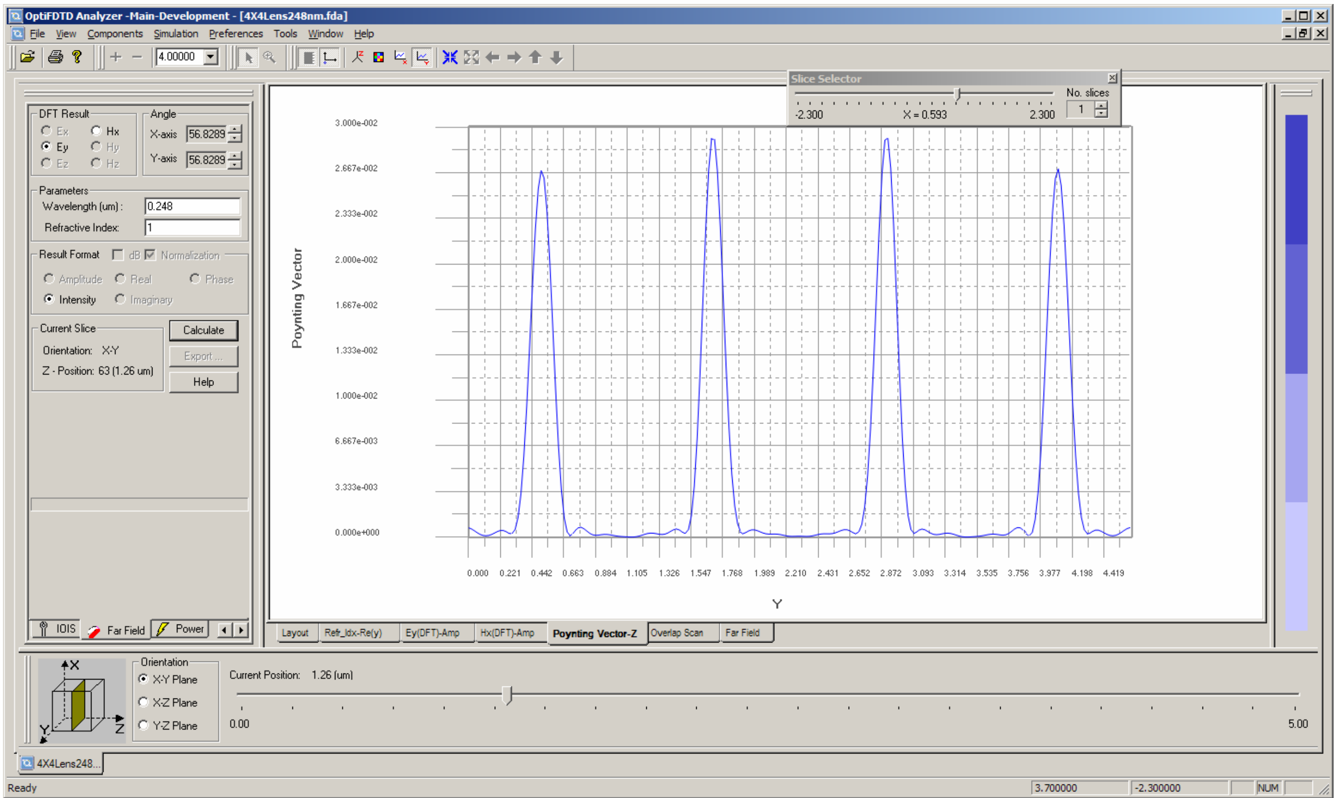
87.7% power is transmitted

Analyzer ---Observe the steady state response---Poynting vector



Poynting Vector at z=1.26um

Analyzer ---Observe the steady state response---Poynting vector



Poynting vector vs. y at x=0.6um, z=1.26um

Focus beam size can be measured at half width of the peak value, which is 0.1613

Discussion

- **All data can be exported to an ASCII file for further analysis by using third party packages such as Code V (ORA) and ZEMAX.**
- **OptiFDTD includes an interface for users to convert OptiFDTD data to an output file which can be used directly in Code V or ZEMAX.**

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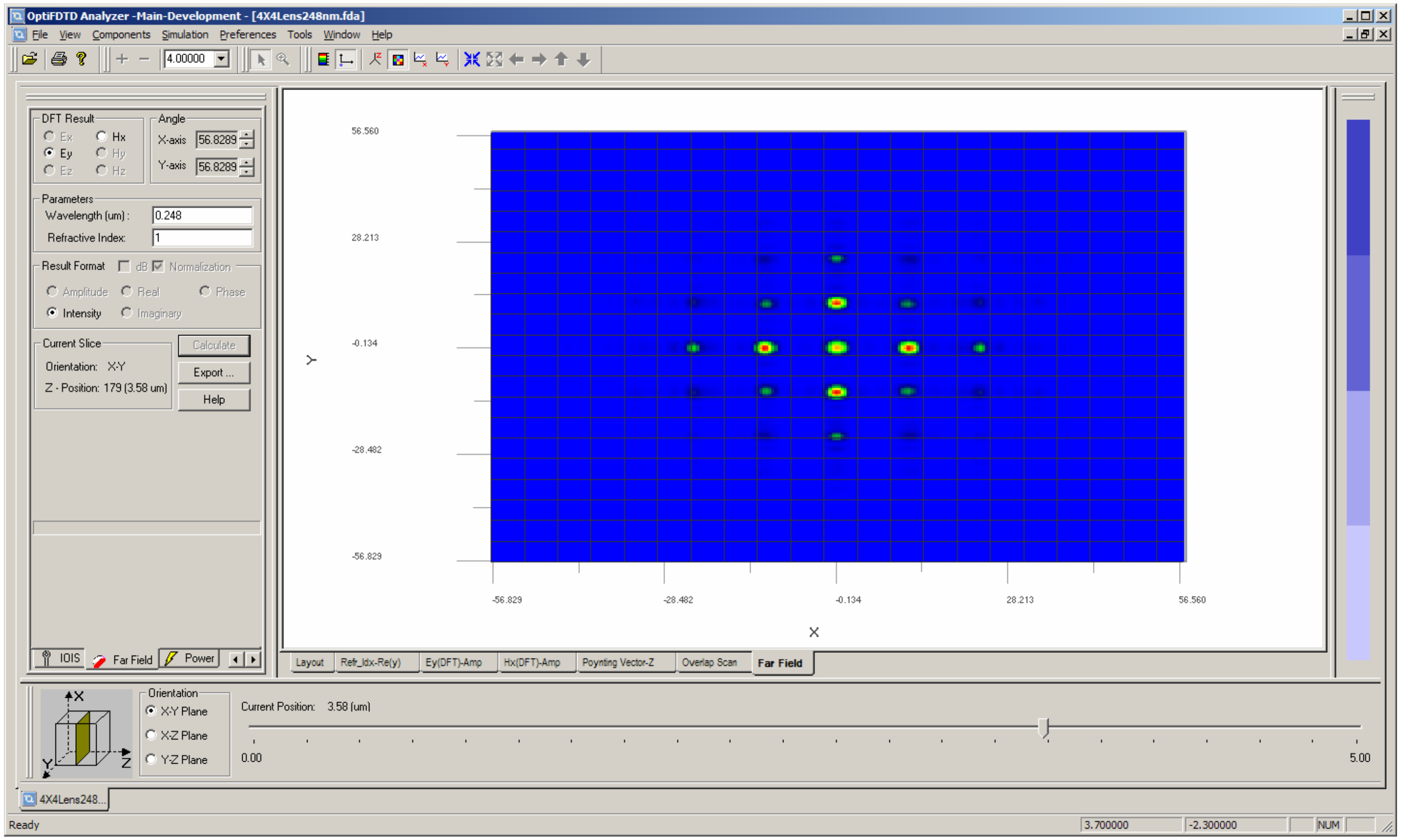
Analyzer ---Far field transform



Far field pattern based near field at xy plane z=1.26

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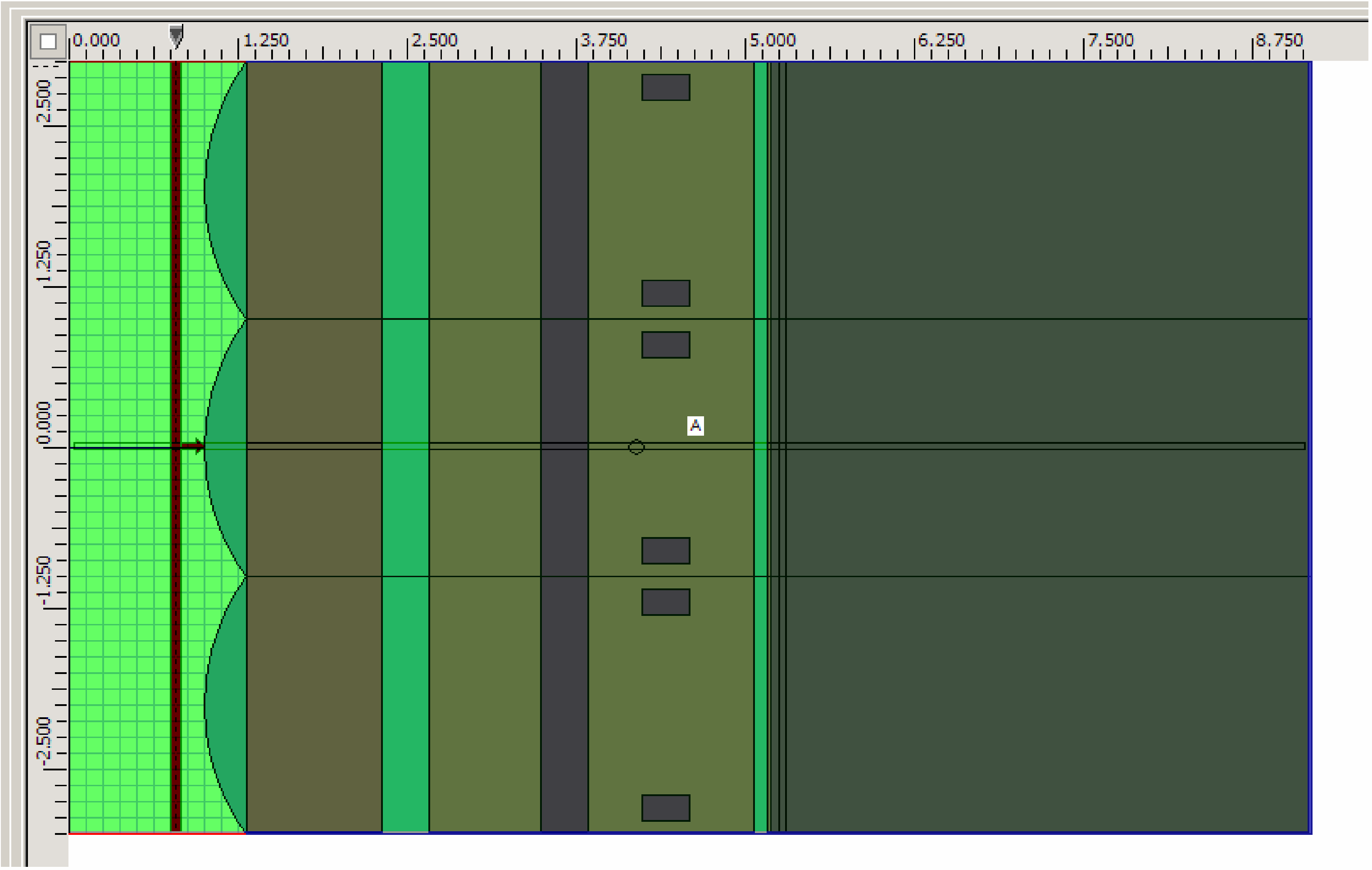
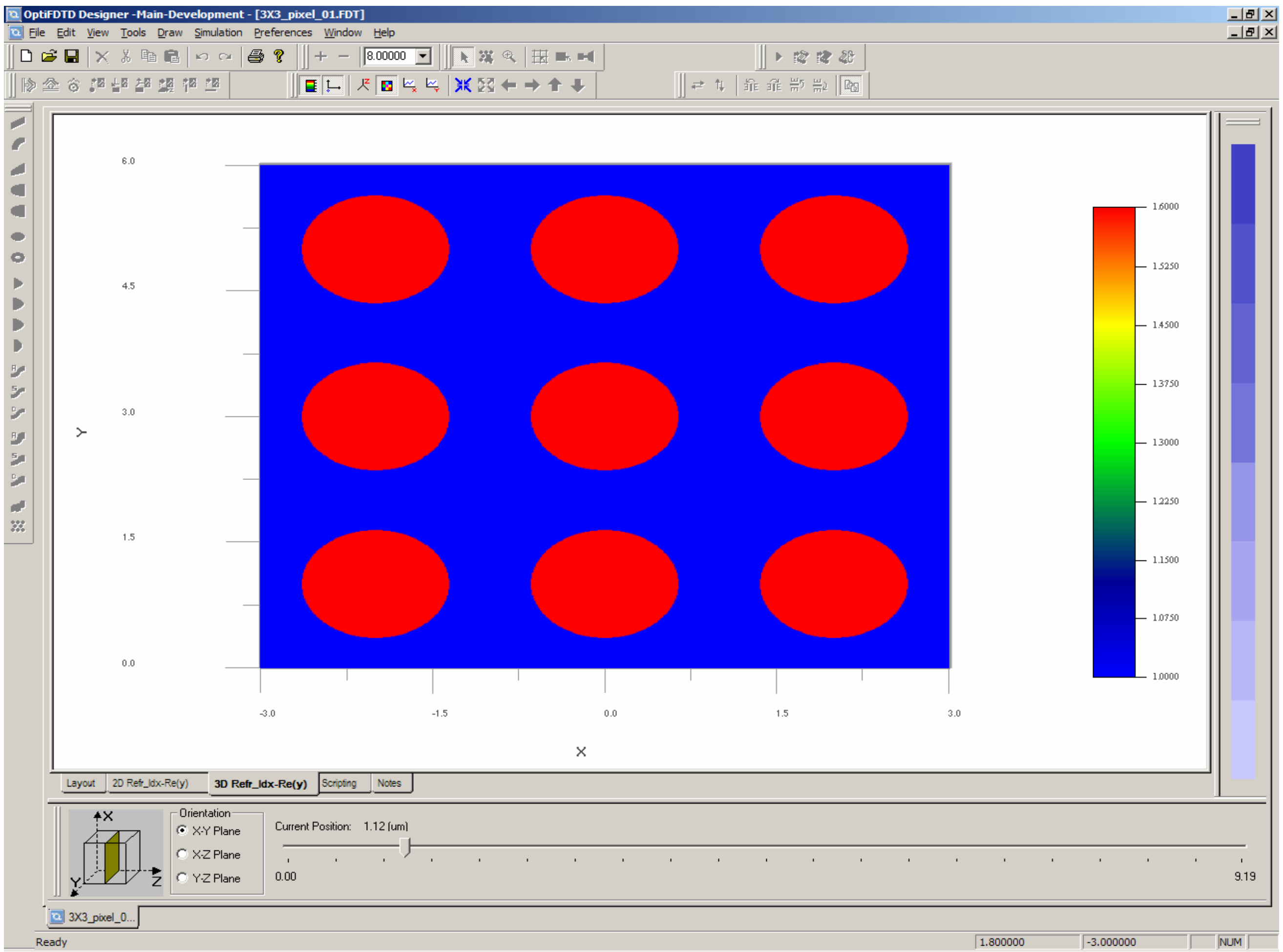
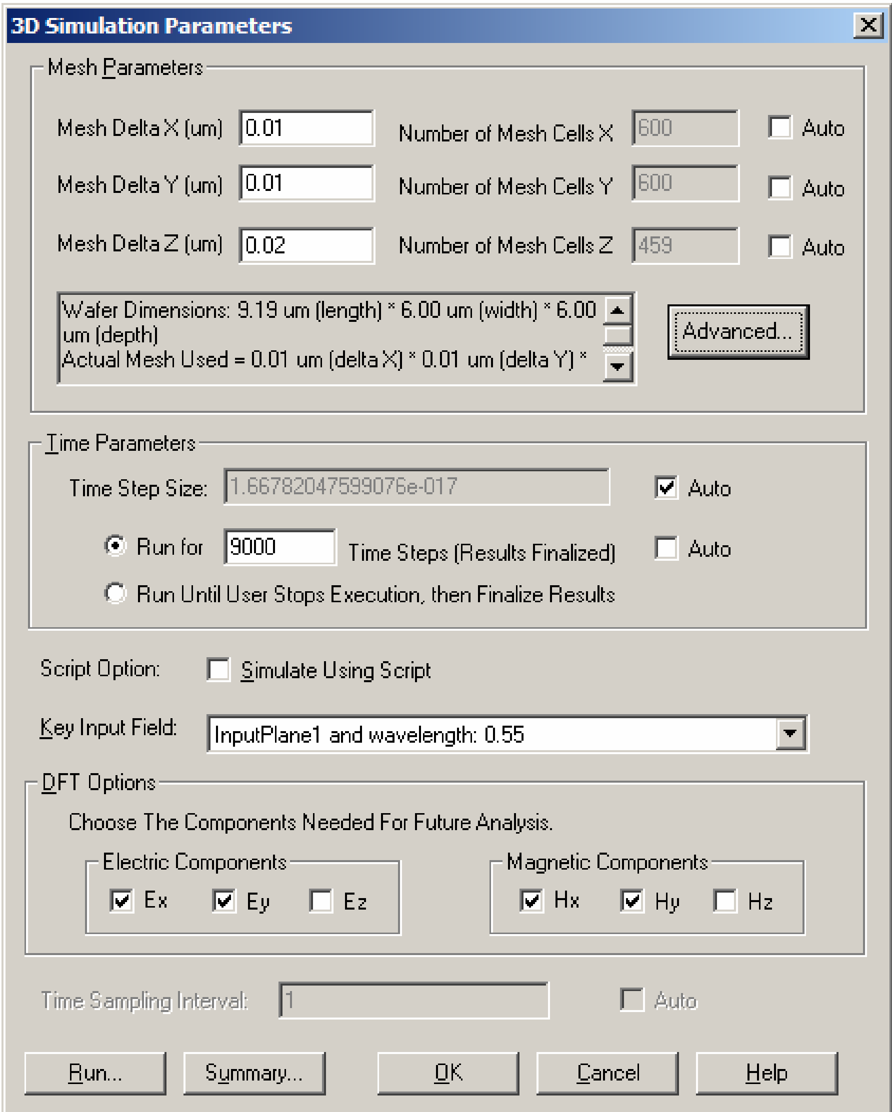
Example2---

1. **3*3 Pixels in layout designer**



2. Refractive index distribution in one x-y slice

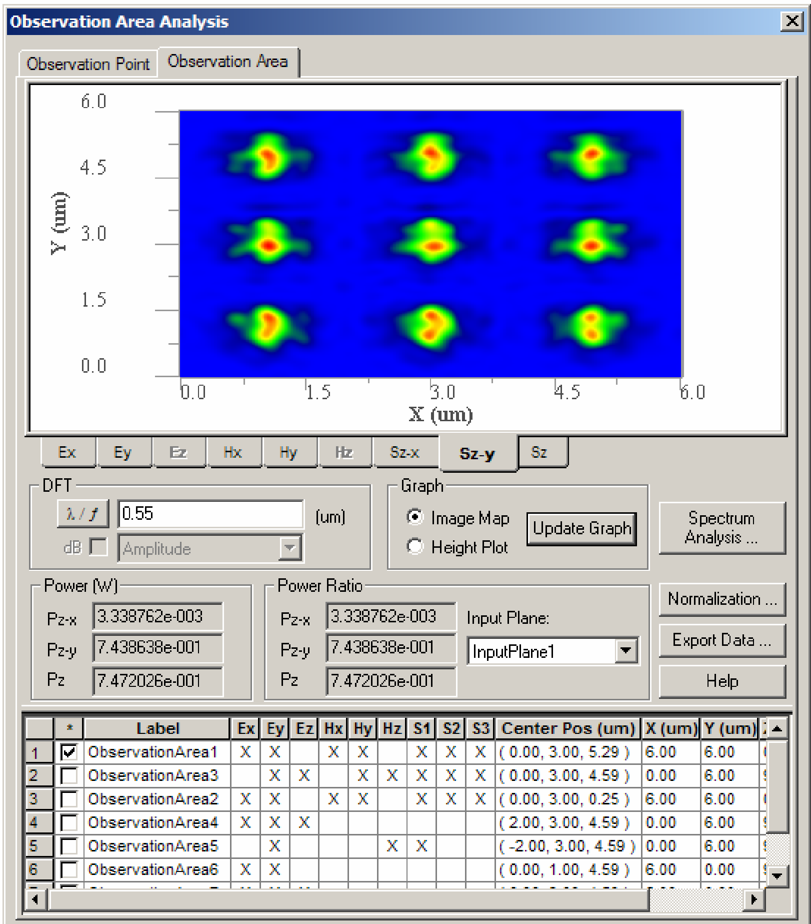




3. Simulation Parameters

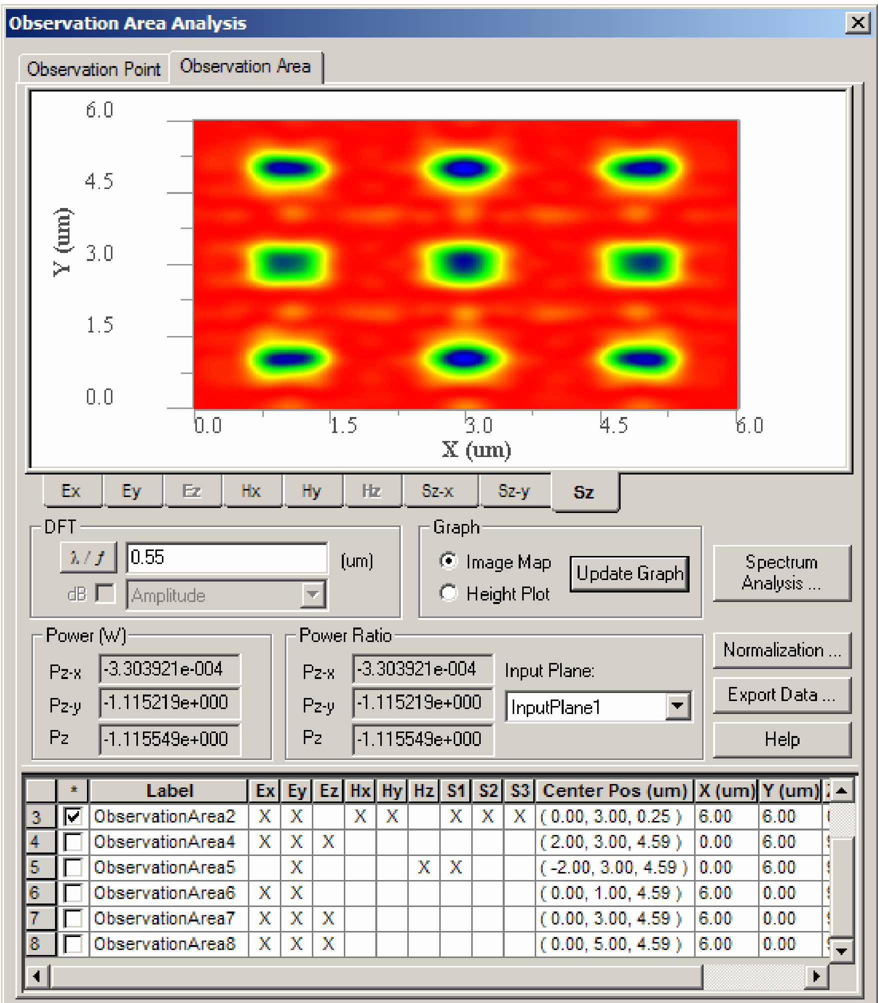
- x, y –direction mesh is set to 0.01um
- Z direction mesh is set to 0.02um
- x, y, z boundary is set as PML boundary condition.
- Total mesh is 600*600*459, plus 12 PML layer in each side.
- The total problem size is 190 million nodes (71% of the 16GB memory).
- Initialization Time: 5.6 minutes
- Computation Time: 14.6 hours
- Finalization: 5 minutes
- Computation Rate (average): 32.8 Mnps (million nodes per second)

4. Simulation results



Y-Polarization Poynting vector in xy Plane, 100nm under Silicon layer

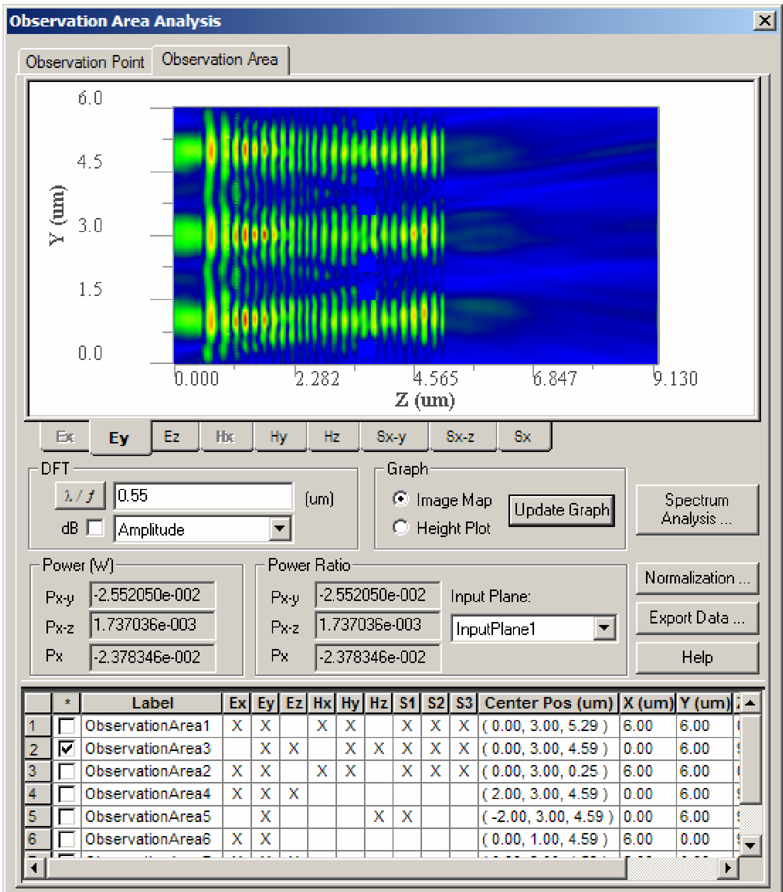
5. Simulation results



Total Poynting vector in xy Plane, 250nm behind input wave

This is the reflected wave. Because reflected wave propagate to negative z direction, so Poynting vector has negative symbol.

6. Simulation results

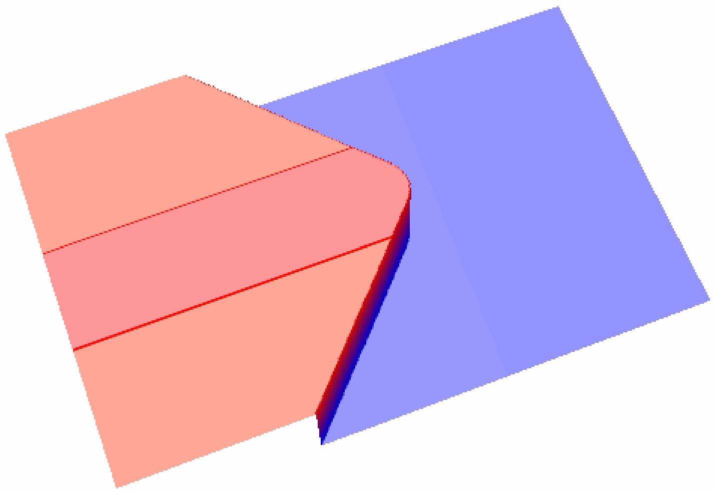


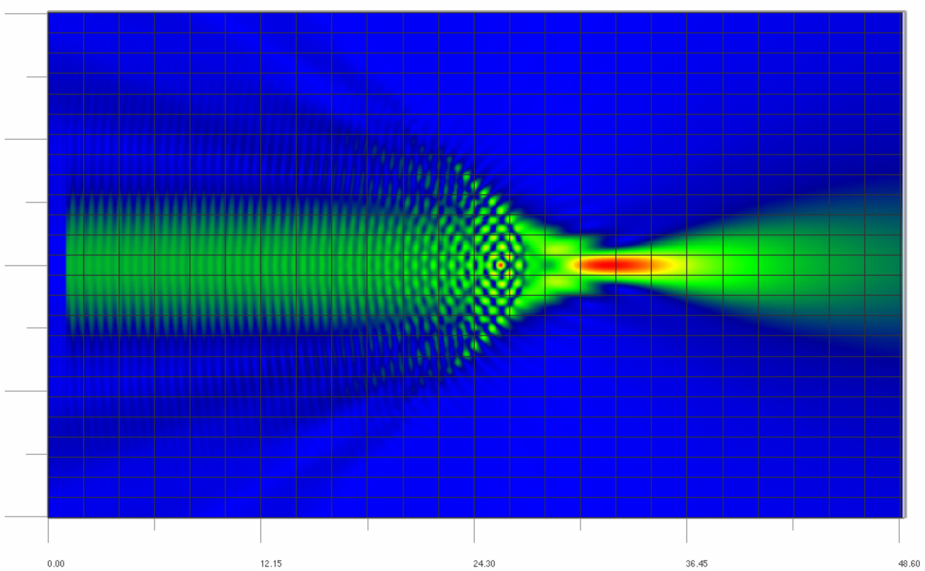
Ey in yz Plane at x=0

(the center pixel)

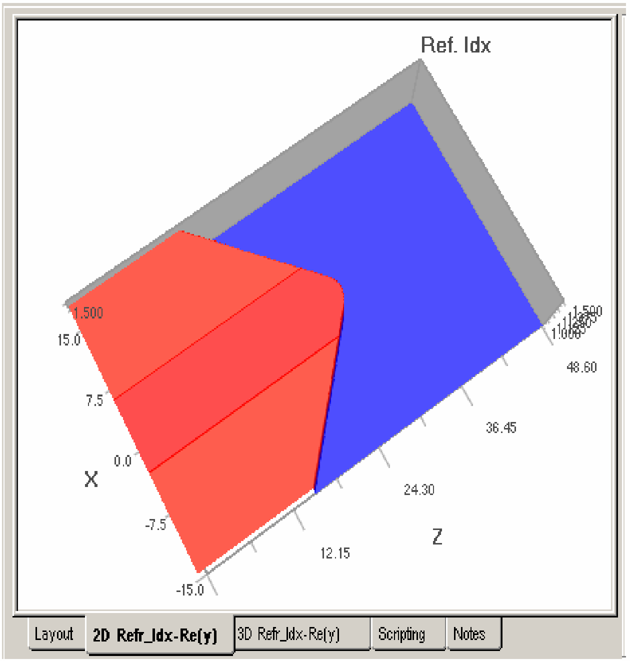
Example 3--- SMF28 fiber lens

----Sample 22 in OptiFDTD (can be used as Live demo)



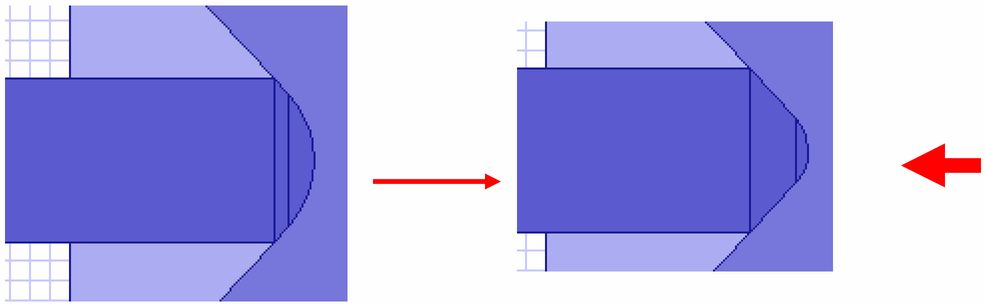


Example 3--- SMF28 fiber lens---sample 28



- Open Sample22 in the OptiFDTD sample folder
- Click "2D_ref_Idx_re(y) button under the layout sub-window to observe index distribution, (Click "Height" plot shortcut toolbar and Drag the graph can change the view angle.)
- The layout is a center cut of the SMF28 Fiber with termination tapered and polished as Lens. When Lens radius is changing, the taper length will be changed too, and the wave focusing distance and size will be also changed. The simulation will check the focusing distance and focusing size.

Example 3--- SMF28 fiber lens---sample 28
---Checking how to sweep the Lens radius



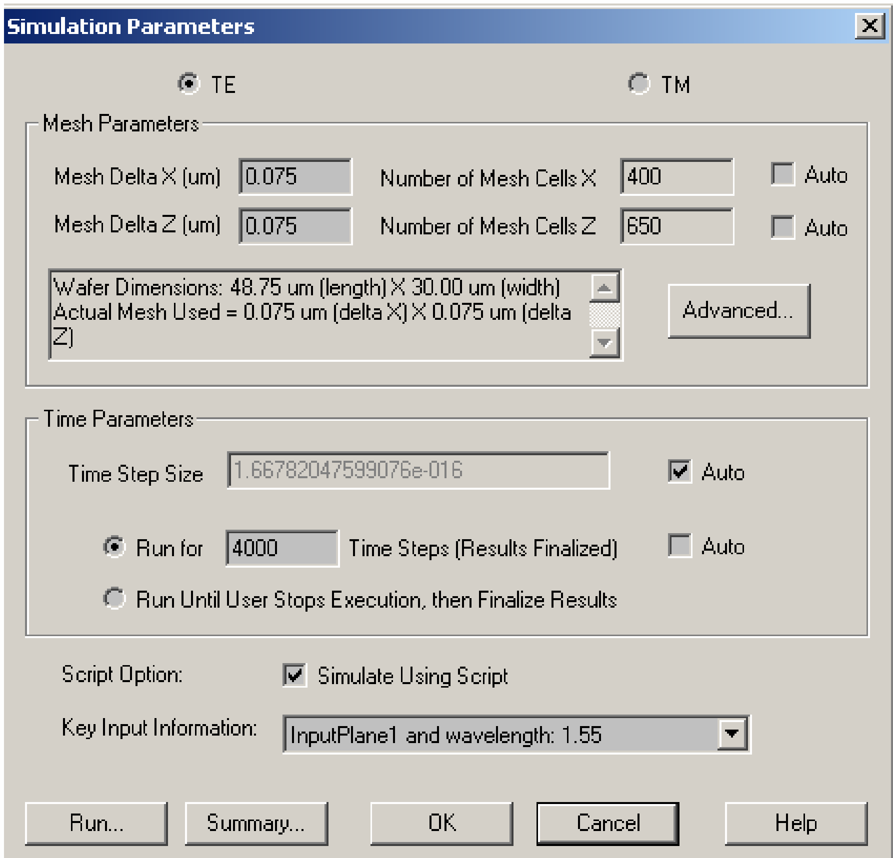
```
Dim iIt
Dim dRmax

iIt = 12
dRmax = 4.1/sin(43*3.1415926536 8/180)

For i=1 to iIt
    dRIt = dRmax - 0.3 * i
    ParamMgr.SetParam "R", dRIt
    WGMgr.Sleep 500
    ParamMgr.Simulate
Next
```

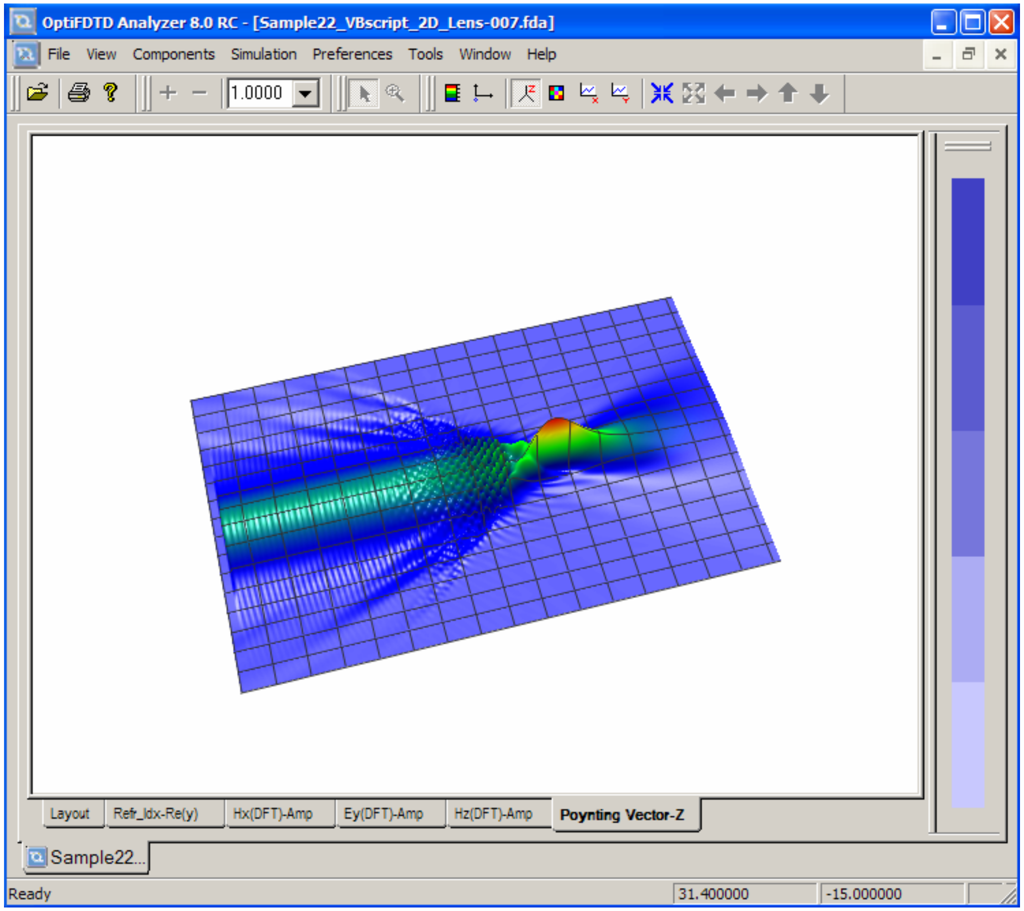
- **Click Layout button**
- **Double click on the Lens Object, you will see Lens Radius is defined by an variable “R”, Other objects positions are also associated with this R when R is changing.**
- **Click Simulation Menu and Click on “Editor parameters:, you will find we defined variable R and Some other parameters associate with “R”**
- **Click “Test Script" or the Play short cut toolbar, you will find the radius and the taper length is changing in the layout.**
- **Click “VB script” button under the layout graph sub-window, you will find the VB scripting code. This is the code to control scanning parameters. When “R” is re-defined, All the associate parameters will be changed.**

Example 3--- SMF28 fiber lens (Simulation using Script)



- **Click 2D simulation Parameters, Please note "Simulation using Script" is selected**
- **The scanning simulation will call FDTD Engine 12 times corresponding the iteration number for Lens Radius R**
- **Simulation will generate 12 results file, open each results file can measure the focusing distance and focusing size.**
- **Or advanced user can call the final results with VB without open each results file (please Check tutorial lesson 16 for this feature)**

Sample 3---Lens in Sample22, post-data analysis



Click field components of Poynting vector to check the steady state response.

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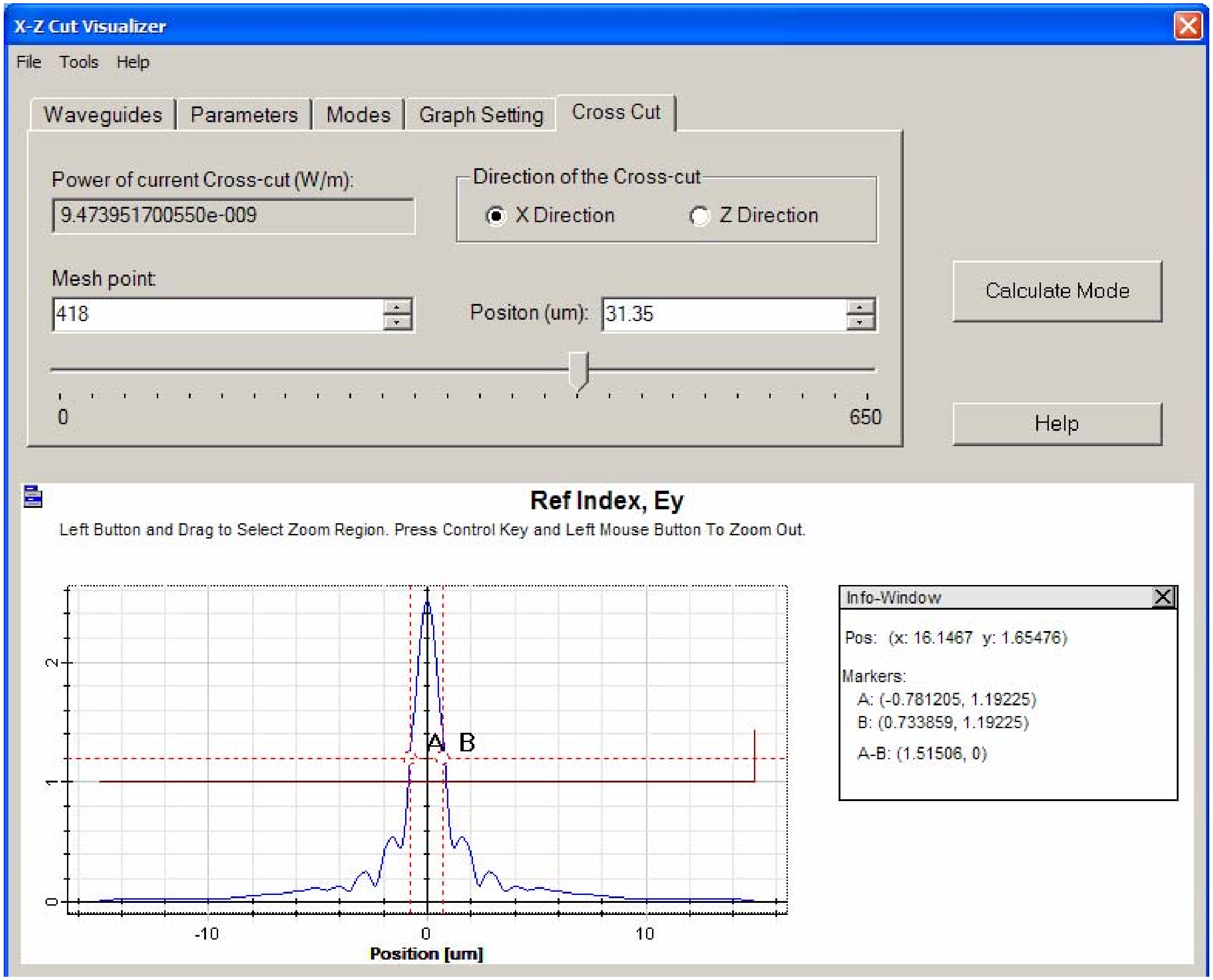
Sample 3---Lens in Sample22, post-data analysis



Click Crosscut viewer and right on the graph to select graph tools to measure the focusing distance and size.