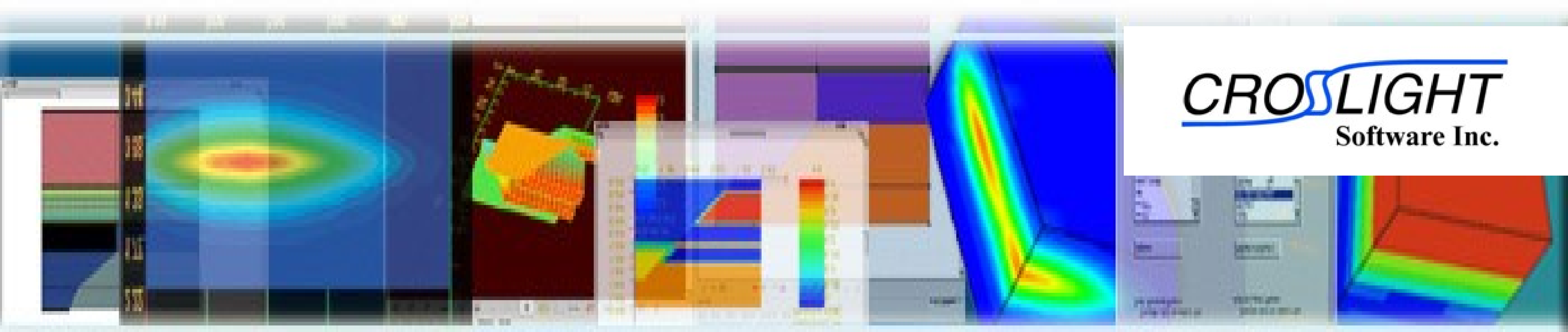


CROSSLIGHT Software Inc.

Lighting up the Semiconductor World…

A Full 3D Vectorial FDFD Optical Solver: CrosslightFDFD

3D Optical solution

3D Modal solver

- For a given structure, it is required to define the possible modes.
- Then, for each mode, it is required to calculate:
  - Modal Wavelength or propagation constant
  - Electromagnetic field
- Available solvers
  - Cavity solver (Resonance analysis)
  - Waveguide solver

3D Propagation simulation

- Our main object is modelling the wave as it propagates through the structure.
  - Calculate the Scattering parameters

3D Optical solution

- In Crosslight, the Finite Difference Frequency Domain (FDFD) method was selected to implement the optical solver
- Advantages of the FDFD method
  - 1. Compared to the FDTD, FDFD is faster
    - A typical FDFD run takes minutes while an FDTD simulation runs up to several hours for a comparable system and hardware
  - 2. Compared to the FDTD, FDFD is accurate specially for the highly resonant structure [1]
  - 3. The FDFD method in not dependent on the mesh generation (compared to the Finite element method[2])

3D Modal solver

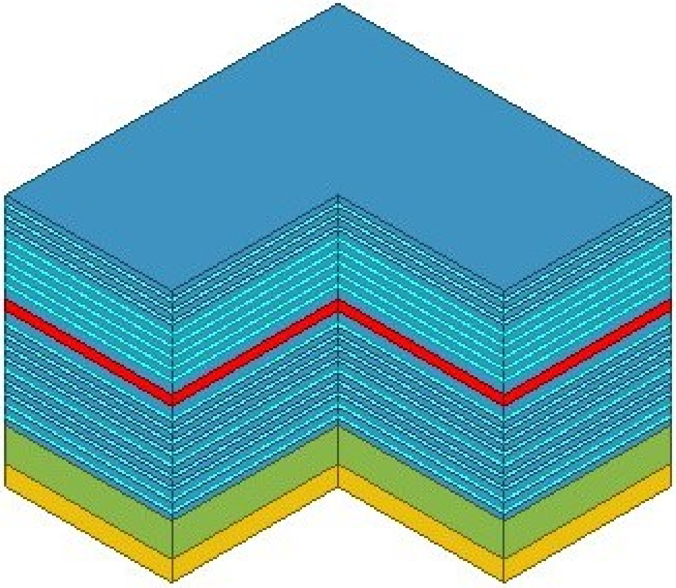
3D Modal solver

- Used to analyze the device and calculate the possible modes (resonance / guiding)
  - For each mode
    - Mode wavelength / propagation constant
    - Mode electromagnetic fields
    - Mode wave intensity

3D Modal solver - Application

1- Rectangular VCSEL cavity

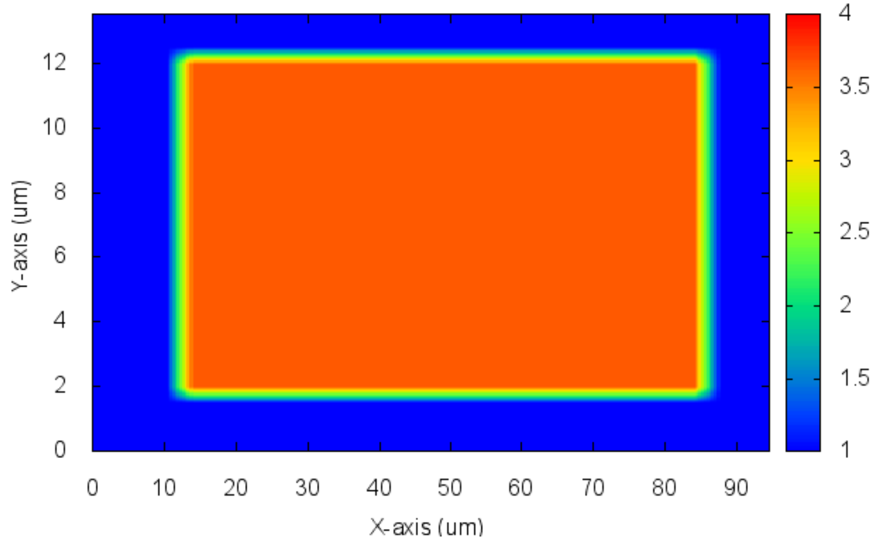
- VCSEL structure
  - Rectangular cross section
    - 10×70 μm
  - Bottom DBR
    - 29 layer
  - Top DBR
    - 19 layer



3D Modal solver - Application

1- Rectangular VCSEL cavity

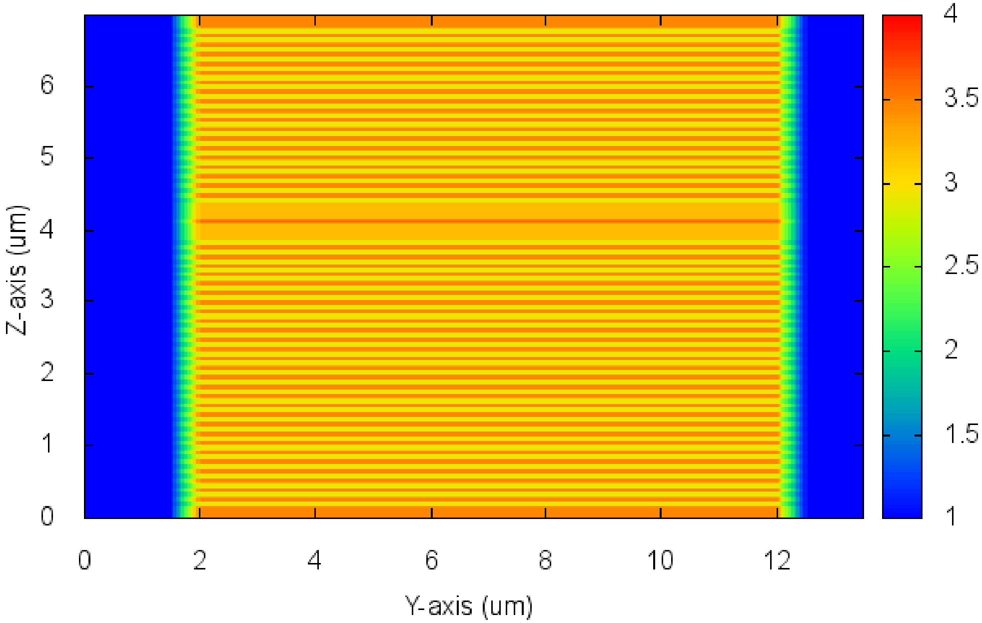
- Cavity structure
  - Cross-sectional material
    - Center of the cavity



3D Modal solver - Application

1- Rectangular VCSEL cavity

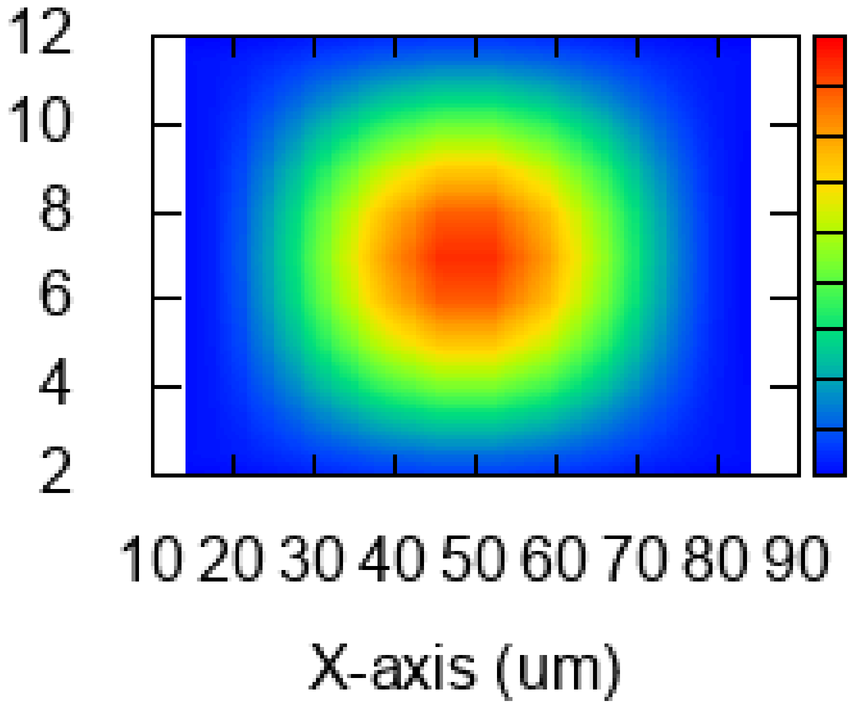
- Cavity structure
  - Cross-sectional material
    - Center of the structure



3D Modal solver - Application

1- Rectangular VCSEL cavity

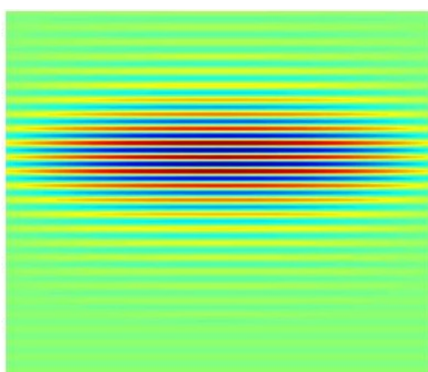
- Results
  - Mode 01
    - λ = 837.24 nm
    - Cross-sectional wave intensity
      - Center of the Cavity

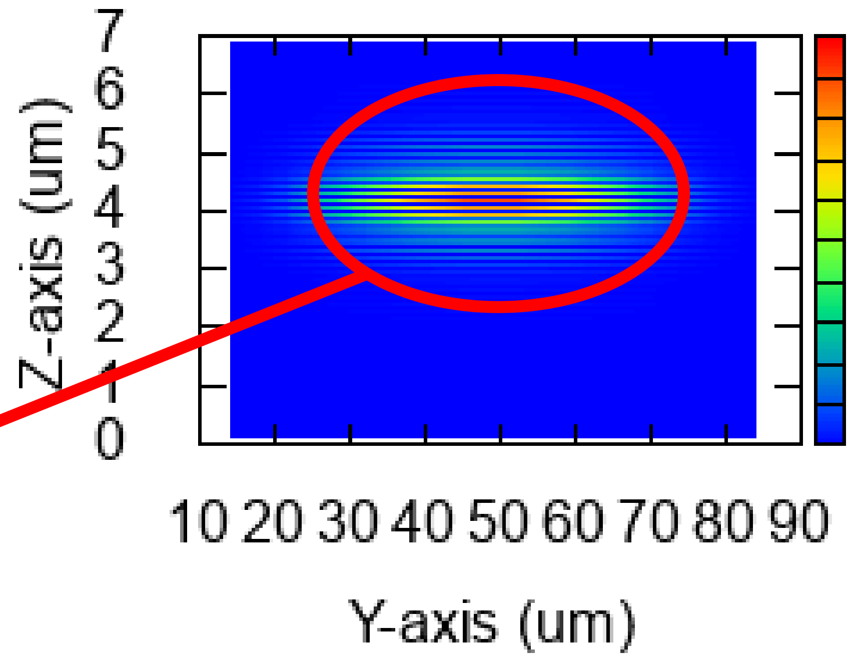


3D Modal solver - Application

1- Rectangular VCSEL cavity

- Results
  - Mode 01
    - λ = 837.24 nm
    - Cross-sectional intensity

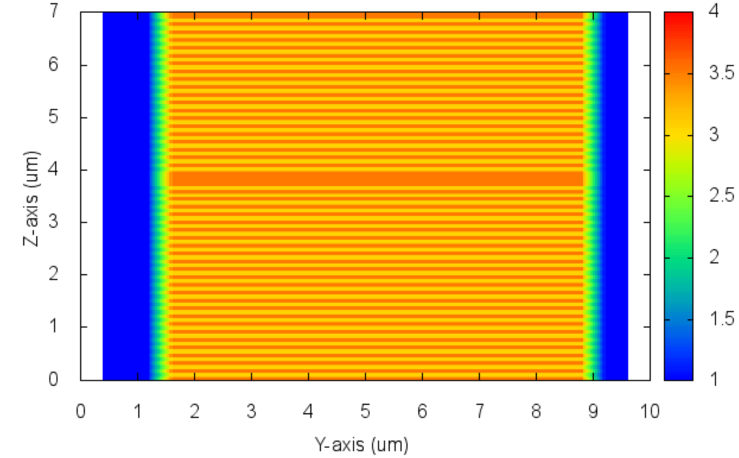


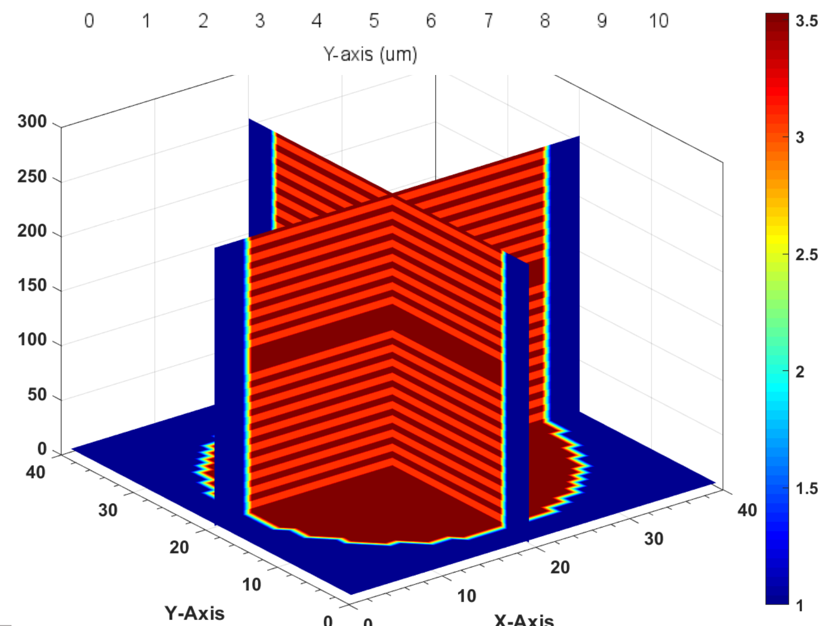


3D Modal solver - Application

2- Circular cross-sectional VCSEL cavity

- VCSEL structure
  - Circular cross section
    - Radius = 3.75 µm
  - Bottom DBR
    - 25 layer
  - Top DBR
    - 20 layer





3D Modal solver - Application

- 2- Circular cross-sectional VCSEL cavity
  - VCSEL structure
    - Circular cross section
      - Radius = 3.75 µm
    - Bottom DBR
      - 25 layer
    - Top DBR
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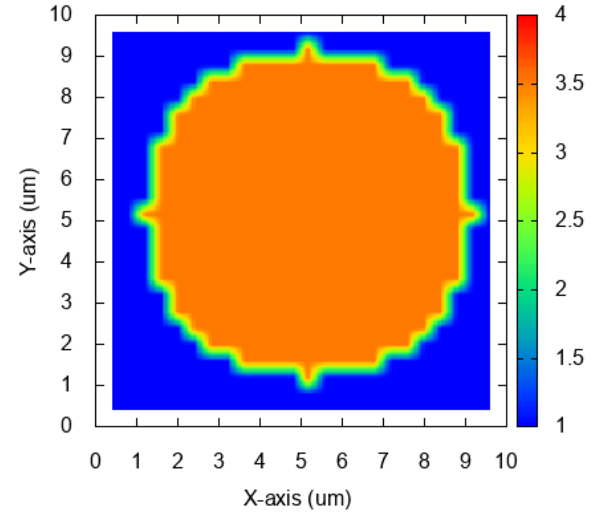
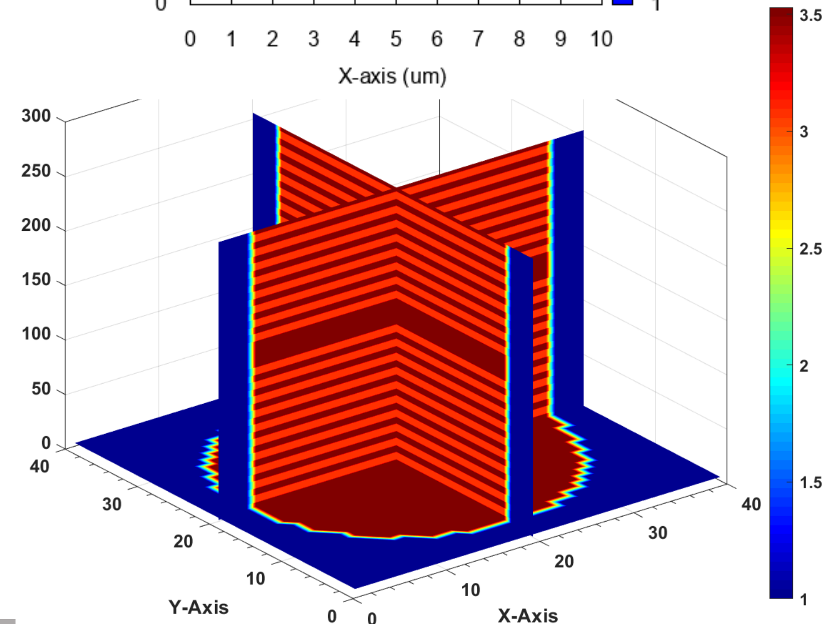
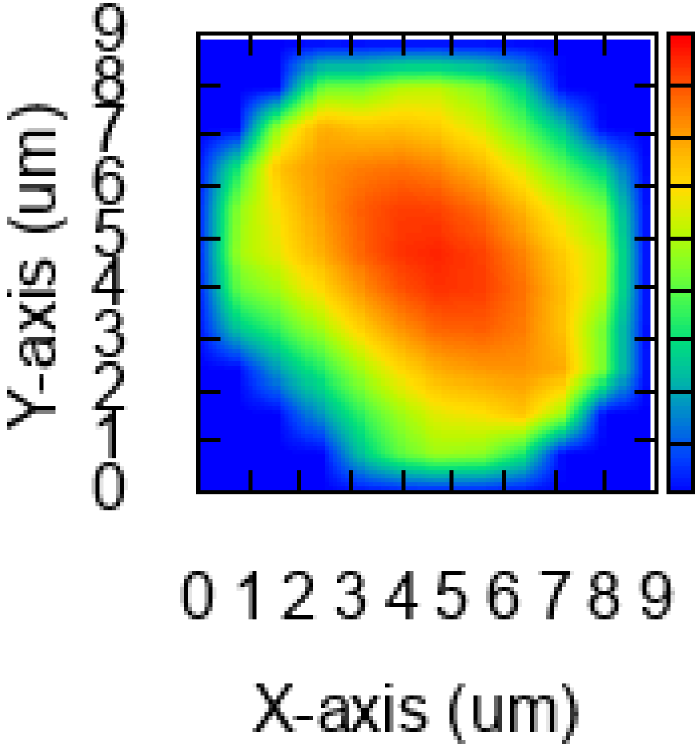




3D Modal solver - Application

2- Circular cross-sectional VCSEL cavity

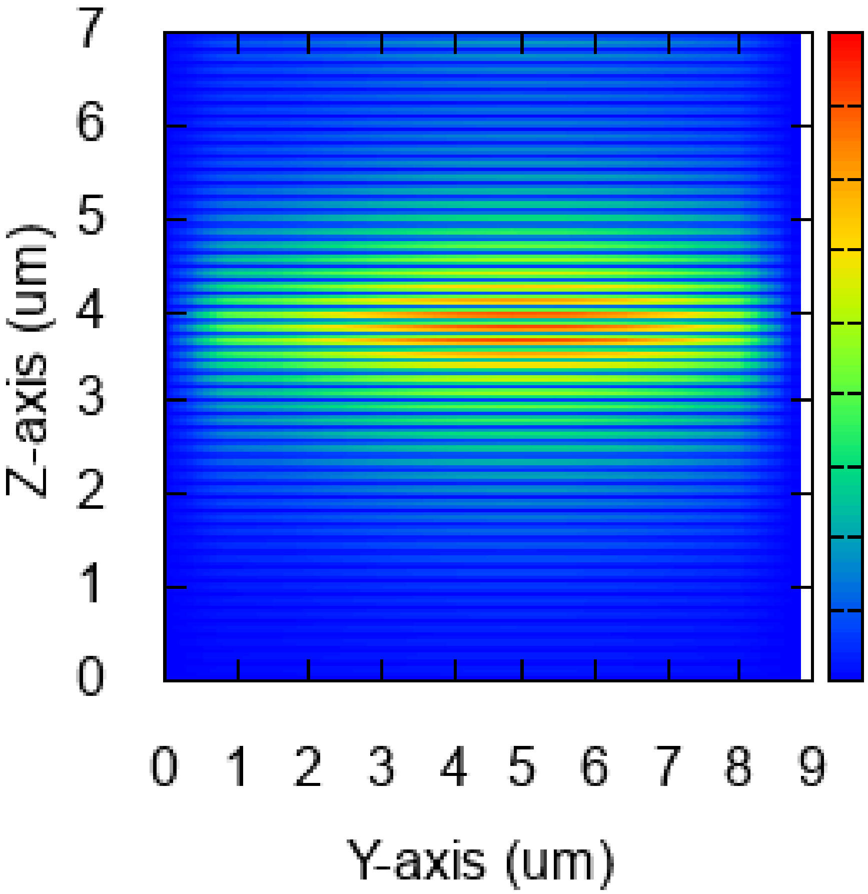
- Results
  - Mode 01
    - Operating wavelength
      - λ = 984.397 nm
    - Cross-sectional fields
      - Center of the cavity



3D Modal solver - Application

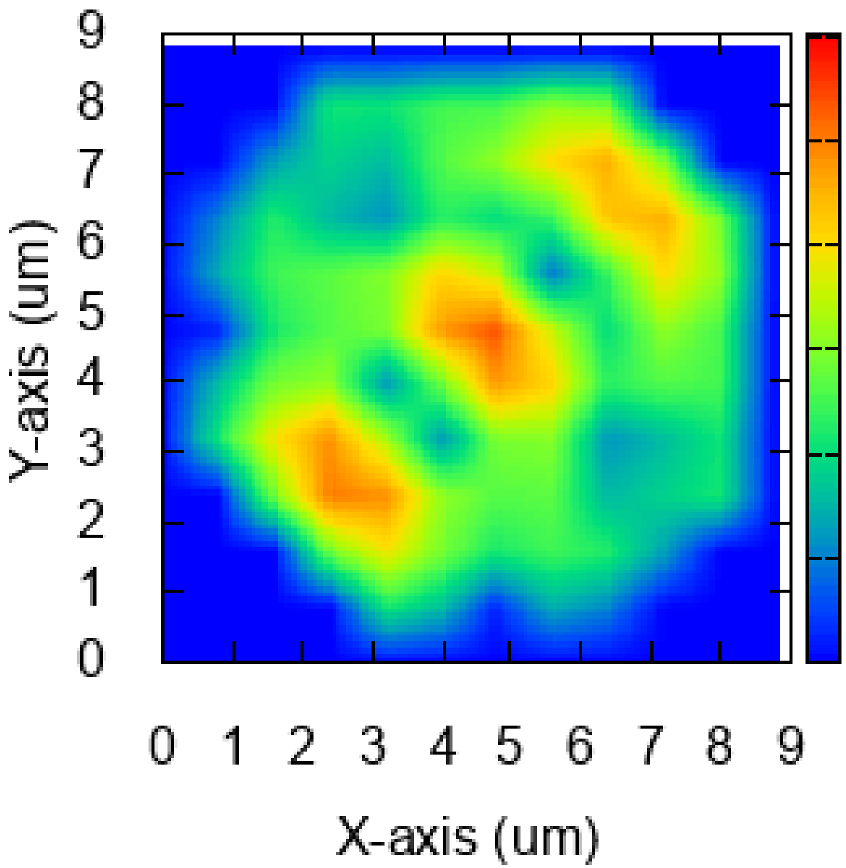
2- Circular cross-sectional VCSEL cavity

- Mode 01
  - Operating wavelength
    - λ = 984.397 nm
  - Cross-sectional fields
    - Center of the cavity
    - Center of the structure



3D Modal solver - Application

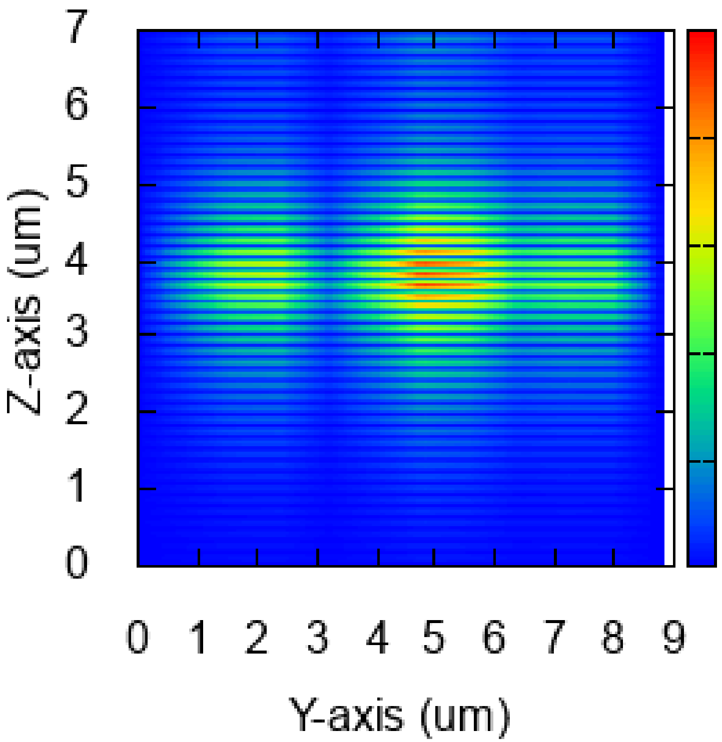
- 2- Circular cross-sectional VCSEL cavity
  - Mode 02
    - Operating wavelength
      - λ = 983.041 nm
    - Cross-sectional fields
      - Center of the cavity



3D Modal solver - Application

2- Circular cross-sectional VCSEL cavity

- Mode 02
  - Operating wavelength
    - λ = 983.041 nm
  - Cross-sectional fields
    - Center of the cavity
    - Center of the structure



3D Propagation Simulation

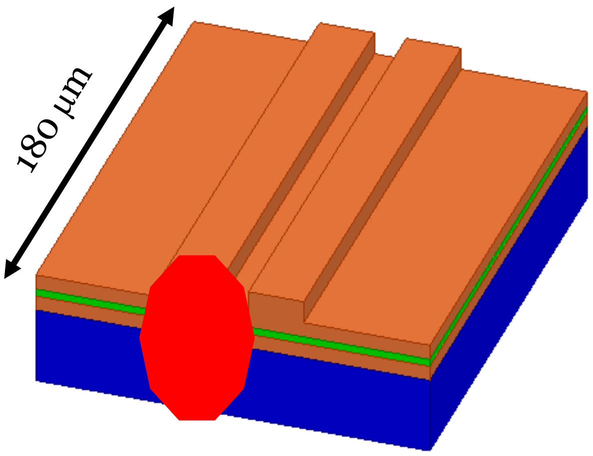
3D Propagation simulation

- Used to simulate the electromagnetic fields as it propagates through the device.
- The analysis is carried in two steps
  1. Define the input/output position (Port-position)
  2. Calculate the propagating fields inside the device

3D Propagation simulation - Application

1- Directional Coupler

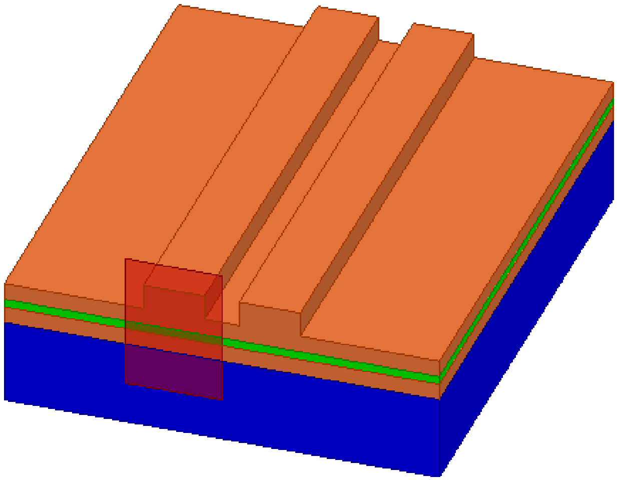
- A 180 μm directional coupler is be analyzed .



3D Propagation simulation - Application

1- Directional Coupler

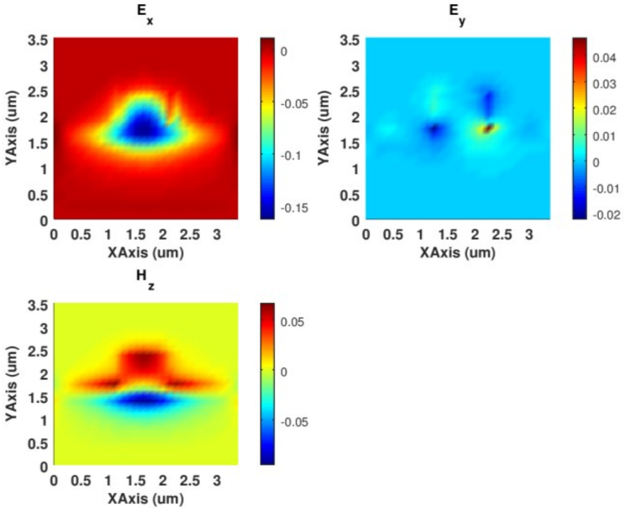
- Step 01
  - Define the input port
    - User select the input port position.



3D Propagation simulation - Application

1- Directional Coupler

- Step 01
  - Define the input port
  - For the input port, define the port modal fields
    - TE mode

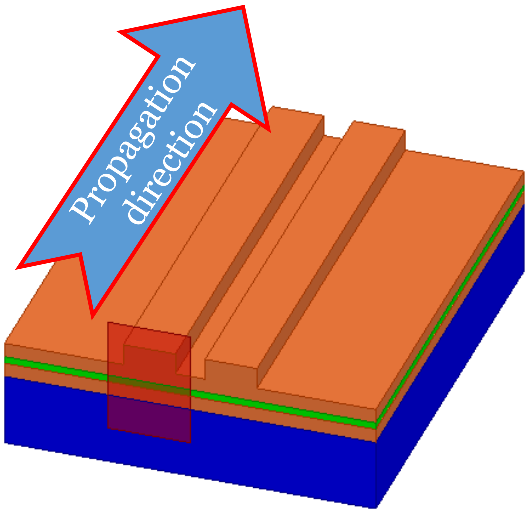


TE mode
$n_{eff} = 1.7434$

3D Propagation simulation - Application

1- Directional Coupler

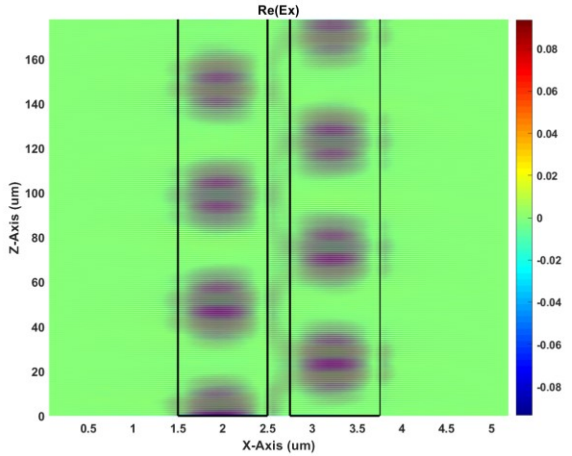
- Step 02
  - Apply 3D FDFD analysis with the source



3D Propagation simulation - Application

1- Directional Coupler

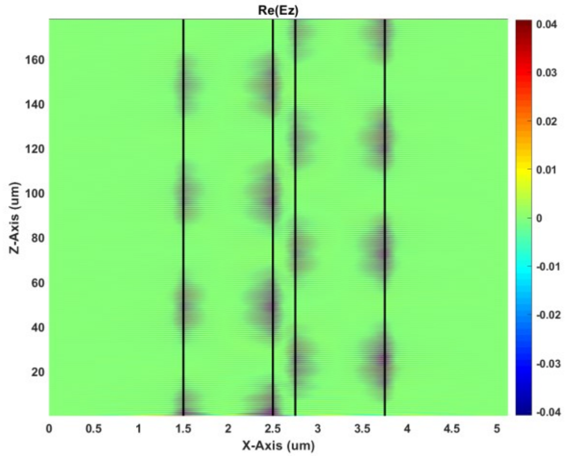
- Step 02
  - Apply 3D FDFD analysis with the source
  - Field results
    - E_x



3D Propagation simulation - Application

1- Directional Coupler

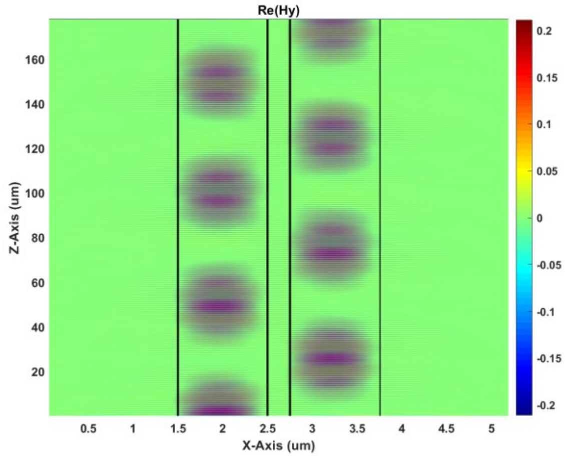
- Step 02
  - Apply 3D FDFD analysis with the source
  - Field results
    - E_x
    - E_z



3D Propagation simulation - Application

1- Directional Coupler

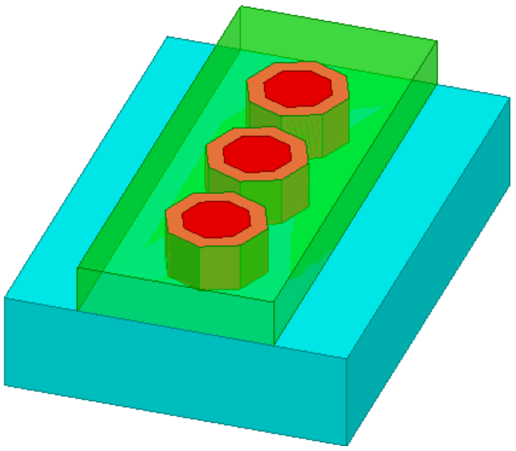
- Step 02
  - Apply 3D FDFD analysis with the source
  - Field results
    - E_x
    - E_z
    - H_y



3D Propagation simulation - Application

2- Nanowire array

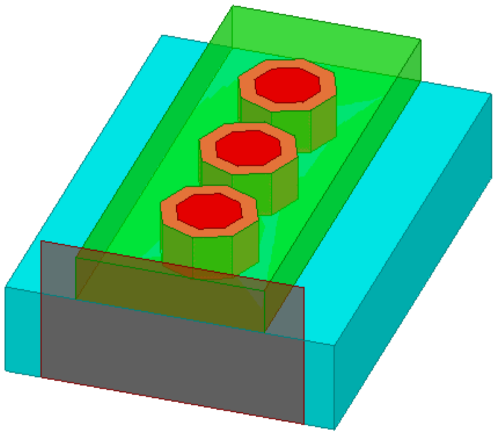
- The structure consists of an array of nanocolumn
  - It is required to analyze the propagating fields along the 3D structure



3D Propagation simulation - Application

2- Nanowire array

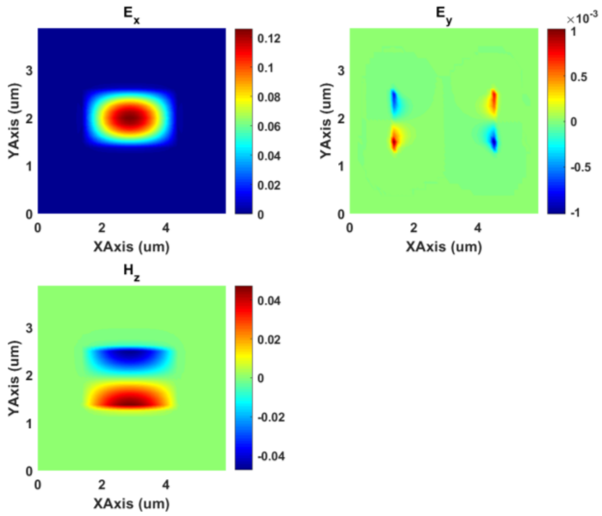
- Step 01
  - Define the input port
    - User select the input port position.



3D Propagation simulation - Application

2- Nanowire array

- Step 01
  - Define the input port
  - For the input port, define the port modal fields
    - TE mode

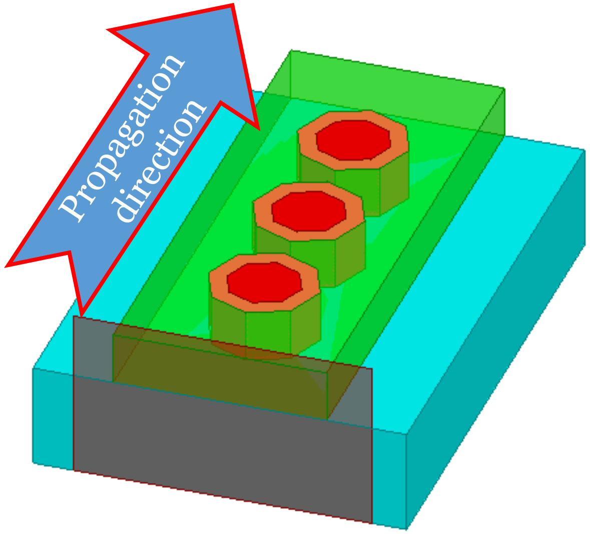


TE mode

3D Propagation simulation - Application

2- Nanowire array

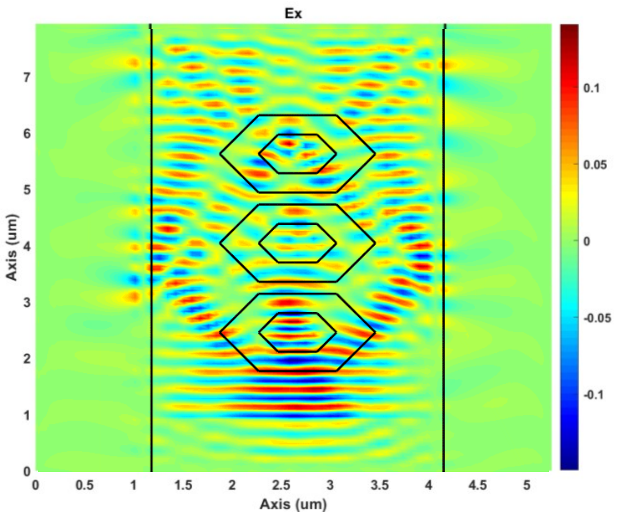
- Step 02
  - Apply 3D FDFD analysis with the source



3D Propagation simulation - Application

2- Nanowire array

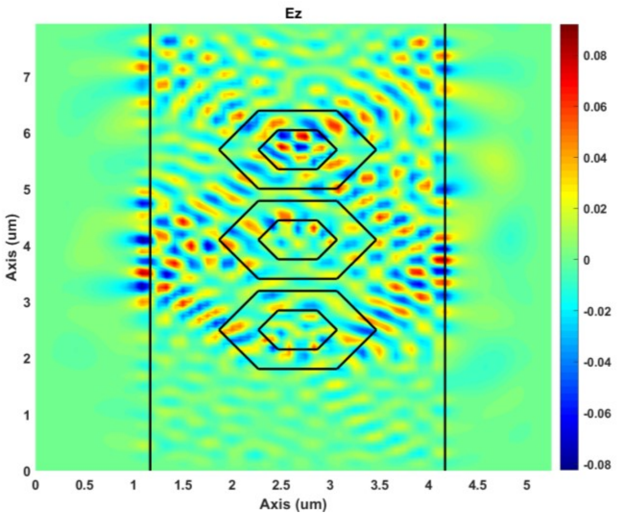
- Step 02
  - Apply 3D FDFD analysis with the source
  - Field results
    - E_x



3D Propagation simulation - Application

2- Nanowire array

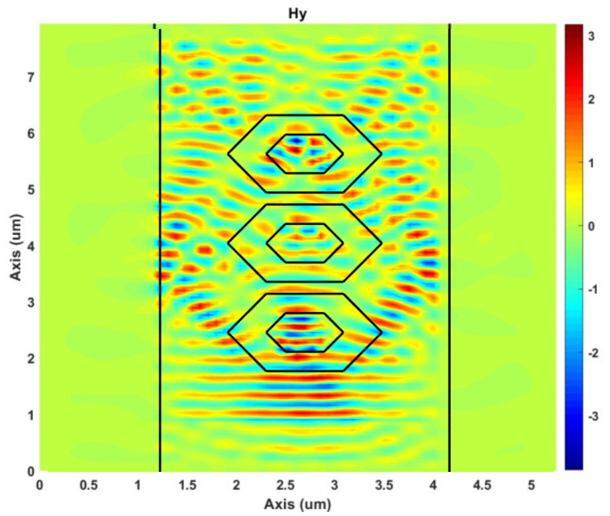
- Step 02
  - Apply 3D FDFD analysis with the source
  - Field results
    - E_x
    - E_z



3D Propagation simulation - Application

2- Nanowire array

- Step 02
  - Apply 3D FDFD analysis with the source
  - Field results
    - E_x
    - E_z
    - H_y



Thank you !