# TACHE 6 : COUPLING OF NWS-BASED PHC RESONATOR TO SOI WAVEGUIDE

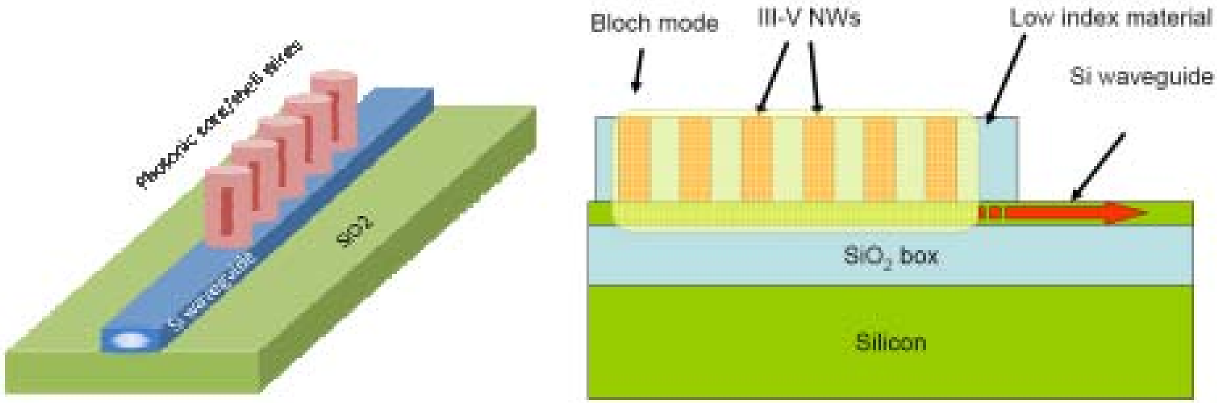
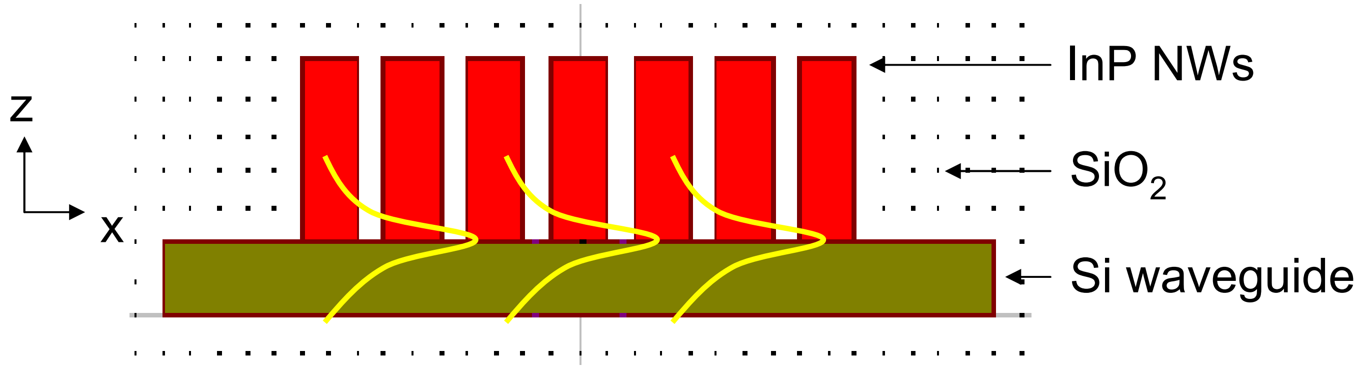


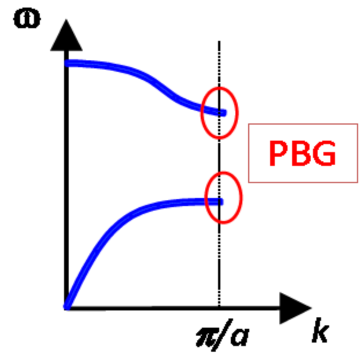

Figure 7 : Schematic view of a resonant light source based on 1D array of photonic core-shell NWs on top of a SOI waveguide.

Objective:

Study the optic mode in the whole nanostructure to choose a mode with high E energy density inside the nanowires.

1. Design of the resonant cavity




1st study:

- 1D periodic nanophotonic structure network;
- Explore guided modes in the NWs - Si waveguide structure at the edge of ZB to get slow group velocity mode for high energy;
- Technological constraints: what limites the dimensions of the NWs (diameter, height, periodic).

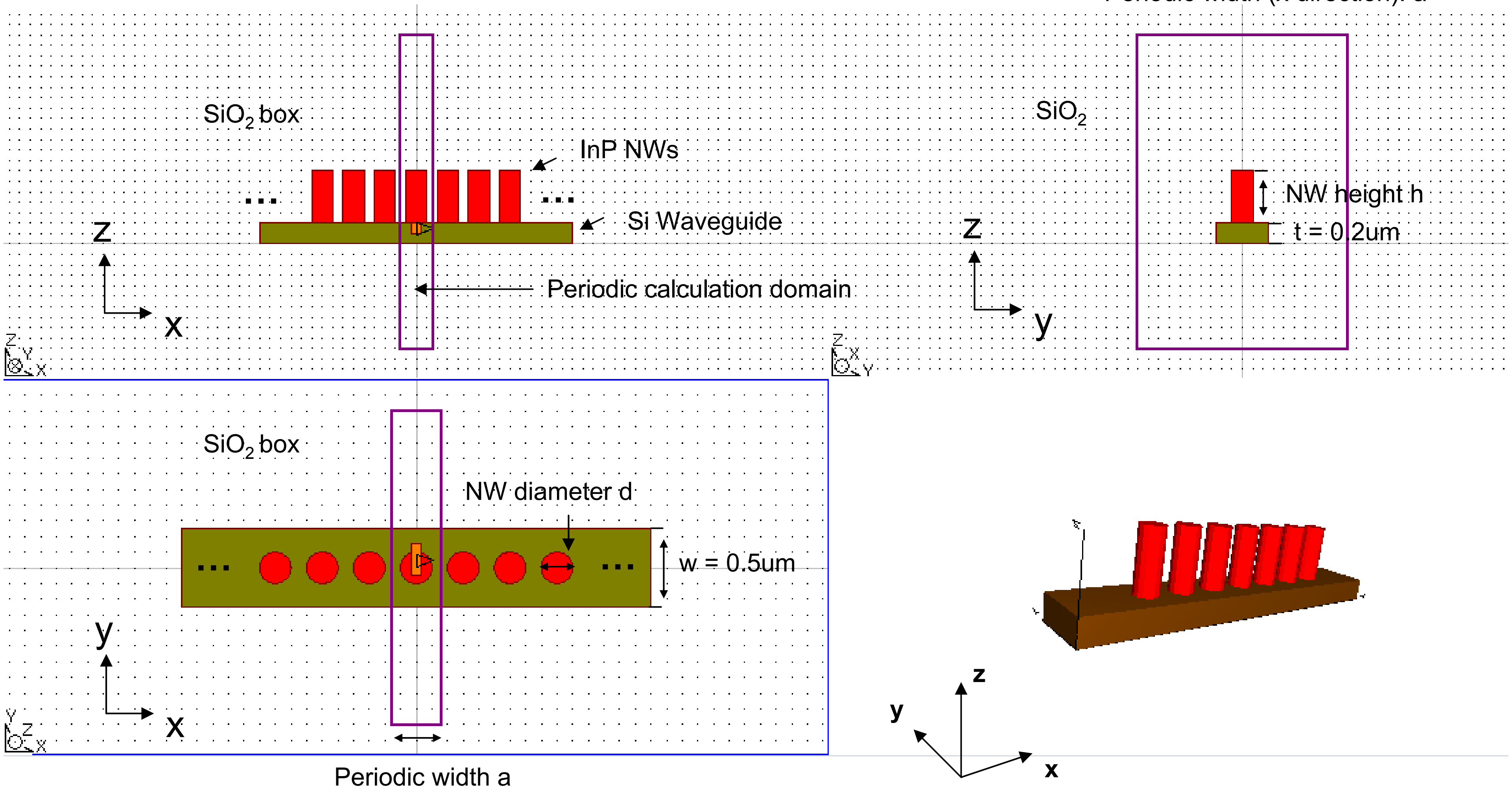
## 2. Definition of 3D NWs structure in FDTD

### Important parameters:

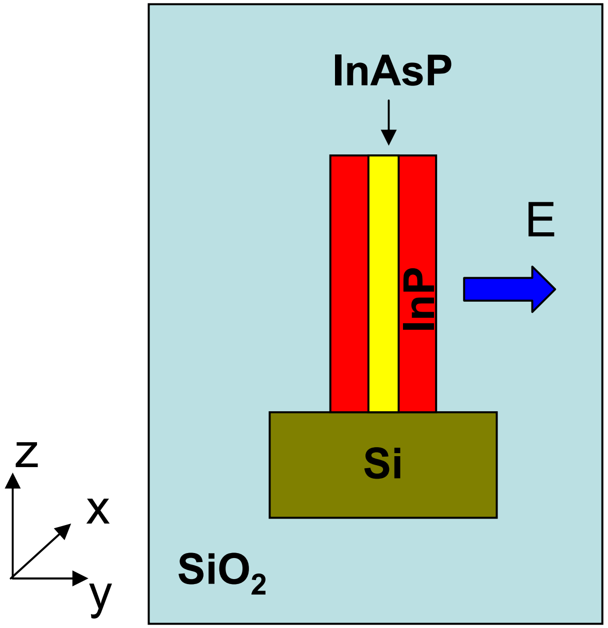
Nanowire: h, d

Si waveguide: t, w

Periodic width (x direction): a

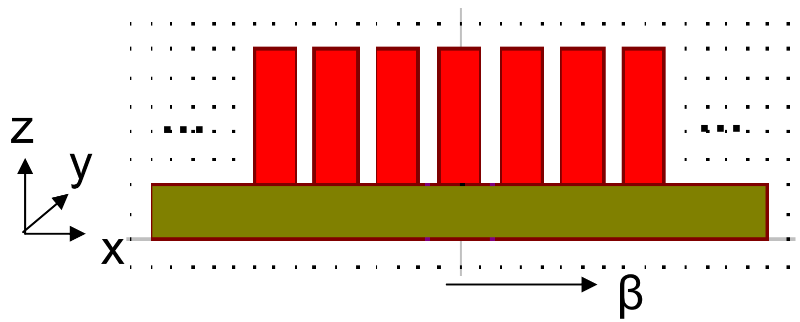


3. Polarization of NW emitters:




- The polarization direction is perpendicular to the NW axis.
- In the studied structrue, the polarization will be in the XY plane.

Polarization in the waveguide




Simulation defination:

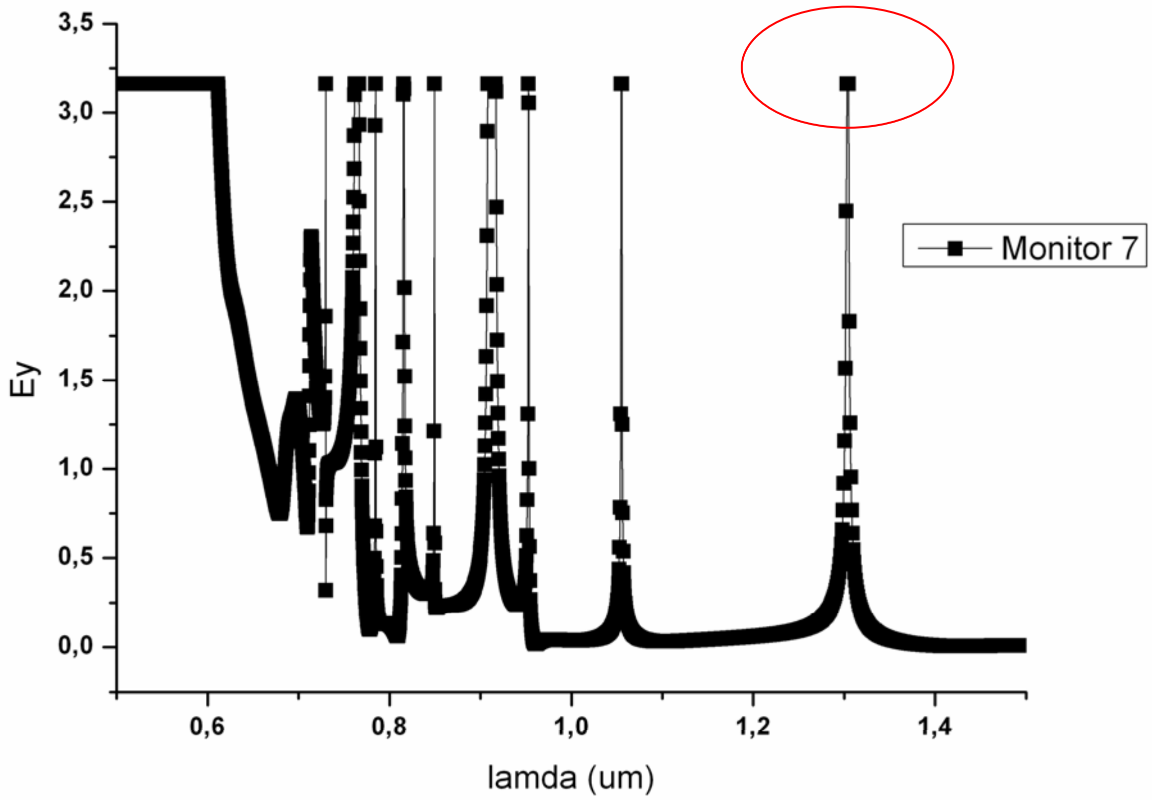
Propogation direction → X;

TE → $E_{mainly}$ is Ex;

TM → $E_{mainly}$ is Ey.

From the FDTD silulation, we can get the spectrum of all the modes in the structure.

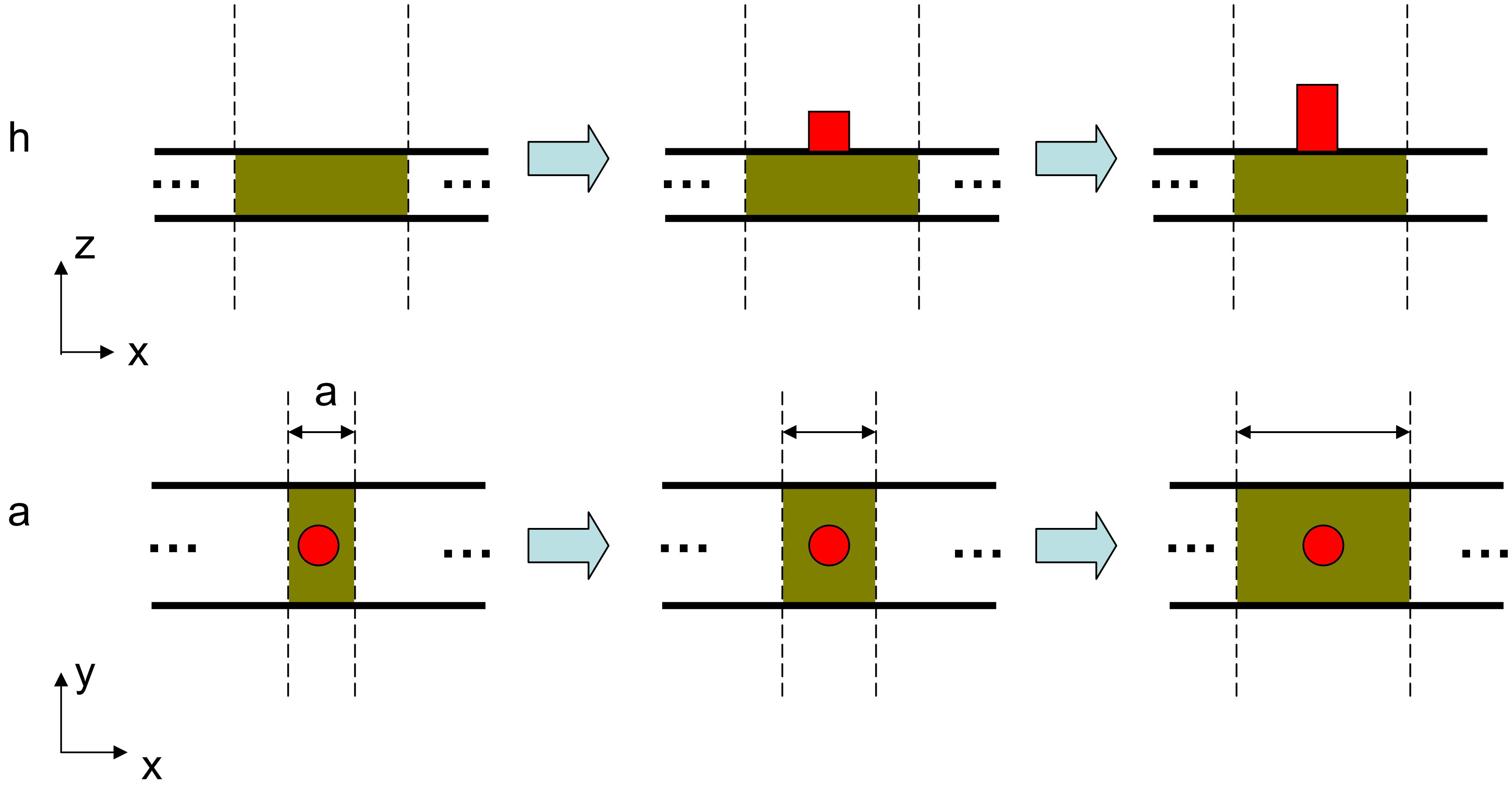
For example:




Then we will study the electromagnetic fields distribution and electrical energy density in the appropriate fundamental mode.

4. Spectrum varies with parameters in the structure

1). Nanowire height h and periodic width a



a). Polarization Ey

NW d = 0.1um, NW height h from 0.1 to 1.0um, Periodic_width a from 0.16 to 0.3um

| h(um) / a(um) | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **0.16** | | **0.965** | **0.966** | **0.965** | **0.965** | **0.965** | **0.965** | **0.965** | **0.965** | **0.965** | **0.965** |
| **0.2** | **1.139** | **1.147** | **1.143** | **1.143** | **1.143** | **1.143** | **1.143** | **1.143** | **1.143** | **1.143** | **1.143** |
| **0.22** | | **1.226** | **1.22** | **1.22** | **1.22** | **1.22** | **1.22** | **1.22** | **1.22** | **1.22** | **1.22** |
| **0.24** | **1.299** | **1.303** | **1.303** | **1.303** | **1.303** | **1.303** | **1.303** | **1.303** | **1.303** | **1.303** | **1.303** |
| **0.26** | **1.368** | **1.373** | **1.373** | **1.373** | **1.373** | **1.373** | **1.373** | **1.373** | **1.373** | **1.373** | **1.373** |
| **0.28** | **1.436** | **1.437** | **1.437** | **1.437** | **1.437** | **1.437** | **1.437** | **1.437** | **1.437** | **1.437** | **1.437** |
| **0.3** | **1.497** | **1.507** | **1.507** | **1.507** | **1.507** | **1.507** | **1.507** | **1.507** | **1.507** | **1.507** | **1.507** |

- Periodic width increase ---------- red shift of the fundamental mode resonance wavelength;
- Nanowire height -------------- no effect;
- Indicating that the wave in these modes is confined inside the Si waveguide, not in the NWs.

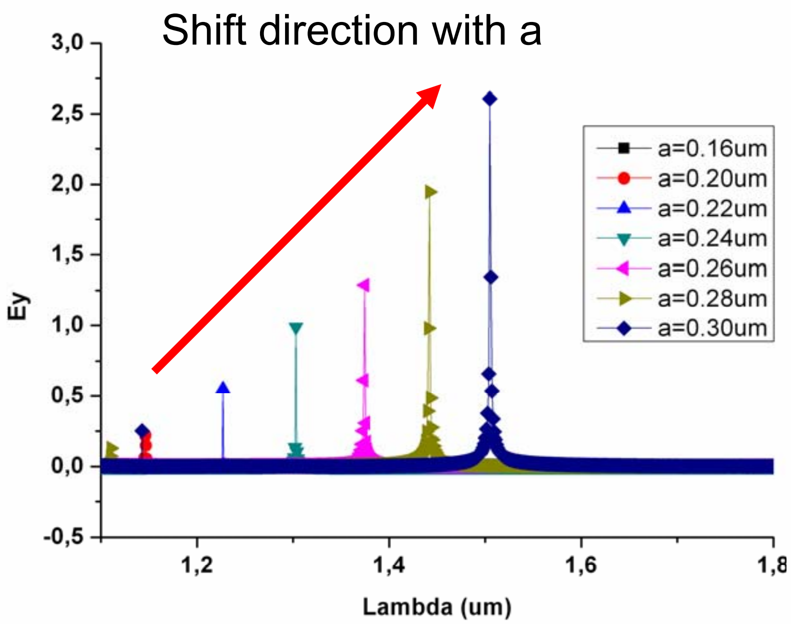
b). Polarization: Ex and Ez

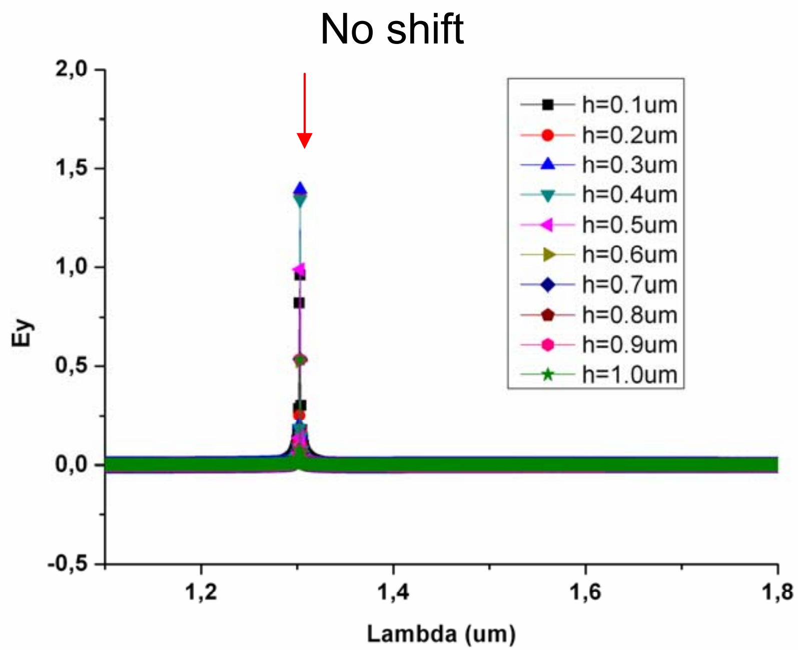
NW d = 0.2um, NW height h from 0.1 to 1.0um, PBC_width a from 0.16 to 0.3um

| h(um) / a(um) | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.16 | | | | | | 0.907 | | | | | |
| 0.2 | | | | | | 1.042 | | | | | |
| 0.22 | | | | | | 1.100 | | | | | |
| 0.24 | | 1.153 | | | | 1.153 | | | | | 1.153 |
| 0.26 | | | | | | 1.203 | | | | | |
| 0.28 | | | | | | 1.248 | | | | | |
| 0.3 | | | | | | 1.292 | | | | | |

- Periodic width increase ------- red shift of the fundamental mode resonance wavelength;
- Nanowire height -------------- no effect.

Spectrum effects of periodic width a and nanowire height (polarization Ey)

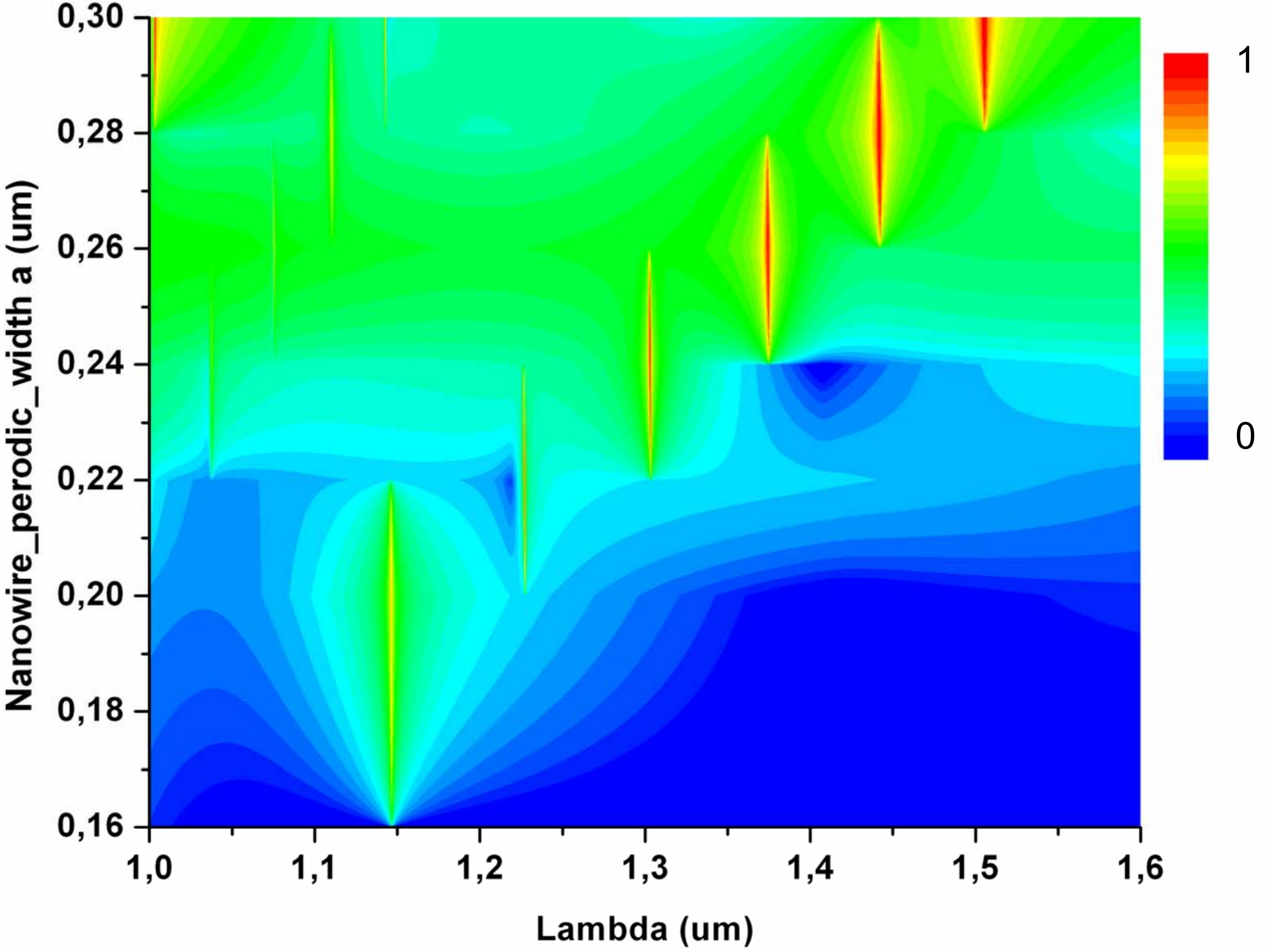


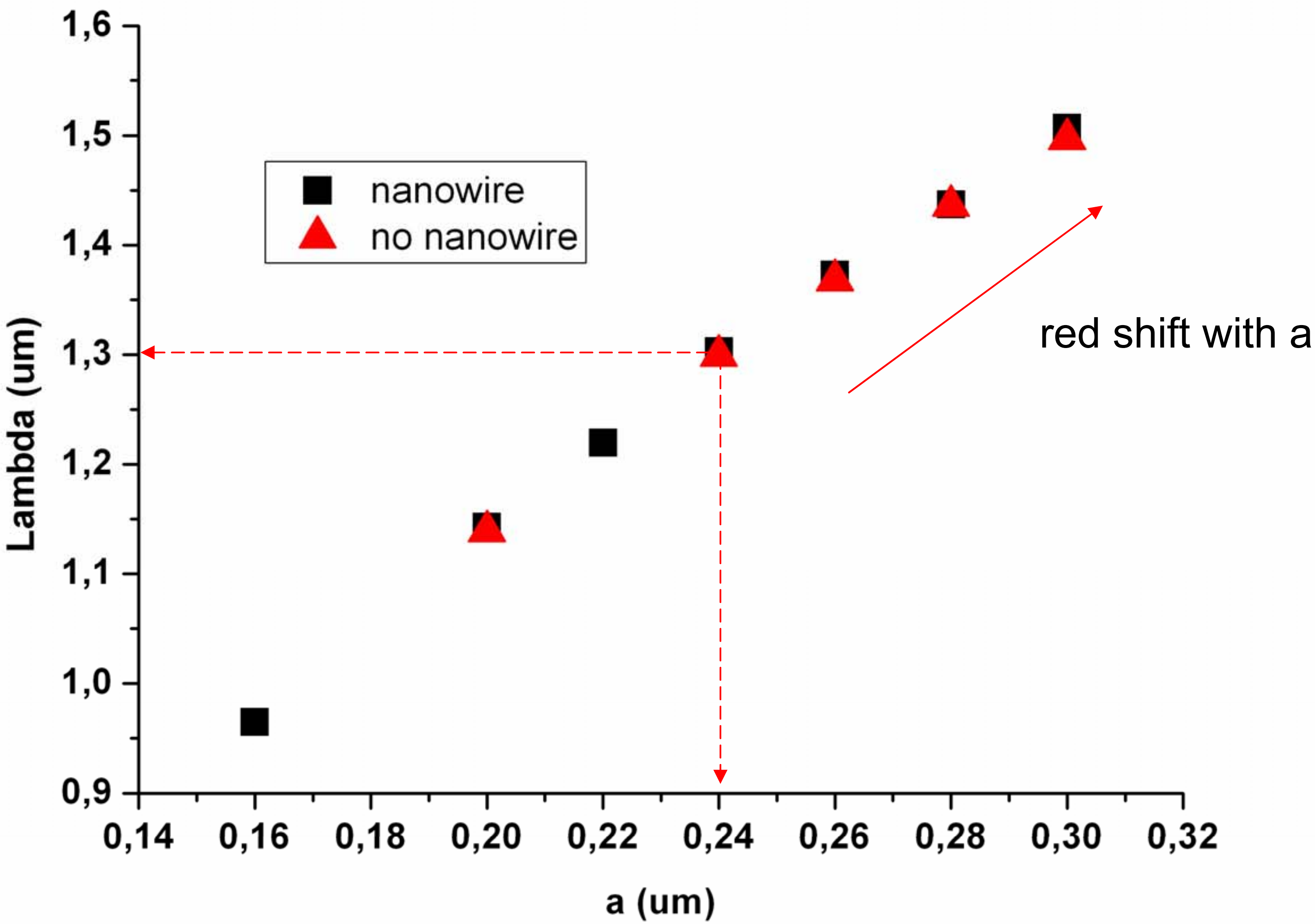




Red shift exists with the increase of periodic width a;

No effect with NWs height in the fundamental mode.

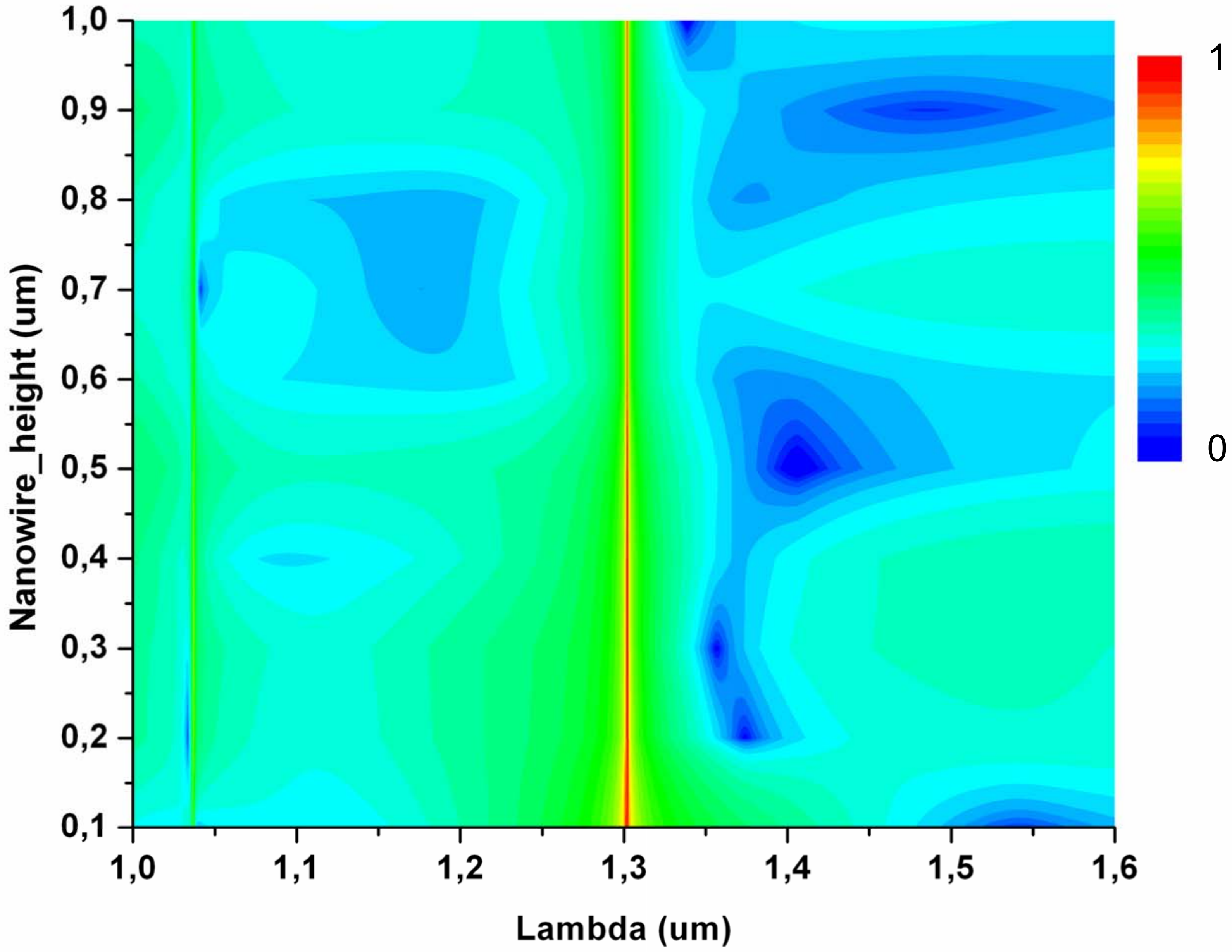
Spectrum map, nanowire_height = 0.5um, a from 0.16um to 0.3um



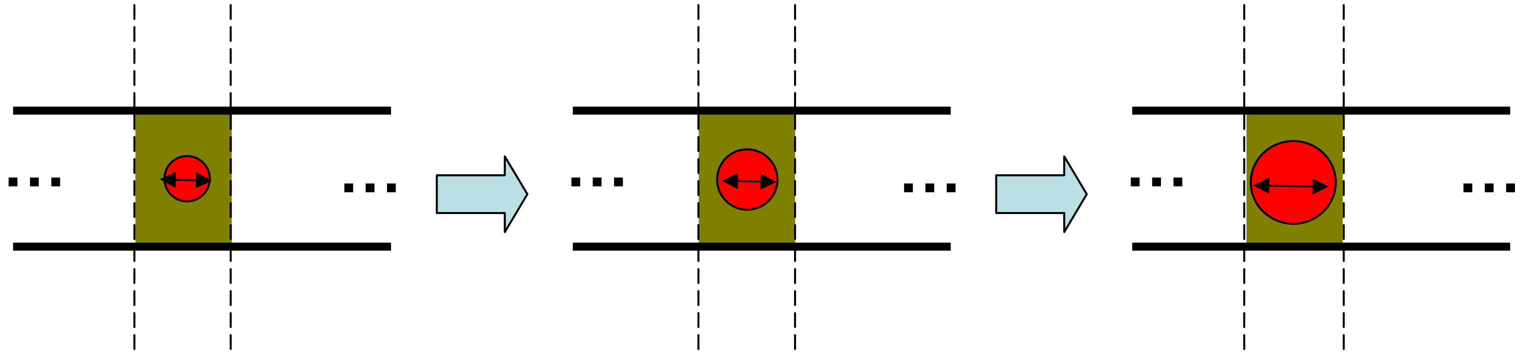



With a = 0.24um, the wavelength of fundamental mode locates at 1.3um.

Spectrum map, a = 0.24 um, nanowire_height h from 0.1um to 1.0um



2). Nanowire diameter d



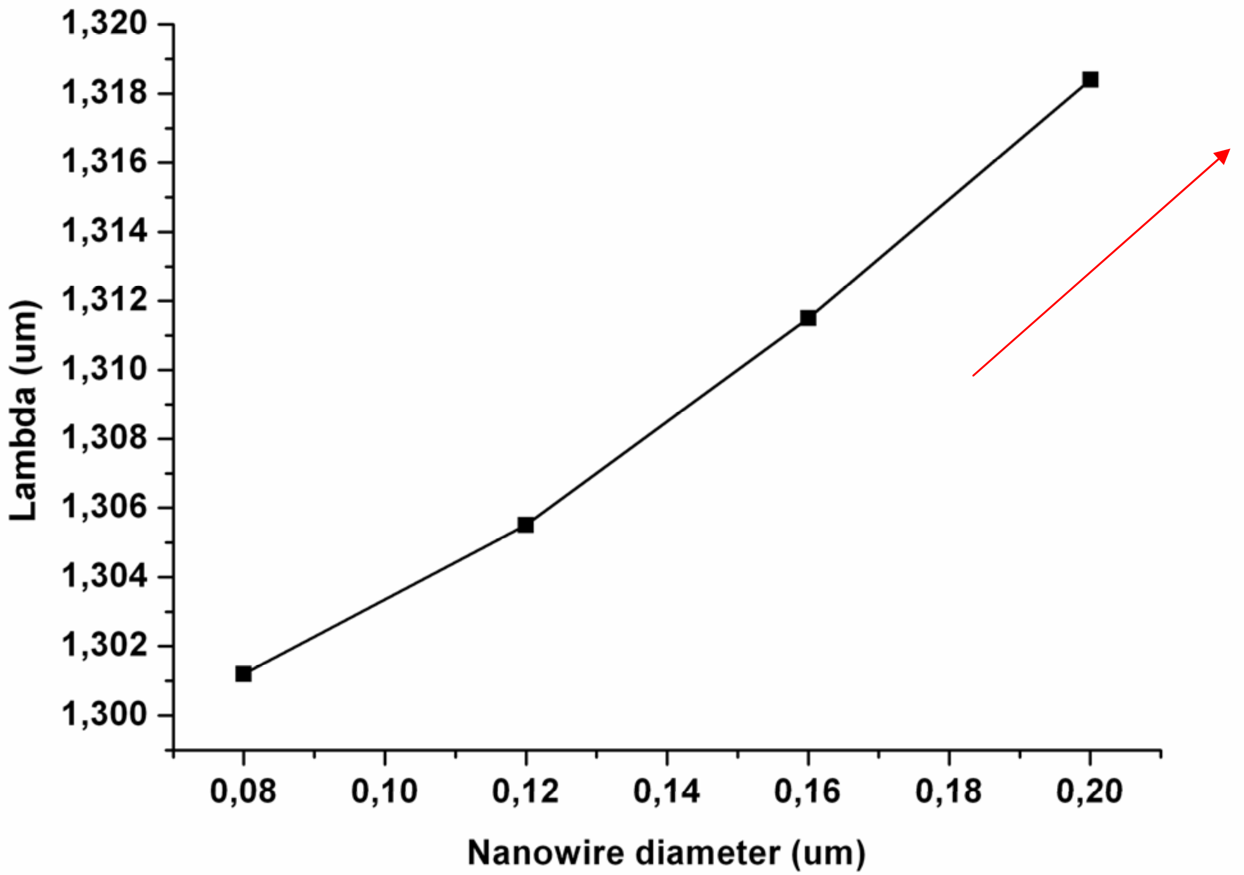
Polarization: Ey

Periodic a: 0.24um -----(1.3um in resonance wavelength)

NW height h: 0.5um

First resonance wavelength vs. Nanowire diameter

| Nanowire diameter (um) | 0.08 | 0.12 | 0.16 | 0.20 | +∞ |
|---|---|---|---|---|---|
| Lambda (um) | 1,3012 | 1,3055 | 1,3115 | 1,3184 | 1.3850 |



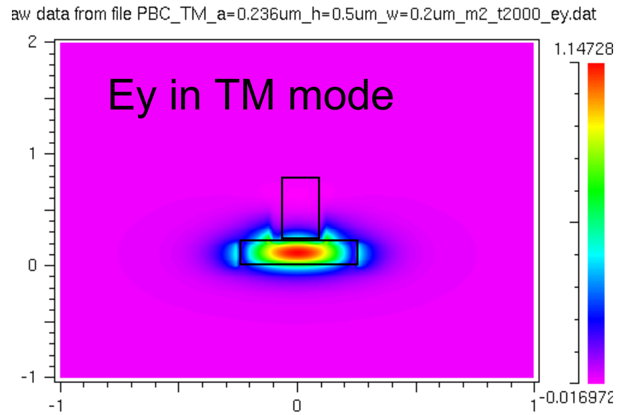

- The wavelength red shift with d;

- The effect of NW diameter is very small to the shift of lambda comparing to the diameter changes of NW.

# Field distrubution at fundamental mode:

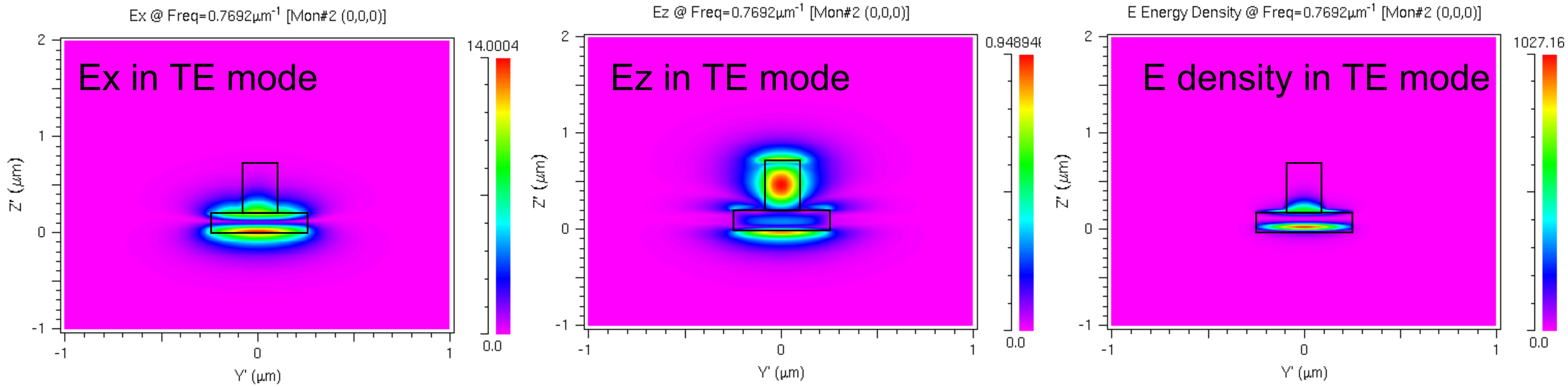
## TM mode:

a = 0.236um, h = 0.5um, d = 0.2um,
t = 0.2um, w = 0.5um,
foudamental mode λ = 1.3um.




## TE mode:

a = 0.28um, h = 0.5um, d = 0.2um, t = 0.2um,
w = 0.5um, foudamental mode λ = 1.3um.




Although strong Ez exists inside the NWs. However, Ez is the miner part of E, So the E density distribution is similar to Ex. E energy inside NWs is still weak.

Conclusion:

1. Resonance wavelength $\lambda$ has red shift with periodic width a;

   1). With a = 0.24um, the wavelength of fundamental mode locates at 1.3um.

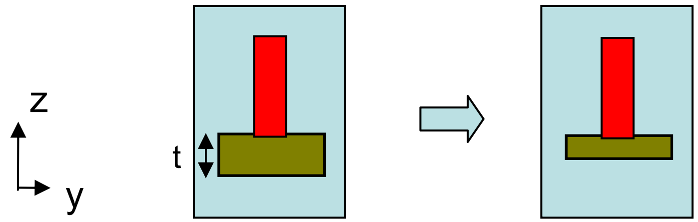
2. NW height has no effect on the resonance wavelength $\lambda$ in BOTH POLARIZATION;

3. NW diameter has small effect to the wavelength shift comparing to the diameter changes of NW.

4. As varing the geometry of NWs can't get strong E energy inside the NWs, we consider to study the geometry of Si waveguide.

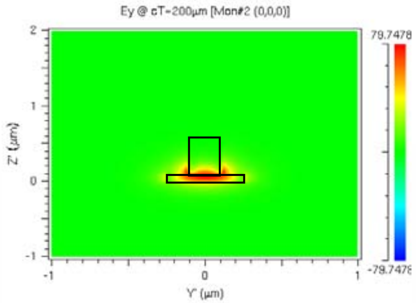
5. Effect of Si waveguide

1). Waveguide thickness t

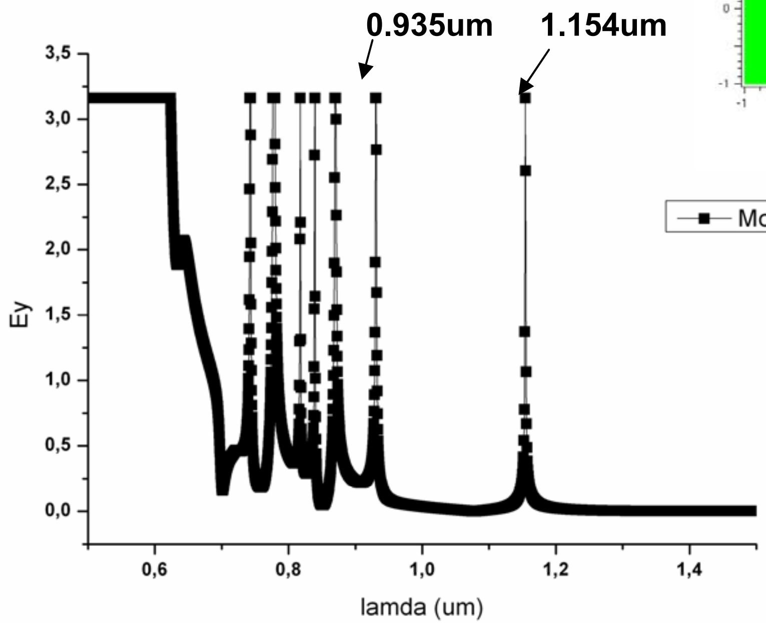



Polarization: Ey; Periodic a: 0.24um -----(1.3um in resonance wavelength)

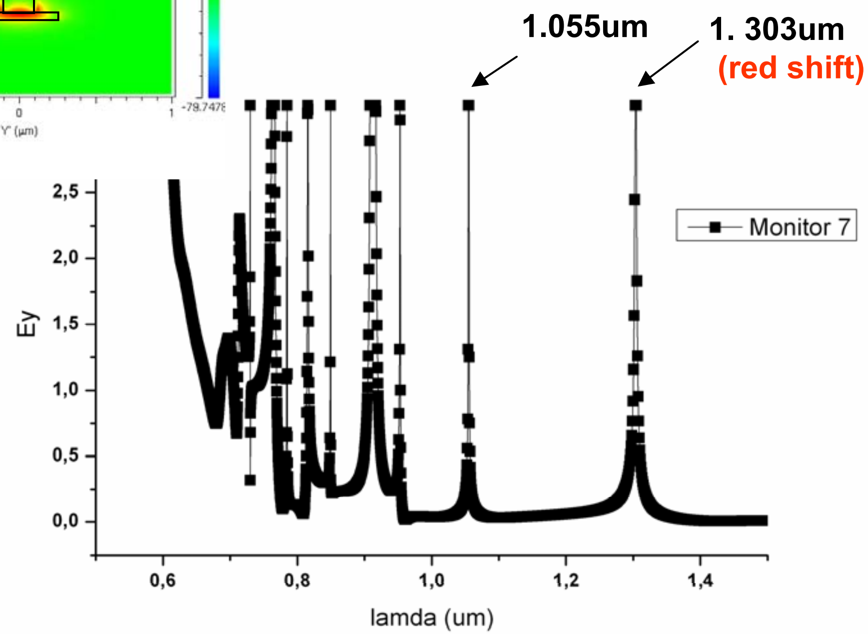
NW height h: 0.5um; NW diameter a: 0.2um



t = 0.1um

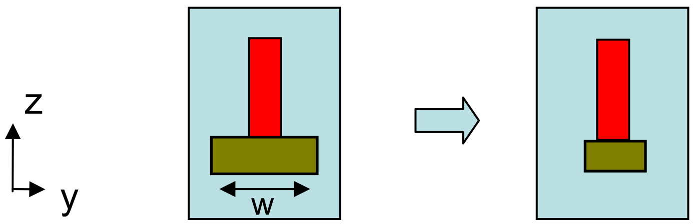



t = 0.2um



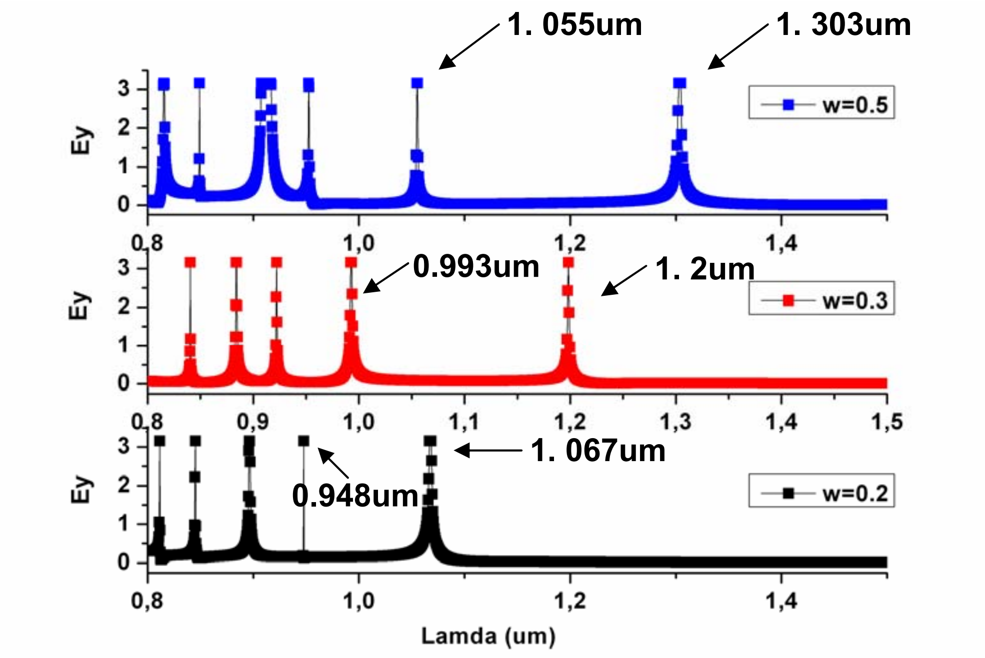

- Red shift exists with the increase of Si waveguide thickness;
- The thinner the Si waveguide, the stronger the field inside the NWs.

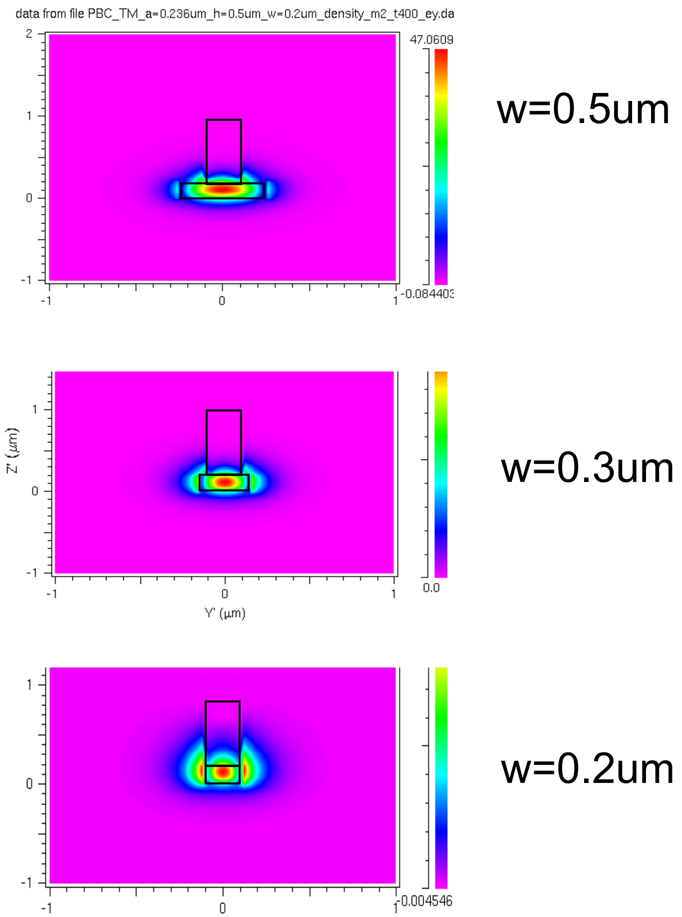
2). Waveguide width w




TM (Ey), d = 0.2um, a=0.24um, t = 0.2um;

w = 0.2um, 0.3um, 0.5um.




- Red shift with w incease;
- Stonger E energy density inside NW with smaller w, but still weak.

## 6. E energy density in NW and Si waveguide in high order mode

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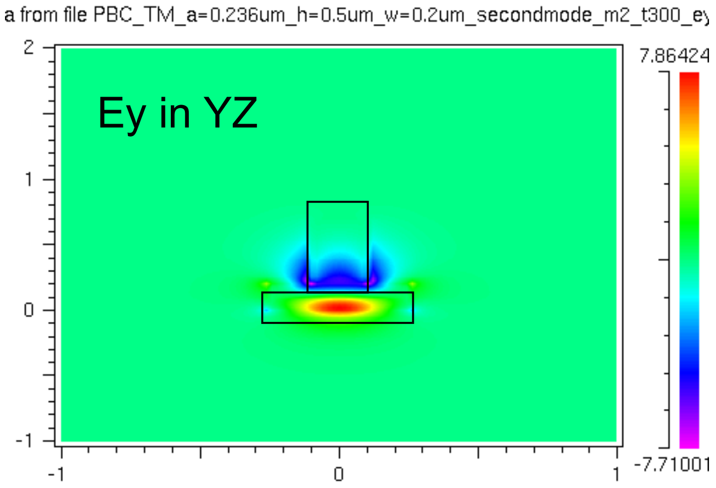
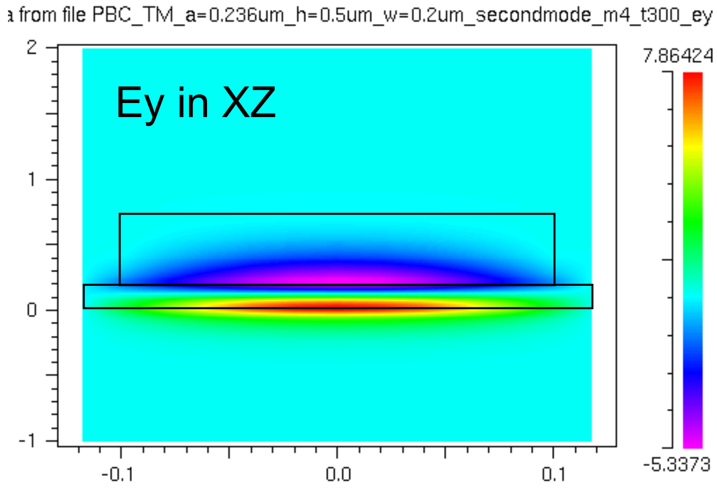
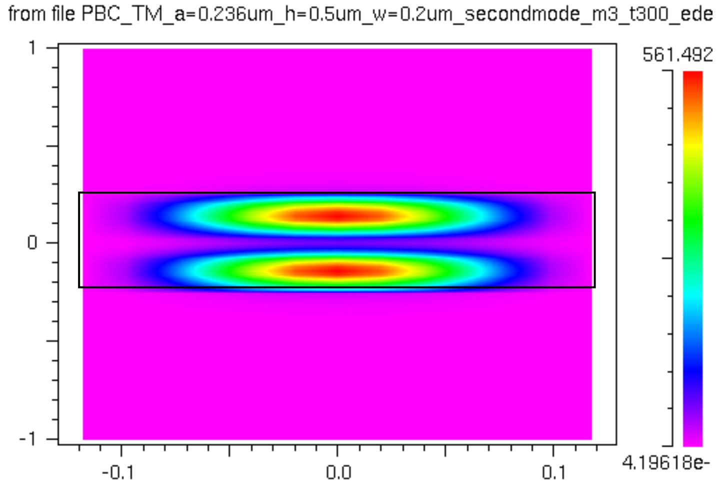
TM (Ey), d = 0.2um, a=0.24um, t = 0.2um;

1). Second order mode: w = 0.5um, λ = 1.055um.

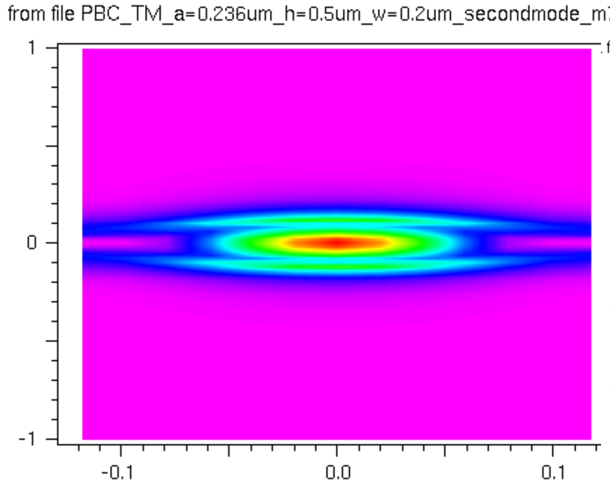


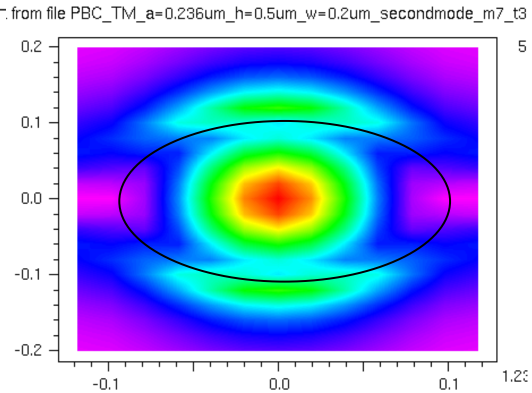




The E field and E energy density is much stronger inside the NWs.



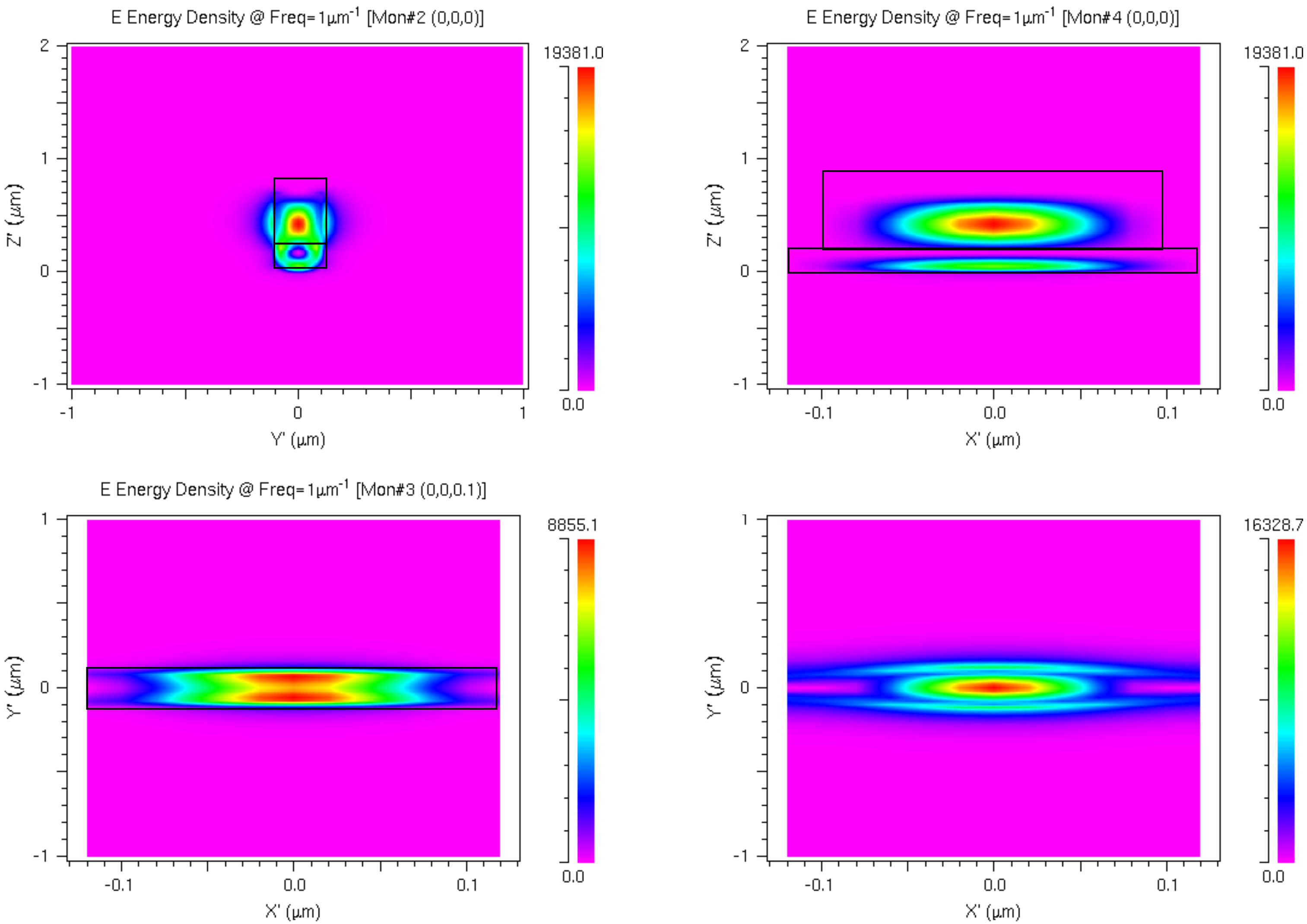

E energy density in XY Si waveguide

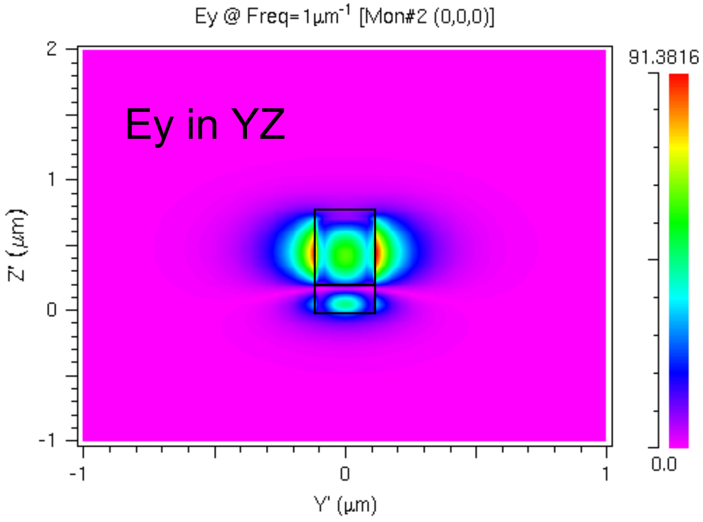


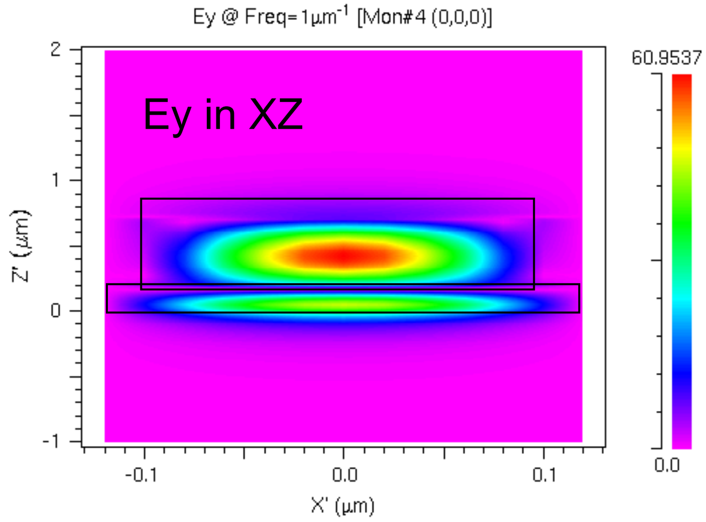




E energy density in XY inside NW

2). Second order mode E density: w = 0.2um, λ = 0.948um.






Conclusion: strong E energy exists inside NWs in high order mode.