

# Simulation of Split Ring Resonator (SRR) at Optical Frequencies

# Split Ring Resonator (SRR)

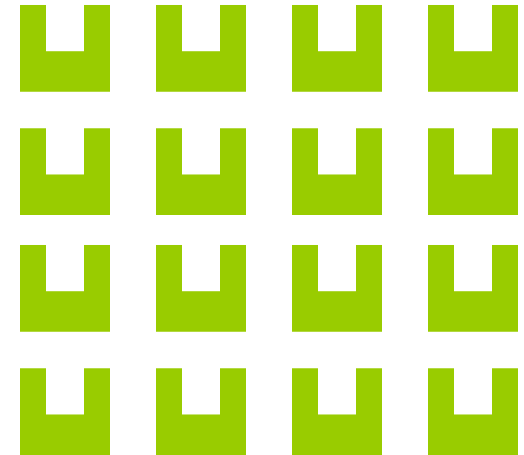
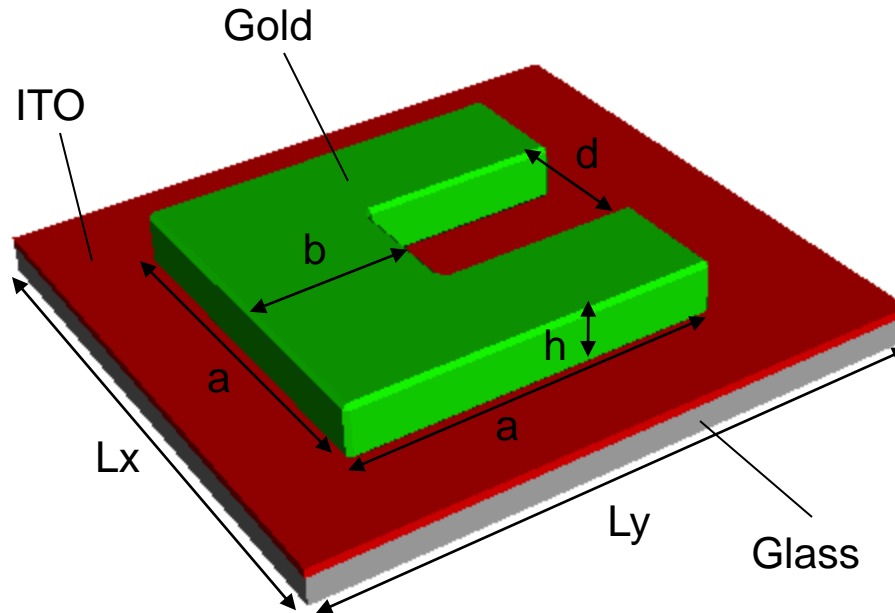
Glass substrate: 15nm,  $\epsilon=2.25$

ITO film: 5nm,  $\epsilon=3.8$

Gold: Drude model:

$$\omega_p = 1.367 \times 10^{16} \text{ (rad/sec)}$$

$$\omega_c = 6.478 \times 10^{13} \text{ (rad/sec)}$$



$$L_x = 315 \text{ nm}$$

$$L_y = 330 \text{ nm}$$

$$a = 200 \text{ nm}$$

$$b = 80 \text{ nm}, 90 \text{ nm}$$

$$d = 70 \text{ nm}$$

$$h = 30 \text{ nm}$$

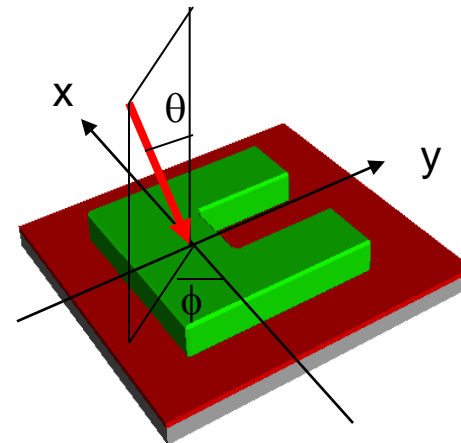
The parameters are based on the work of Enkrich et al [1] and Burger et al [2]

# Simulation Setup

- Drude model used (via “**drude**” command, version 4.6) to calculate the complex permittivity of gold

$$\varepsilon(\omega) = 1 - \frac{\omega_p^2}{\omega(\omega + i\omega_c)}$$

- PML2 command (“**pml2**”, version 4.6) used to terminate the absorbing boundaries in z direction
  - Enhancements to standard PML command: (1) automatically optimize PML parameters, (2) run faster in FDTD iterations
  - Allowing boundaries to be placed closer to scattering objects to reduce simulation domain size and, therefore, save memory and run time
- Yee cell size = 5nm
- The following effects are simulated
  - Angle of incidence (theta, phi)
  - S-polarization
  - Dimension b (80nm, 90nm)



# Transmission Calculation

- The transmission through SRR is calculated as follows

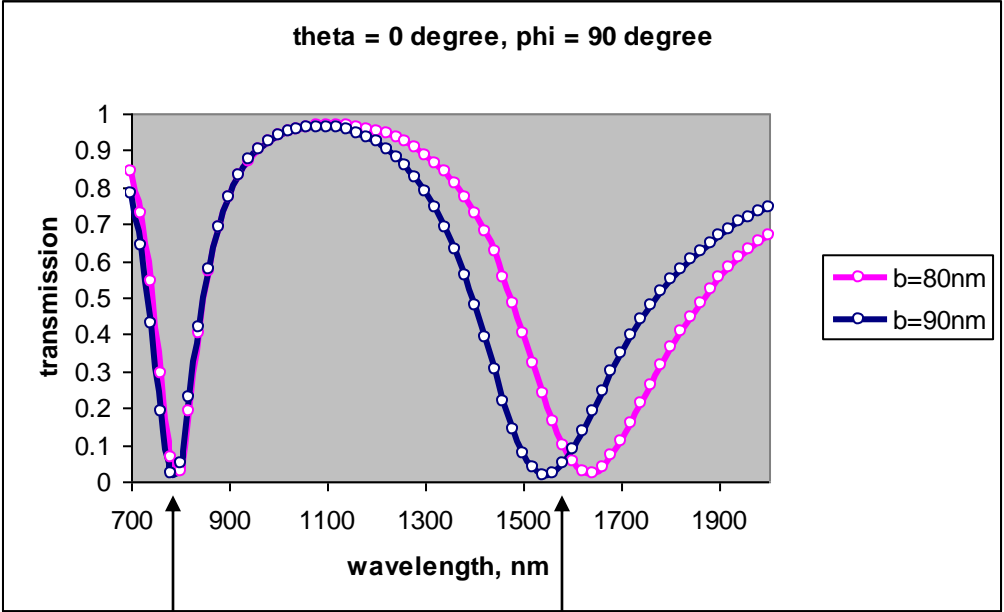
$$T = \frac{I_{SRR}}{I_{NoSRR}}$$

$I_{NoSRR}$  is the e-field intensity of 0-order transmitted planewave w/o gold SRR.

$I_{SRR}$  is the e-field intensity of 0-order transmitted planewave w/ gold SRR.

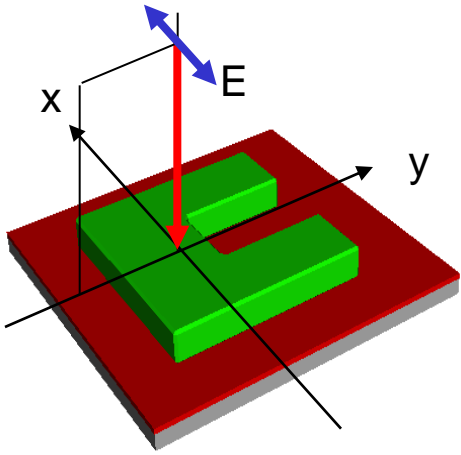
- The “`scat_func`” command with “`ft=true`” option is used to compute diffraction orders of the transmitted field

# Effects of b

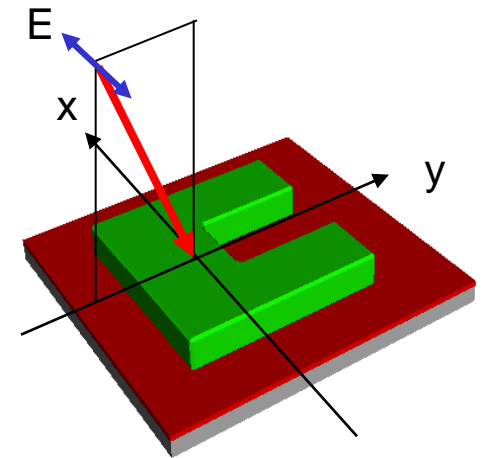
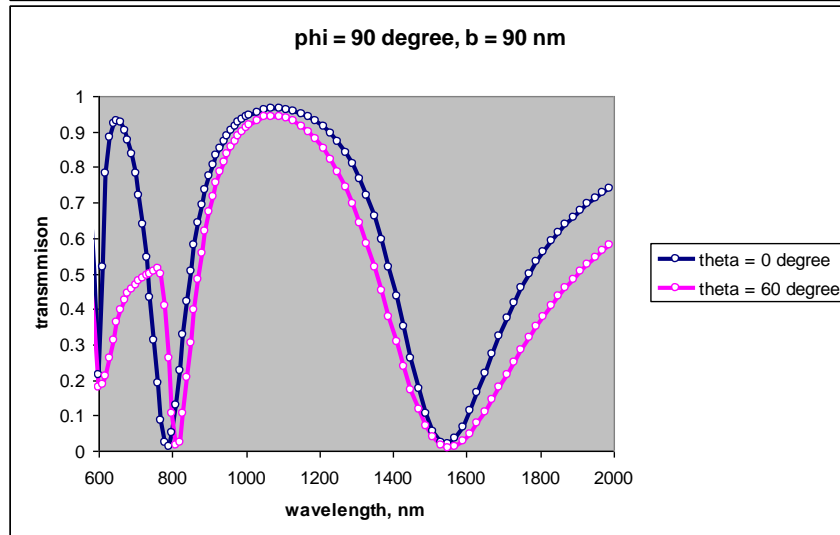
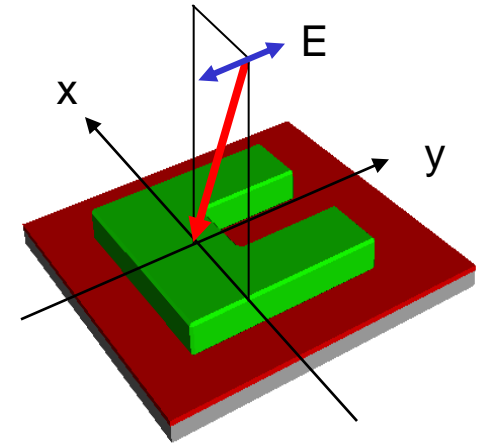
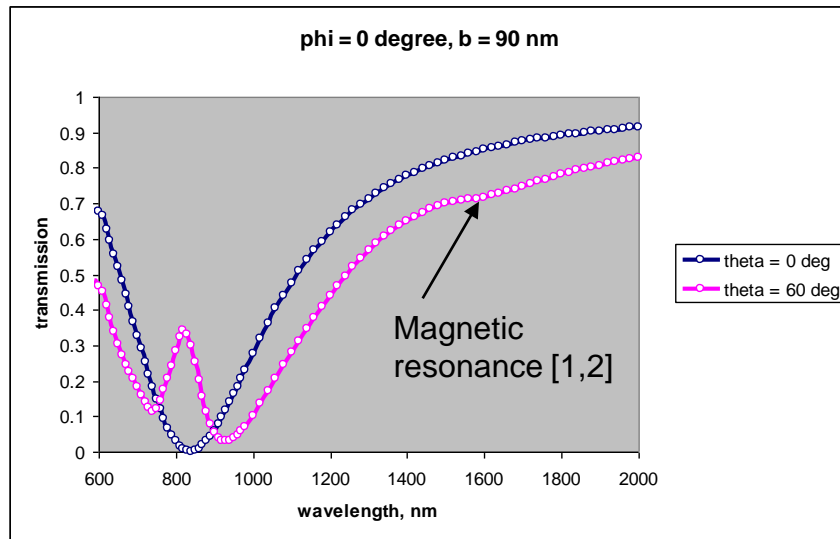


Mie resonance [1,2]

Magnetic resonance [1,2]



# Effects of Incident Angles



# References

- [1] Enkrich et al, "Magnetic Metamaterials at Telecommunication and Visible Frequencies," Physical Review Letters, PRL 95, 203901, 11 Nov. 2005
- [2] Burger et al, "Numerical Investigation of Light Scattering off Split-Ring Resonators," Metamaterials, Proc. of SPIE Vol. 5955, 595503, 2005