Optical Waves Transmission Raised by Localized Surface Plasmons

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NUSOD 2007 @ University of Delaware

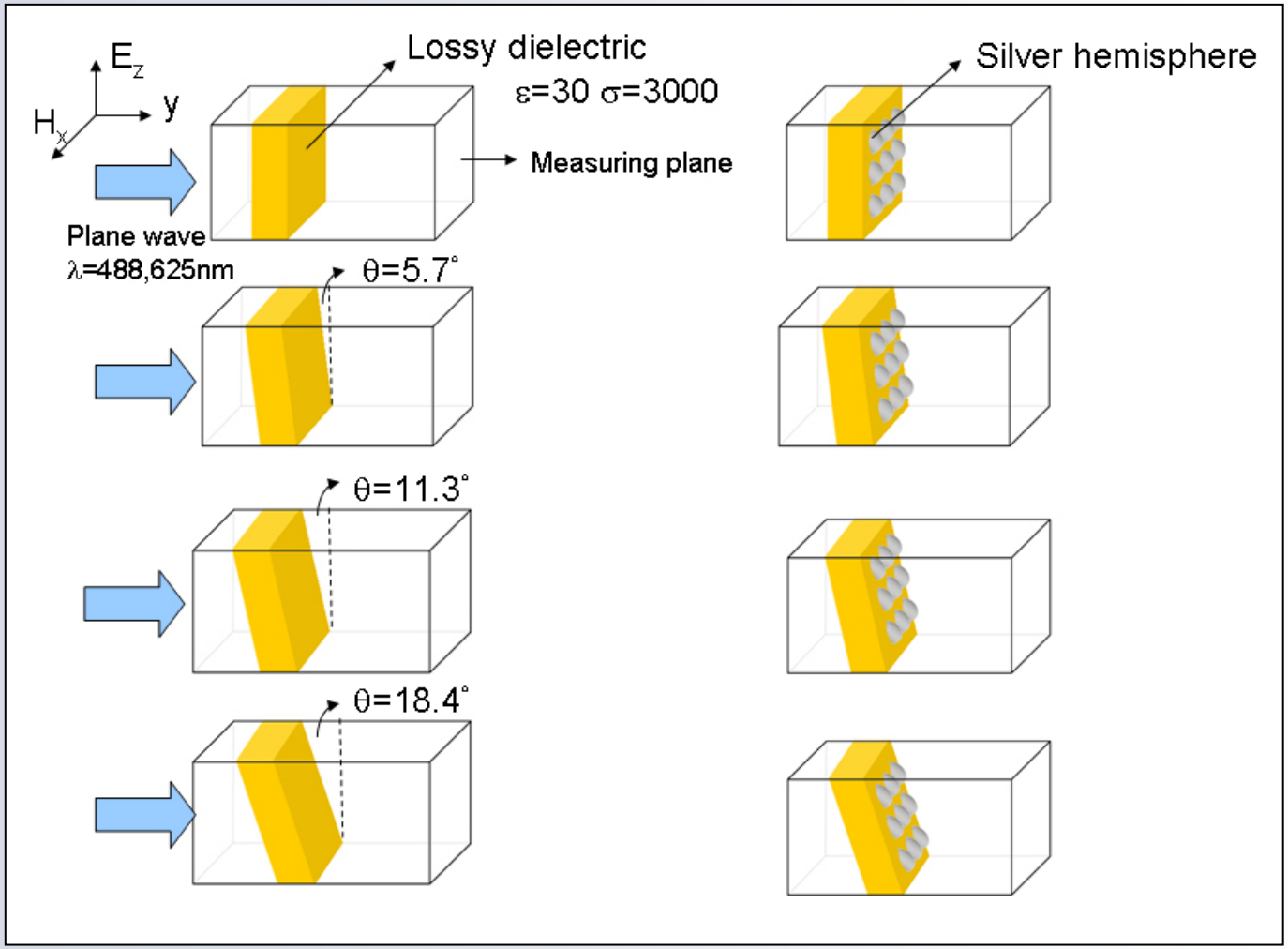
Outline

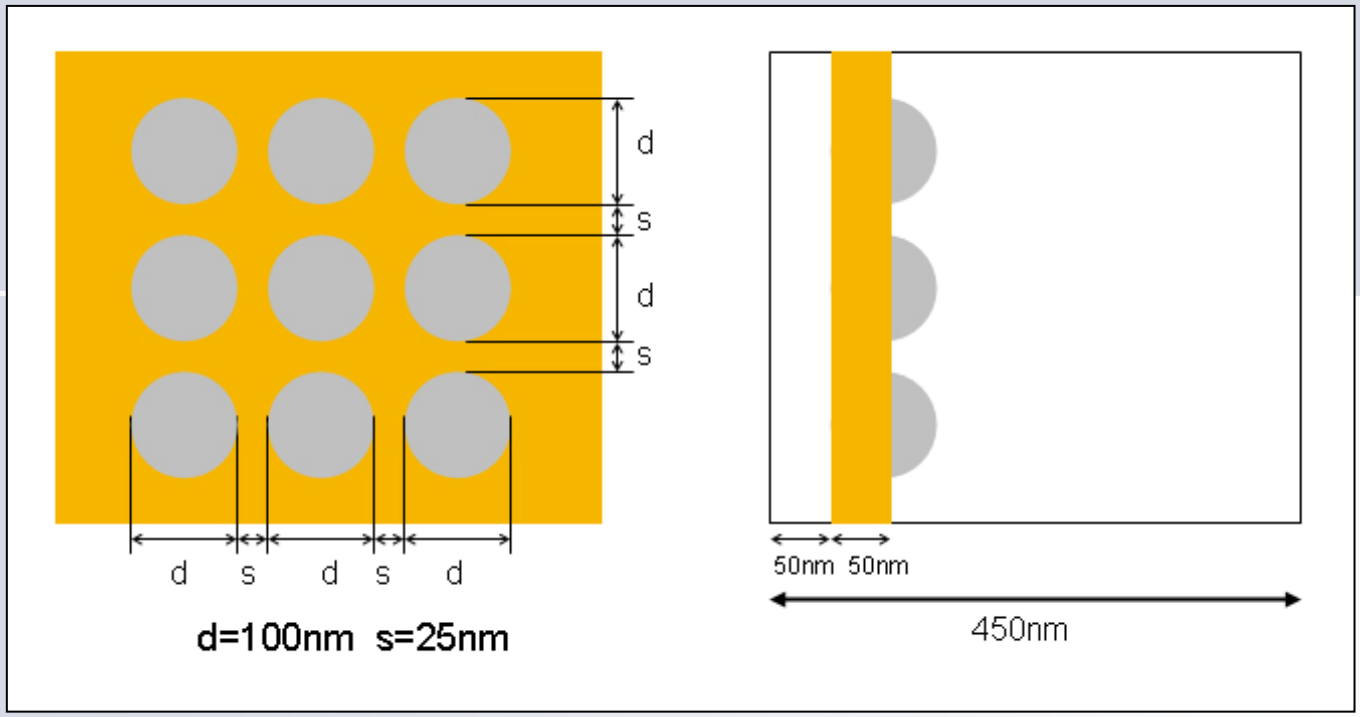
- Introduction
- Numerical Experiments
- Discussion and Summary
- Conclusion

Introduction

- Motivation
  - Periodic corrugated metal thin film can enhance the Light extraction from light-emitting diodes.
  - Metal thin film is good at the frequency the radiative surface plasmons produced, but it is a shield of the other optical waves.
  - How about discontinuous metal nano-objects?
- The mechanism of the enhancement
  - The coupling of incident waves with the surface plasmon.
  - Theoretically, the optimal conditions for the coupling is derived from Maxwell's equations.
  - However, the analytical solution to the Maxwell's equations are difficult to obtain for complex structures.
- Method for Numerical experiments
  - Three-dimensional Finite-Difference Time-Domain, a reliable method to solve 3D Time-dependent Maxwell's equations.

Numerical Experiments





Enhancement factor: $f = (E^2_{D+SP,\max} - E^2_{D,\max}) / E^2_{D,\max}$, f >0: enhancement; f <0: shield.

Ez is dominant, Ex, Ey are excited components, Ex is very weak and almost able to be neglected.

Conditions in 3D FDTD simulation:

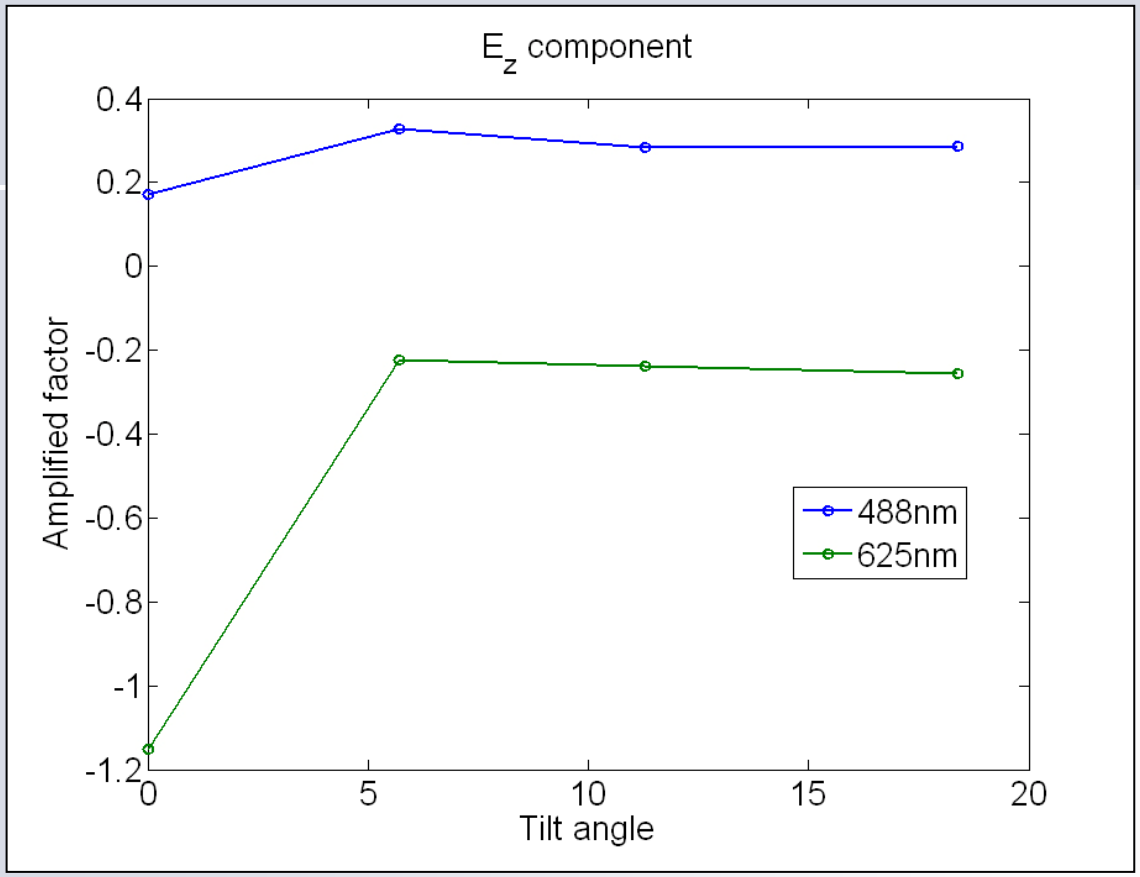
The number of the Yee cells is 100*100*100.

The edge of the cubic Yee cell is 5nm.

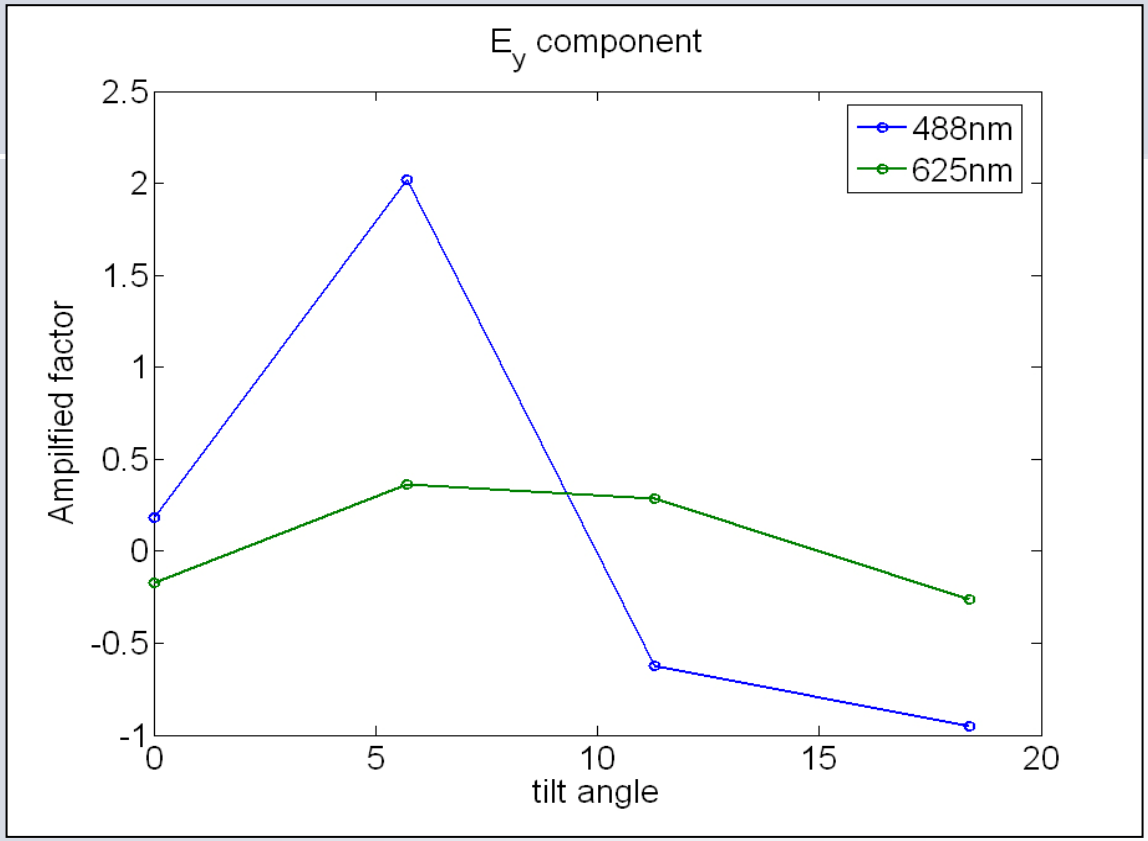
The time step is $8.33*10^{-18}$ second.

The amplitude of incident wave is normalized to 1.

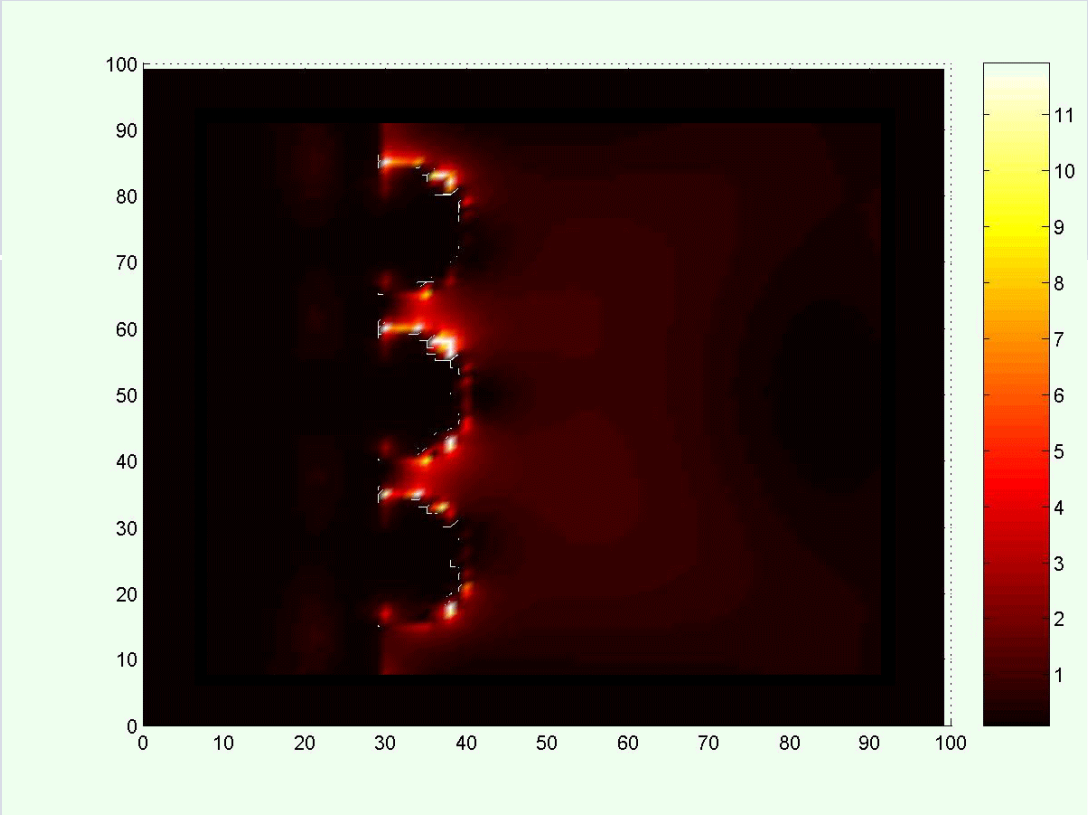
The boundary condition is Perfect Matched Layer (PML).



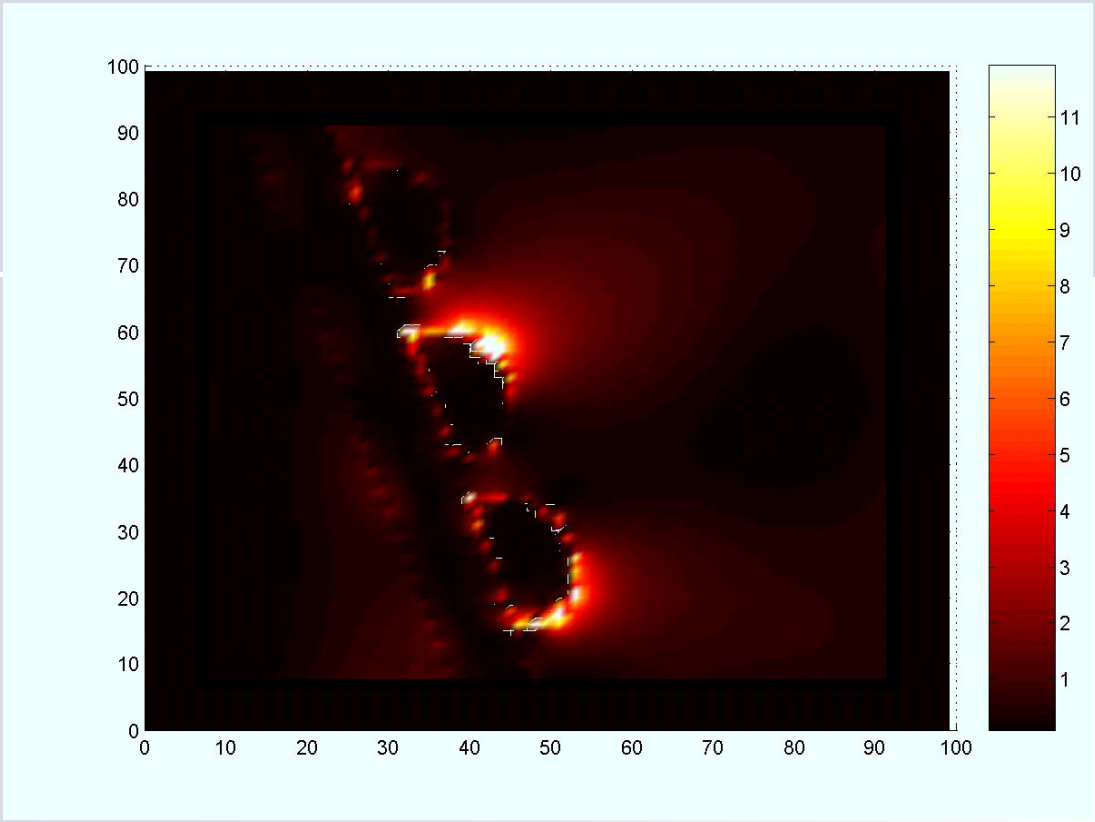
•The array of hemispheres has an enhancement effect only for 488nm.
•The tilt has no significant influence on 488nm.
•For 625nm, it has a negative effect on transmission, but the tilt can reduce the negative effect.



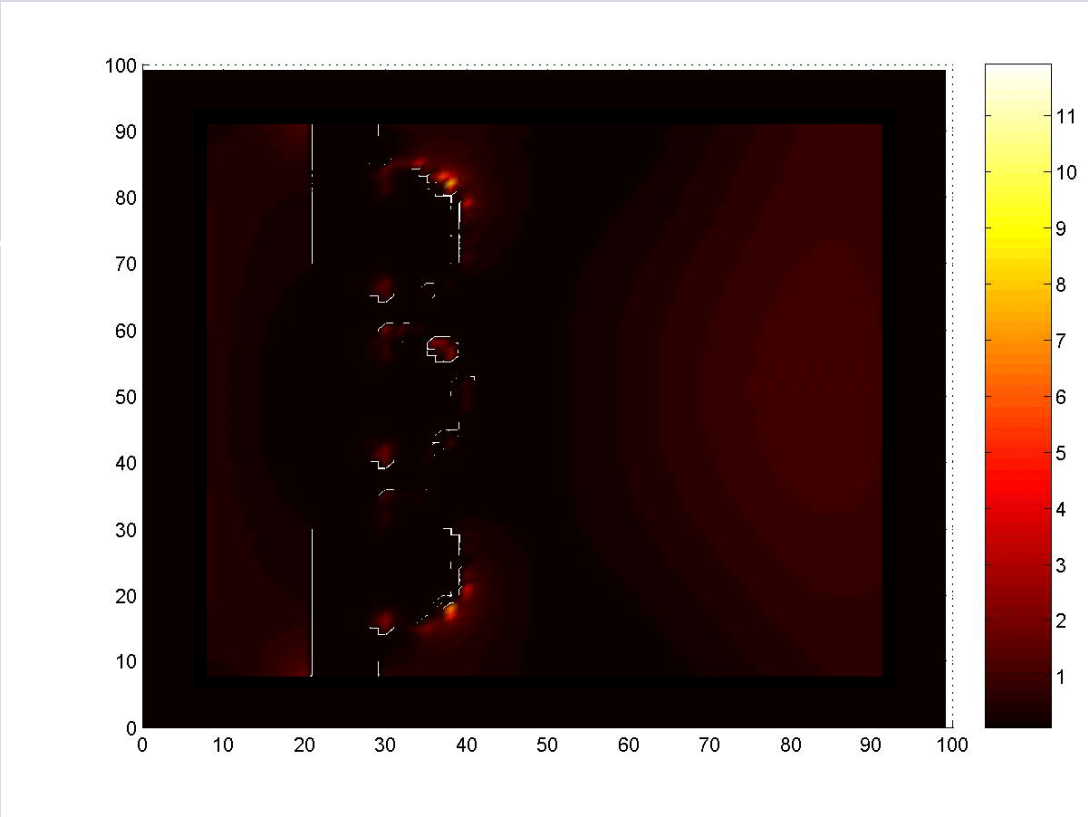
•The situation is complicate for Ey, it is very sensitive to tilt angle.
•For 5.7° tilt, the array both has an enhancement.
•The amplified factor changes from positive to negative with tilt angle, more obvious for 488nm.



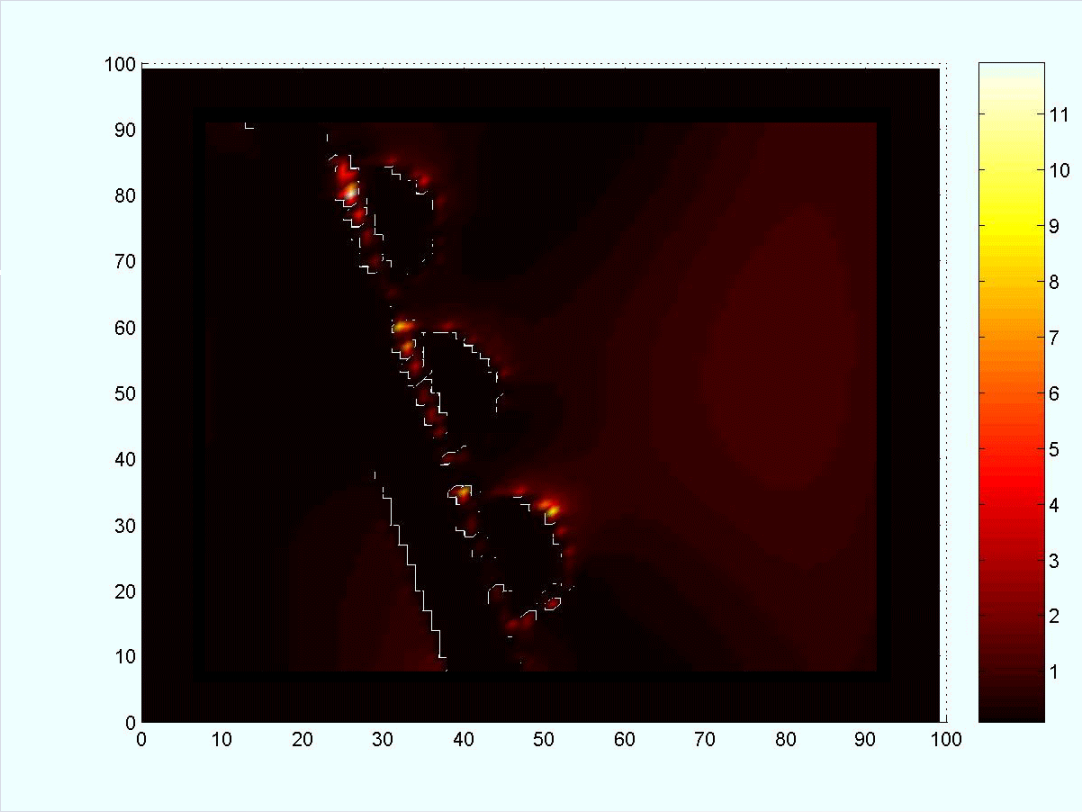
- The time variation of the distribution of wave intensity, λ=488nm, θ=0° .
- The animation is from 500th to 1000th time steps.
- It can be seen the coupling of incident wave with surface plasmons, and the enhanced waves propagate away from the array.



- The time variation of the distribution of wave intensity, λ=488nm, θ=18.4° .
- The animation is from 500th to 1000th time steps.
- The position where the enhanced waves leave away from the array is shifted due to the tilt.



- The time variation of the distribution of wave intensity, λ=625nm, θ=0° .
- The animation is from 500th to 1000th time steps.
- It can be seen the surface plasmons are highly localized on the interface of the dielectric and hemispheres array, thus the transmission would be reduced.



- The time variation of the distribution of wave intensity, λ=625nm, θ=18.4° .
- It seems that the tilt has no effect on the surface plasmons radiating.

Discussion and Summary

- The optimal conditions to raise the light extraction is highly dependent on wavelength for a discontinuous nanostructured.
- The tilt angle has no significantly positive effect on the transmission.
- The excited Ey component is very sensitive with tilt angle, the hemispheres array might be a polarizer to filter it.
- It is still a challenge to construct a plasmonic nanostructure which is good for continuous optical waves.

Conclusion

- Surface plasmon radiation can be viewed on the simulations, the animations provide further details on the coupling mechanism.
- The study of the raise of transmission is also helpful to apply to light absorption, e.g. solar cell.
- Theoretically, the optimal conditions for surface plasmon resonance is difficult to obtain for complex structures, the simulation is an indispensable tool in studying the plasmonics.

Thank You for Your Attention.