



Manipulation of Light in the Nanoworld



Development Team Members:

Boyang Liu, Ki Young Kim, David E. Ashkenaz,
 Group Coordinator: Seng-Tiong Ho
 Visualization Collaborator: Jim Chen, Yeh Fei
 Other Collaborator : Jonathan Andreasen, Hui Cao

Approach

Pedagogy

(anchoring an Idea in the world of the students)

The **macro** world of students awareness

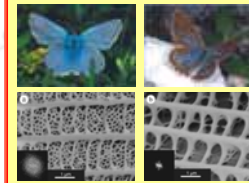
The **nano** world that can affect their lives

Concept

(Linking known concepts applied at nanoscale)

Size determines the nature of Interaction between Light and Matter – Examples

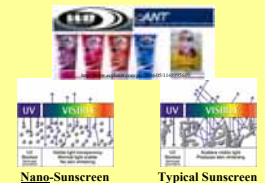
Butterfly Wing



Beetle Wing



Commercial Cosmetic (Sunscreen)



http://www.nsf.gov/edu/inf/nano-online/2002_butterfly/index.html

Conventional Physics: Interference

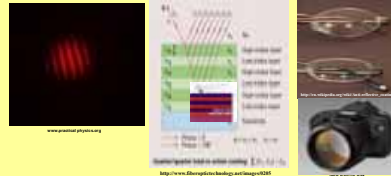
All waves have interference, combining constructively and destructively

- Optic and acoustic wave
- Thin film interference
- Bragg reflection

Optical wave



Thin Film Interference



Interference on CD surface

Anti-reflective coating

Simulation Tools

Simulation Tool:

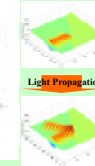
- Interactive User Interface
- Finite Difference Time Domain (FDTD) Method
- Electromagnetic field of the light is calculated to high precision

Simulation of Interference

Interactive User Interface



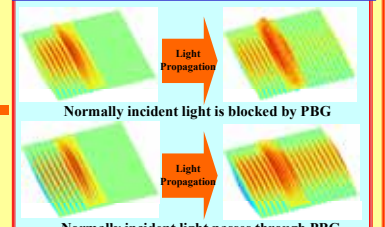
Bragg reflection Simulation



Light Propagation



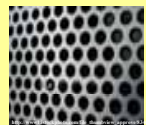
Simulation of Photonic Band Gap



Nano Concept: Photonic Band Gap

- PBG Nanostructure materials.
- Confined light in nanostructure depends on structure size
- Design Project combines PBG nanostructure synthesis and simulation

Big Holes on Grill (1cm diameter)



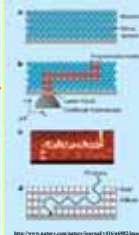
Nano Holes!

Light confined in PBG nanostructure

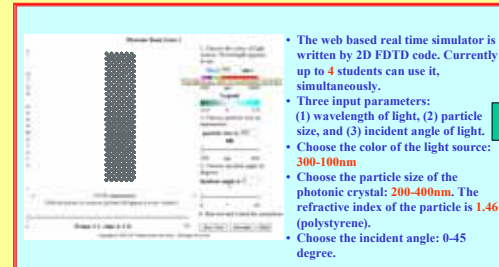
Nano Holes Squeeze & Confine Light, $< \lambda$ (300nm diameter)

Periodic refractive index

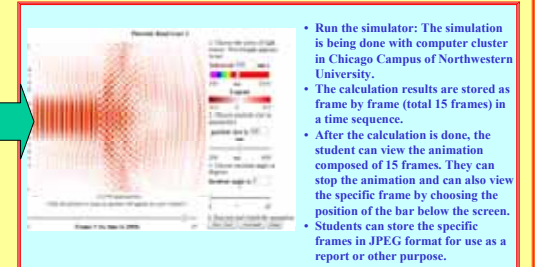
Periodic change of refractive index is formed, similar to Bragg reflection!



Field Test: User Interface of Real Time Simulator



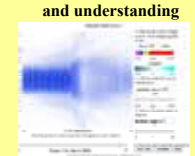
- The web based real time simulator is written by 2D FDTD code. Currently up to 4 students can use it, simultaneously.
- Three input parameters: (1) wavelength of light, (2) particle size, and (3) incident angle of light.
- Choose the color of the light source: 300-100nm
- Choose the particle size of the photonic crystal: 200-400nm. The refractive index of the particle is 1.46 (polystyrene).
- Choose the incident angle: 0-45 degree.



- Run the simulator: The simulation is being done with computer cluster in Chicago Campus of Northwestern University.
- The calculation results are stored as frame by frame (total 15 frames) in a time sequence.
- After the calculation is done, the student can view the animation composed of 15 frames. They can stop the animation and can also view the specific frame by choosing the position of the bar below the screen.
- Students can store the specific frames in JPEG format for use as a report or other purpose.

Design Project

Simulation for Prediction and understanding



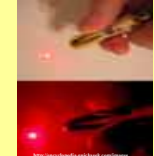
Online user interface for PBG

Synthesis of PBG material



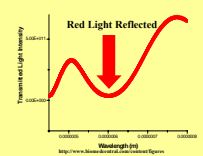
Students work in team

Determination of λ_{PBG}



Different colored light shining

Comparison and analysis



Reports and analysis

Potential Extension



Color Addition