ECE 595, Section 10
Numerical Simulations
Lecture 22: Full 3D Bandgaps

Prof. Peter Bermel
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Recap from Wednesday

- Bandstructure Symmetries
- 2D Photonic Bandstructures
- Periodic Dielectric Waveguides
- Photonic Crystal Slabs
Outline

• Recap from Wednesday
• 3D Lattice Types
• Full 3D Bandgap Structures
  – Yablonovite
  – Woodpile
  – Inverse Opals
  – Rod-Hole 3D PhCs
3D Lattice Types

Blue = simple cubic lattice
Blue + Red = fcc lattice
All = diamond lattice
Yablonovovite

- First PhC, fabricated by Eli Yablonovitch group
- Built for microwaves via mechanical drilling
Yablonovite

- Determined to have full 3D PBG after a pseudogap detected in first structure, as fabricated and tested by Gmitter
Woodpile

- Woodpile has alternating rod directions with half-period offsets, forming an fcc structure
Woodpile structures display a large bandgap with a relatively simple geometry.
Inverse Opals

- Created via 3-step process:
  - Silica sphere assembly
  - LPCVD silicon infill
  - Silica etch (HF)
Inverse Opals

- Bandstructure shows significant full 3D bandgap
Rod-Hole 3D PhC

- Consist of alternating 2D PhC slab-like layers of rods and holes
Rod-Hole 3D PhC

- 3D bandgap is fairly large
- Dramatically different from the individual 2D PhC slabs
Rod-Hole 3D PhC

Cross-sectional view

Top view
Role-Hole 3D PhC: Air Defect

Removing a single rod creates 3D confinement in a very small volume.
Rod-Hole 3D PhC: Dielectric Defect

Similar 3D confinement also observed when increasing the radius of a single rod
Rod-Hole 3D PhC: Waveguide

Can create a waveguide much like in 2D PhCs by removing a whole row of rods
Rod-Hole 3D PhC: Surface States

Termination of 3D structure gives rise to surface states – cf. surface plasmons
Next Class

- Is on Monday, March 4
- Will discuss electronic bandstructures
- Recommended reading: Kittel, Intro to Solid State Physics, Chapter 9