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

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March 1, 2013

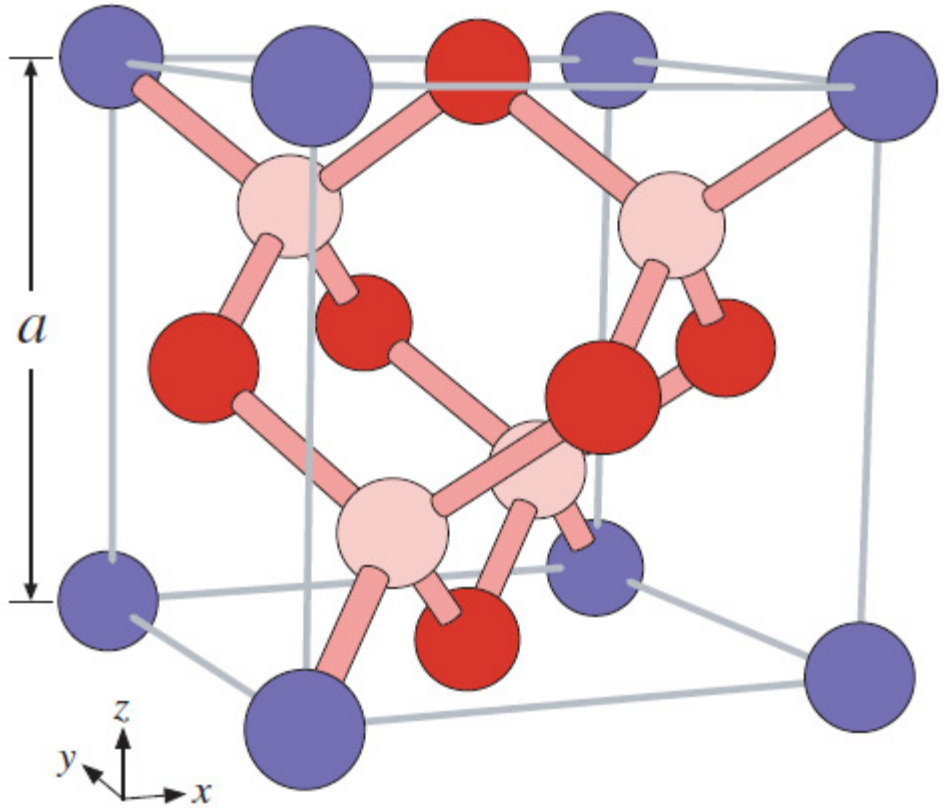
Recap from Wednesday

- 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

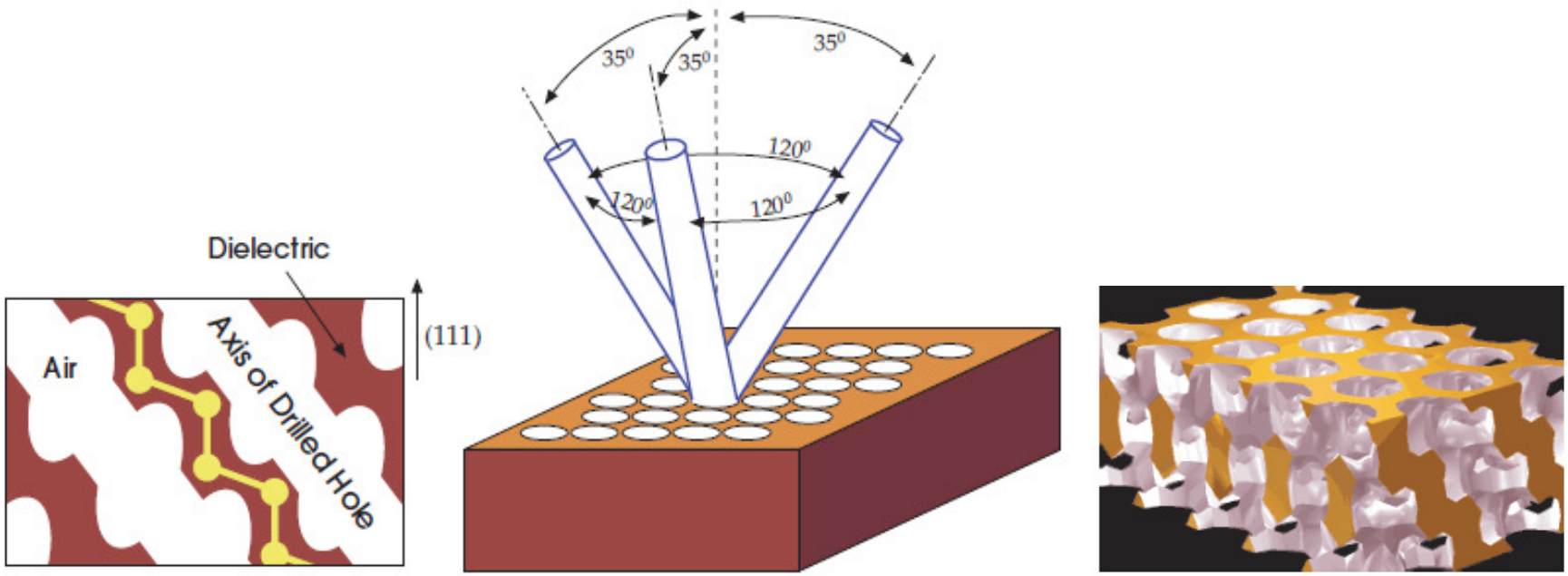


Blue = simple cubic lattice

Blue + Red = fcc lattice

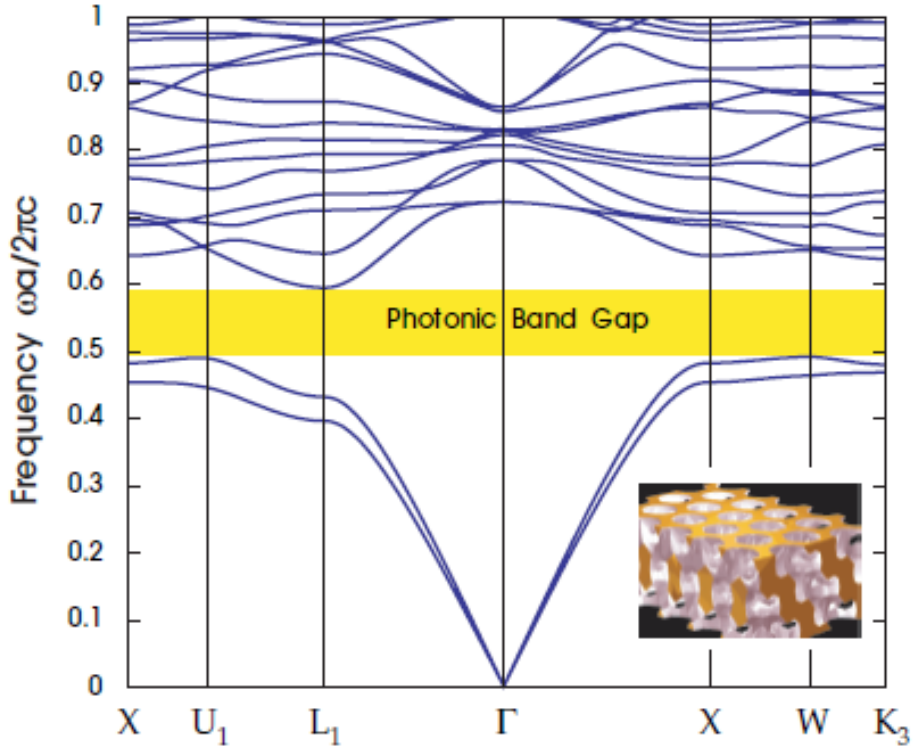
All = diamond lattice

Yablonovite



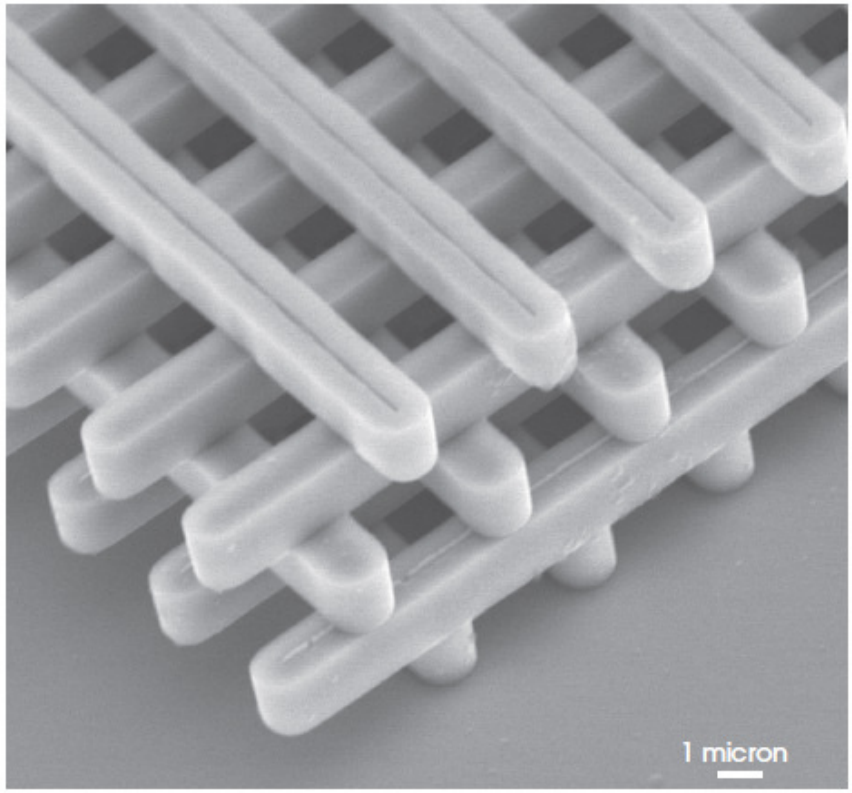
- First PhC, fabricated by Eli Yablonovitch group
- Built for microwaves via mechanical drilling

Yablonovite



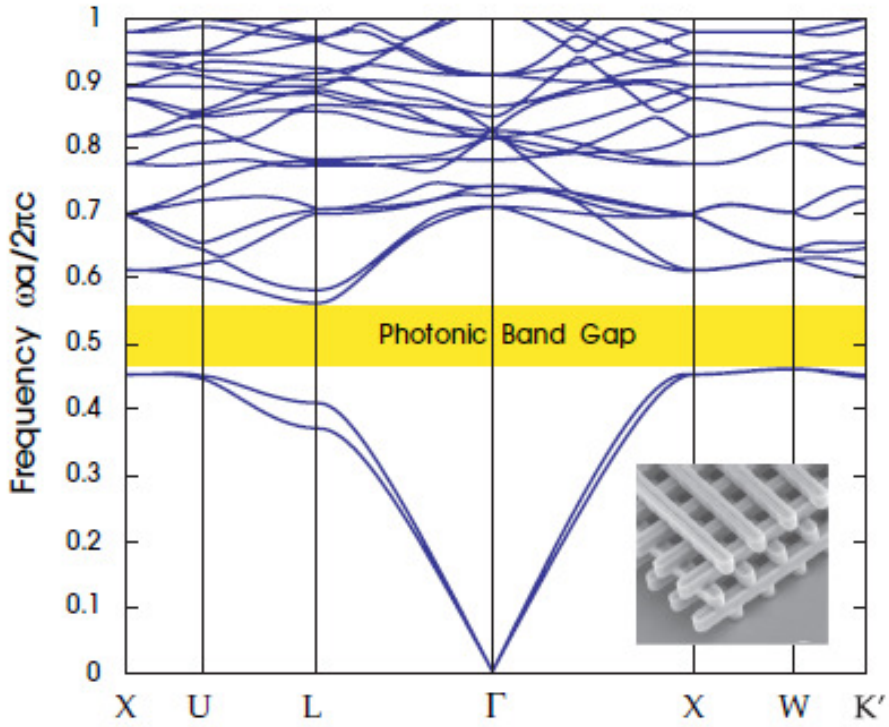
- Determined to have full 3D PBG after a pseudogap detected in first structure, as fabricated and tested by Gmitter

Woodpile



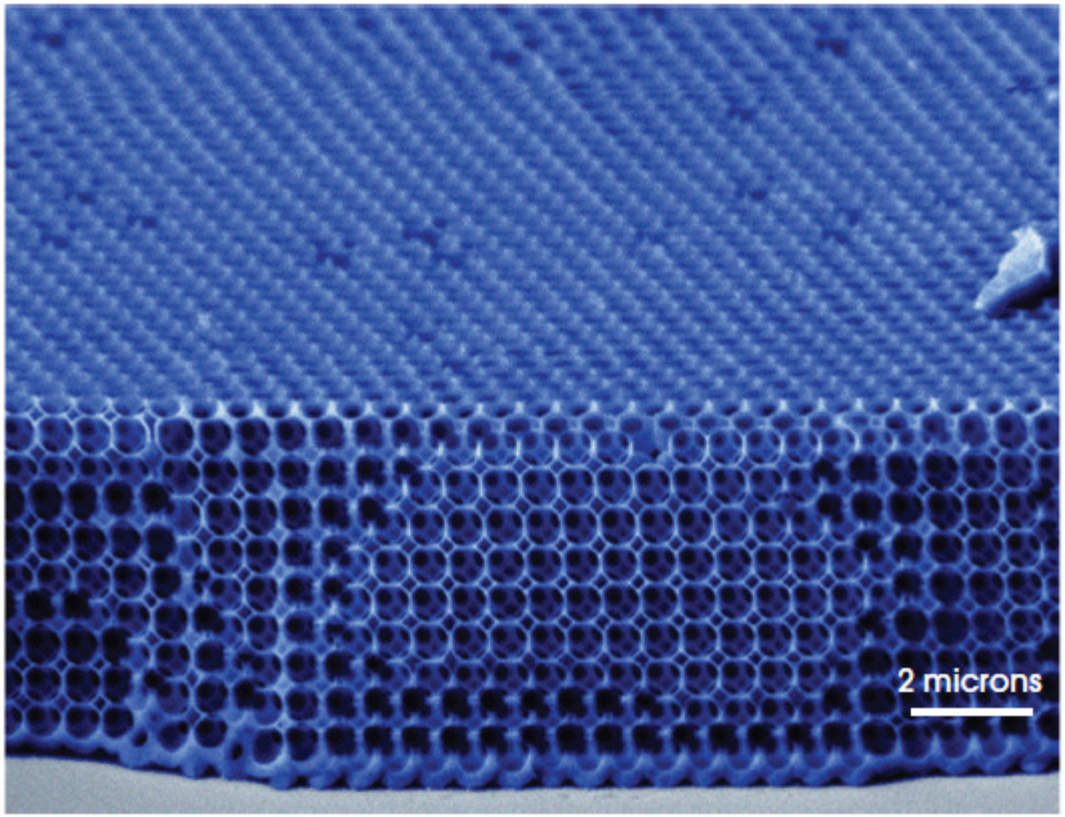
- Woodpile has alternating rod directions with half-period offsets, forming an fcc structure

Woodpile



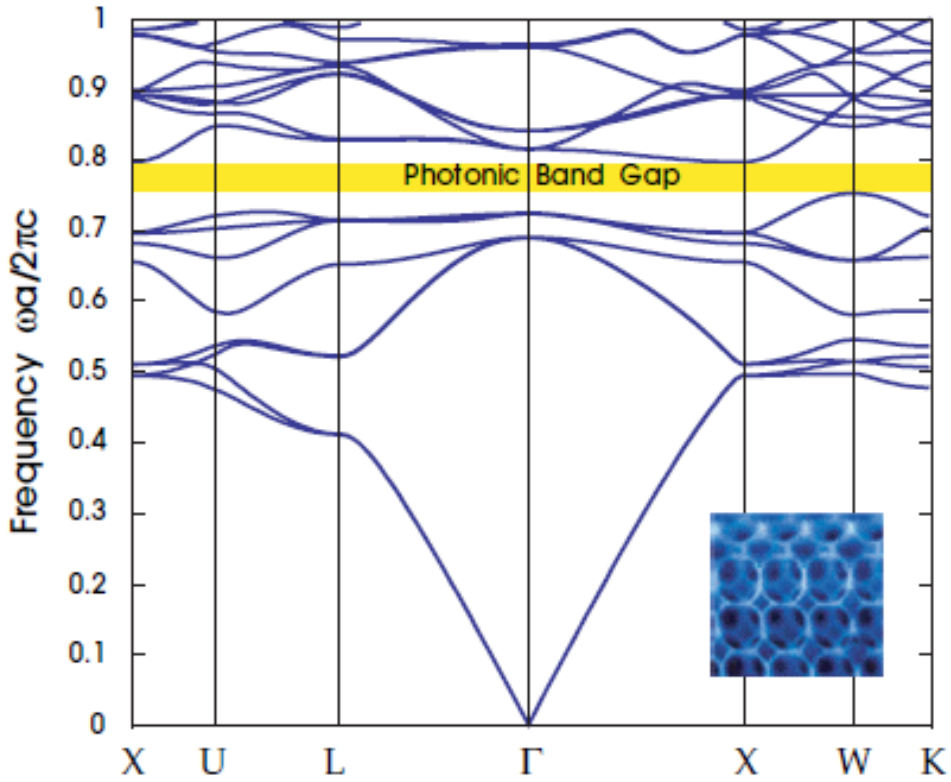
- Woodpile structures display a large bandgap with a relatively simple geometry

Inverse Opals



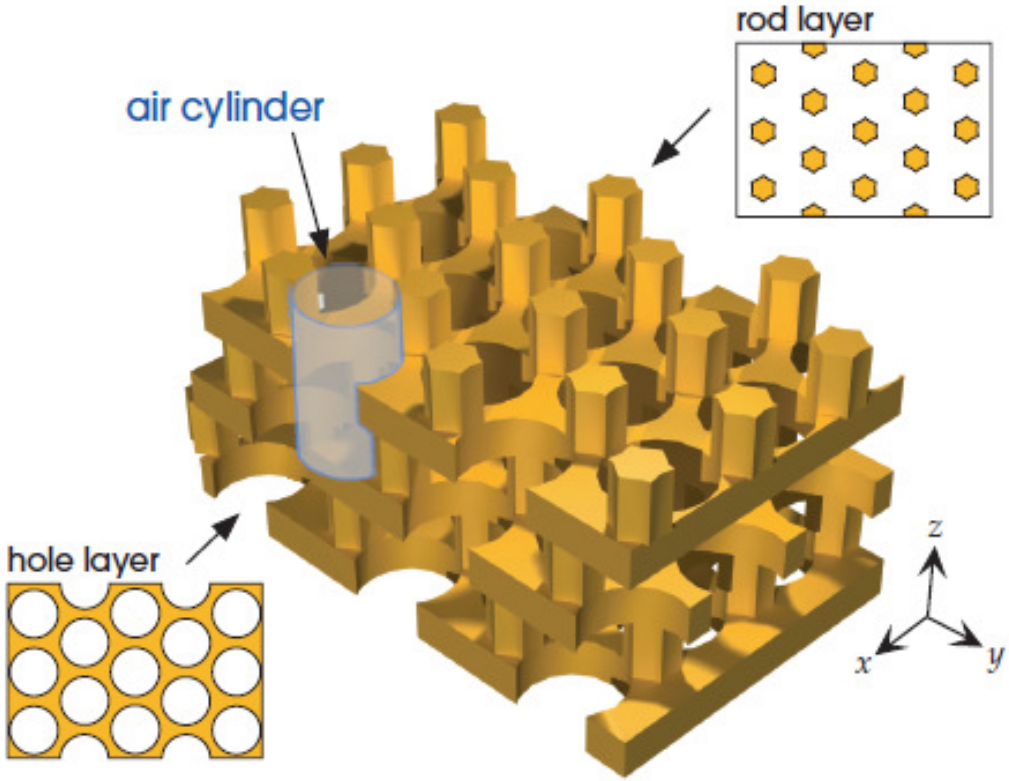
- Created via 3-step process:
  - Silica sphere assembly
  - LPCVD silicon infill
  - Silica etch (HF)

Inverse Opals



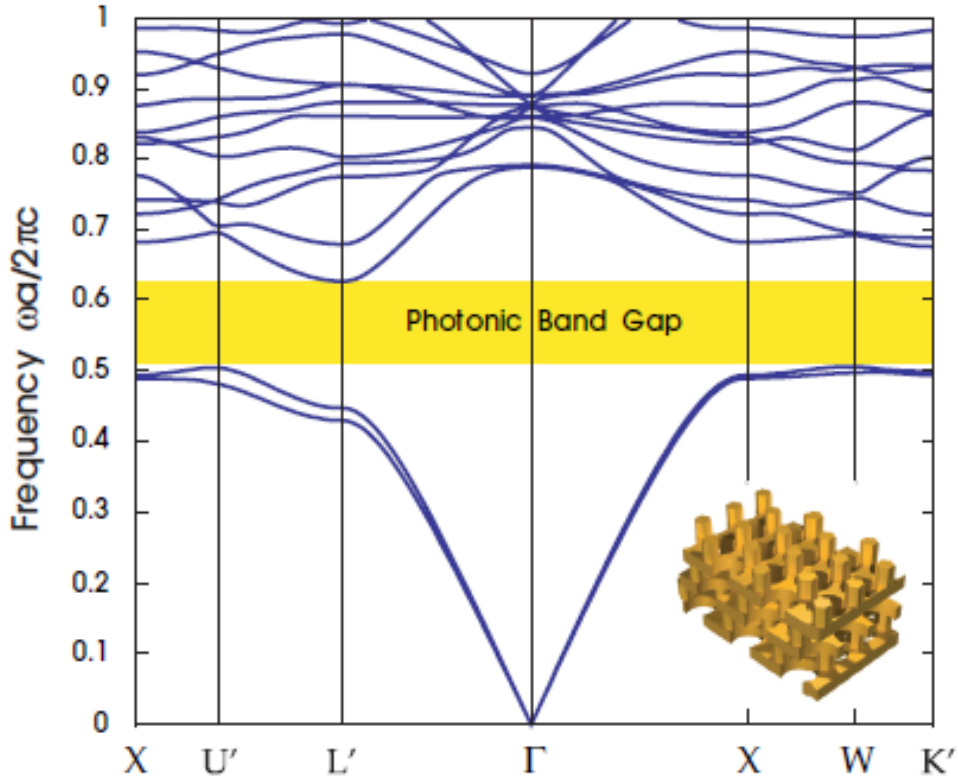
- Bandstructure shows significant full 3D bandgap

Rod-Hole 3D PhC



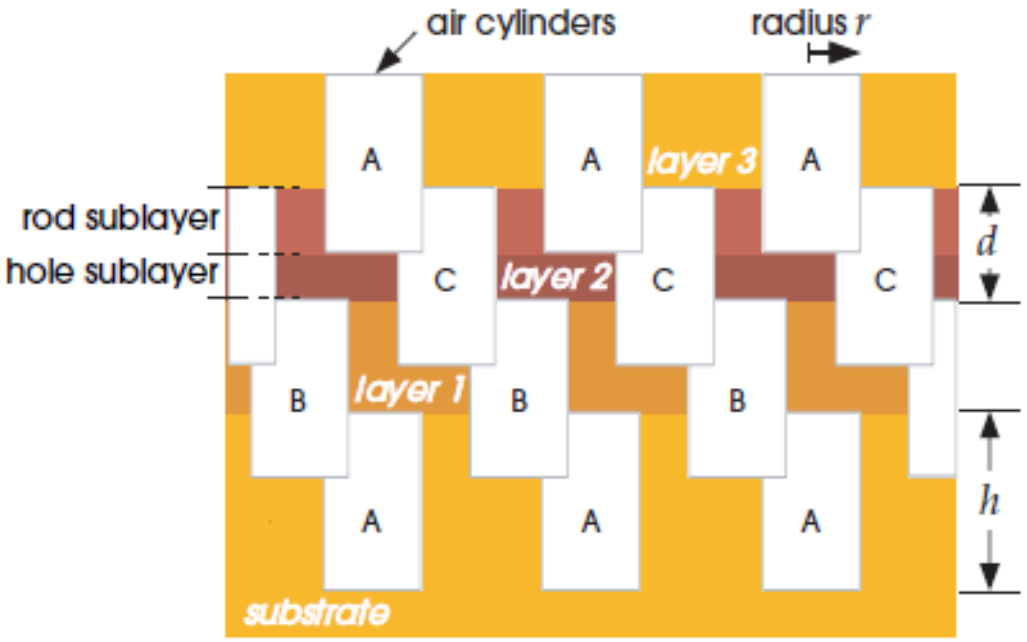
- Consist of alternating 2D PhC slab-like layers of rods and holes

Rod-Hole 3D PhC

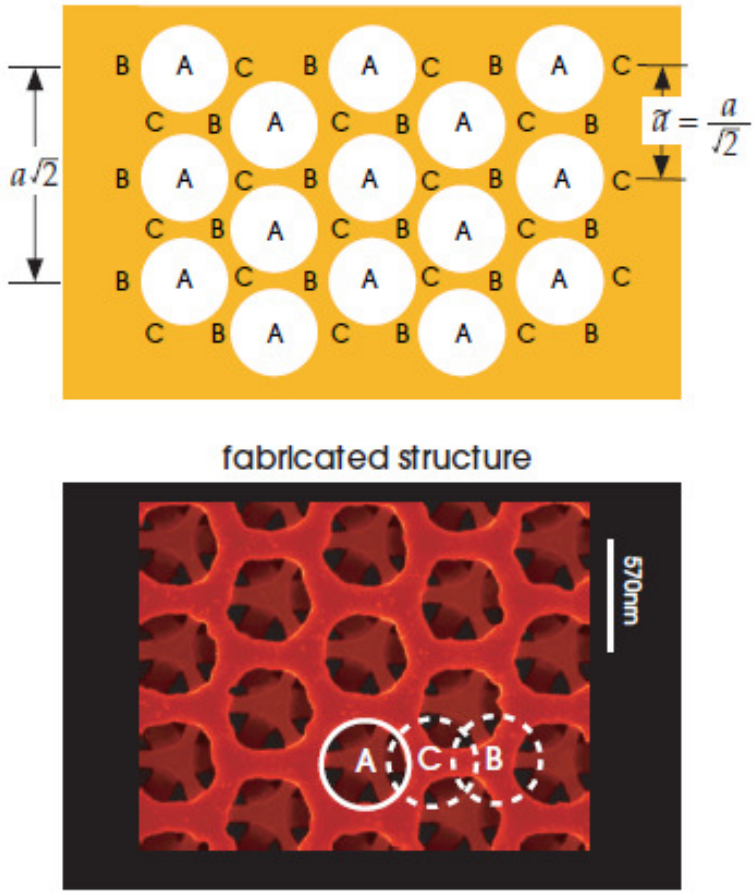


- 3D bandgap is fairly large
- Dramatically different from the individual 2D PhC slabs

Rod-Hole 3D PhC

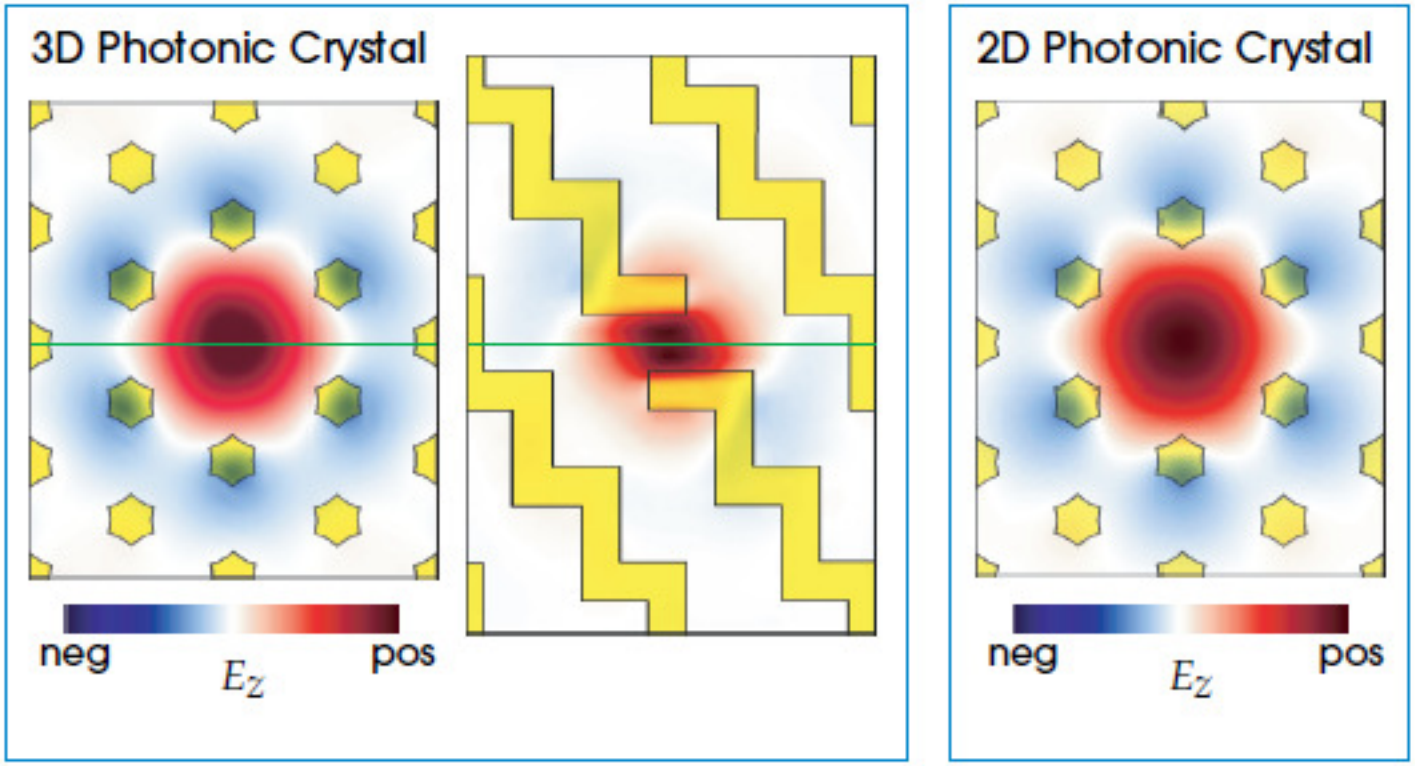


Cross-sectional view



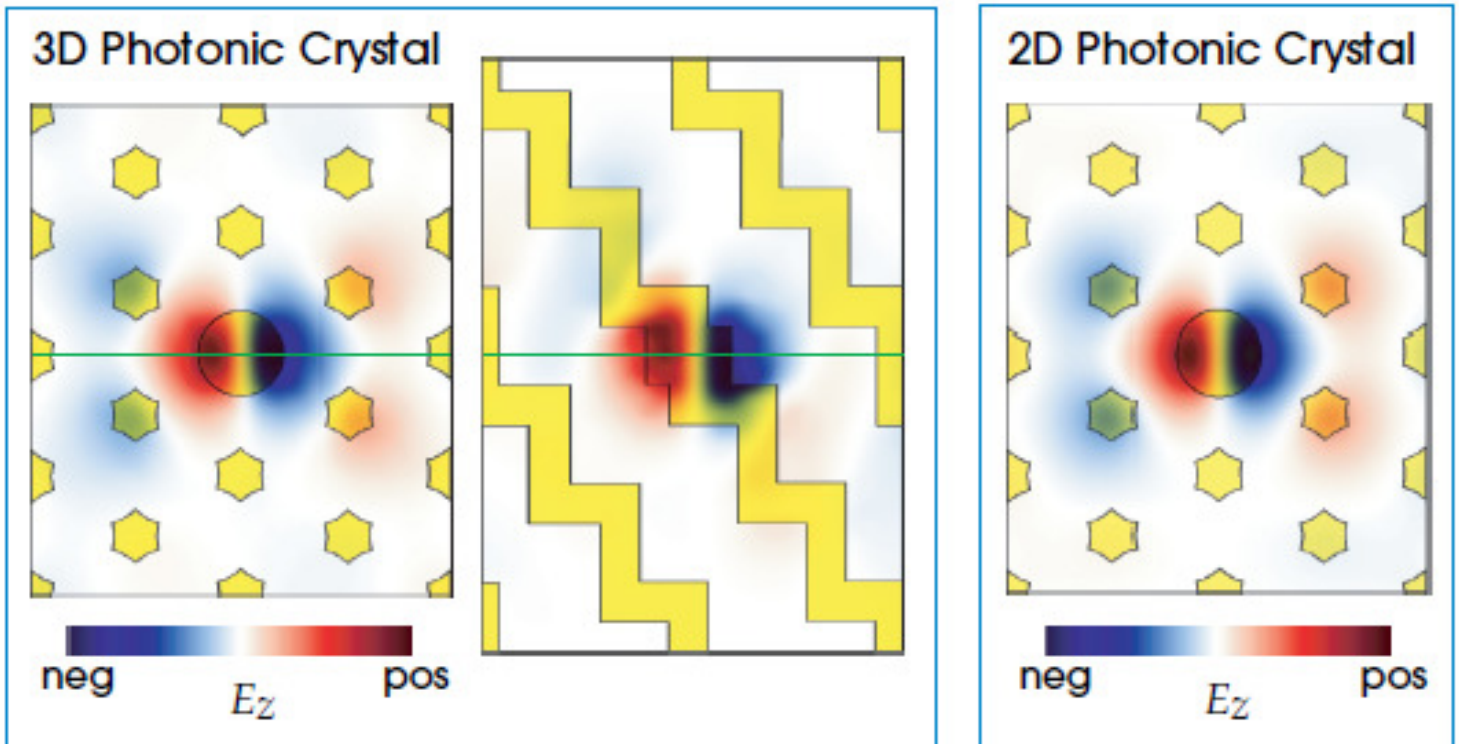
Top view

Role-Hole 3D PhC: Air Defect



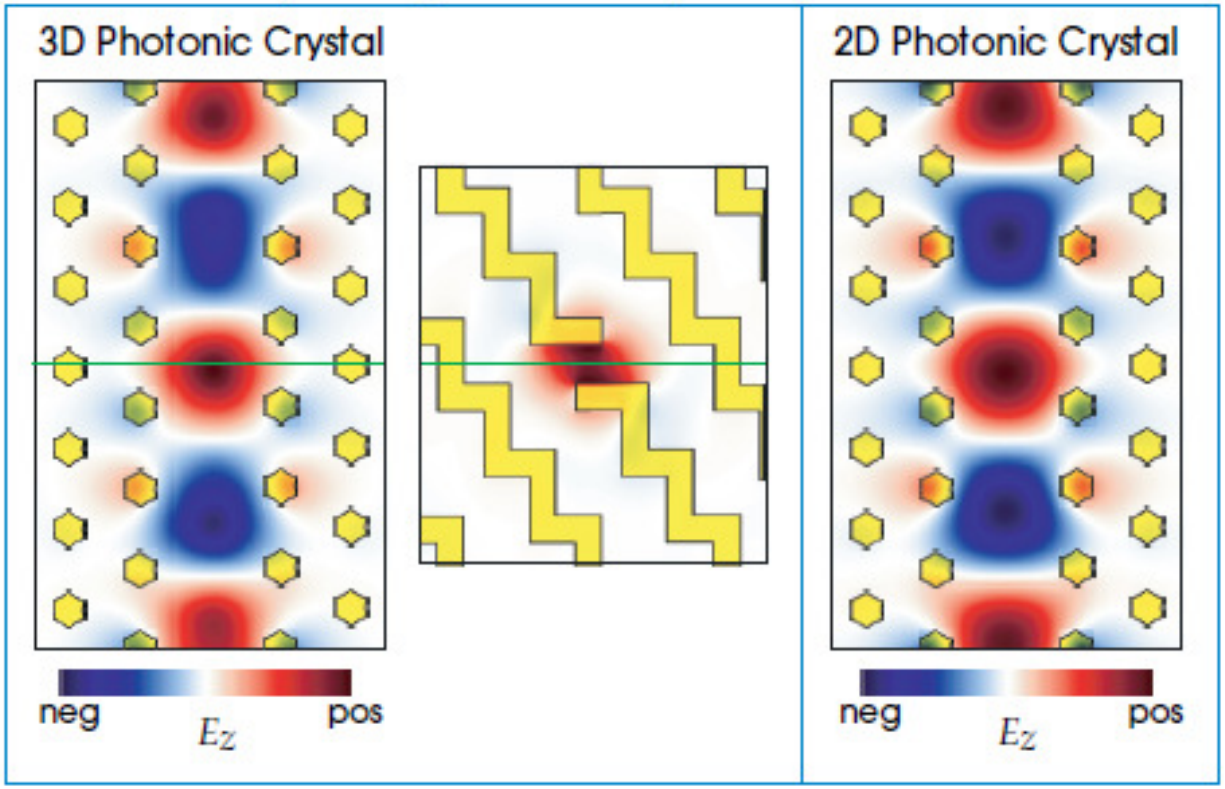
Removing a single rod creates 3D confinement in a very small volume

Rod-Hole 3D PhC: Dielectric Defect



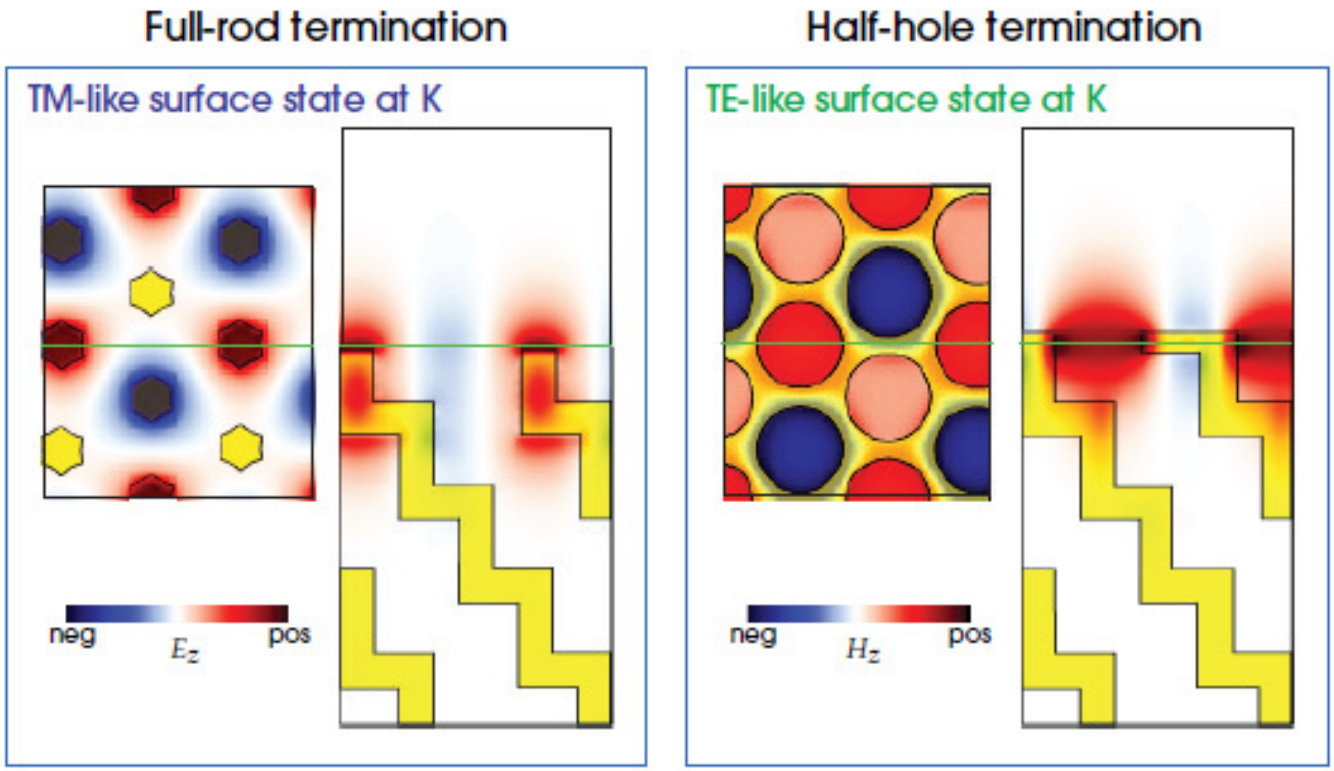
Similar 3D confinement also observed when increasing the radius of a single rod

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