Electromagnetics:
Electromagnetic Field Theory

Applications of Multiple Scattering

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Lecture Outline

- Bragg Gratings
- Photonic Crystals

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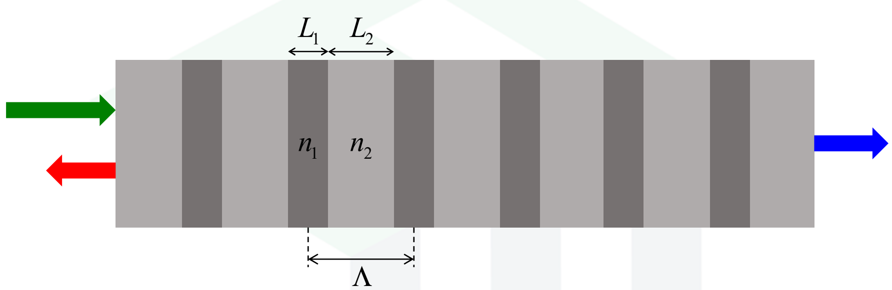
Bragg Gratings

What is a Bragg Grating?

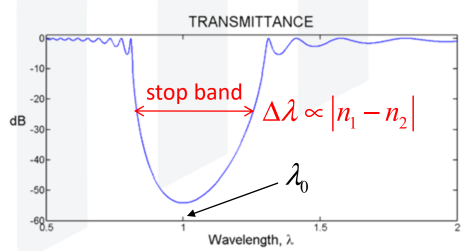


<u>Design</u>

$$L_1 = \frac{\lambda_0}{4n_1}$$

$$L_2 = \frac{\lambda_0}{4n_2}$$

Quarter-wave layers



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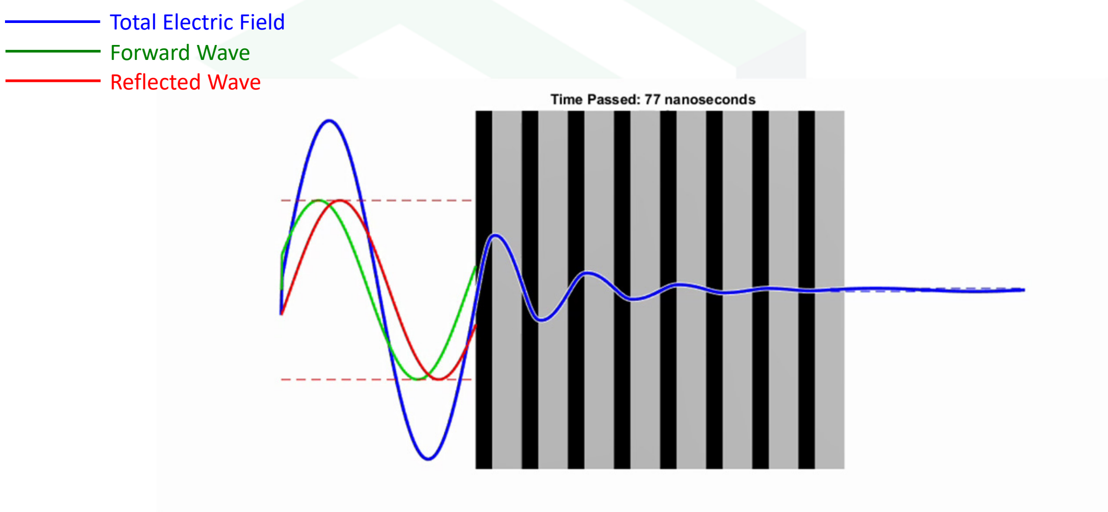
Simulation of a Bragg Grating



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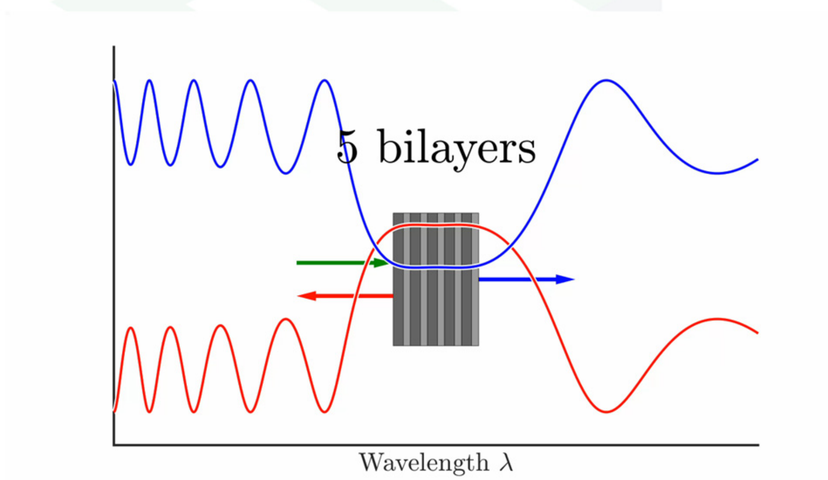
Effect of Number of Layers

The number of layers in a Bragg grating primarily effects the strength of reflection and transmission within the reflection band.



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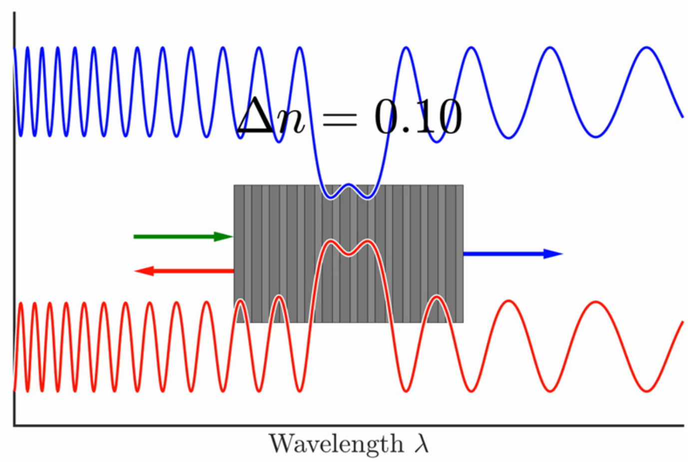
Effect of Index Contrast

The dielectric contrast of a Bragg grating primarily effects the <u>bandwidth</u> of the reflection band.



Example

Design a Bragg grating to reflect 980 nm light using silicon dioxide (n_{SiO2} = 1.52) and silicon nitride (n_{SiN} = 1.9) to provide 20 dB suppression.

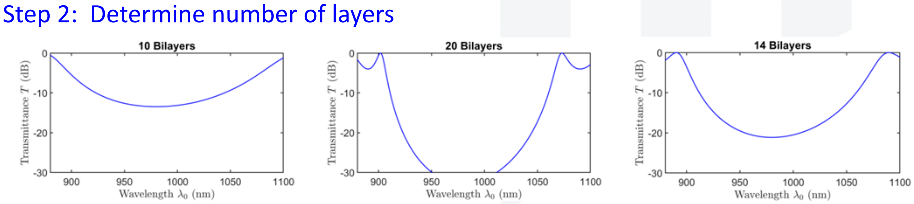
Solution

Step 1: Given refractive indices, calculate layer thicknesses.

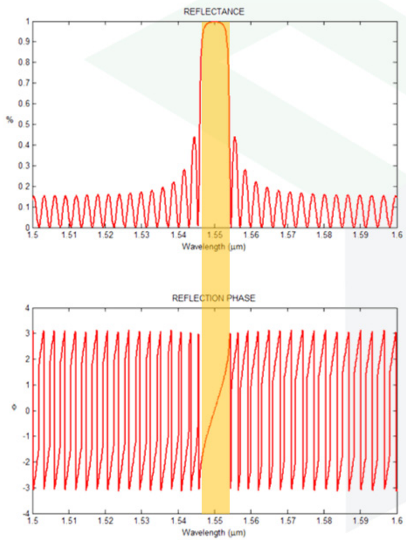
$$d_{SiO_2} = \frac{\lambda}{4} = \frac{\lambda_0}{4n_{SiO_2}} = \frac{980\text{ nm}}{4(1.52)} \boxed{= 161.2\text{ nm}}$$

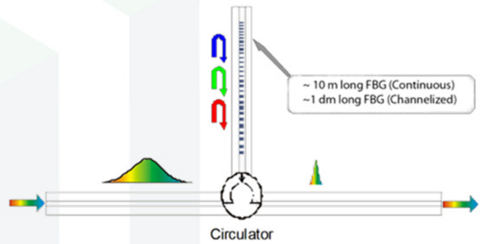
$$d_{SiN} = \frac{\lambda}{4} = \frac{\lambda_0}{4n_{SiN}} = \frac{980\text{ nm}}{4(1.9)} \boxed{= 128.9\text{ nm}}$$

Step 2: Determine number of layers



Dispersion Compensation Using Chirped Bragg Gratings





http://electronicdesign.com/communications/fiber-bragg-gratings-dispersion-compensation-technology-40g-and-100g-optical-transpor

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Photonic Crystals

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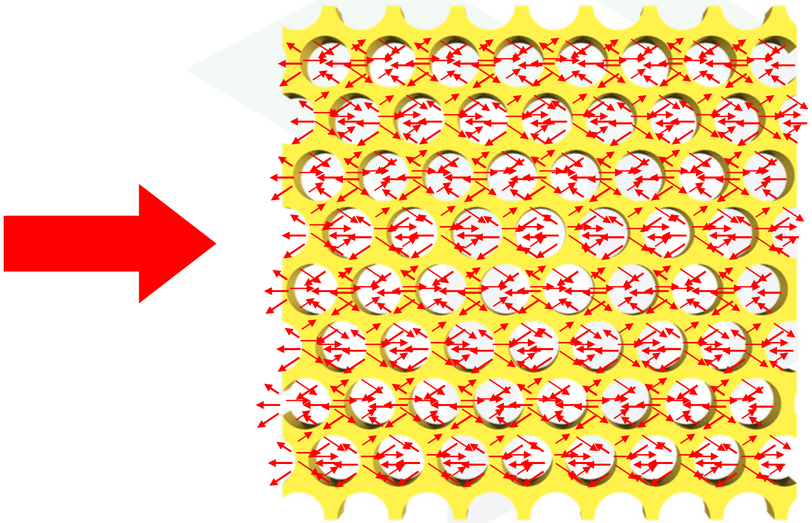
Very Complicated Multiple Scattering!



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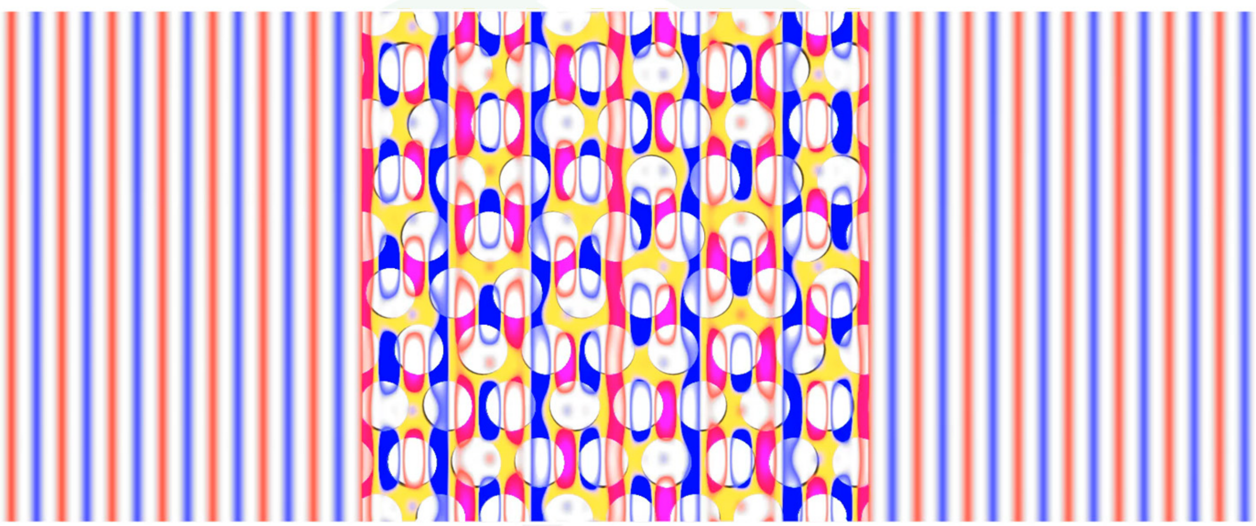
Bloch Waves Replace Plane Waves



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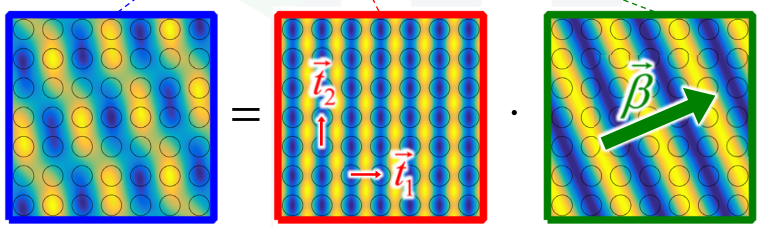
The Bloch Theorem

Waves inside of a periodic structure are analogous to plane waves, but they are modulated by an envelope function. It is the envelope function that takes on the same symmetry and periodicity as the structure.

$$\vec{E}(\vec{r}) = \vec{A}(\vec{r})\, e^{j\vec{\beta}\bullet\vec{r}}$$



Overall field is the combination of the envelope and plane wave term.

Envelope function has the same symmetry and periodicity as the periodic structure.

Plane-wave like phase "tilt" term.

$\vec{\beta} \equiv$ Bloch wave vector

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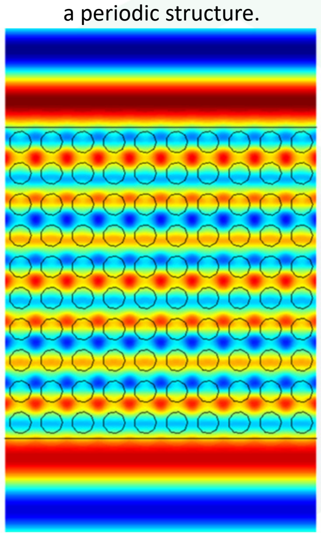
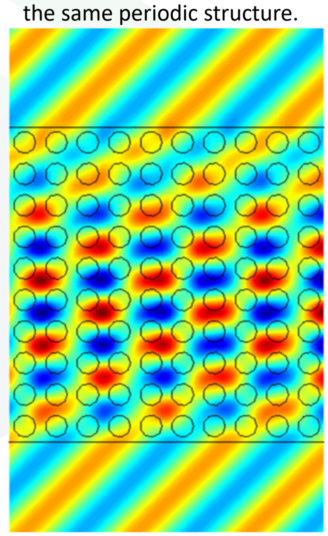
Example Waves in a Periodic Lattice

Wave normally incident onto a periodic structure.



Wave incident at 45° onto the same periodic structure.



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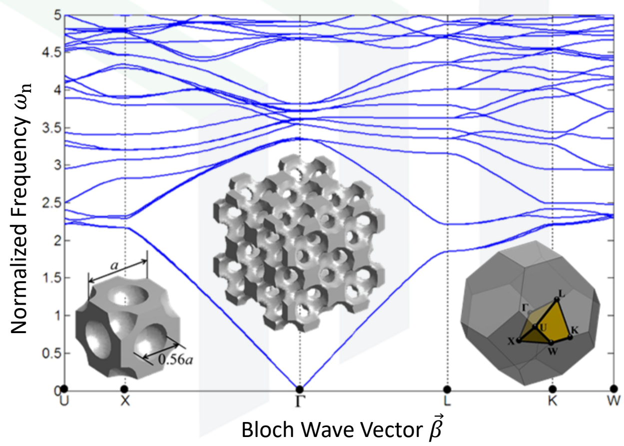
Photonic Crystals

Photonic crystals are periodic structures that control photons in analogous ways to how electrons are controlled inside of semiconductors.



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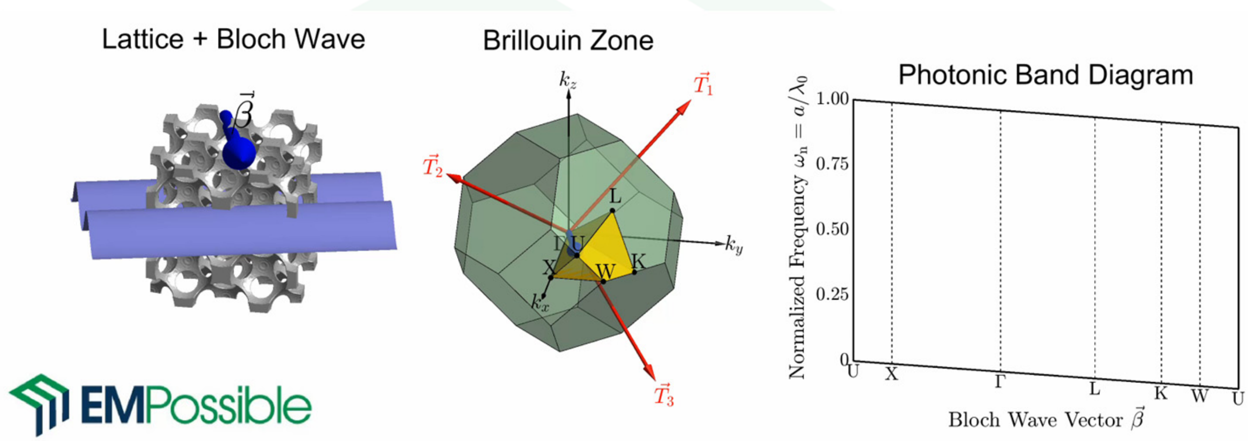
Photonic Band Diagrams



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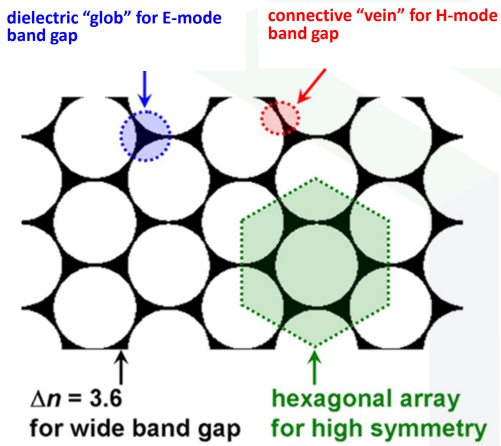
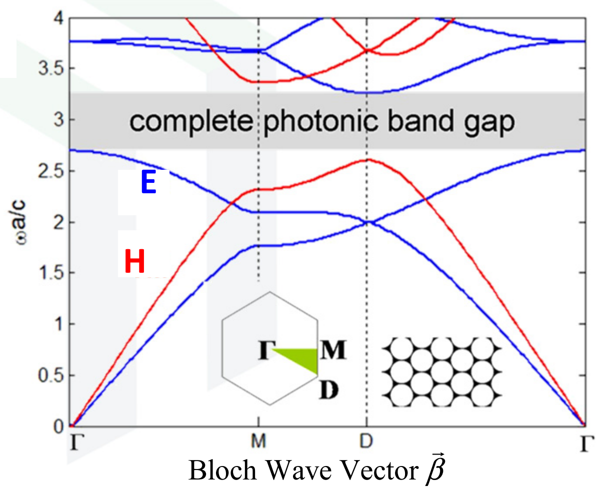
Photonic Band Gaps





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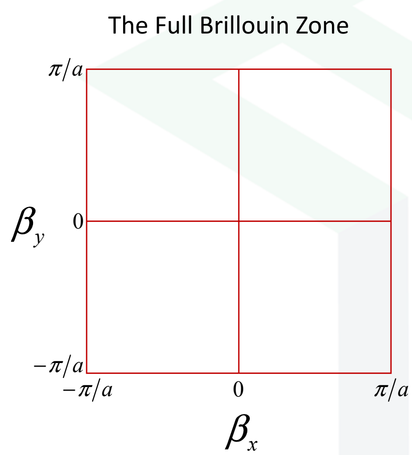
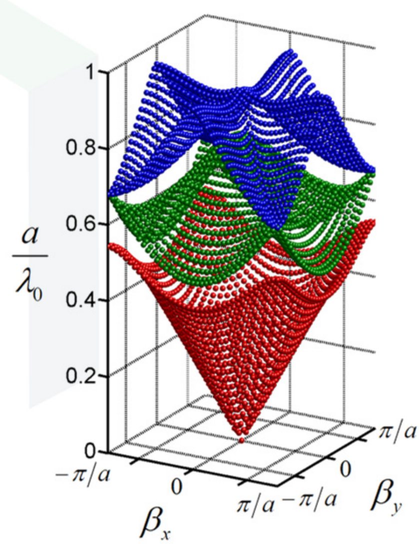
The Complete Band Diagram





There is an infinite set of eigen-frequencies associated with each point in the Brillouin zone. These form "sheets" as shown at right.

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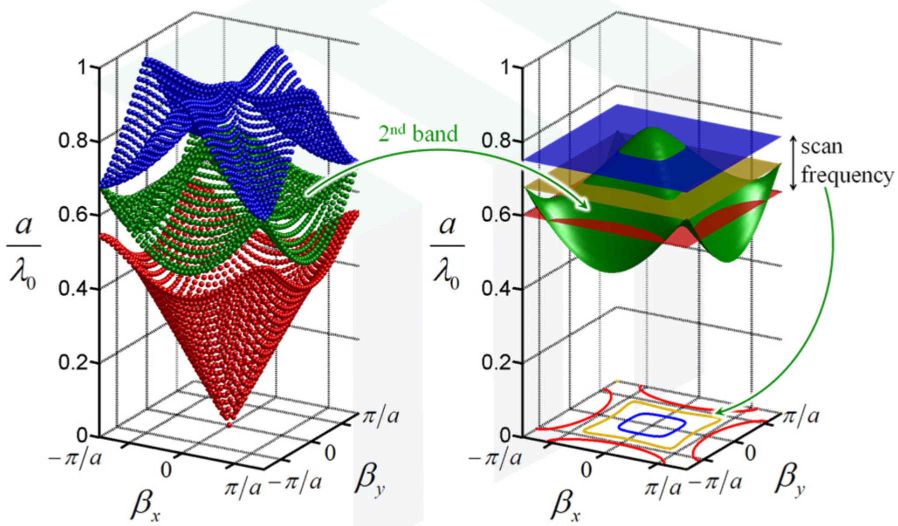
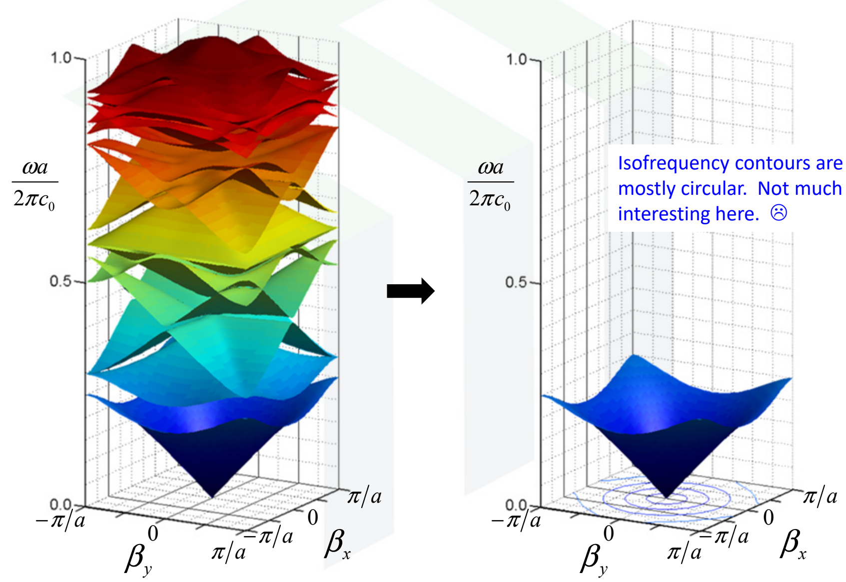
Constructing Isofrequency Contours (Index Ellipsoids)



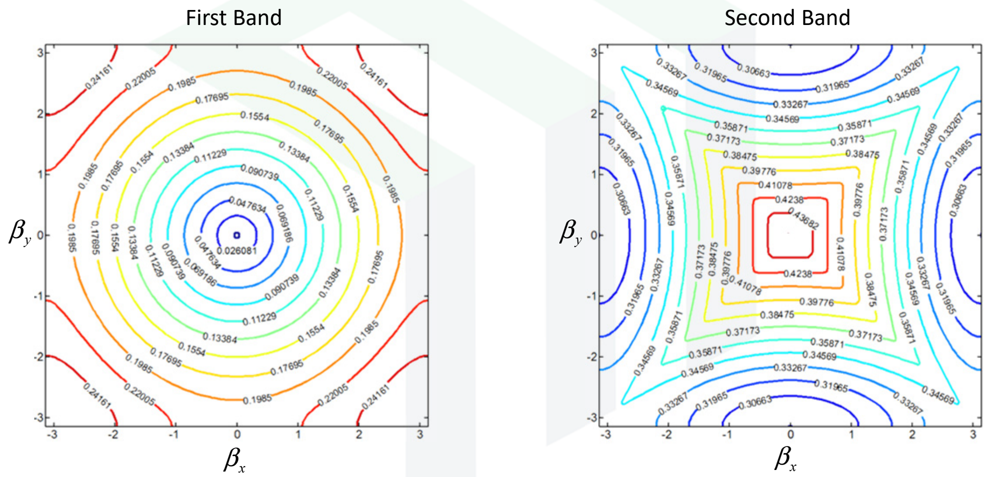
Index ellipsoids are "isofrequency contours" in k-space.

Isofrequency Contours From First-Order Band

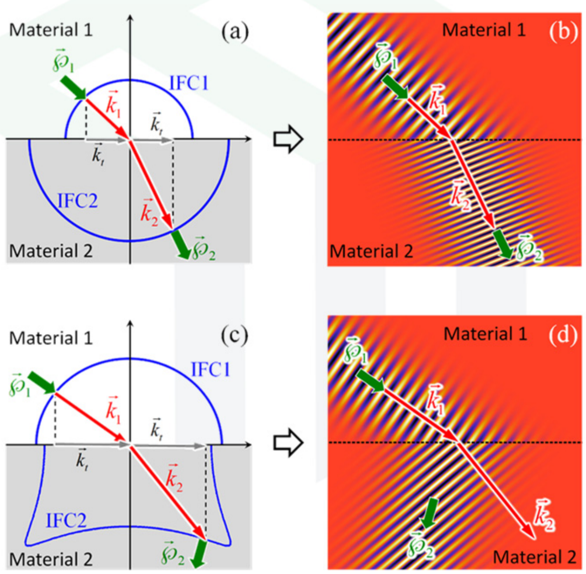


Isofrequency contours are mostly circular. Not much interesting here. ☹

Standard View of Isofrequency Contours



Negative Refraction Without Negative Refractive Index



Self-Collimating Photonic Crystals