Tidy3D iOptics OPTICA

Future-Ready FDTD Skills

A Virtual Workshop Series for **All Levels**

FLEXCOMPUTE

Session 3

Designing Filters and Reflectors

with EM Wave Interference

Dr. Tom Chen

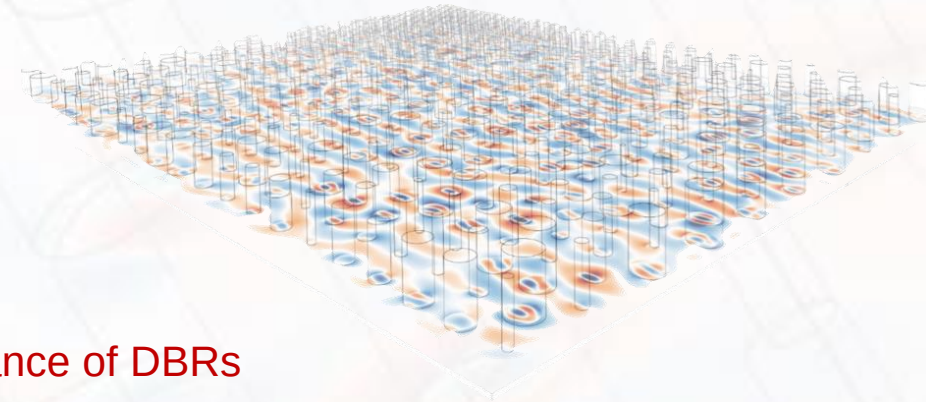
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February 23, 2023 • 1PM CST

OVERVIEW

- Distributed Bragg Reflector (DBR)
  - Fresnel reflection
  - Reflection of thin film
  - DBR
  - Bragg condition



- Hands-on activity
  - FDTD simulations to calculate the reflectance of DBRs

- EM wave interference
  - Waveguide Bragg gratings
  - Diffractive gratings
  - Grating couplers

Constructing a dielectric mirror

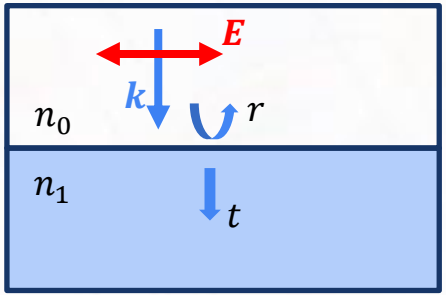
- Common mirrors have a metallic (gold, silver, etc.) coating as the reflective layer.
- At shorter wavelength (visible and UV), metal mirrors are lossy.
- Solution: construct a mirror purely made of dielectrics.

Fresnel equation

- Fresnel equations:

$$r = \frac{n_0 - n_1}{n_0 + n_1} \qquad t = \frac{2n_0}{n_0 + n_1}$$

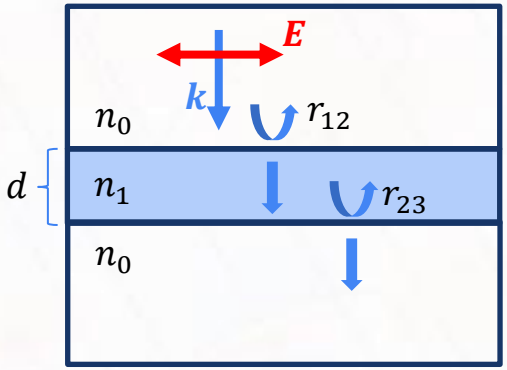
$$R = \left|\frac{n_0 - n_1}{n_0 + n_1}\right|^2$$



- For example, visible light incident on glass (n~1.5) from air (n~1),

$$R = \left|\frac{1 - 1.5}{1 + 1.5}\right|^2 = 4\%$$

Thin film Fresnel equation

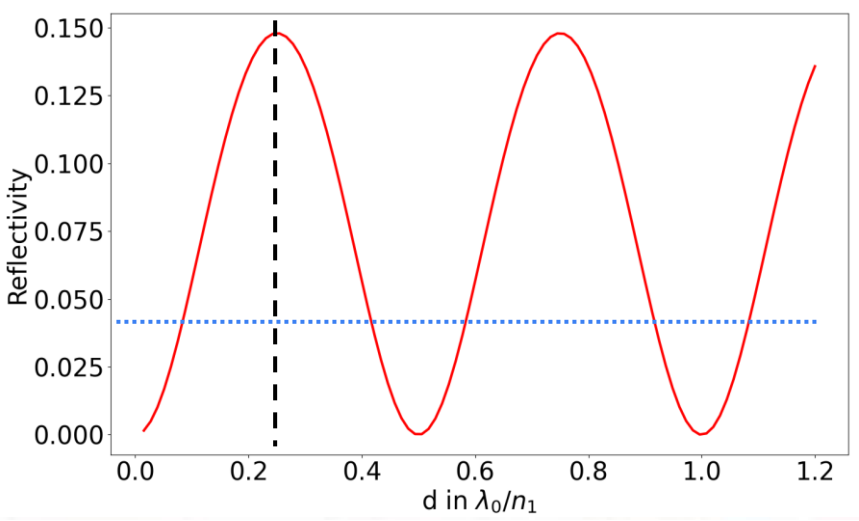


- Thin film with thickness d:

$$r = \frac{r_{12} + r_{23}e^{2i\beta}}{1 + r_{12}r_{23}e^{2i\beta}}$$

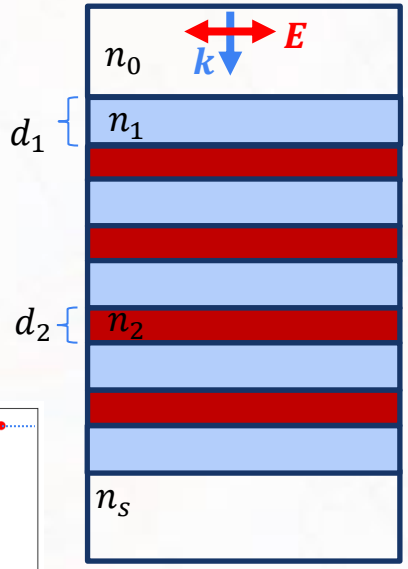
$$r_{12} = \frac{n_0 - n_1}{n_0 + n_1} \qquad r_{23} = \frac{n_1 - n_0}{n_1 + n_0} \qquad \beta = \frac{2\pi n_1 d}{\lambda_0}$$

- Can I choose a specific d such that the Reflectivity is larger than 4%?

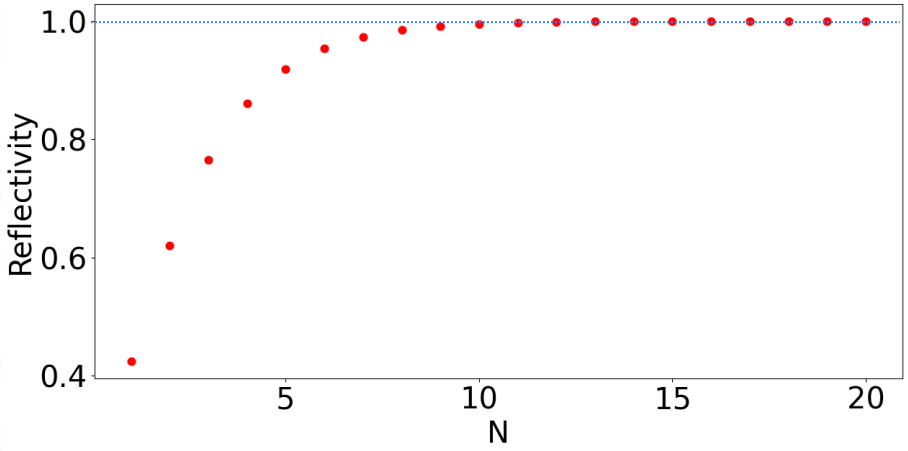


Distributed Bragg reflector (DBR)

- N-pairs of thin films with refractive index n_1 and n_2
- The thicknesses are $d_1 = \frac{\lambda}{4n_1}$ and $d_2 = \frac{\lambda}{4n_2}$



$$r = \frac{n_s n_0 n_1^{2N} - n_2^{2N+2}}{n_s n_0 n_1^{2N} + n_2^{2N+2}}$$



Bragg Condition

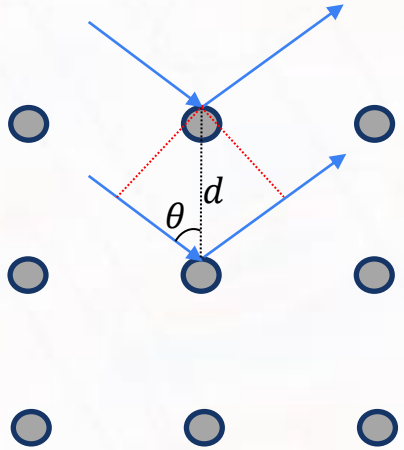
- The general Bragg condition states

$$n\lambda = 2dcos\theta$$

- Apply it to the DBR case,

$$\theta = 0$$

$$d = n_1 d_1 + n_2 d_2$$



Therefore

$$n\lambda_0 = 2(n_1 d_1 + n_2 d_2)$$

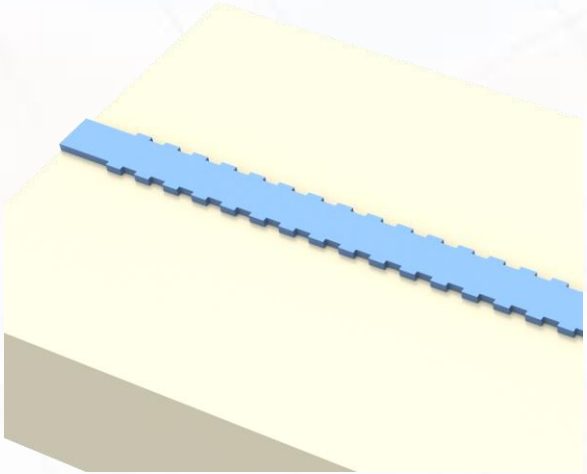
For $n = 1$, $\frac{1}{2} = \left(\frac{n_1 d_1}{\lambda_0} + \frac{n_2 d_2}{\lambda_0}\right)$. One solution is $d_1 = \frac{\lambda_0}{4n_1}$ and $d_2 = \frac{\lambda_0}{4n_2}$.

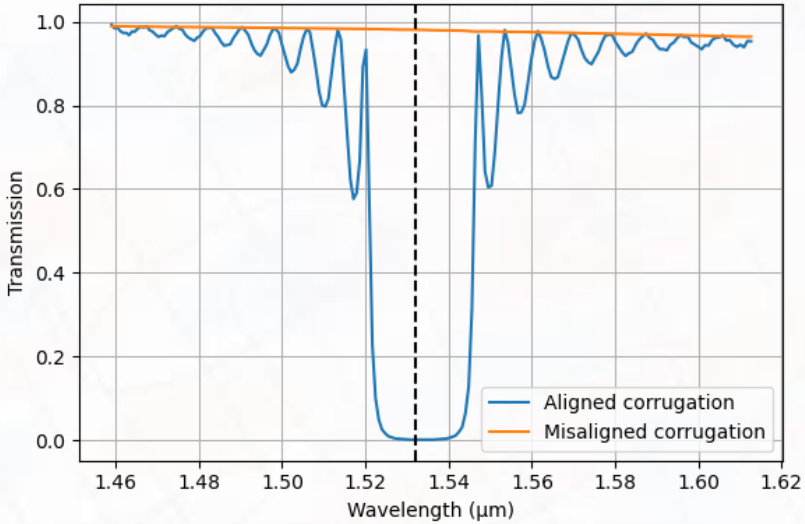
Hands-on activity

FDTD simulations to calculate the reflectance of DBRs

Waveguide Bragg gratings

- The same DBR principle can be applied to optical fibers and waveguides.



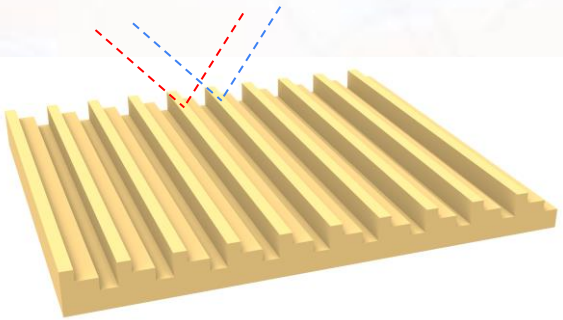


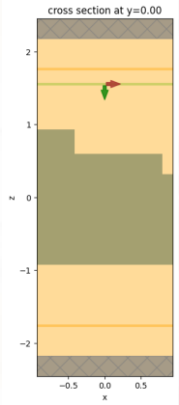
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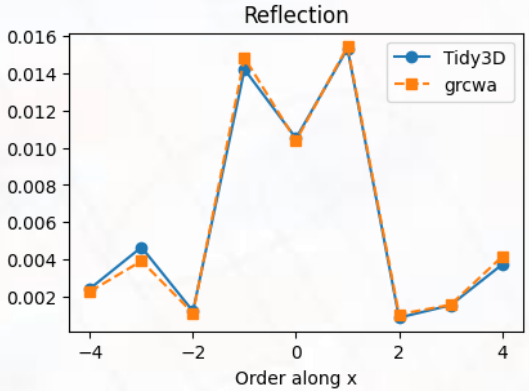
Diffractive gratings

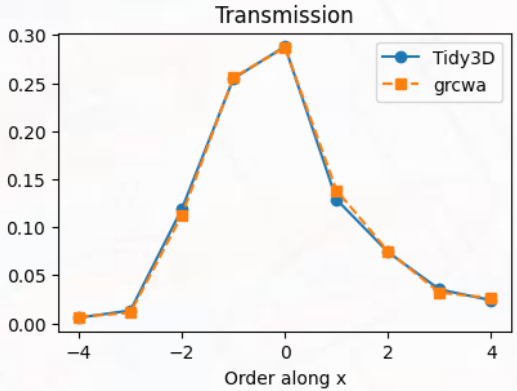
- Gratings diffract light to certain directions (orders) due to constructive interference.

$$n\lambda = d(sin\alpha + sin\beta)$$







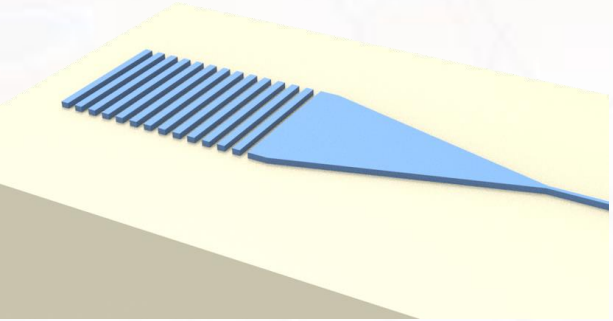


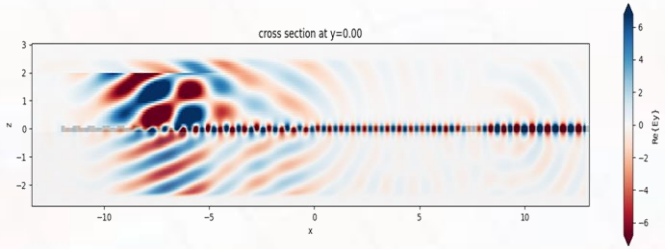
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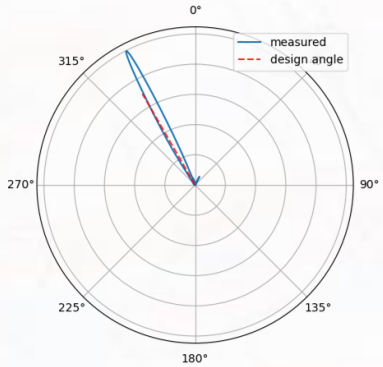
Grating couplers

- Grating couplers use diffraction to couple light between optical fiber and waveguide

$$k_z = \beta - mK$$







https://www.flexcompute.com/tidy3d/examples/notebooks/GratingCoupler/

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February 9th - March 8th
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The FDTD Method
Feb 9 Dr. Weiliang Jin • *Princeton, Stanford*



Multimode Photonics Design
Feb 16 Dr. Lucas Gabrielli • *Cornell*



Designing Filters + Reflectors
Feb 23 Dr. Tom Chen • *Stony Brook*



Photonic Crystal Slabs
Mar 1 Dr. Momchil Minkov • *EPFL, Stanford*



Inverse Design in Photonics
Mar 8 Dr. Tyler Hughes • *Stanford*

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