Diffraction Efficiency of a Binary Grating

MeepCon 2022 Tutorial

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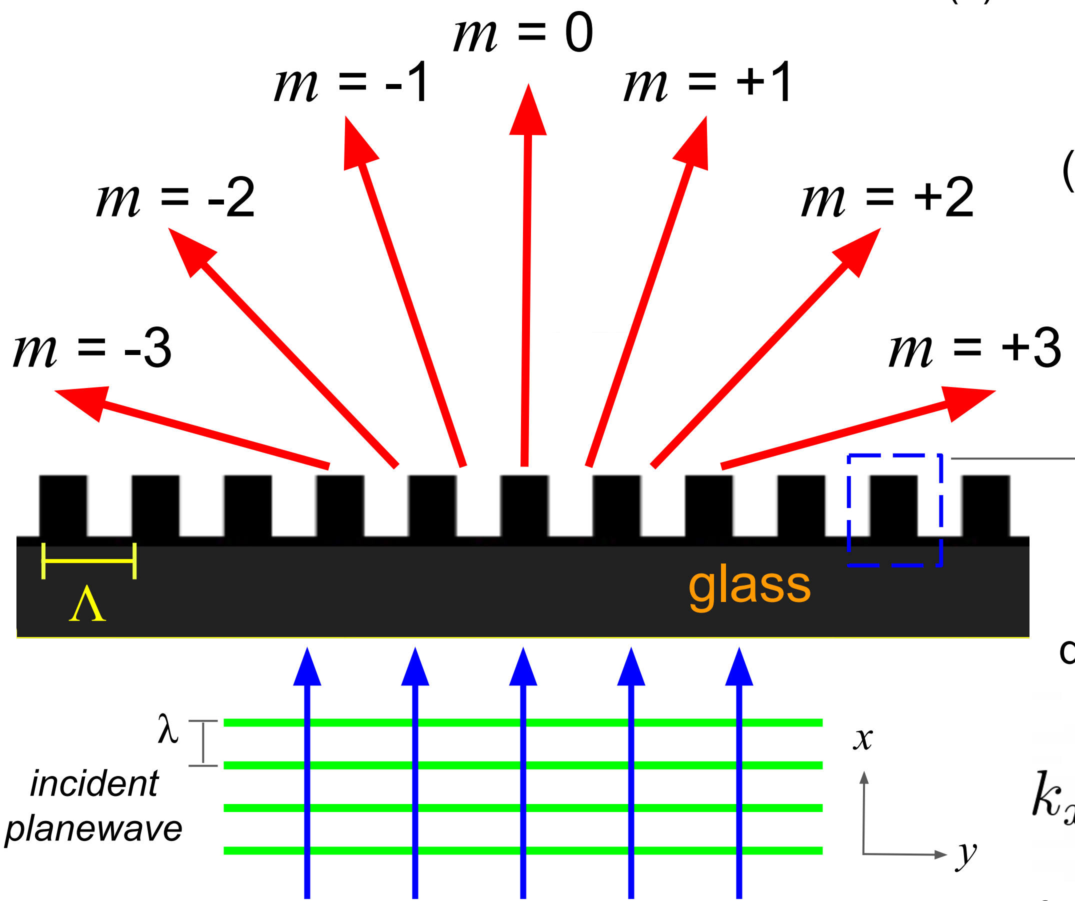
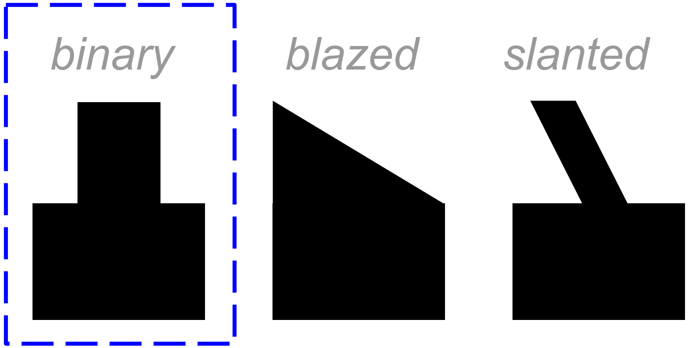
Review: Diffraction Gratings

two main types of gratings:
(1) *surface relief* and (2) holographic (photopolymer)



design **unit cell** to obtain desired reflection/transmission spectrum (e.g., maximize power of a single order)



diffraction orders are the **real** solutions of:

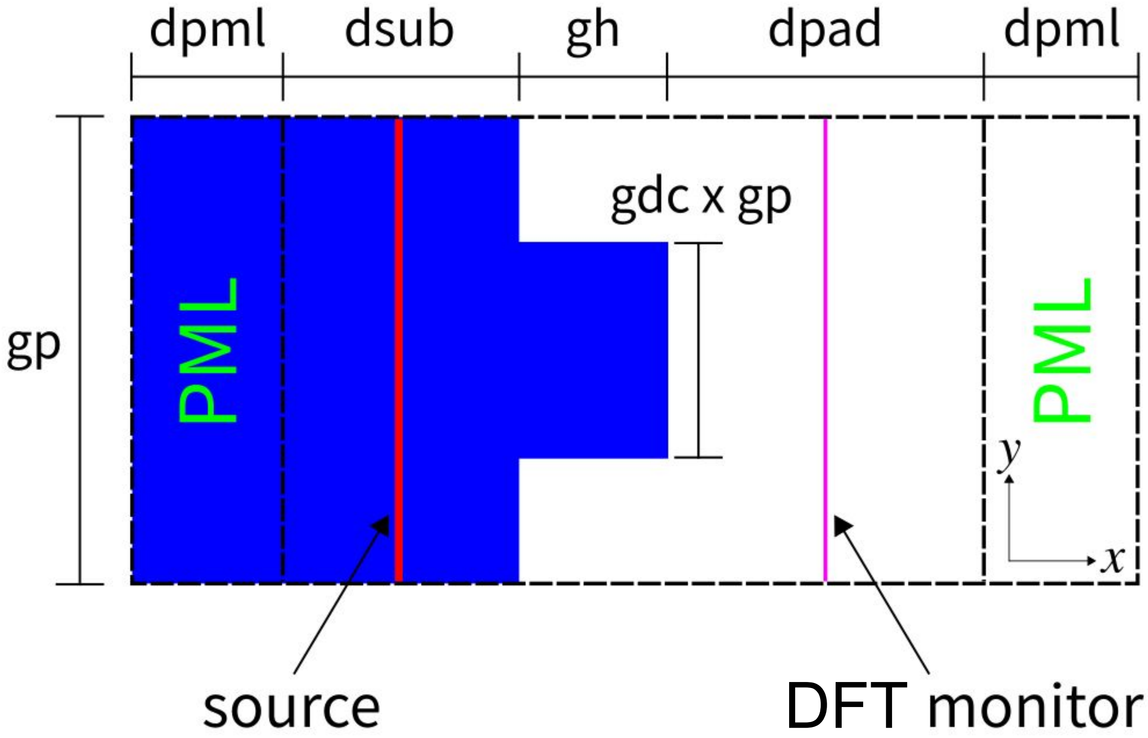
$$k_x = \sqrt{\omega^2 n^2 - \left(k_y + \frac{2\pi m}{\Lambda}\right)^2}$$

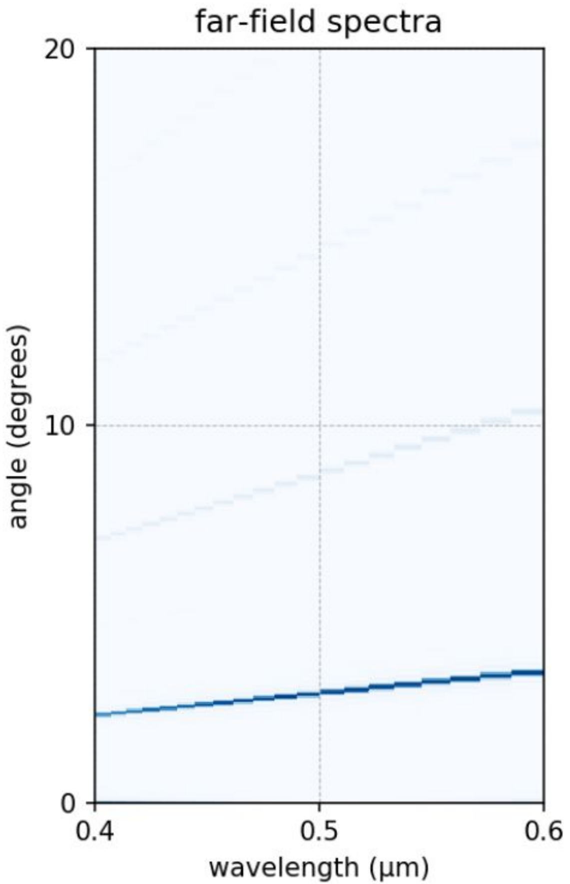
if $\Lambda \cong \lambda$, results are polarization dependent (S or P)

e.g., for λ = 0.5 μm, Λ = 10.0 μm, n = 1.0, k_y = 0, $|m|_{max}$ = 20

Unit-Cell Simulation Layout

single simulation yields broadband spectral response





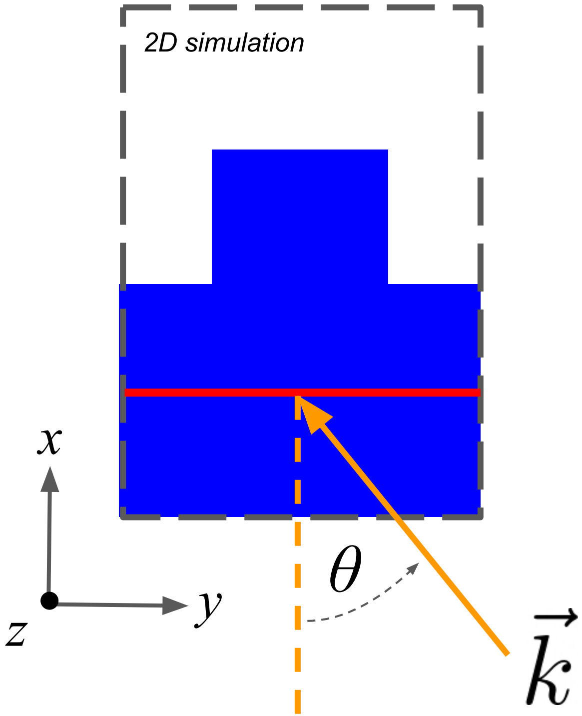
Three Primary Features to Review for this Calculation

(1) Broadband Oblique Source

(2) Mode Decomposition of Planewaves

(3) Super cell of a 2D Triangular Lattice

(1) Broadband Oblique Source



θ = 0° is along $+x$ direction
and θ > 0° is counter clockwise
rotation about z axis

dispersion relation for planewave in homogeneous medium with index n

$$\omega = \frac{c|\vec{k}|}{n}$$

in Meep units, c = 1:

$$\vec{k} = (k_x, k_y) = n\omega\,(cos(\theta), sin(\theta))$$

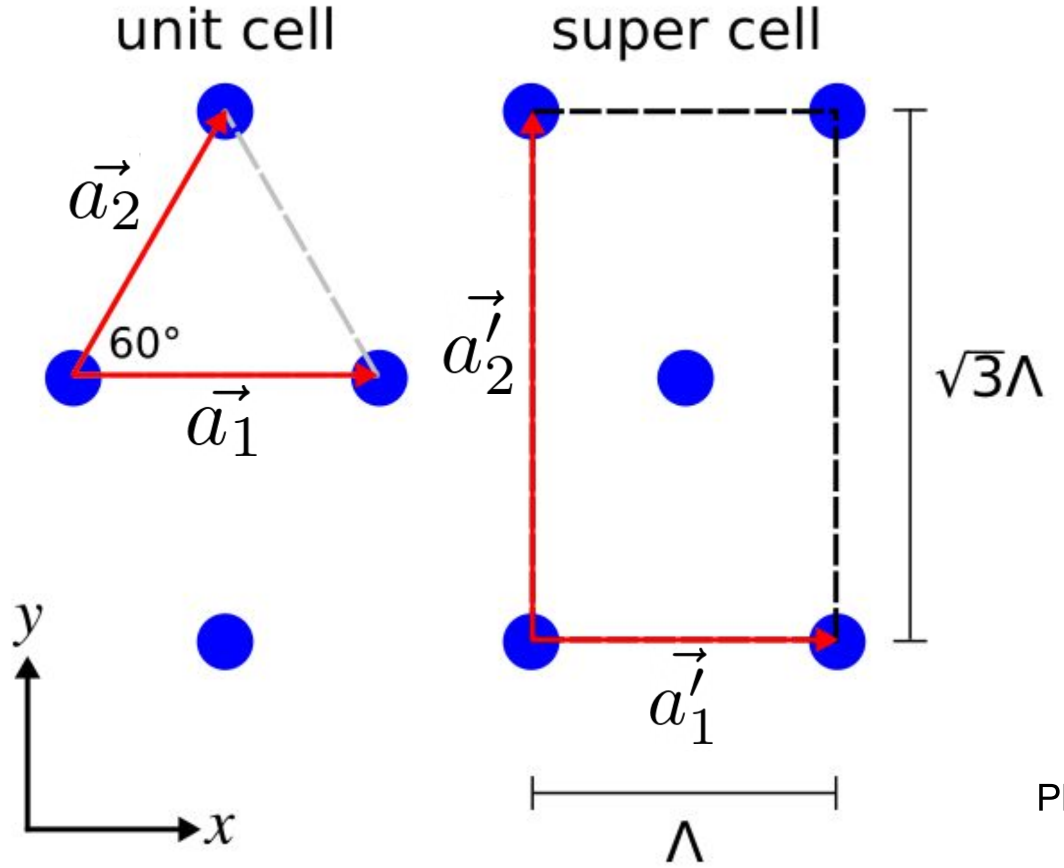
if $\theta \neq 0°$, for any frequency $\omega' \neq \omega$ of a pulsed source, the incident angle θ' is *not* the same as θ:

$$\boxed{\theta' = \sin^{-1}\left(\frac{k_y}{n\omega'}\right)}$$

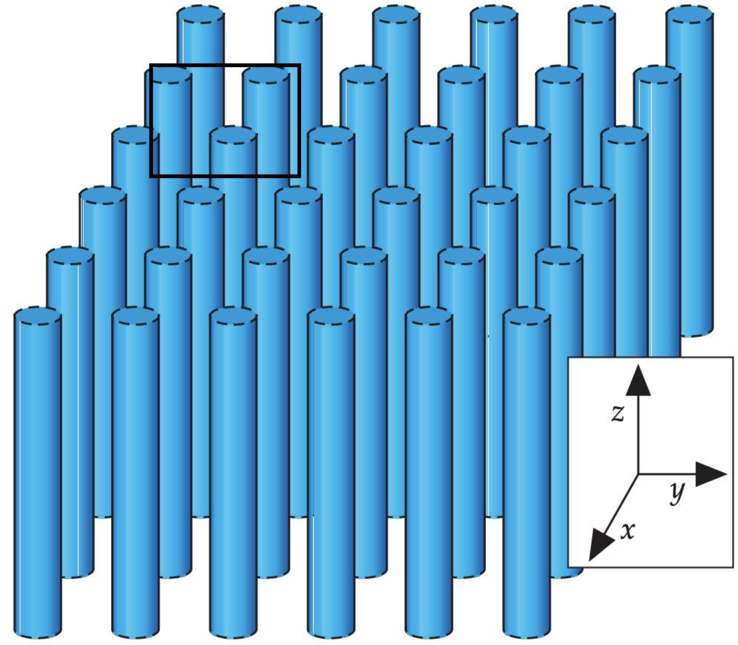
(2) Mode Decomposition of Planewaves

- computing the diffraction efficiency involves calculating the *power in a given order* normalized by the input power of the source (which requires a separate run with just homogeneous medium)
- the order is specified by (1) an integer m and (2) the polarization S or P
- the power in a mode is equivalent to the squared magnitude of the complex mode coefficient which is otherwise known as the scattering (S) parameter or S-matrix element: $|\alpha_n^{\pm}|^2 = P_n^{\pm}$
- to specify a diffraction order in Meep, use a DiffractedPlanewave object which is passed to the get_eigenmode_coefficients function

(3) Super cell of a 2D Triangular Lattice

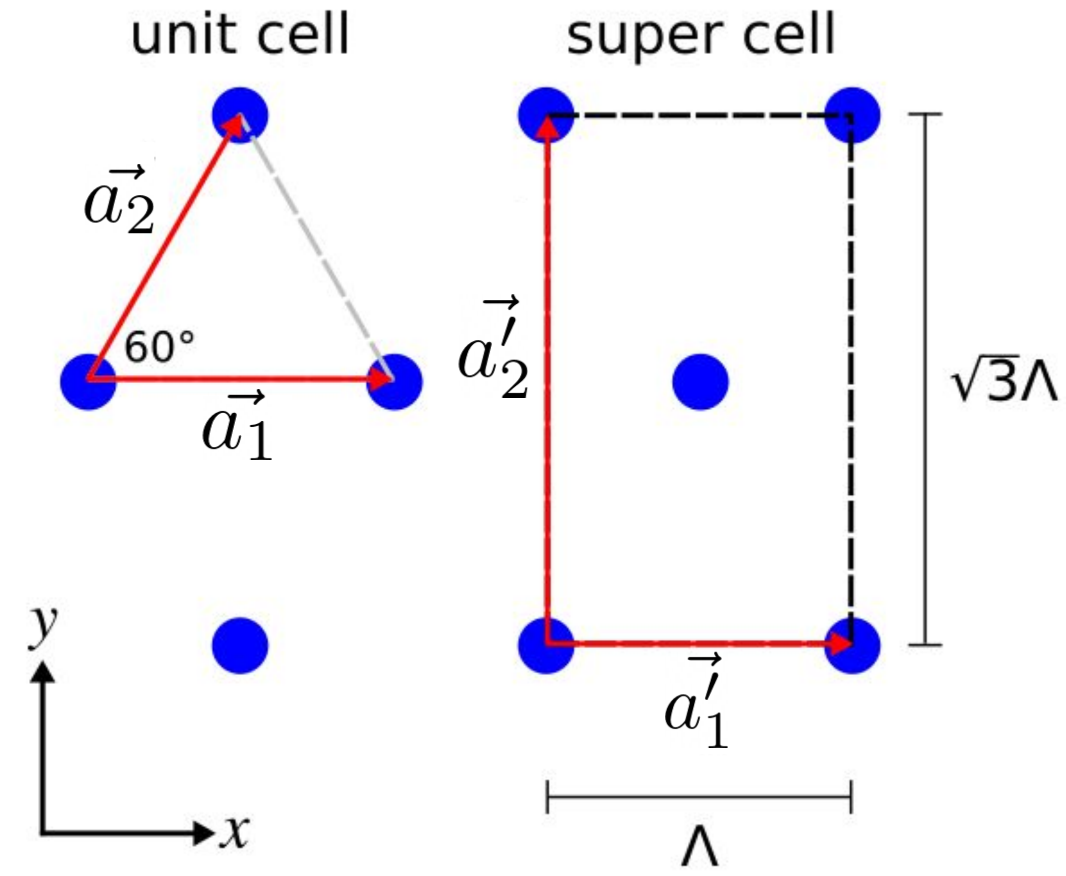


square lattice



Photonic Crystals: Molding the Flow of Light
(Second Edition, 2008)

(3) Super cell of a 2D Triangular Lattice



direct and reciprocal lattice vectors

unit cell

$$\vec{a_1} = (\Lambda, 0) \qquad \vec{b_1} = \frac{2\pi}{\Lambda}(1, -1/\sqrt{3})$$

$$\vec{a_2} = \left(\frac{\Lambda}{2}, \frac{\sqrt{3}}{2}\Lambda\right) \qquad \vec{b_2} = \frac{2\pi}{\Lambda}(0, 2/\sqrt{3})$$

$$\vec{k_{||}} = m_1\vec{b_1} + m_2\vec{b_2}$$

super cell

$$\vec{a'_1} = (\Lambda, 0) \qquad \vec{b'_1} = \frac{2\pi}{\Lambda}(1, 0)$$

$$\vec{a'_2} = (0, \sqrt{3}\Lambda) \qquad \vec{b'_2} = \frac{2\pi}{\Lambda}(0, 1/\sqrt{3})$$

$$\vec{k_{SC}} = n_1\vec{b'_1} + n_2\vec{b'_2}$$

$\vec{k_{SC}} = \vec{k_{||}}$ yields condition for real orders:

$$\boxed{n_1 = m_1\,,\, n_2 = -m_1 + 2m_2}$$