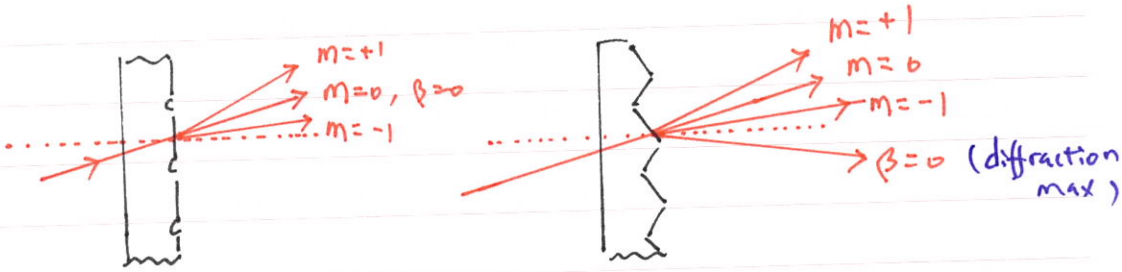
12-6 Blazed Gratings

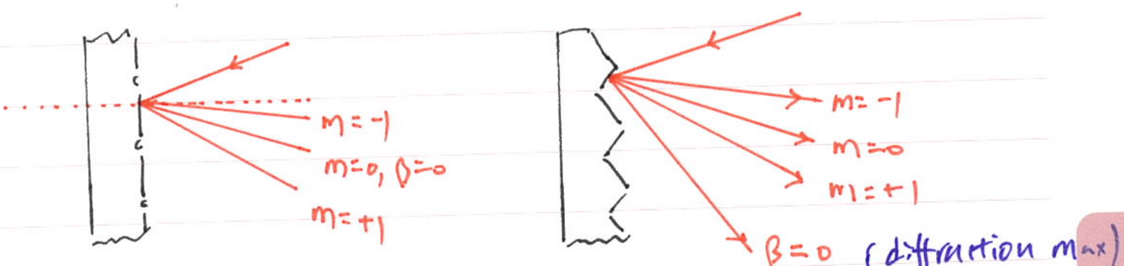
- grating efficiency = $\dfrac{\text{diffracted light energy}}{\text{incident} \quad ''}$
- zeroth-order diffraction : no dispersion → waste of energy
  → reducing grating efficiency
- The more N (groove #), the more energy throughput.
- Blazing : groove shaping tech so that the diffraction max shifts into another order.

A.



(unshaped) (shaped)

B.



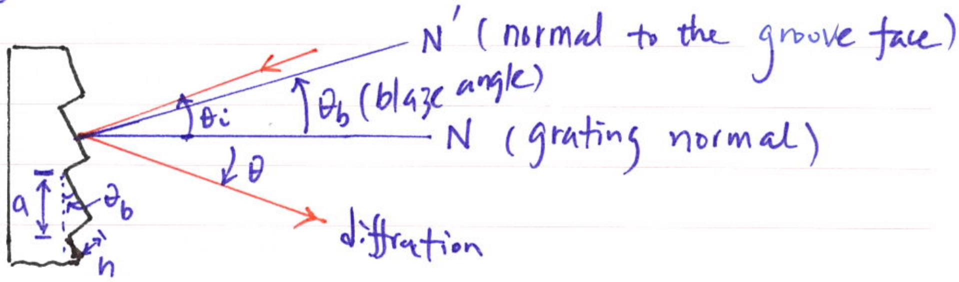
(unshaped) (shaped)

↓

* The grating max → principal max
(m>1)

(Blazing)

< Blaze angle, θ_b >



· shaping : diffraction max → principal max
(redirect)

· $\theta = \theta_m$: grating diffraction to the principal max

(i) Condition 1 : <mirror reflection = principal max>

$$\rightarrow \theta_i - \theta_b = \theta_m + \theta_b \quad : \underline{\text{mirror reflection}}$$

$$(i) \rightarrow \theta_b = \frac{\theta_i - \theta_m}{2}$$

(ii) Condition 2 : grating eq for principal max

$$(ii) \rightarrow m\lambda = a(\sin\theta_i + \sin\theta_m) \qquad (12\text{-}14)$$

$\therefore$ (i) = (ii)

$$\rightarrow m\lambda = a[\sin\theta_i + \sin(2\theta_b - \theta_i)] \qquad (12\text{-}15)$$

A. Littrow : incident light direction // groove face normal N'

$$\rightarrow \theta_b = \theta_i$$

$$\rightarrow \theta_m = -\theta_i$$

$$\therefore m\lambda = \underbrace{2a\sin\theta_b}_{=2h} \quad \text{or} \quad \theta_b = \sin^{-1}\left(\frac{m\lambda}{2a}\right)$$

B. $\theta_i = 0$ (along grating normal N)

$$\rightarrow \theta_b = -\frac{1}{2}\theta_m \quad \text{or} \quad \theta_b = \frac{1}{2}\sin^{-1}\left(\frac{m\lambda}{a}\right)$$

ex) a. 1200 groove/mm

$\lambda = 600$ nm

Blazing to the 1st principal max.

Q. what is θ_b?

Sol). $a = \frac{1}{1200}$ (mm)

(i) Using Littrow mount Eq., along N'

$$\theta_b = \sin^{-1}\left(\frac{m\lambda}{2a}\right) = \sin^{-1}\left(\frac{(1)(6\times10^{-4})}{2(1/1200)}\right) = 21.1^\circ.$$

(ii) For incident light along the grating normal N,

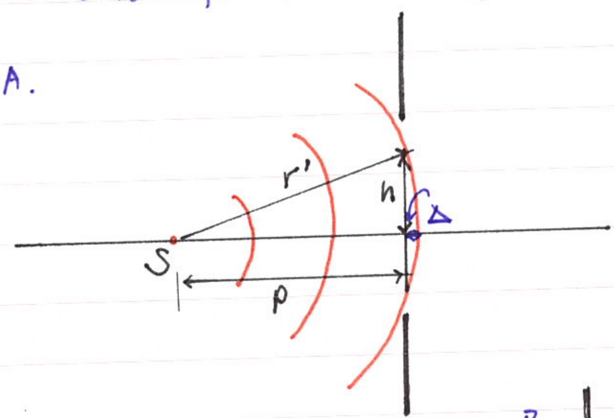
$$\theta_b = \frac{1}{2}\sin^{-1}\left(\frac{m\lambda}{a}\right) = \frac{1}{2}\sin^{-1}\left(\frac{(1)(6\times10^{-4})}{1/1200}\right) = 23.03^\circ$$

CH13. Fresnel Diffraction

- Fraunhofer : incident light is plane wave!
- Fresnel : not true! → spherical wave
  → near field → Diffration pattern is actual shape w/ edge fringes.

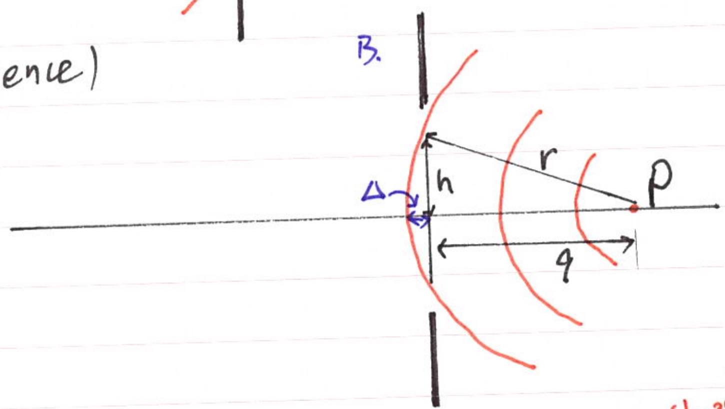
13-2 Criterion for Fresnel Diffraction

A.



(Incidence)

B.



(Diffraction)

$(1-x)^{-\frac{1}{2}} = 1 - \frac{x}{2} + \cdots$ (Talyor exp)

A. $\Delta = r' - \sqrt{r'^2 - h^2}$; $\Delta = r' - r'\left(1 - \frac{h^2}{r'^2}\right)^{\frac{1}{2}} \sim \frac{h^2}{2r'} > \lambda$

$(r' \sim p)$

B. $\Delta \sim \frac{h^2}{2q} > \lambda$

$\therefore$ Fresnel (nearfield): $\frac{1}{2}\left(\frac{1}{p} + \frac{1}{q}\right) h^2 > \lambda \rightarrow \boxed{d < \frac{A}{\lambda}}$

Far field (11-16) : $L \gg \frac{A}{\lambda}$

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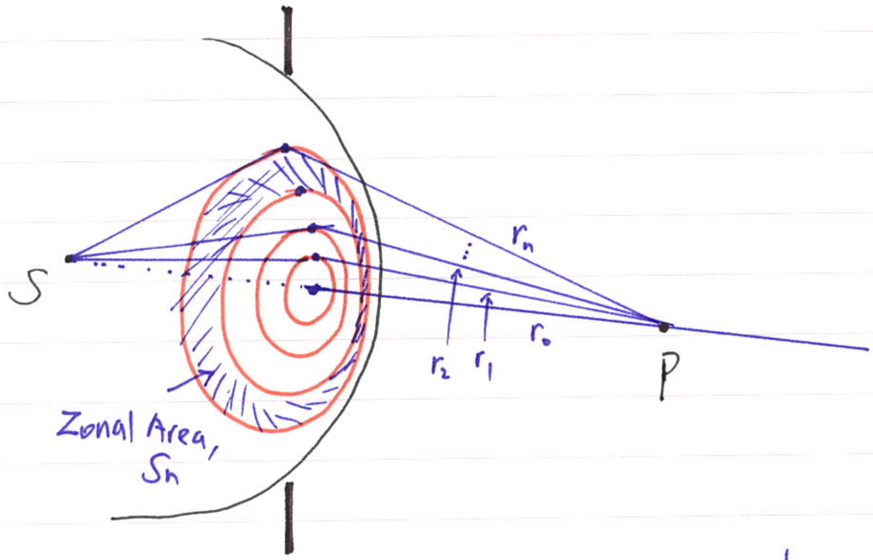
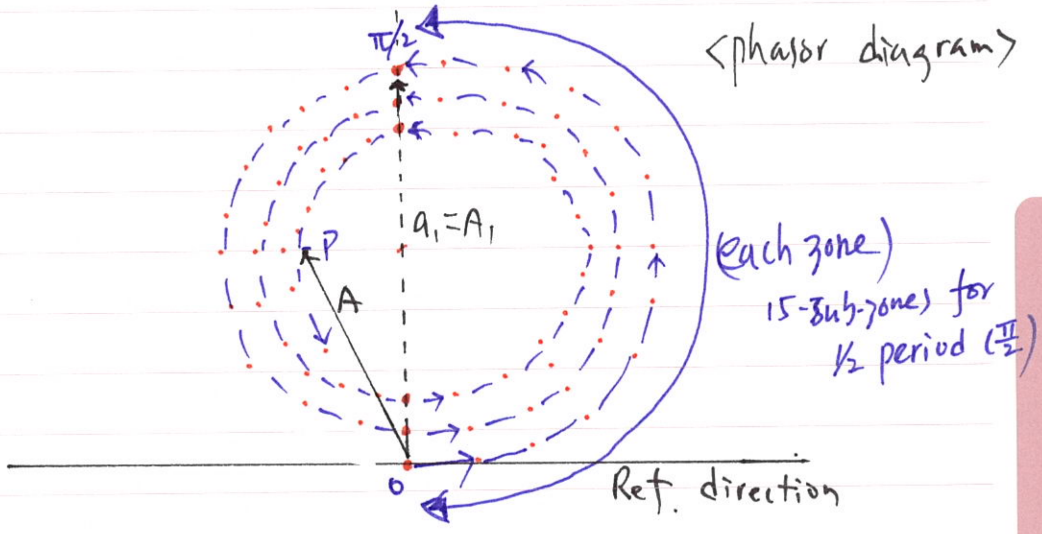
13-4 Fresnel diffraction from circular aperatures

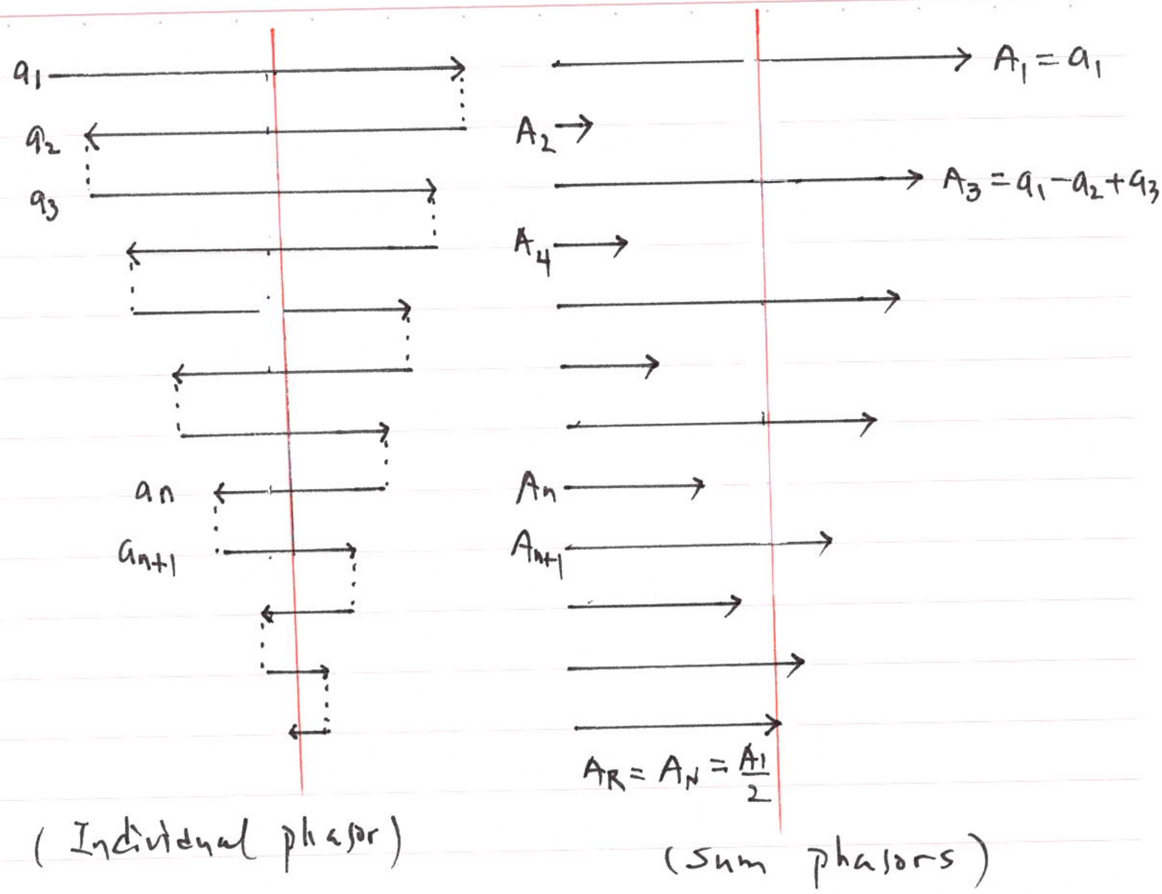


- Zone : circular symmetry for the phase (path) difference in π ($\lambda/2$)
  - $\rightarrow$ $r_1 = r_0 + \frac{\lambda}{2}$, $r_2 = r_0 + \lambda$, $\cdots$, $r_n = r_0 + n\frac{\lambda}{2}$
  - $\rightarrow$ each zone is out of phase with the preceding zone!
  - $\rightarrow$ each zone is also sub-divided ~~for a~~ $[0 - \pi]$

<phasor diagram>



- phasor a_1 : $\frac{\pi}{2}$ shift $\rightarrow$ spiral inward!
- At P, $A_n = a_1 + a_2 e^{i\pi} + a_3 e^{i2\pi} + \cdots + a_n e^{i(n-1)\pi} = a_1 - a_2 + a_3 - a_4 + \cdots + a_n$



$$A_N \doteq \frac{a_1}{2} - \frac{a_N}{2}, \quad N \text{ even}$$

$$A_N \doteq \frac{a_1}{2} + \frac{a_N}{2}, \quad N \text{ odd}$$

<Interpretation>

1. If N is small, $a_1 \sim a_N$

   then the resultant amplitude is

   $$\begin{cases} A_N \sim 0 & \text{for } N \text{ even} \\ A_N \sim a_1 & \text{for } N \text{ odd} \end{cases}$$

2. If N is large, $a_N \sim 0$,

   then

   $$A_N \sim \frac{a_1}{2} \quad (\text{both } N \text{ even and odd})$$

<experimental test>

- At P, ~~for~~ $A_p = a_1$, for the 1st Fresnel zone,

  by blocking all other zones except the 1st zone.

  → open to the 2^{nd} zone, then $A_p = 0$

  → open to all zones, then $A_p = \frac{a_1}{2}$

  → I_p (with all opening) $= \frac{1}{4} I_1$

- At P,

  If the 1st zone is blocked by a disk,

  then $A_p = \frac{a_2}{2} \sim \frac{a_1}{2}$

  → blocking the 1st zone $\sim$ all open

  → Poisson disagreed!

  → Fresnel & Arago experimentally ~~dep~~ proved!

  The diffraction spot is called Poisson's spot. (see Fig. 13-6)