4 JANUARY 2010

MIDTERM 1 PM 20 JANUARY 1/20/2010

MAKEUP CLASS 1/22 [?] 4-6 PM ?

DIFFRACTION → APPROXIMATIONS TO REALITY

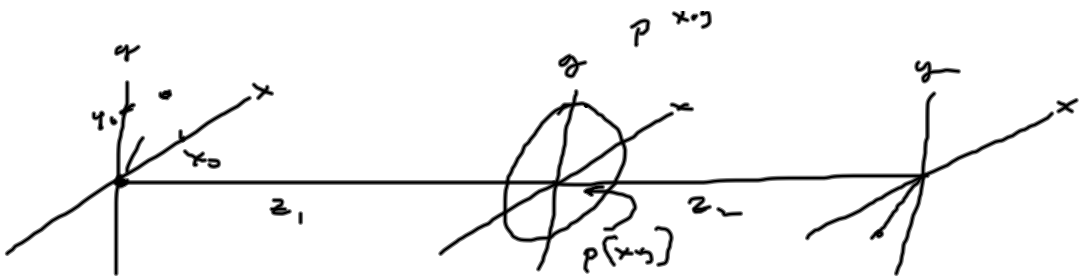
↑ USEFUL

(1) RAYLEIGH - SOMMERFELD ⇒ SPHERICAL WAVES, ∠SV (INCONVENIENT)

(2) FRESNEL ⇒ PARABOLOIDAL WAVES (QUADRATIC PHASE), ∠SI

(3) FRAUNHOFER ⇒ PLANE WAVE (LINEAR PHASE), ∠SV CONVENIENT

SPHERICAL SURFACES ⇒ PARABOLOIDAL (SAG FORMULA) $s(r) = \frac{r^2}{2R}$ QUADRATIC PHASE



$f(x,y)$ $\quad h(x,y)$ $\quad g(x,y)$

$f,\ \lambda_0$

$\delta(x-x_0,\ y-y_0)$ $\qquad h[x-x_0,\ y-y_0]$

$\uparrow$ $\qquad\qquad$ $\uparrow$

$M_T x_0$ $\qquad M_T y_0$

$$M_T = -\frac{z_2}{z_1}$$

SINGLE WAVE-CONCEPT $\Rightarrow$ DEFINITE PHASE RELATIONSHIP $\Rightarrow$ ~~$h(x,y) \propto P\left[\frac{x}{\lambda_0 z_2}\right.$~~

DETERMINISTIC

$$h[x,y] \propto P\left[\frac{x}{\lambda_0 z_2},\ \frac{y}{\lambda_0 z_2}\right]$$

$$H(\xi,\eta) \propto P[-\lambda_0 z_1 \xi,\ -\lambda_0 z_2 \eta]$$

RANDOM PHASE CASE

$\lambda_0 \longrightarrow \lambda_m$ ("MEAN" WAVELENGTH)

QUASI POLYCHROMATIC LIGHT

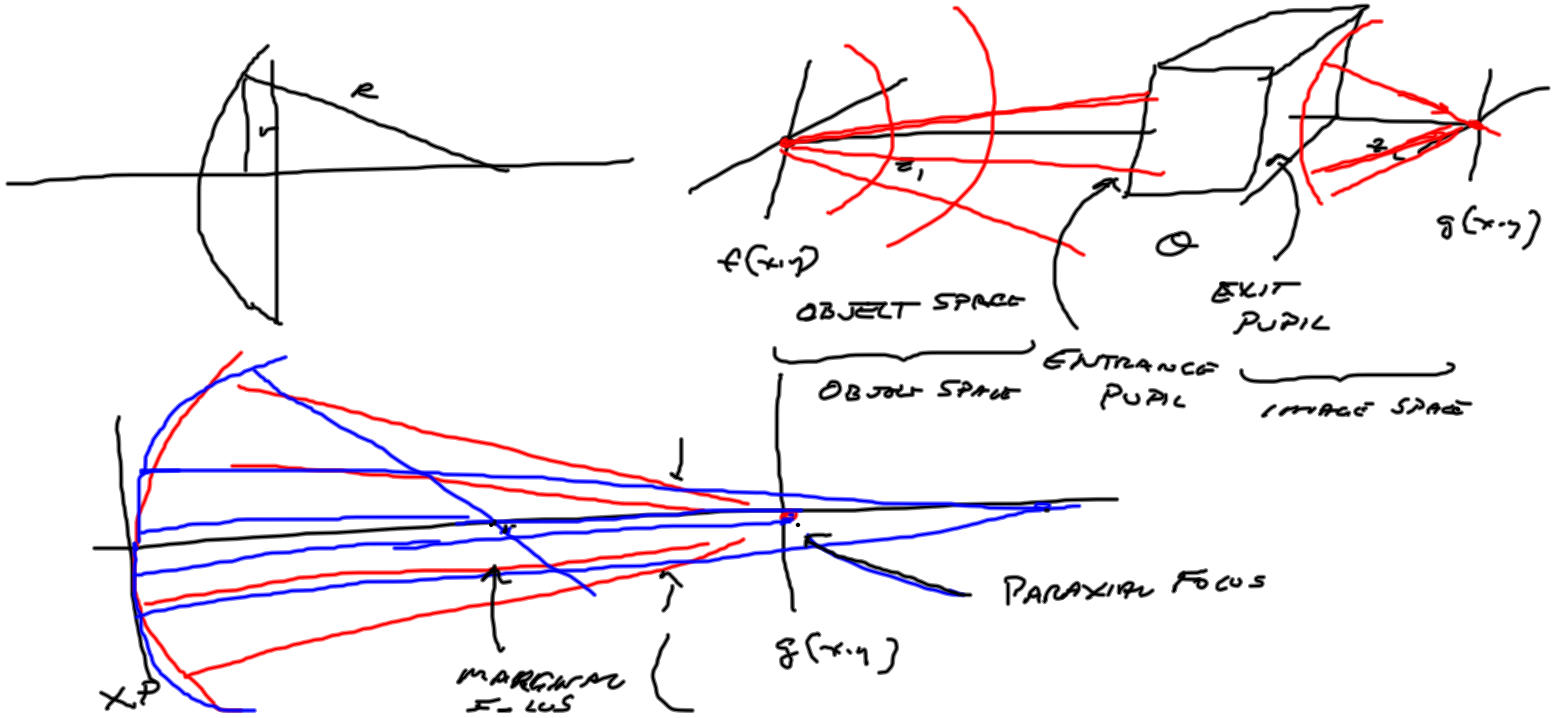
$$h[x,y] \propto |h[x,y]|^2 \geq 0$$

$$\mathcal{H}[\xi,\eta] \propto H[\xi,\eta] \star H[\xi,\eta]$$ (VIA WIENER-KHINTCHINE THEOREM)

SPHERES $\Longrightarrow$ PARABOLOIDS

DEVIATIONS FROM IDEAL

⇒ FABRICATION ERRORS

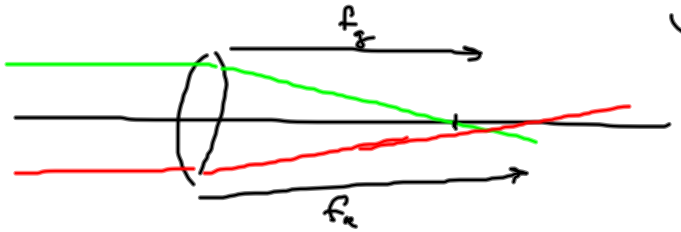


ABERRATIONS – DEVIATIONS FROM IDEAL "PERFORMANCE"

TBD

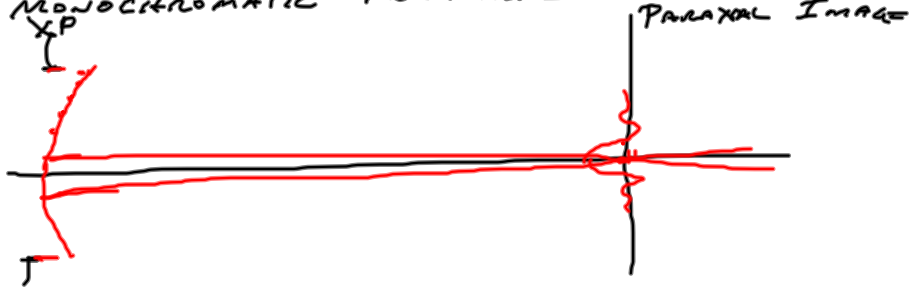
(1) CHROMATIC – VARIATIONS WITH λ

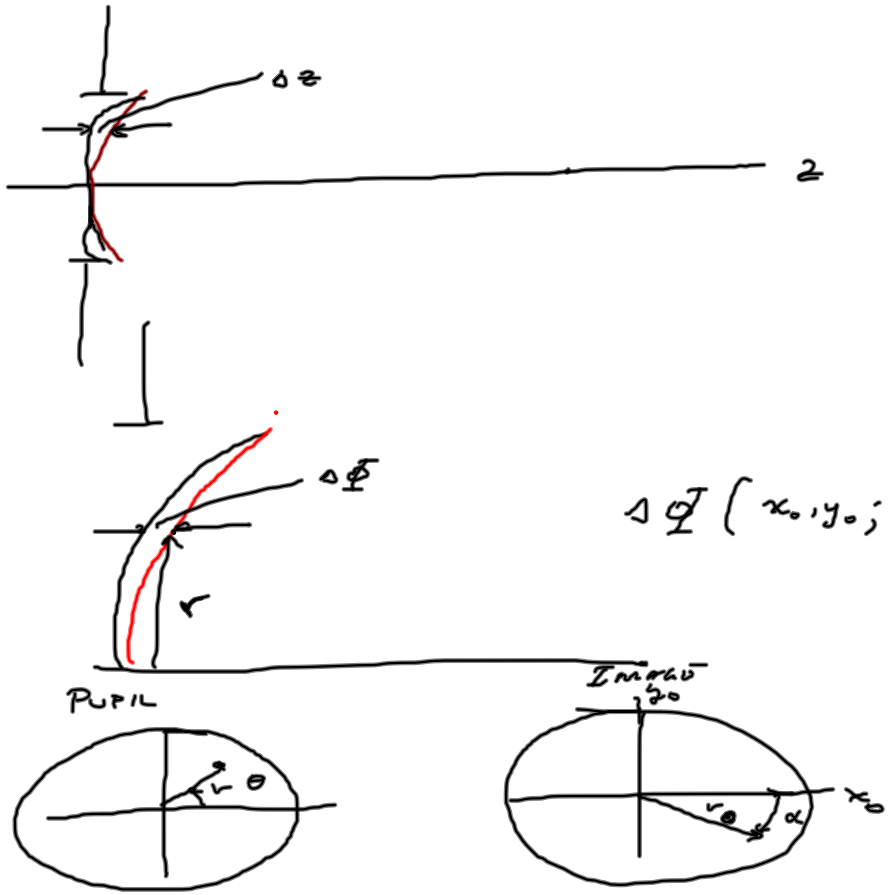
$$n(\lambda) = \frac{c}{v(\lambda)}$$



DISPERSION

(2) MONOCHROMATIC ABERRATIONS





$\Delta\varphi\,[x_0, y_0; x, y] \rightarrow \Delta\phi[r, \theta; r_0, \alpha]$

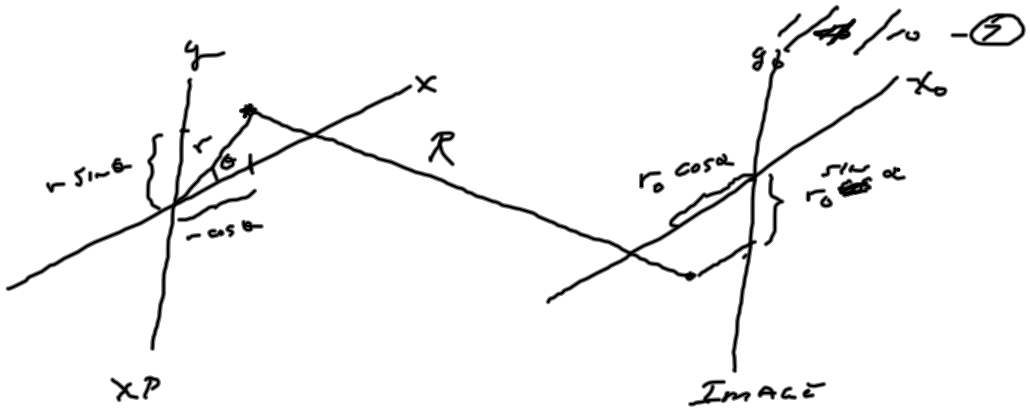
IF XP IS CIRCULARLY SYMMETRIC

$\Rightarrow$ $\theta - \alpha$ THAT MATTERS

$\varphi \equiv \theta - \alpha$

$$\underline{\phi} = 2\pi \frac{R}{\lambda_0}$$

R



$$R^2 = z^2 + (r\cos\theta - r_0\cos\alpha)^2 + (r\sin\theta - r_0\sin\alpha)^2$$

$$= z^2 + r^2\cos^2\theta + r_0^2\cos^2\alpha + r^2\sin^2\theta + r_0^2\sin^2\alpha - 2rr_0(\cos\theta\cos\alpha + \sin\theta\sin\alpha)$$

$$= z^2 + r^2 + r_0^2 - 2rr_0\cos(\underbrace{\theta - \alpha}_{\varphi})$$

$$R = z\left(1 + \frac{r^2 + r_0^2}{z^2} - \frac{2rr_0}{z^2}\cos\varphi\right)^{1/2}$$

1/4/10 – (8)

$$(1+u)^n = 1 + nu + \frac{n(n-1)}{2!}u^2 + \cdots$$

$$= z\left(1 + \frac{1}{2}\left(\frac{r^2 + r_0^2}{z^2} - \frac{2rr_0}{z^2}\cos\varphi\right) - \frac{1}{8}\left(\frac{r^2 + r_0^2}{z^2} - \frac{2rr_0}{z^2}\cos\varphi\right)^2 + \cdots\right)$$

TRUNCATE SERIES

CONSTANT PISTON

QUADRATIC DEFOCUS

PISTON ERROR

TIP-TILT

$$R \Rightarrow \phi = \frac{2\pi}{\lambda_0} \cdot R \Rightarrow \frac{2\pi}{\lambda_0} \cdot z + \frac{\pi}{\lambda_0 z} r^2 + \frac{\pi}{\lambda_0 z} r_0^2 - \frac{2\pi}{\lambda_0 z} rr_0 \cos\varphi$$

$$+ \frac{2\pi z}{8\lambda_0}\left(\left(\frac{r^2 + r_0^2}{z^2}\right)^2 - \left(\frac{2rr_0}{z^2}\cos\varphi\right)^2 + \frac{4rr_0(r^2 + r_0^2)\cos\varphi}{z^4}\right)$$

$$+ \frac{2\pi z}{4\lambda_0}\left(-\frac{r^4}{z^4} + \frac{r_0^4}{z^4} - \frac{2r^2r_0^2}{z^4} - \frac{4r^2r_0^2\cos^2\varphi}{z^4} + \frac{4r^3r_0\cos\varphi}{z^4} + \frac{4rr_0^3\cos\varphi}{z^4}\right)$$

SEIDEL ABERRATIONS

$$\Delta\underline{\phi}(r, r_0, \varphi) = \underline{\phi}_{\text{DESIRED}}(r, r_0, \varphi) - \underline{\phi}_{\text{ACTUAL}}(r, r_0, \varphi)$$

DESCRIBE $\Delta\underline{\phi}$ IN TERMS OF 10 COMPONENTS

(1) $\Delta\underline{\phi} = \frac{2\pi z}{\lambda_0}$ — CONSTANT PHASE DUE TO PROPAGATION

(2) $\Delta\underline{\phi} = \pi \frac{r^2}{\lambda_0 z}$ — QUADRATIC PHASE AT XP DEFOCUS (ABERRATION?)

LSI

(3) $\Delta\underline{\phi} = \pi \frac{r_0^2}{\lambda_0 z}$ — QUAD PHASE AT IMAGE PLANE PISTON ERROR (ABERRATION?)

(4) $\Delta\underline{\phi} = -2\pi \frac{r r_0}{\lambda_0 z} \cos\varphi$ BILINEAR PHASE TIP OR TILT MOVES IMAGE TIP-TILT

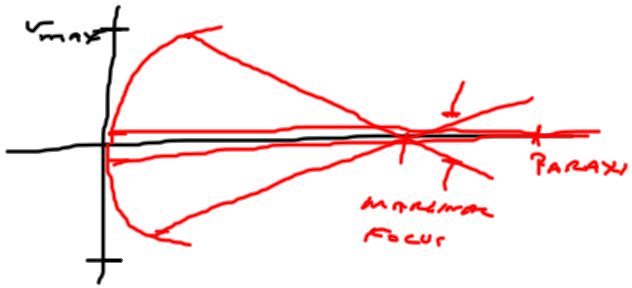
SEIDEL ABERRATIONS

1/4/10 — (10)

(5) SPHERICAL ABERRATION

$$\Delta\Phi = \frac{\pi z}{4\lambda_0}\cdot\left(-\frac{r^4}{z^4}\right) = -\frac{\pi r^4}{4\lambda_0 z^3} \propto r^4 \quad (\text{PUPIL HEIGHT})^4$$

LSI (IMAGE HEIGHT r_0 HAS NO EFFECT)



STOP DOWN LENS TO REDUCE EFFECT OF SPHERICAL ABERRATION