4 January 2010

**Midterm** 18th - 20th January 1/20/2010

**Makeup Class** 1/22 (?) 4-6 PM (?)

**Diffraction 
Approximations to Reality**

Useful

(1) *Rayleigh - Sommerfeld* \(\Rightarrow\) Spherical Waves, LSV

(2) Fresnel \(\Rightarrow\) Paraboloidal Waves (Quadratic Phase), LSV

(3) Fraunhofer \(\Rightarrow\) Plane Wave (Linear Phase), A LSV

Convenient

Spherical Surfaces \(\Rightarrow\) Paraboloidal (Some Formula)

\[ S(r) = \frac{1}{z^2} \]

Quadratic Phase
\[ f(x_0, y_0) \]

\[ h(x, y) \]

\[ g(x, y) \]

\[ S(x_0, y_0) \]

\[ m_r = -\frac{\beta}{\theta} \]

Single wave-convergent \( \Rightarrow \) **Definite Phase Relationship** \( \Rightarrow h(x, y) \]

\[ \frac{\partial}{\partial y} \]

\[ m_x \neq m_y \]

**Deterministic**

\[ h(x_0) \propto P \left[ \frac{x}{\lambda_0 z_2}, \frac{y}{\lambda_2 z_2} \right] \]

\[ h(x, y) \propto P \left[ -\lambda_0 z_2 x, -\lambda_2 z_2 y \right] \]
Random Phase Case

\[ \lambda_0 \rightarrow \lambda' \quad ("\text{mean" wavelength}) \]

Quasi-polychromatic light

\[ h(xy) \leq |h(xy)|^2 \geq 0 \]

\[ H[\xi, \eta] \leq H[\xi, \eta] \ast H[\xi, \eta] \quad \text{(via Wiener-Khintchine Theorem)} \]

Spheres $\rightarrow$ Paraboloids
Deviations from Ideal

Fabrication Errors
ABERRATIONS - Deviations from ideal "Performance"

TBD

(1) CHROMATIC - variations with $\lambda$

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

\[\begin{aligned}
15 & \quad 2 \\
n & \quad \lambda \\
\end{aligned}\]

DISPERSION

(2) MONOCROMATIC ABERRATIONS

PARAXIAL IMAGE
\[ \delta \Phi (x_0, y_0; x, y) \rightarrow \delta \Phi [v, \theta; v_0, \alpha] \]

If \( XP \) is circularly symmetric:

\[ \Rightarrow \theta - \alpha \text{ that matters} \]

\[ \varphi \equiv \theta - \alpha \]
\[ \overline{\Phi} = 2\pi \frac{R}{\lambda_0} \]

\[ R \]

\[ R^2 = z^2 + (v \cos \theta - v_0 \cos \alpha)^2 + (v \sin \theta - v_0 \sin \alpha)^2 \]
\[ = z^2 + v^2 \cos^2 \theta + v_0^2 \cos^2 \alpha + v^2 \sin^2 \theta + v_0^2 \sin^2 \alpha - 2vv_0 \cos \theta \cos \alpha + 2vv_0 \sin \theta \sin \alpha \]
\[ = z^2 + v^2 + v_0^2 - 2vv_0 \cos (\theta - \alpha) \]

\[ \overline{\Phi} \]

\[ \text{Image} \]

\[ z_\parallel \]

\[ z \]

\[ v \]

\[ v_0 \]

\[ \alpha \]

\[ \theta \]
\[
\Delta \phi(r, r_0, \varphi) = \Phi_{\text{diffr}}(r, r_0, \varphi) - \Phi_{\text{known}}(r, r_0, \varphi)
\]

Describe \( \Delta \phi \) in terms of 10 components

1. \( \Delta \phi = \frac{2\pi r}{\lambda_0} \) - Constant phase due to Propagation

2. \( \Delta \phi = \pi \frac{r^2}{\lambda_0^2} \) - Quadratic phase at XP Defocus (Aberration?)

3. \( \Delta \phi = \pi \frac{r_0^2}{\lambda_0^2} \) - Quad phase at image plane Piston Error (Aberration?)

4. \( \Delta \phi = -2\pi \frac{\varphi - \varphi_0}{\lambda_0^2} \) - Birefringence Phase Tip or Tilt Moves Image Tip - Tilt
(5) Spherical Aberration

\[ \Delta \Phi = \frac{\pi z}{4\lambda_0} \left( \frac{-r^4}{2^4} \right) = \frac{\pi}{4\lambda_0} \frac{r^4}{2^3} \propto r^4 \] (Pupil Height)^2

 CSI (Image Height \( v_0 \) has no effect)

Stop down lens to reduce effect of spherical aberration

Paraxial Focus