OPTI 380A
Intermediate Optics Lab 8: Interference

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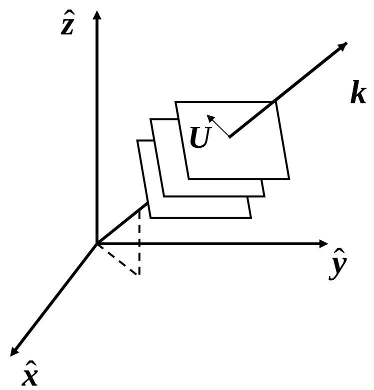
Plane Waves

$$\boldsymbol{U}(\boldsymbol{r},t)=\boldsymbol{U_0}e^{j(\boldsymbol{k}\cdot\boldsymbol{r}-\omega t)}$$

Wave fronts $\perp \boldsymbol{k}$.

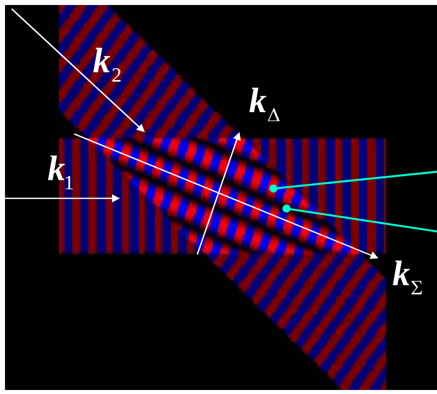
Max separation between planes = λ.

$\boldsymbol{U}_0 \perp \hat{\boldsymbol{k}}$ in linear, isotropic media

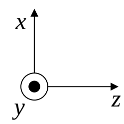


Two Vector Plane Waves -Dynamics

(Time Domain Dynamics)



- For $\lambda_1 = \lambda_2$, $\omega_\Delta = 0$ and modulation is stationary.
- For $\lambda_1 = \lambda_2$, $\boldsymbol{k}_\Delta \perp \boldsymbol{k}_\Sigma$
- Power flow is along *constructive* lines.
- Total energy is conserved due to *destructive* lines.



Red = negative field amplitude
Blue = positive field amplitude

Two Vector Plane Waves - Irradiance

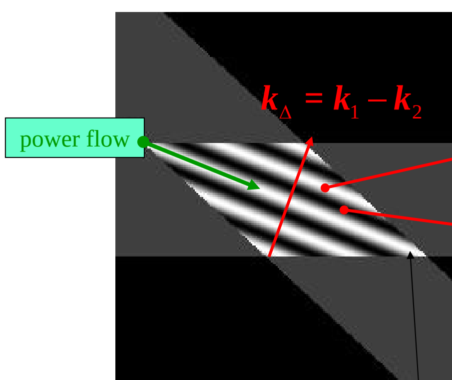
(Time Averaged Irradiance)

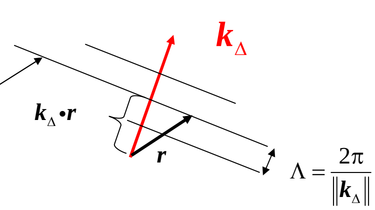
(We will drop the *y* subscript for now and assume β=0.)

$$I(\boldsymbol{r}) = CA^2\left[1 + \cos\left(\boldsymbol{k}_\Delta \bullet \boldsymbol{r}\right)\right]$$

When $(\boldsymbol{k}_1 - \boldsymbol{k}_2)\bullet\boldsymbol{r} = 2\pi m$, a *bright* fringe occurs from *constructive* interference.

When $(\boldsymbol{k}_1 - \boldsymbol{k}_2)\bullet\boldsymbol{r} = 2\pi(m+1/2)$, a *dark* fringe occurs from *destructive* interference.





fringe field is collection of planes of constant $\boldsymbol{k}_\Delta \bullet \boldsymbol{r}$.

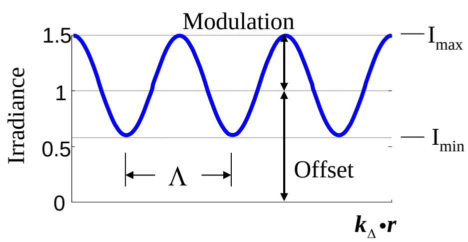
Two Vector Plane Waves - Visibility

Consider the combination of two unequal amplitude plane waves. Assume $\theta = 0$.

interference term

$$I(\boldsymbol{r}) = C\left[A_1^2 + A_2^2 + 2A_1A_2\cos(\boldsymbol{k}_\Delta \bullet \boldsymbol{r})\right]$$
$$= C\left[A_1^2 + A_2^2 + 2A_1A_2\cos(\boldsymbol{k}_\Delta \bullet \boldsymbol{r})\right] = I_1 + I_2 + \overbrace{2\sqrt{I_1 I_2}\cos(\boldsymbol{k}_\Delta \bullet \boldsymbol{r})} \qquad (p_{12} = 1)$$

where I_1 and I_2 are irradiance values for waves 1 and 2, respectively. If $I_1 \neq I_2$, the total irradiance across a section of the observation plane might look like:



$$visibility = V = \frac{Offset}{Modulation} = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} = \frac{2\sqrt{I_1 I_2}}{I_1 + I_2} p_{12}$$

$$0 \le V \le 1$$

Scalar Spherical Waves

A solution to the wave equation in spherical coordinates is:

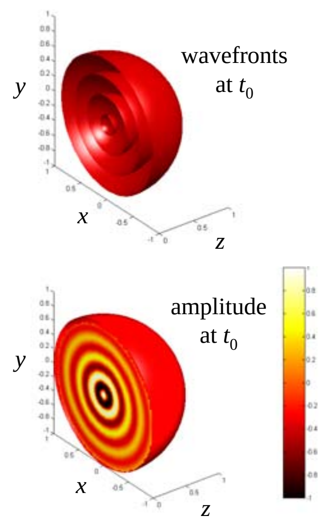
$$U(r,t) = \frac{1}{r} e^{j(kr - \omega t)} \quad ,$$

where

$$r = \sqrt{x^2 + y^2 + z^2}$$

and $\psi = kr - \omega t$.

Wave crests (also called *wavefronts*) at ψ = constant expand outwardly from the source point as a function of time. Wavefronts are perpendicular to $\boldsymbol{r}$.



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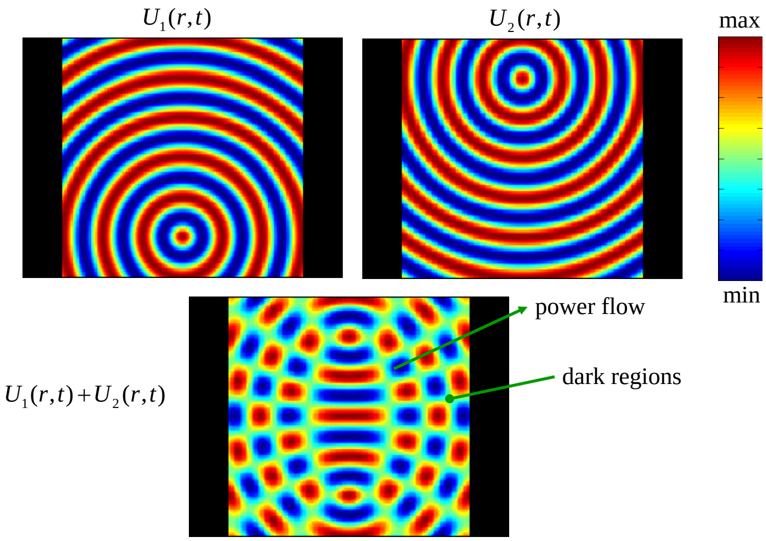
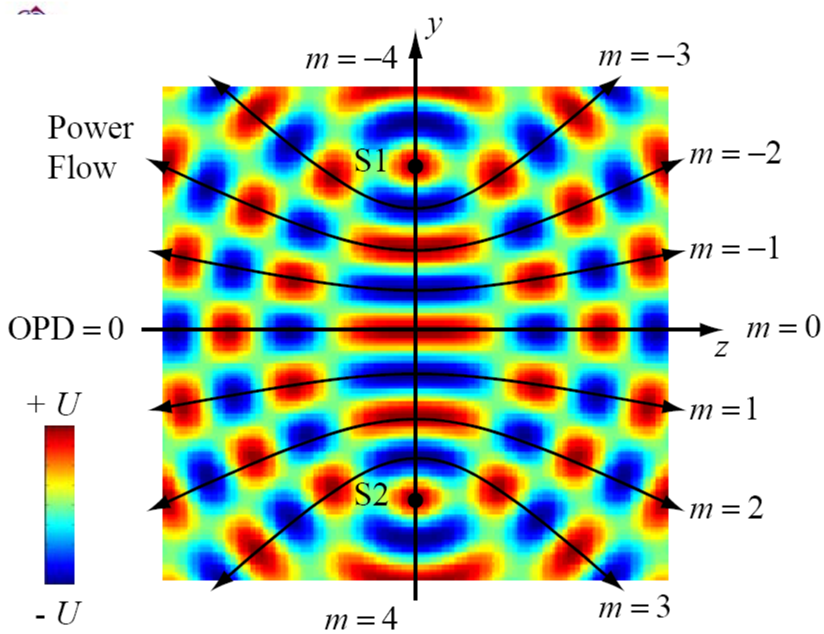
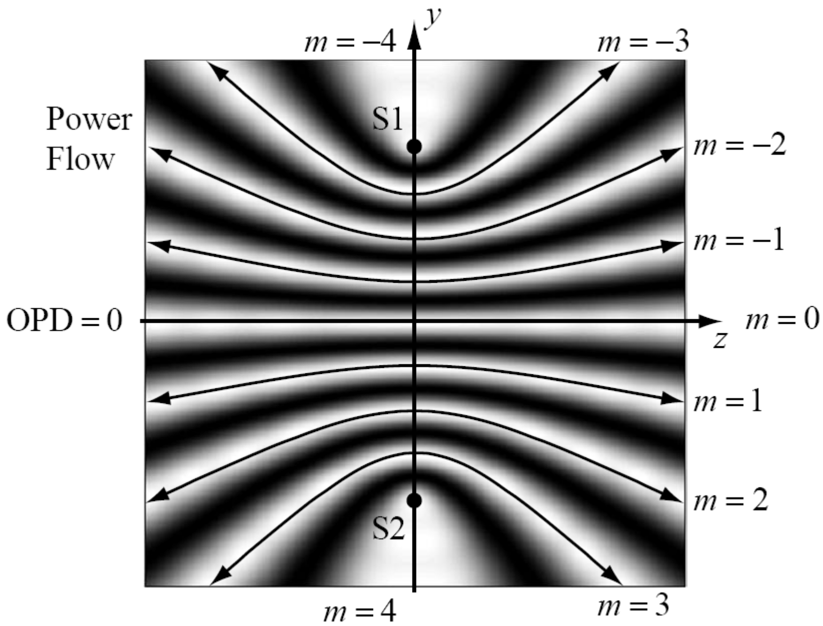
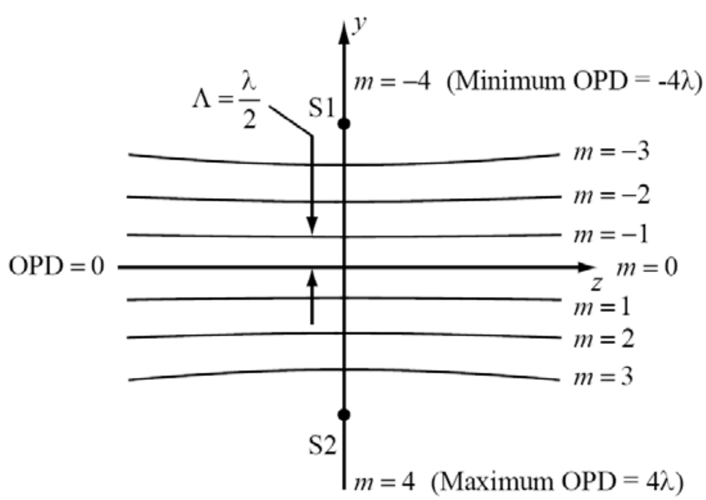
Two Spherical Waves





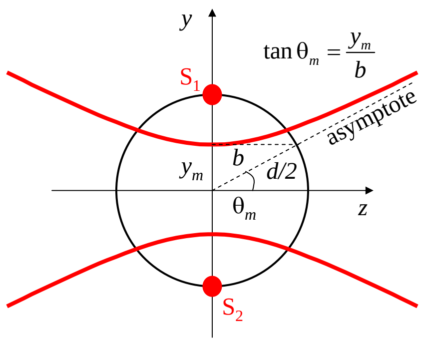


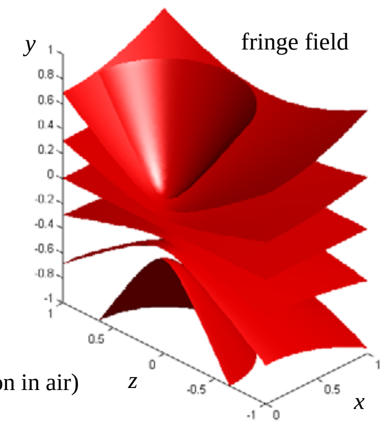
10/19/2009 OPTI380A - Lab 8: Interference 9



10/19/2009 OPTI380A - Lab 8: Interference 10

Two Spherical Waves – Fringe Surfaces





$$\frac{y^2}{y_m^{\ 2}} - \frac{x^2+z^2}{b^2} = 1 \quad ,$$

(Observation in air)

where $y_m = -\frac{1}{2} m\lambda$ and $b^2 = (d/2)^2 - y_m^{\ 2}$. These are *hyperboloidal sheets* in 3D

Two-Point Interference with a Ripple Tank

(Part C of This Week's Experiment)

- Each actuator (dipper) acts like a point source

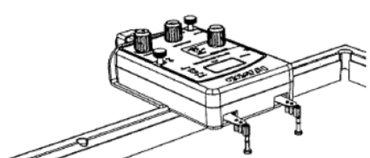
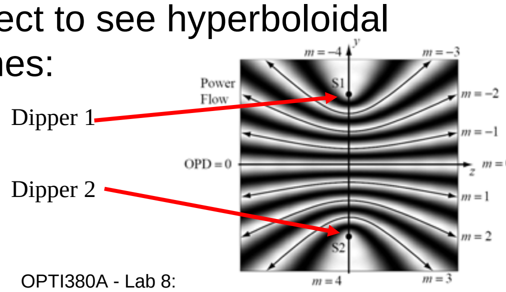


Figure 4.3: Standard Dippers

- We would expect to see hyperboloidal interference lines:



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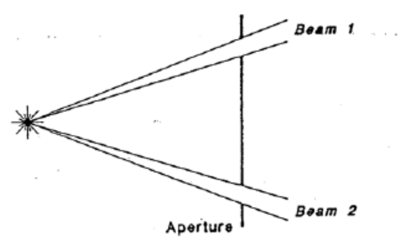
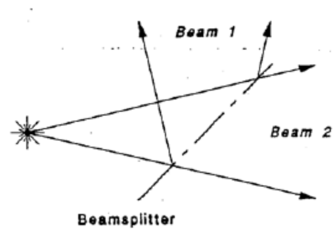
Interferometers

- Division of Wavefront
  - Samples wavefront at different points
- Division of Amplitude
  - Creates copies of the wavefront

Division of Wavefront



Division of Amplitude



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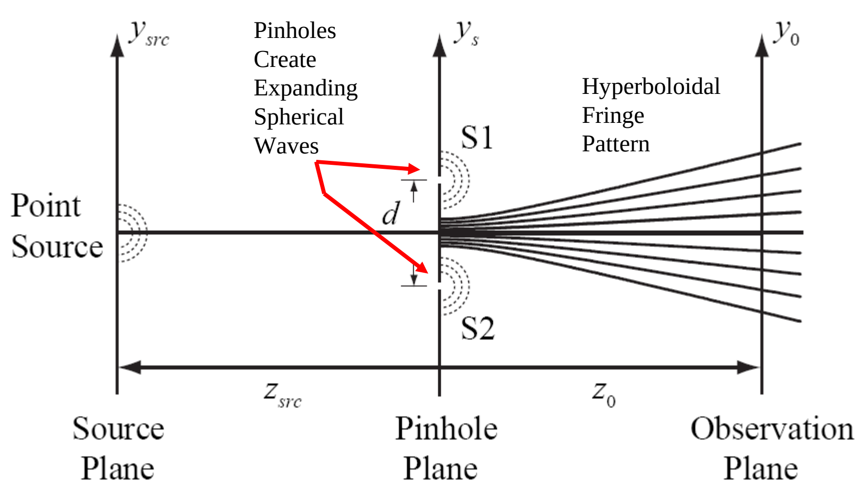
Part A: Young’s Double Slit Interferometer

(Model)



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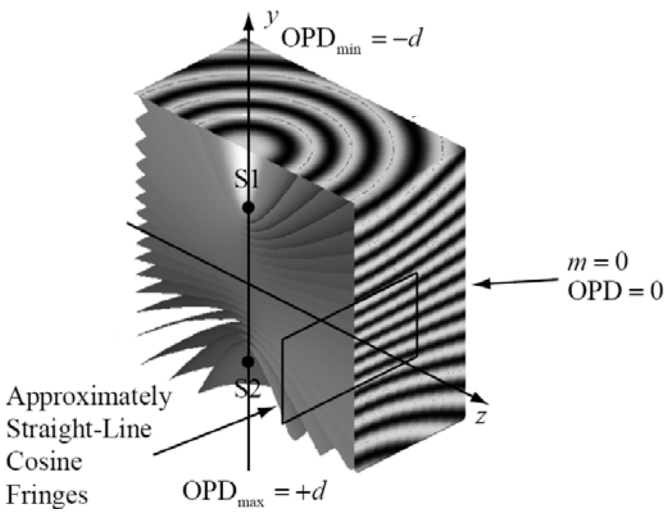
YDPI with z_0 Large



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Young's Double Slit Interferometer (YDSI)

(Implementation)

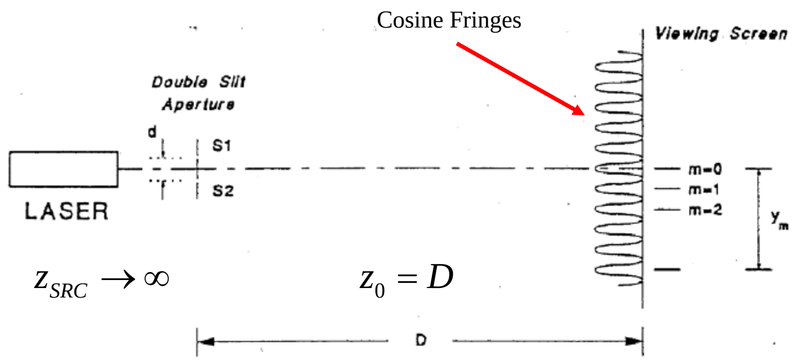


Figure 8.4. Setup for Young's Double Slit experiment (**NOT TO SCALE**).

YDSI Optical Paths

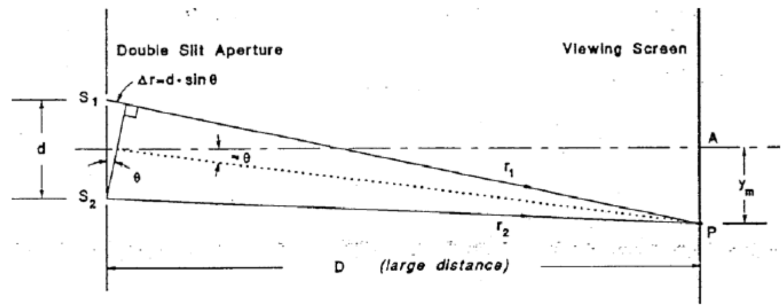
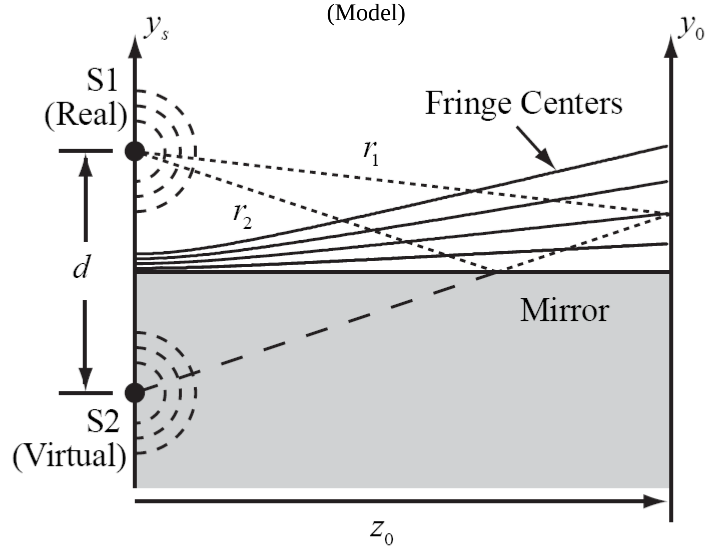


Figure 8.5. Optical paths in Young's Double Slit experiment.

$$y_m \approx \frac{mD\lambda}{d}$$

Part B: Lloyd's Mirror

(Model)



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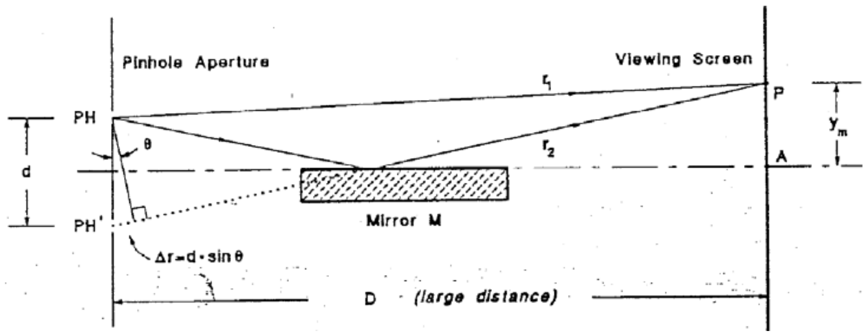
Lloyd's Mirror

(Optical Paths)



$$y_m \approx \frac{mD\lambda}{d}$$

(Reverse fringe contrast due to Fresnel reflection from mirror.)

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Lloyd's Mirror

(Implementation)

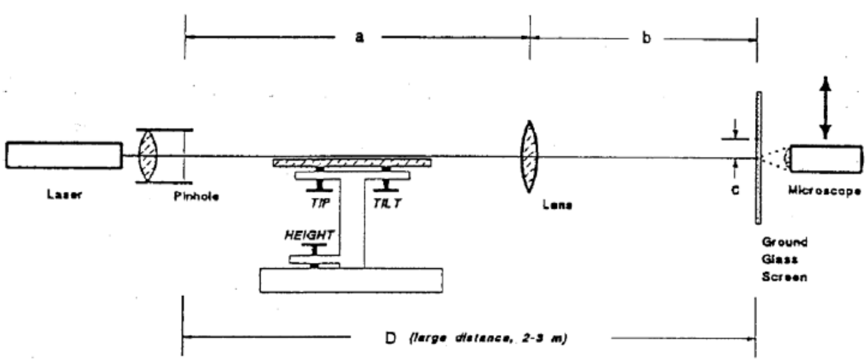

Figure 8.6. Setup used for Lloyd's Mirror (**NOT TO SCALE**).

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Good Website for YDSI

- http://www.falstad.com/mathphysics.html