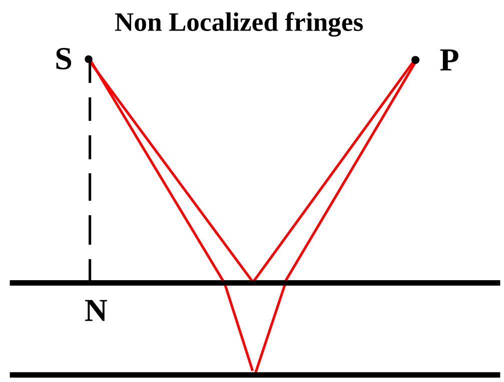
Part 4
Basic Classical Interferometers

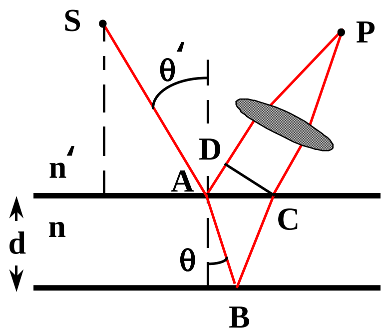
- Plane Parallel Plate
- Fizeau
- Michelson
- Twyman-Green
- Mach-Zehnder
- Lateral Shear
- Radial Shear

Plane Parallel Plate - Point Source



By symmetry, fringes in plane parallel to plate are circular about normal SN

Plane Parallel Plate - Extended Source (Path Difference)



$$\Delta l = 2nd\cos\theta$$

Optical path difference

$$\Delta l = (AB + CB)n - n' AD$$

$$AB = CB = \frac{d}{\cos\theta}$$

$$AD = AC\sin\theta'; AC = 2d\tan\theta$$

$$= 2d\tan\theta\sin\theta'$$

$$n'\sin\theta' = n\sin\theta$$

$$\Delta l = \frac{2nd}{\cos\theta} - 2n'd\frac{\sin\theta}{\cos\theta}\frac{n\sin\theta}{n'}$$

$$= \frac{2nd}{\cos\theta}[1 - \sin^2\theta]$$

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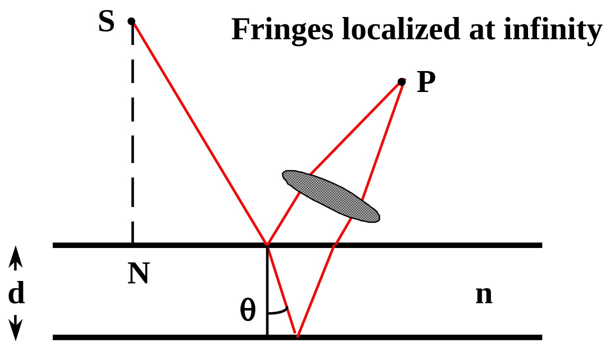
Plane Parallel Plate - Extended Source (Haidinger Fringes)



$$\delta = \frac{2\pi}{\lambda}2nd\cos\theta \pm \pi$$

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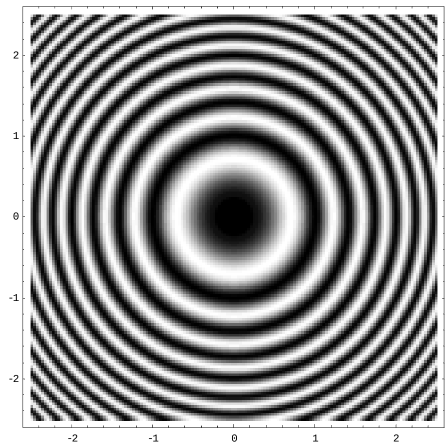
Haidinger Fringes



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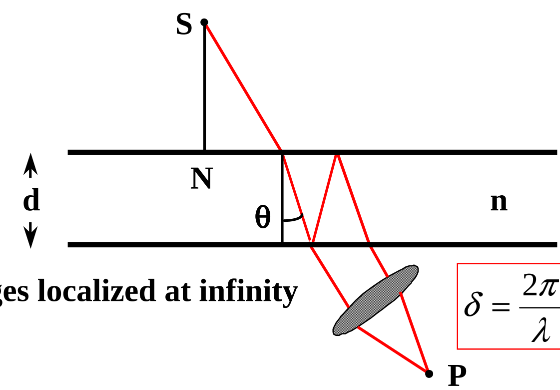
Plane Parallel Plate - Extended Source (Transmitted Light)



Fringes localized at infinity

$$\delta = \frac{2\pi}{\lambda} 2nd \cos\theta$$

Low reflectance surfaces give low visibility fringes.
Transmitted and reflected fringe patterns are complimentary.

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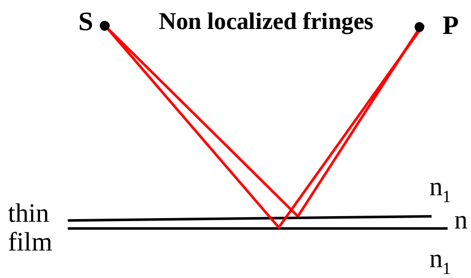
Fizeau Fringes - Point Source (1862)

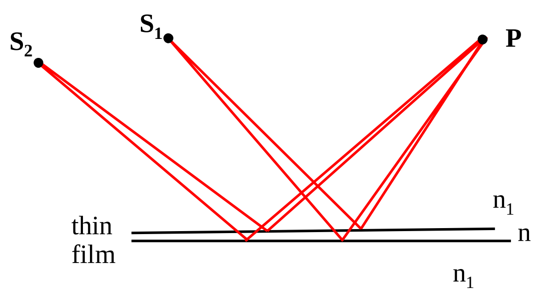


$$\delta = \frac{2\pi}{\lambda} 2nd \cos\theta \pm \pi$$

d is film thickness (function of position)

θ is angle within film (function of position)

Fizeau Fringes - Broad Source (1862)



Fringes localized near film

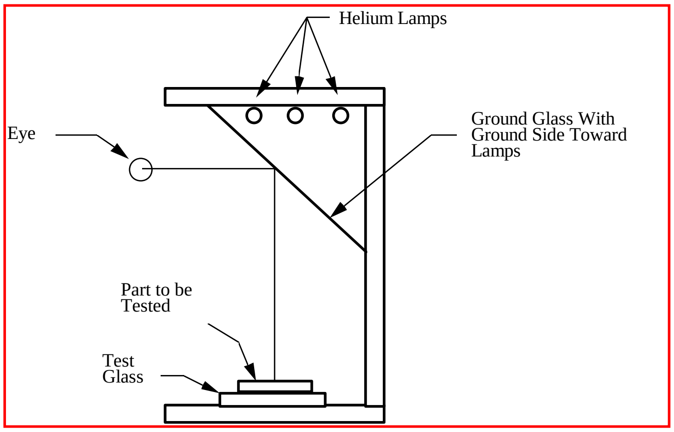
Near the film rays from source points see approximately same d

Variations in cos θ reduced if

a) camera has small aperture focused on film

b) if $\theta \approx 0$, $\cos\theta \approx 1$ for moderate spread in θ

Classical Fizeau Interferometer



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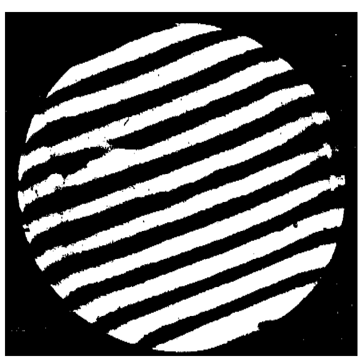
Typical Interferogram obtained using Fizeau Interferometer



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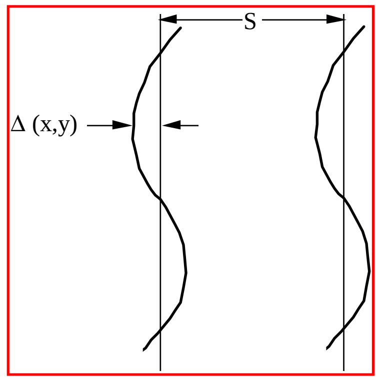
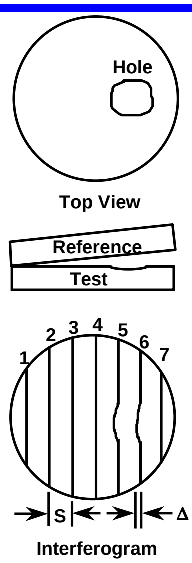
Relationship between Surface Height Error and Fringe Deviation

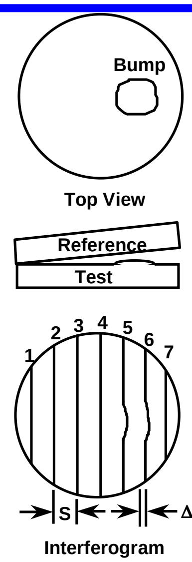


Surface height error = $\left(\frac{\lambda}{2}\right)\left(\frac{\Delta}{S}\right)$

Fizeau Fringes

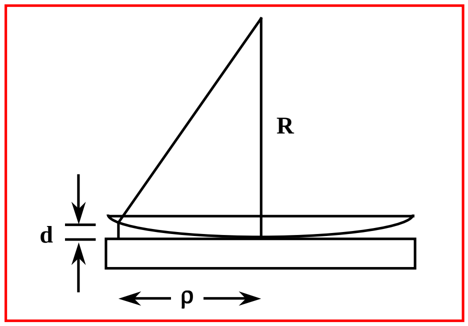


For a given fringe the separation between the two surfaces is a constant.



Height error = (λ/2)(Δ/S)

Newton's Rings



For m th dark fringe from center

$$d_m = m\frac{\lambda}{2}$$

$$\rho_m \approx \sqrt{m\lambda R}$$

Soap Bubbles and Oil Films

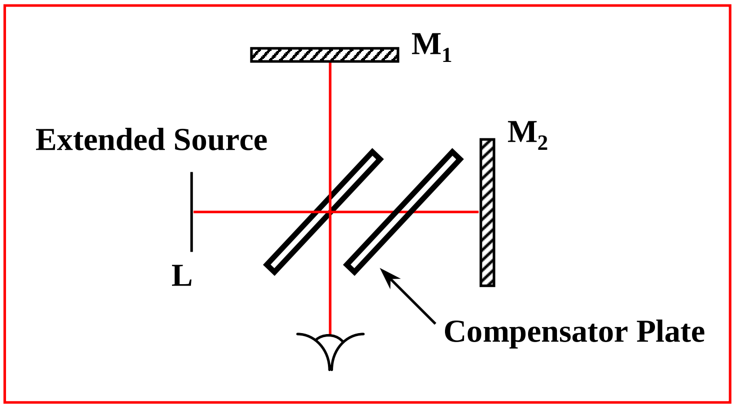
For bright fringe

$$\frac{2\pi}{\lambda}2nd\cos\theta + \pi = m2\pi$$

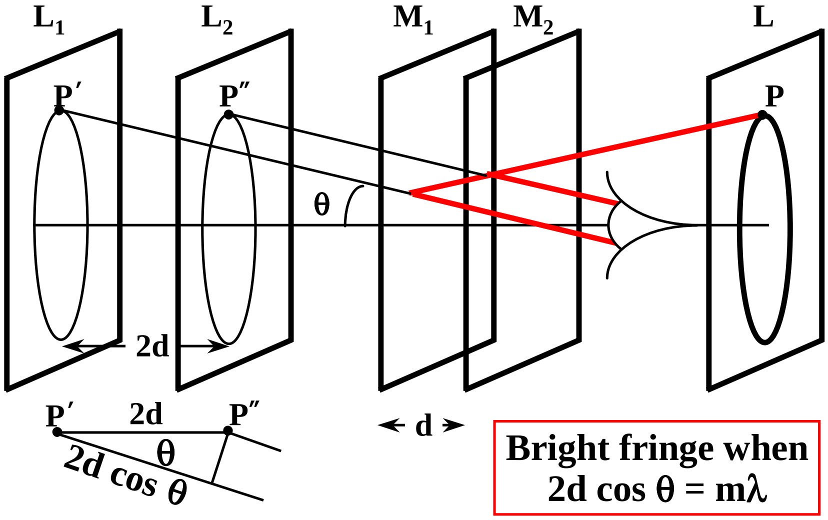
If d>>λ, m varies greatly for change in λ.
If d = few λ, m varies slowly with λ.

Therefore, with thin films see color fringes.
Color changes with variations in thickness and θ.

Michelson Interferometer (1881)

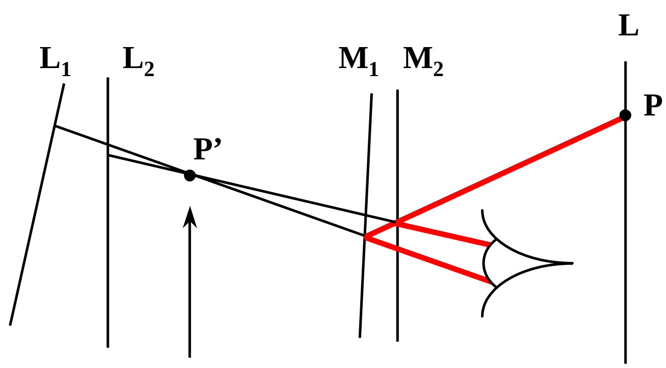


Michelson Interferometer
(Fringes of Equal Inclination - Haidinger)



Bright fringe when
$2d \cos\theta = m\lambda$

Michelson Interferometer
(Fringes of Equal Thickness)



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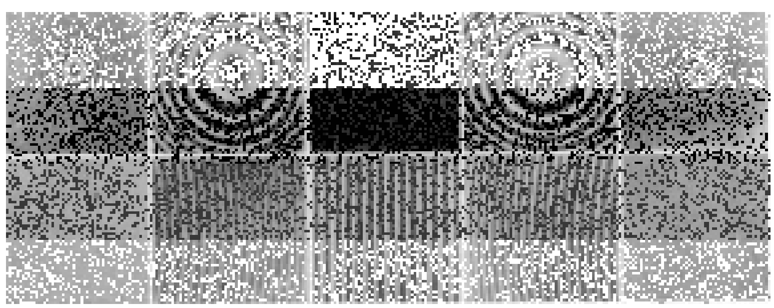
Michelson Interferometer Fringes



Upper row - Fringes of Equal Inclination

Lower row - Fringes of Equal Thickness

Path differences increases outward from the center

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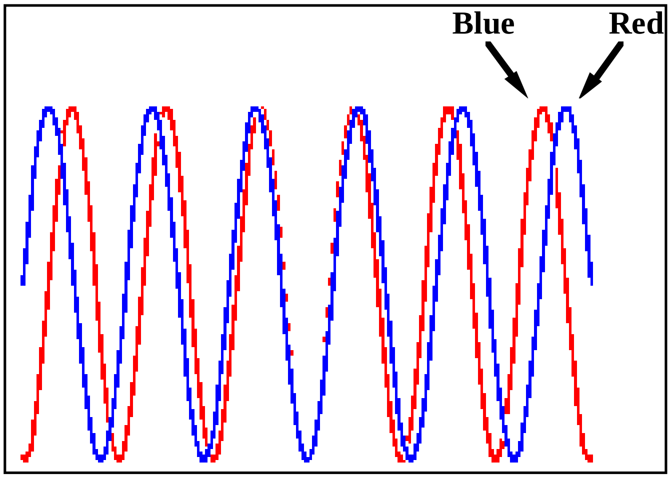
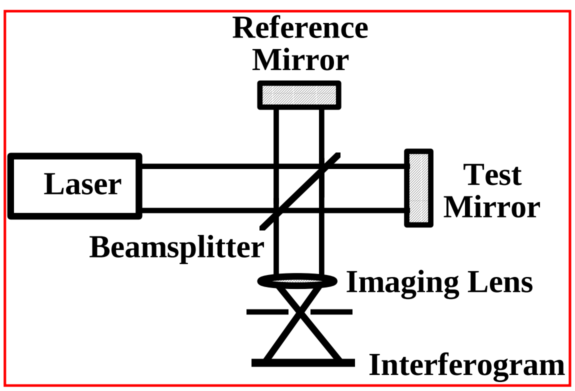
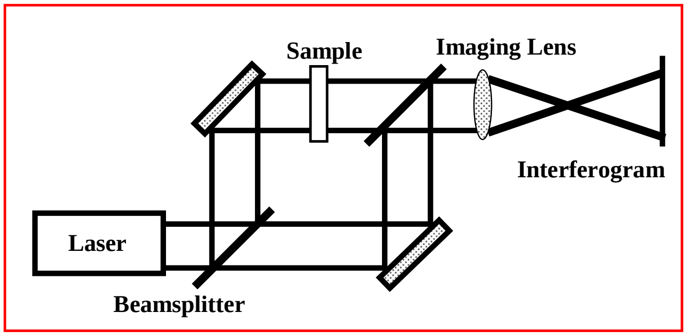
White Light Fringes



Twyman-Green Interferometer (Flat Surfaces)



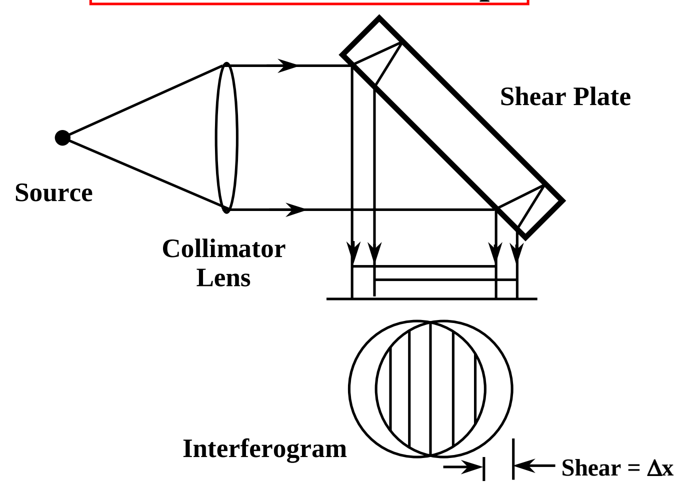
Mach-Zehnder Interferometer



Testing samples in transmission

Lateral Shear Interferometry

Measures wavefront slope



Lateral Shear Fringes

$\Delta W(x,y)$ is wavefront being measured

Bright fringe obtained when

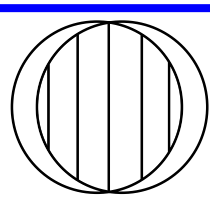
$$\Delta W(x+\Delta x, y) - \Delta W(x,y) = m\lambda$$

$$\left(\frac{\partial \Delta W(x,y)}{\partial x}_{\substack{\text{Average over} \\ \text{shear distance}}} \right)(\Delta x) = m\lambda$$

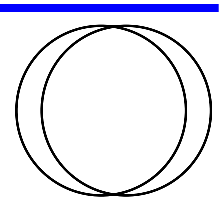
Measures average value of slope over shear distance

Collimation Measurement

No wedge in shear plate

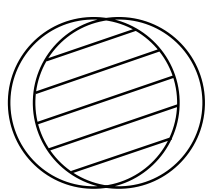


Not collimated

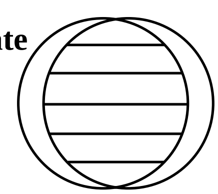


Collimated (one fringe)

Vertical wedge in shear plate



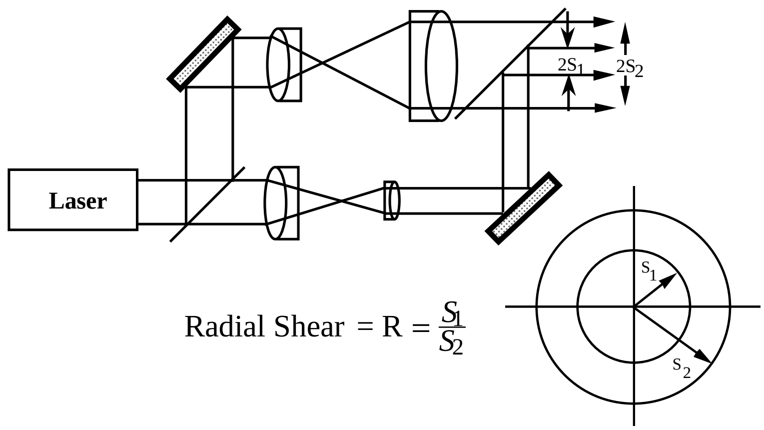
Not collimated



Collimated

Radial Shear Interferometry

Wavefront is interfered with expanded version of itself



Radial Shear $= R = \frac{S_1}{S_2}$

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Analysis of Radial Shear Interferograms

Wavefront being measured

$$\Delta W(\rho,\theta) = W_{020}\rho^2 + W_{040}\rho^4 + W_{131}\rho^3\cos\theta + W_{222}\rho^2\cos^2\theta$$

Expanded beam can be written

$$\Delta W(R\rho,\theta) = W_{020}(R\rho)^2 + W_{040}(R\rho)^4 + W_{131}(R\rho)^3\cos\theta$$
$$+W_{222}(R\rho)^2\cos^2\theta$$

Hence, a bright fringe is obtained whenever

$$\Delta W(\rho,\theta) - \Delta W(R\rho,\theta) = W_{020}\rho^2(1-R^2) + W_{040}\rho^4(1-R^4)$$
$$+W_{131}\rho^3(1-R^3)\cos\theta + W_{222}\rho^2(1-R^2)\cos^2\theta$$

Same as Twyman-Green if divide each coefficient by $(1-R^n)$

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Radial Shear Interferogram

- **Variable Sensitivity Test**
- **Large shear - results same as for Twyman-Green**
- **Small shear - Low sensitivity test**

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