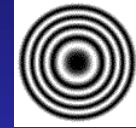
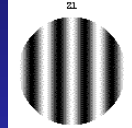
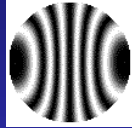
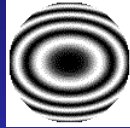


Introduction to Interferometric Optical Testing



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Outline

- 1. Basic Interferometers for Optical Testing
- 2. Phase-Shifting Interferometry
- 3. Specialized Optical Tests
- 4. Long Wavelength Interferometry
- 5. Testing of Aspheric Surfaces
- 6. Measurement of Surface Microstructure
- 7. Absolute Measurements
- 8. Concluding Remarks

Part 1 - Basic Interferometers for Optical Testing

- Two Beam Interference
- Fizeau and Twyman-Green interferometers
- Basic techniques for testing flat and spherical surfaces
- Mach-Zehnder, Scatterplate, and Smartt Interferometers
- Shearing Interferometers
- Typical Interferograms

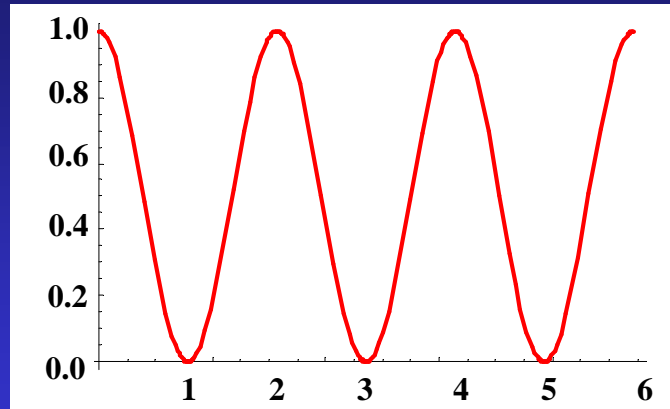
Two-Beam Interference Fringes

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos(\alpha_1 - \alpha_2)$$

$\alpha_1 - \alpha_2$ is the phase difference between the two interfering beams

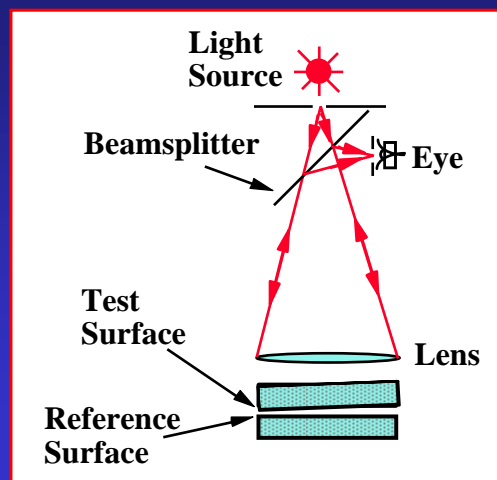
$$\alpha_1 - \alpha_2 = \left(\frac{2\pi}{\lambda}\right)(\text{optical path difference})$$

Sinusoidal Interference Fringes

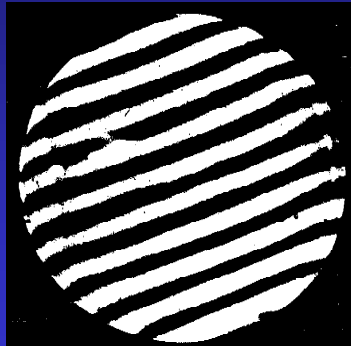


$$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos(\alpha_1 - \alpha_2)$$

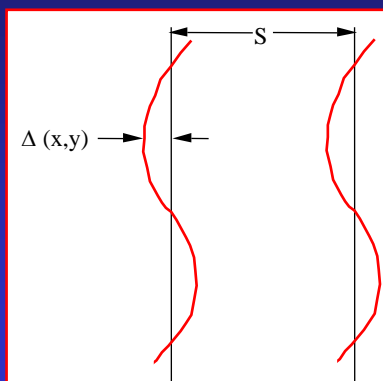
Pioneer Fizeau Interferometer 1862



Typical Interferogram Obtained using Fizeau Interferometer

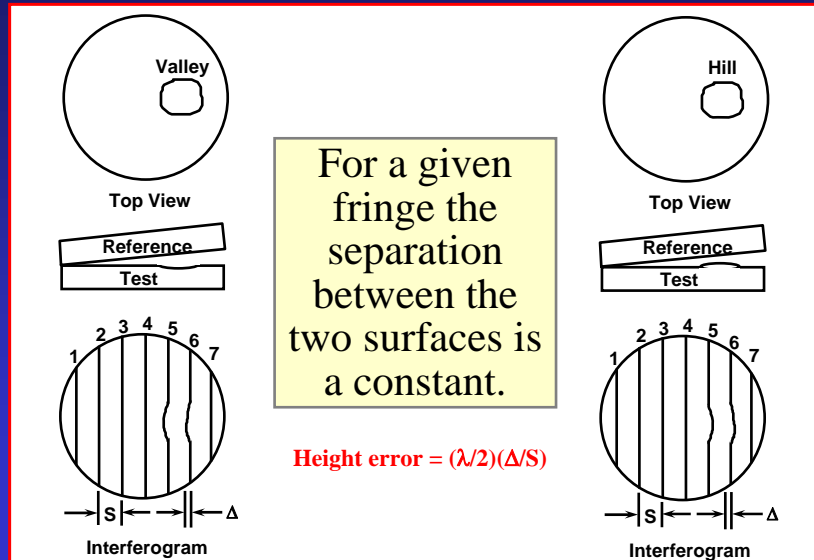


Relationship between Surface Height Error and Fringe Deviation

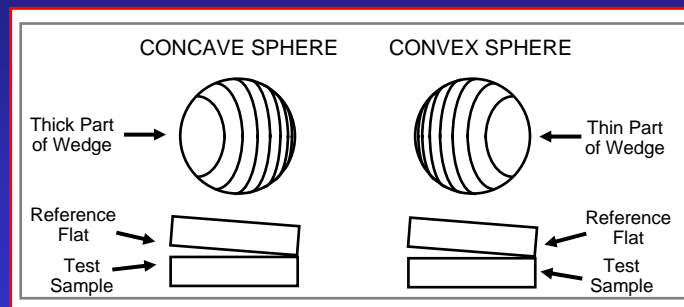


$$\text{Surface height error} = \left(\frac{\lambda}{2}\right)\left(\frac{\Delta}{S}\right)$$

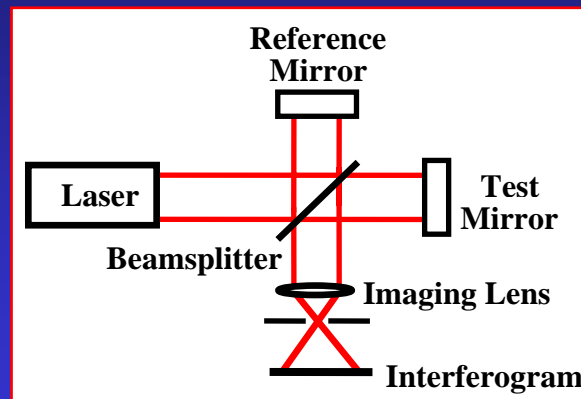
Fizeau Fringes



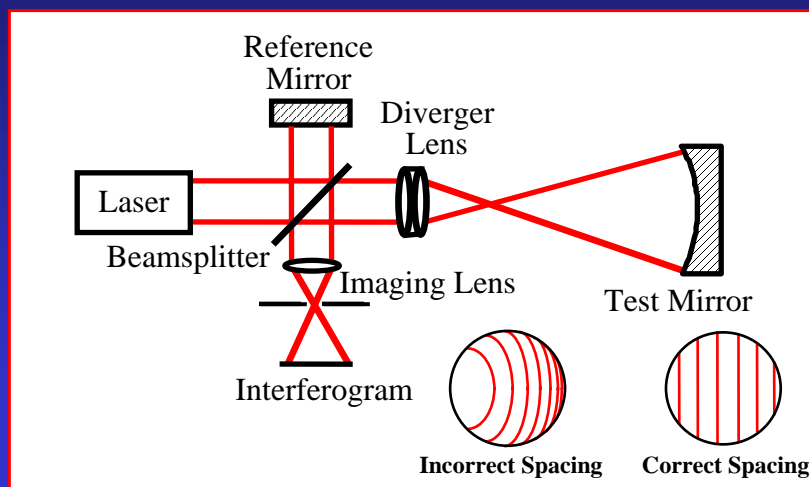
Fizeau Fringes for Concave and Convex Surfaces



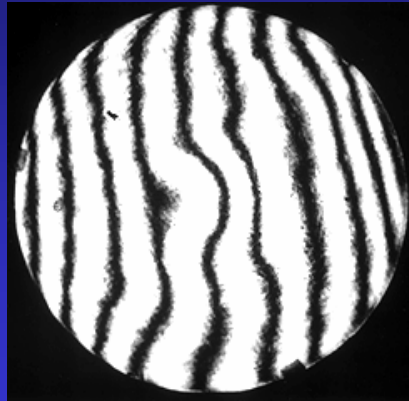
Twyman-Green Interferometer (1918) (Flat Surfaces)



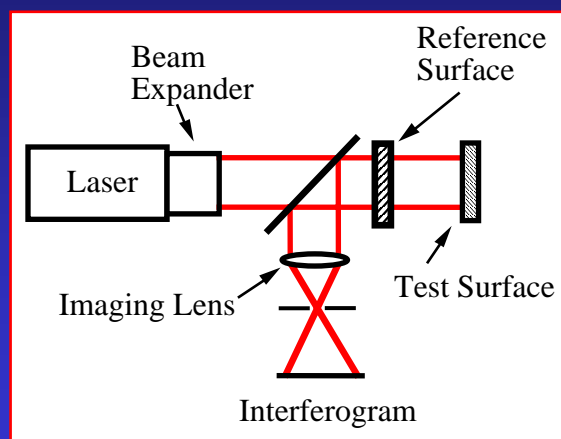
Twyman-Green Interferometer (Spherical Surfaces)



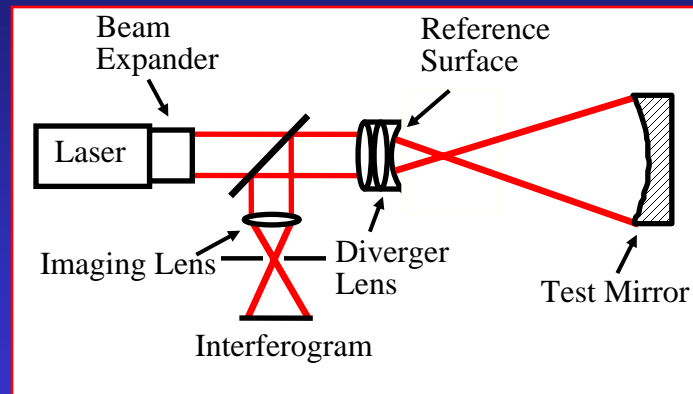
Typical Interferogram



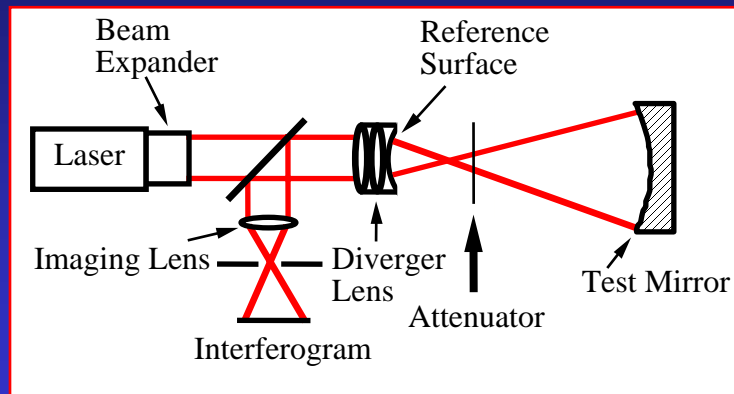
Fizeau Interferometer-Laser Source (Flat Surfaces)



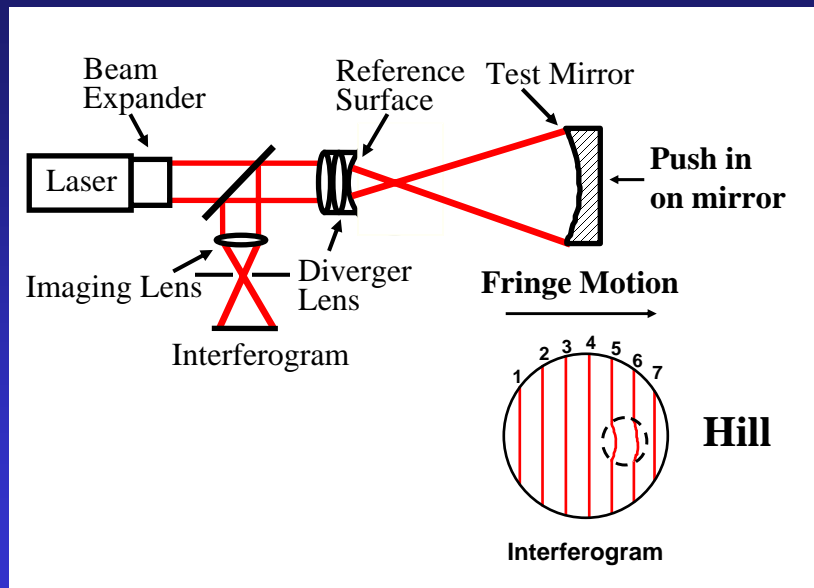
Fizeau Interferometer-Laser Source (Spherical Surfaces)



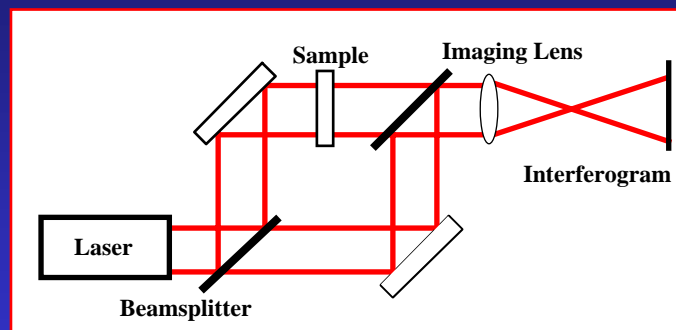
Testing High Reflectivity Surfaces



Hill or Valley?

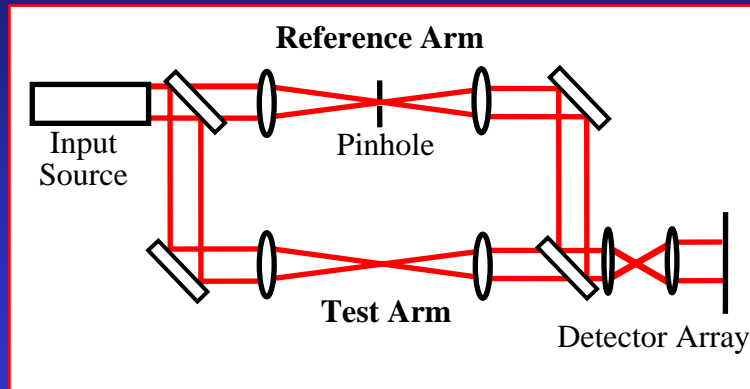


Mach-Zehnder Interferometer

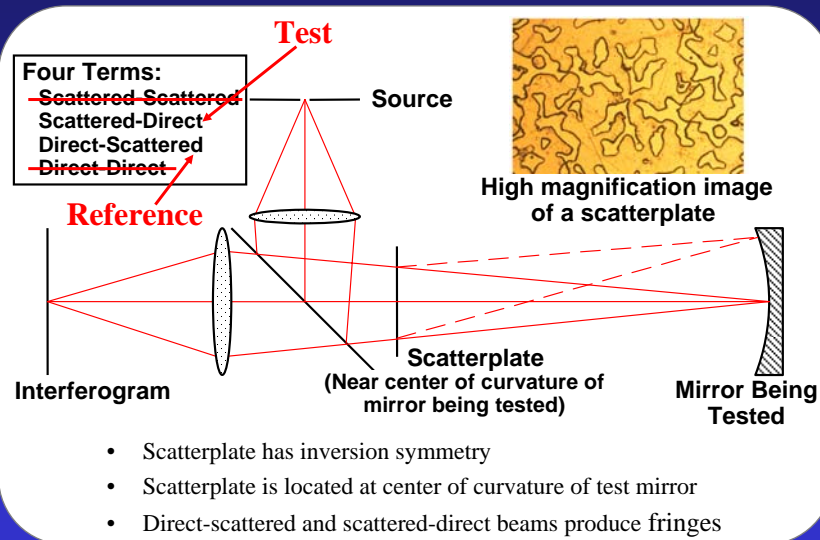


Testing samples in transmission

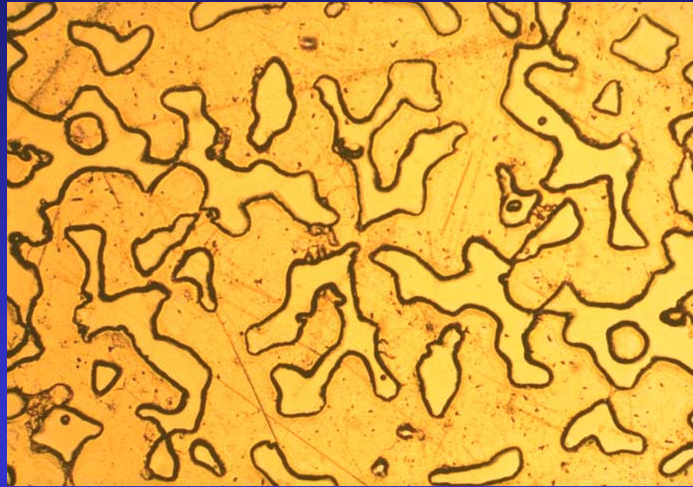
Laser Beam Wavefront Measurement



Scatterplate Interferometer



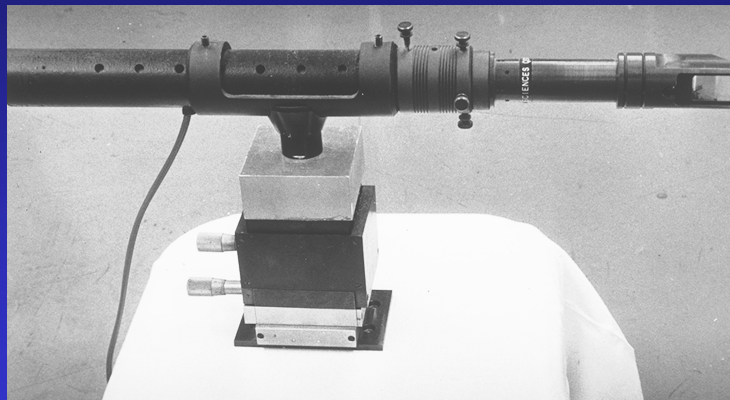
Microscopic Image of Scatterplate



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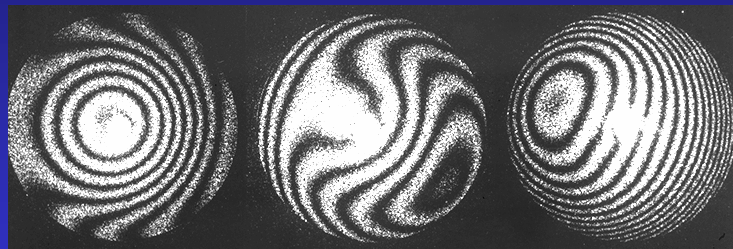
Scatterplate Interferometer



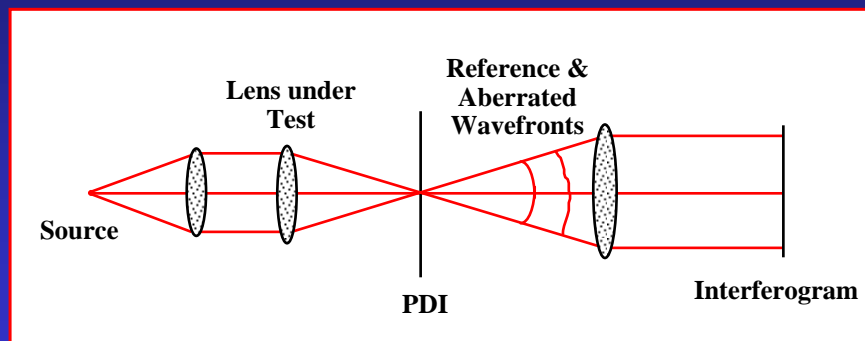
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Scatterplate Interferograms

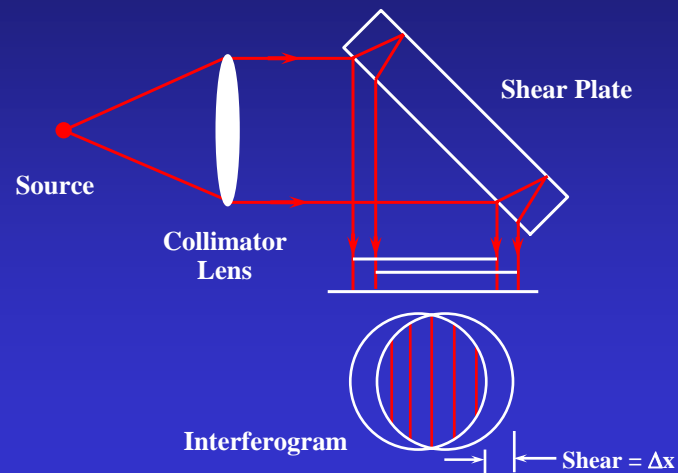


Smartt Point Diffraction Interferometer



Lateral Shear Interferometry

Measures wavefront slope



Lateral Shear Fringes

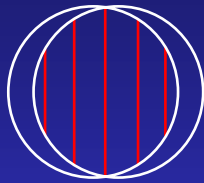
$\Delta W(x, y)$ is wavefront being measured

Bright fringe obtained when
 $\Delta W(x + \Delta x, y) - \Delta W(x, y) = m\lambda$

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

Measures average value of
slope over shear distance

Collimation Measurement

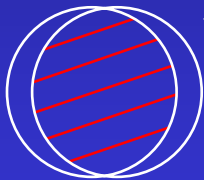


Not collimated

No wedge in shear plate

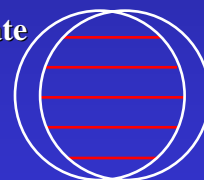


Collimated (one fringe)



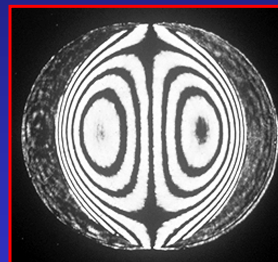
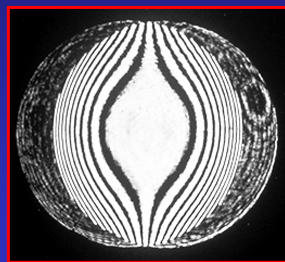
Not collimated

Vertical wedge in shear plate

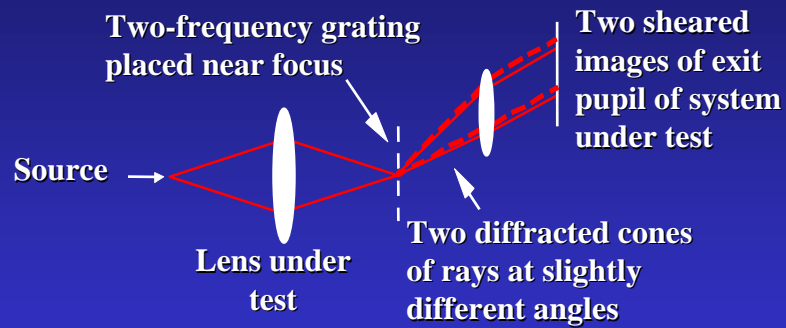


Collimated

Typical Lateral Shear Interferograms

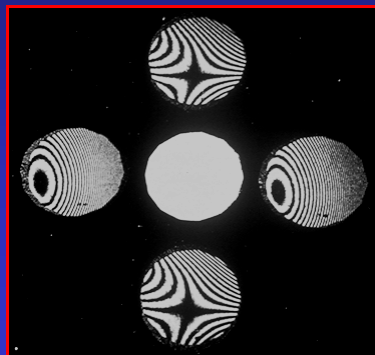


Lateral Shear Interferometer

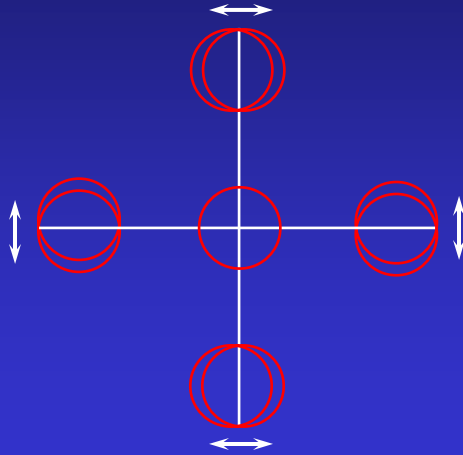


Measures slope of wavefront, not wavefront shape.

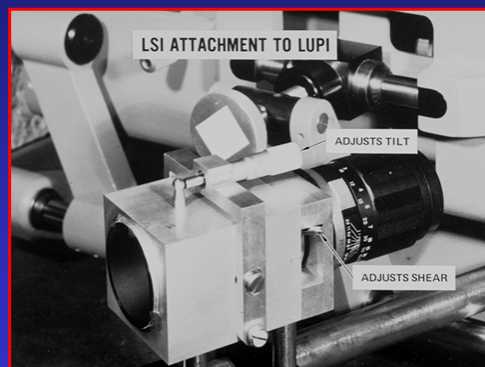
Interferogram Obtained using Grating Lateral Shear Interferometer



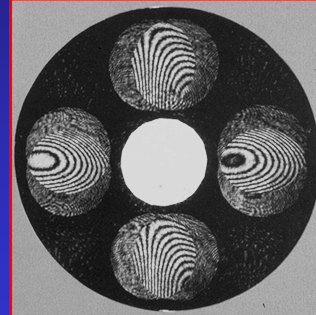
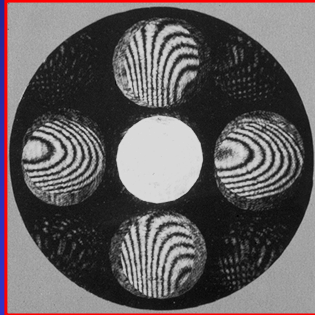
Rotating Grating LSI (Variable Shear)



Rotating Grating LSI

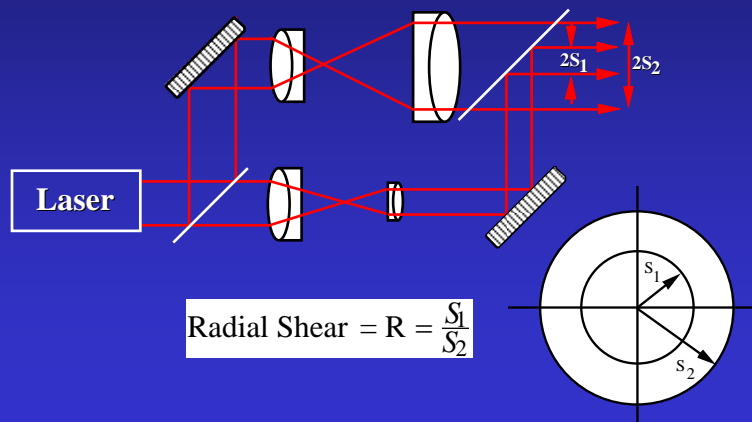


Shearing Interferograms (Different Shear)



Radial Shear Interferometry

Wavefront is interfered with expanded version of itself



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

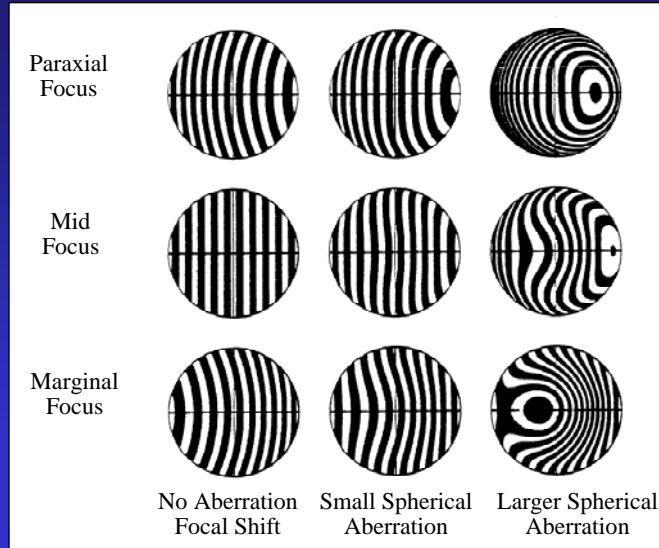
$$\Delta W(\rho, \theta) - \Delta W(R\rho, \theta) = W_{020}\rho^2(1 - R^2) + W_{040}\rho^4(1 - R^4) + W_{131}\rho^3(1 - R^3)\cos \theta + W_{222}\rho^2(1 - R^2)\cos^2 \theta$$

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

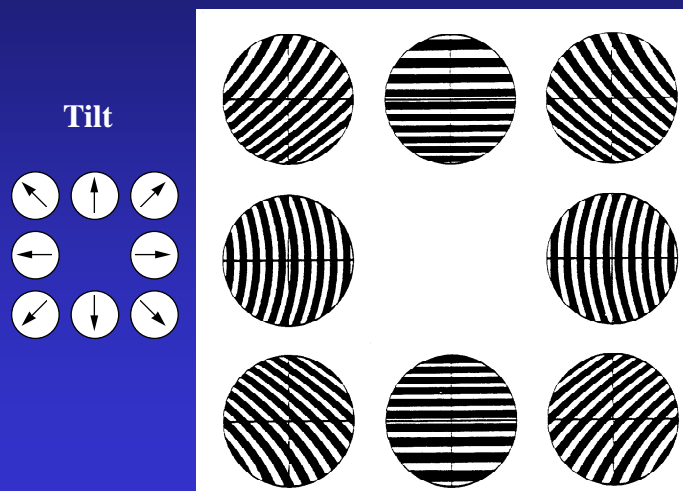
Radial Shear Interferogram

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

Interferograms, Spherical Aberration

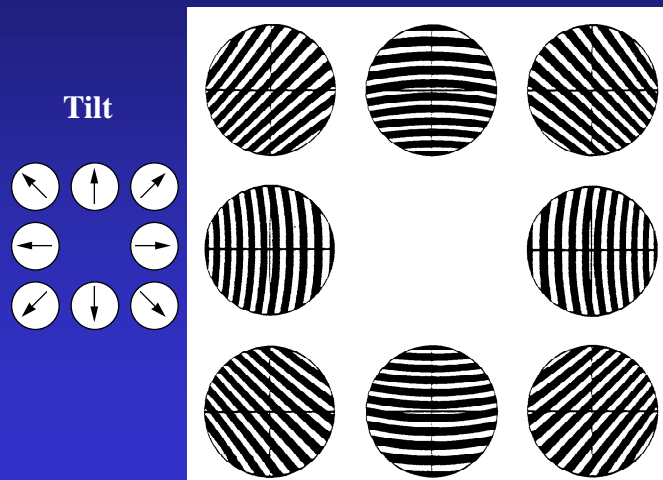


Interferograms Small Astigmatism, Sagittal Focus



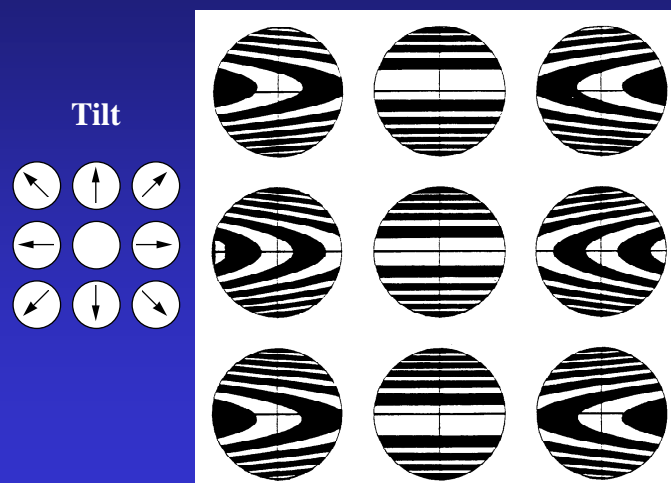
Interferograms

Small Astigmatism, Medial Focus

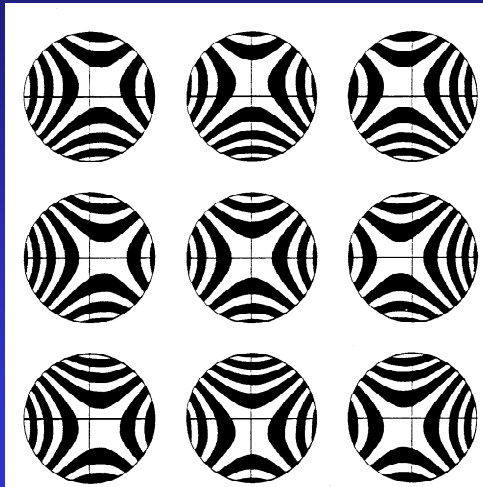
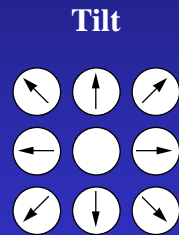


Interferograms, Large Astigmatism,

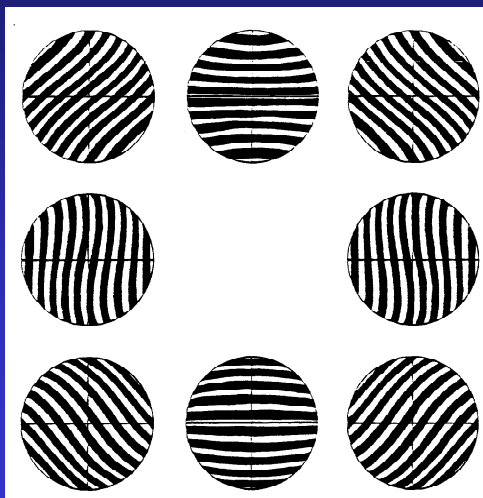
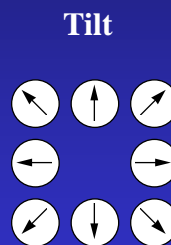
Sagittal Focus, Small Tilt



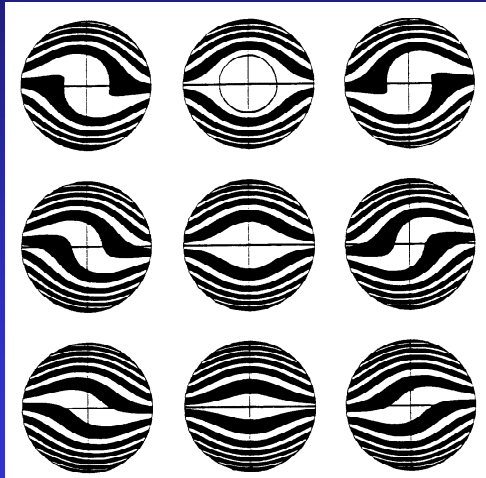
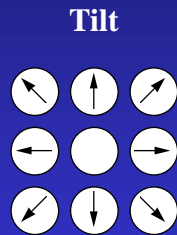
Interferograms, Large Astigmatism, Medial Focus, Small Tilt



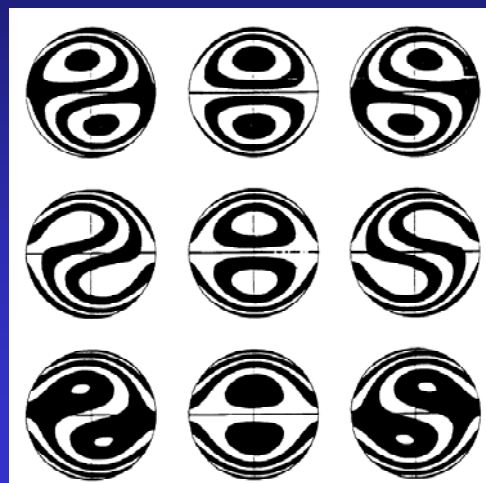
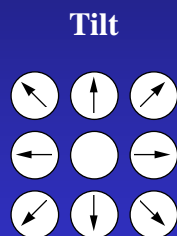
Interferograms Small Coma, Large Tilt



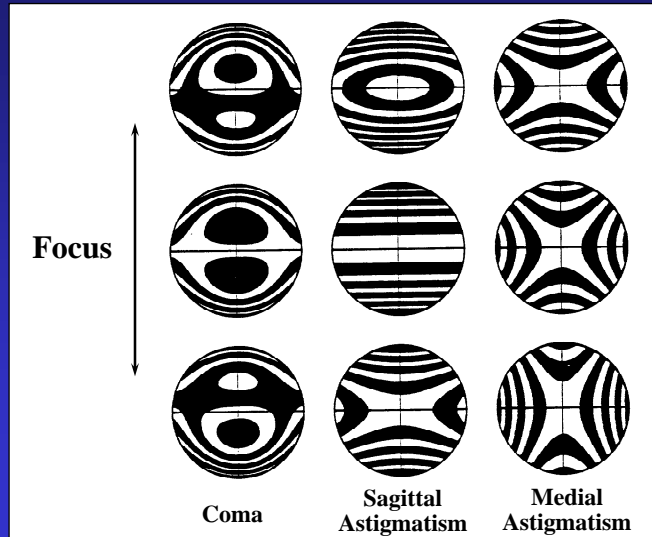
Interferograms Large Coma, Small Tilt



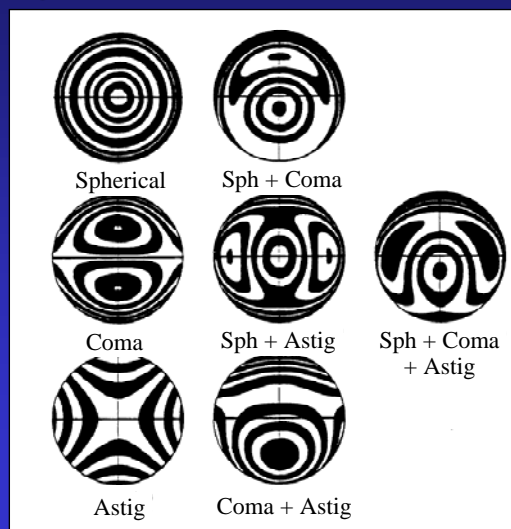
Interferograms Large Coma, Large Tilt



Interferograms Small Focal Shift



Interferograms Combined Aberrations



All wavefronts have 1λ rms departure from best-fitting reference sphere.