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College of Optical Sciences

4.0 Basic Interferometry and Optical Testing

Outline

4.1 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

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

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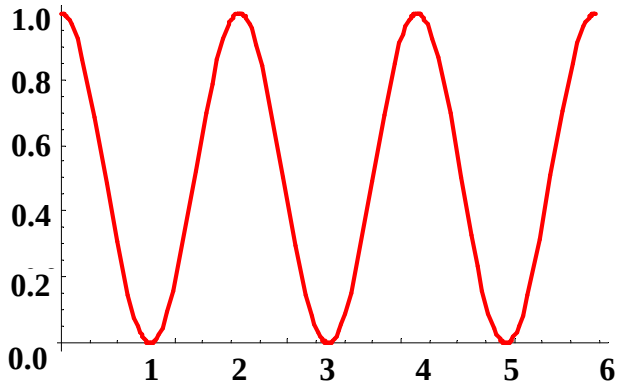
Sinusoidal Interference Fringes



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

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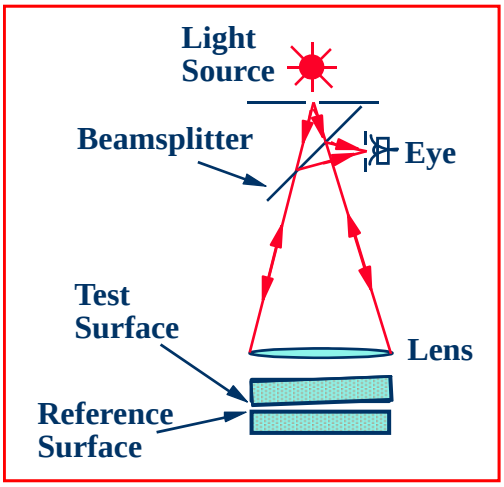
4.2 Pioneer Fizeau Interferometer - 1862



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Typical Interferogram Obtained using Fizeau Interferometer

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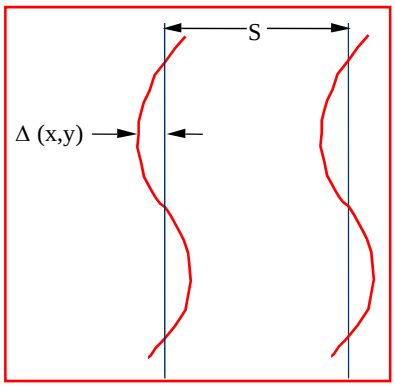
Relationship between Surface Height Error and Fringe Deviation



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

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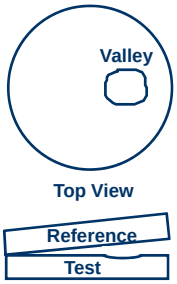
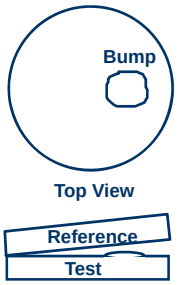
Fizeau Fringes



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

Height error = (λ/2)(Δ/S)



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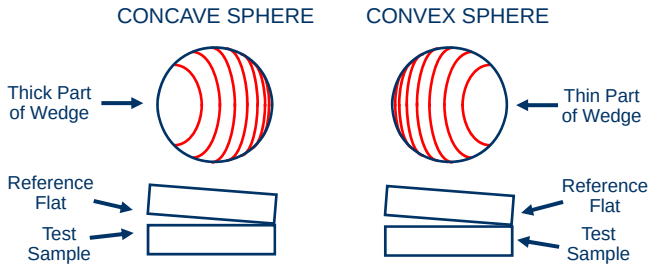
Fizeau Fringes for Concave and Convex Surfaces



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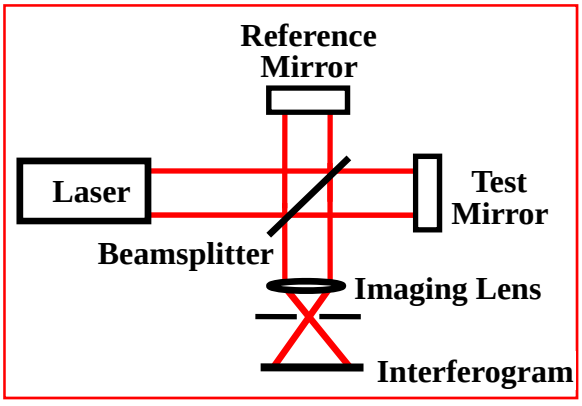
4.3 Twyman-Green Interferometer (Flat Surfaces)

1918



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Use of Rotating Ground Glass to Limit Spatial Coherence of Source

Using a **ground glass diffuser** in an interferometer is useful for destroying spatial coherence. Ground glass is often used to limit the spatial coherence of the source. Coherence is a requirement to obtain interference fringes, but spurious fringes due to stray reflections are a dominant noise source. A laser is focused onto a rotating ground glass diffuser to decrease the spatial coherence and render stray reflections incoherent with the test and reference beams. A stationary diffuser creates a stationary speckle pattern, so the ground glass must be rotated so the speckle pattern changes much faster than the camera integration cycle. Each scatter site on the ground glass has a random phase. Integrated over time, the phase distribution at each location becomes uniform.

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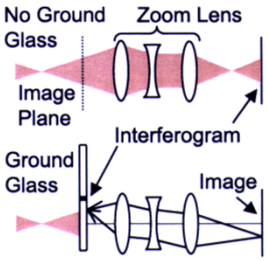
Use of Rotating Ground Glass in Imaging Optics

In order to increase the flexibility of commercial laser-based Fizeau interferometers, a zoom lens can be used to adjust for varying test part sizes. A multi-element zoom lens creates many stray reflections, which cause spurious fringes in the recorded interferogram. Imaging the interferogram onto ground glass before the zoom lens converts the two coherent waves into an incoherent irradiance signal that is imaged to the camera via the zoom lens. Any stray reflections within the zoom lens are incoherent; they add in irradiance and do not cause phase errors. Ground glass scatters light, causing a large amount of loss in the system. A second drawback is that the motor that rotates the ground glass inevitably introduces vibrations, another major noise source in interferometers.



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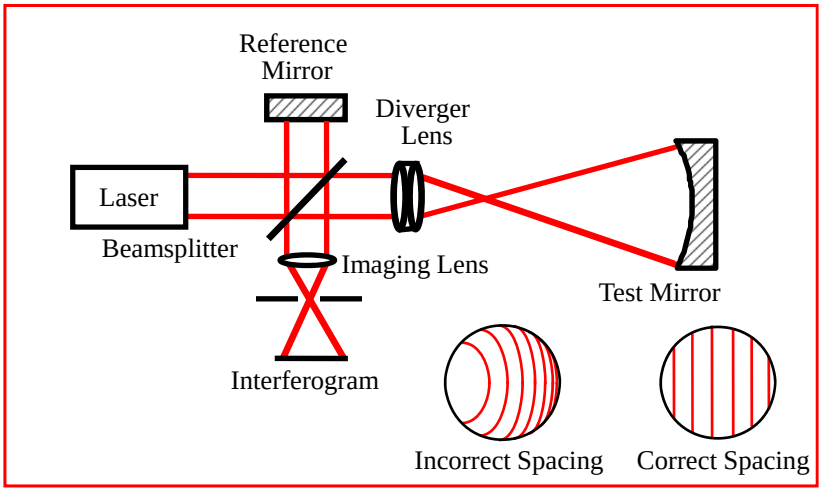
Twyman-Green Interferometer (Spherical Surfaces)



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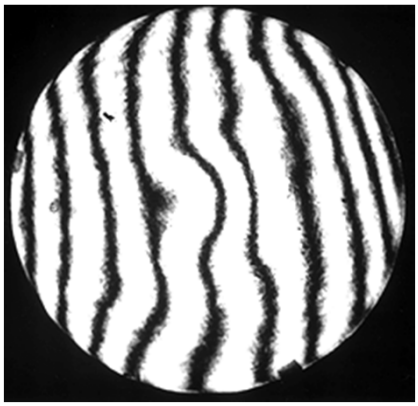
Typical Interferogram



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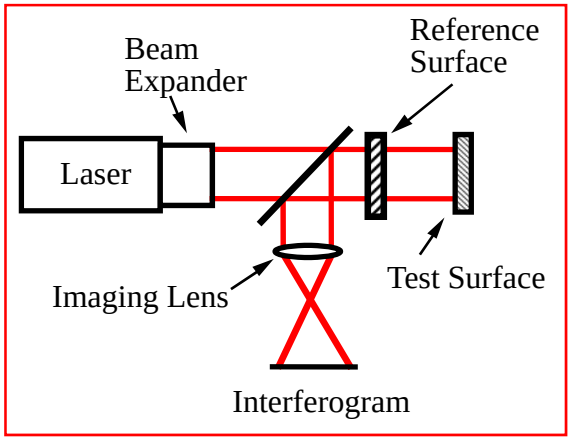
4.4 Fizeau Interferometer-Laser Source (Flat Surfaces)



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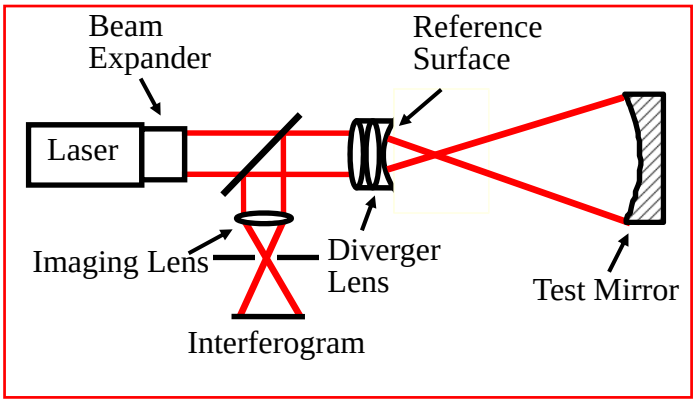
Fizeau Interferometer-Laser Source (Spherical Surfaces)



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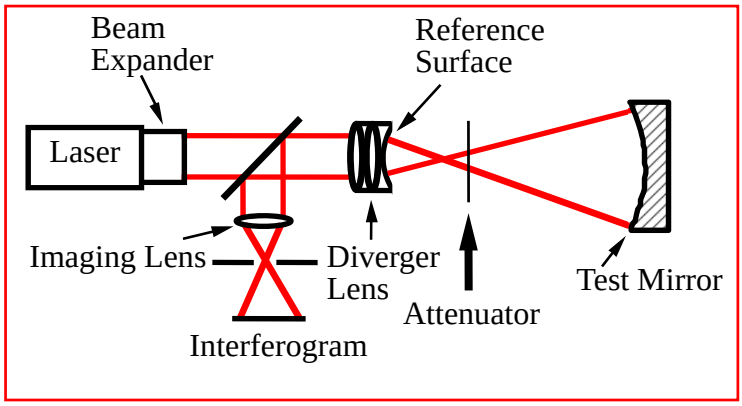
Testing High Reflectivity Surfaces



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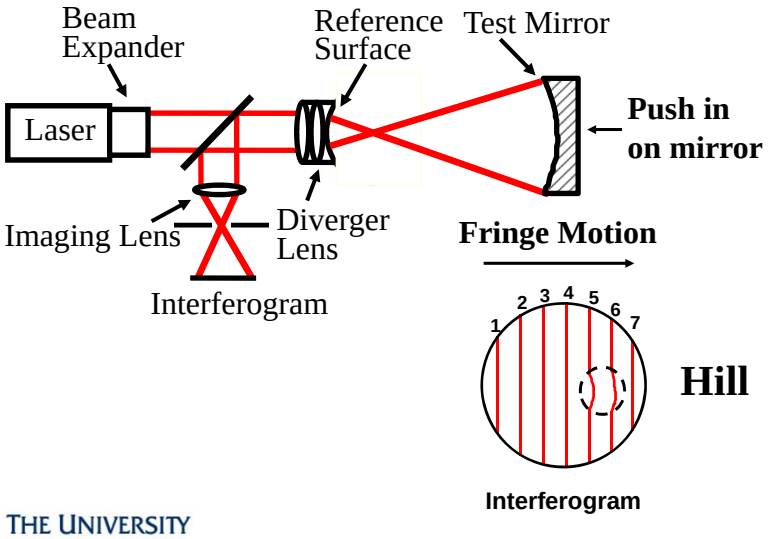
Hill or Valley?



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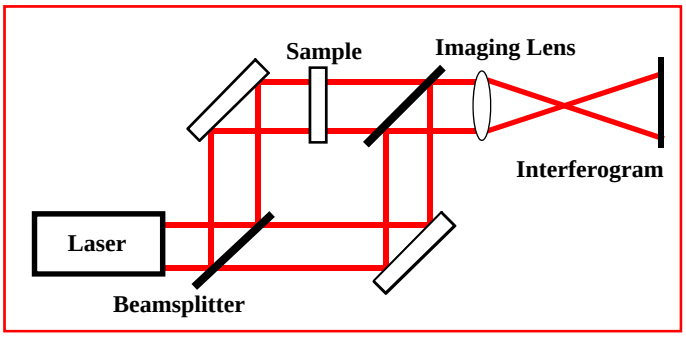
4.5 Mach-Zehnder Interferometer



Testing samples in transmission

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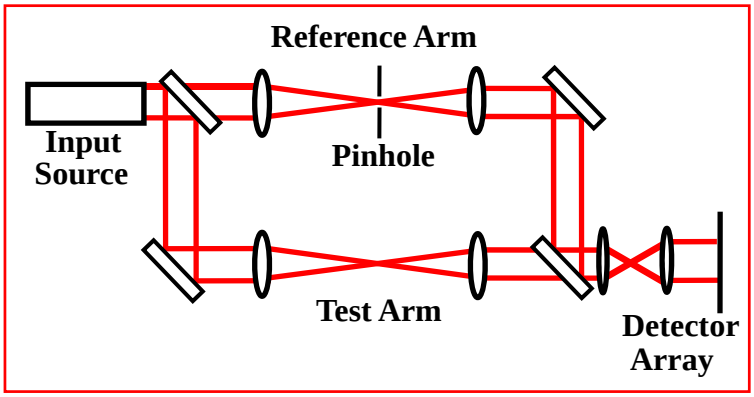
Laser Beam Wavefront Measurement



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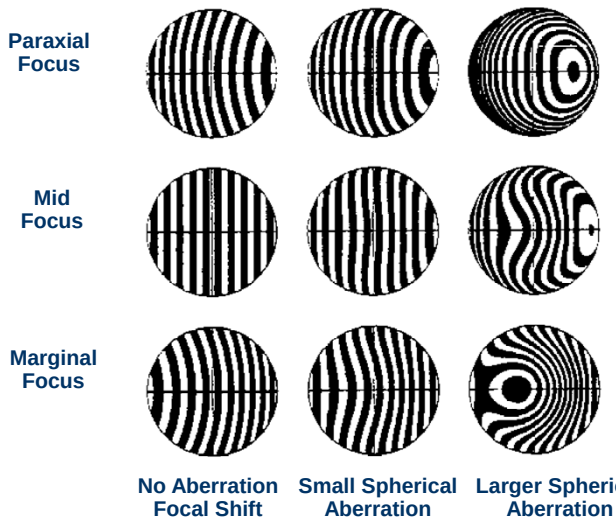
4.6 Interferograms, Spherical Aberration



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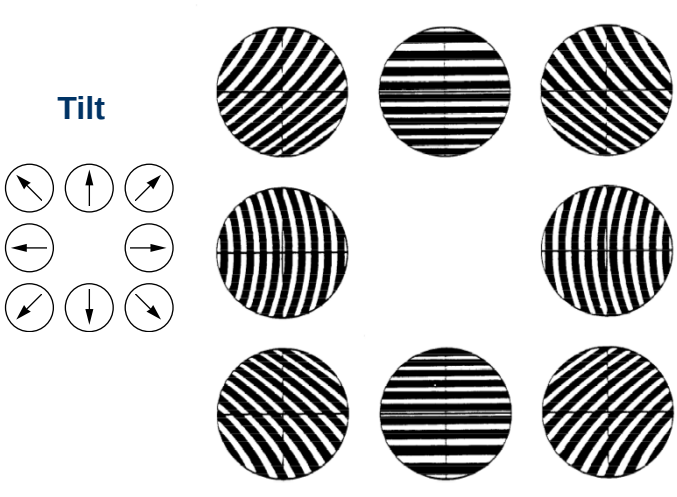
Interferograms
Small Astigmatism, Sagittal Focus



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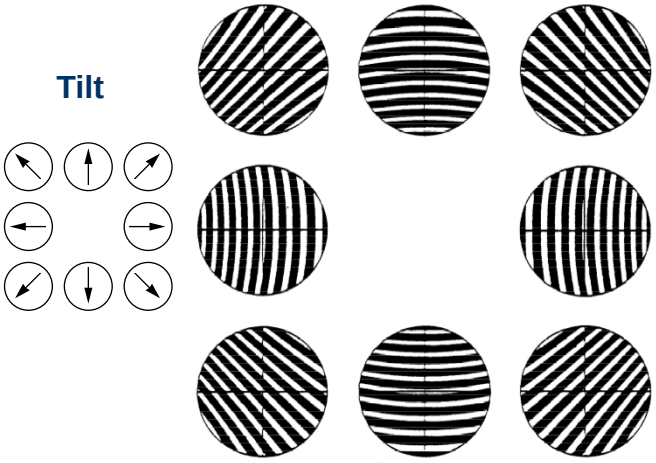
Interferograms
Small Astigmatism, Medial Focus



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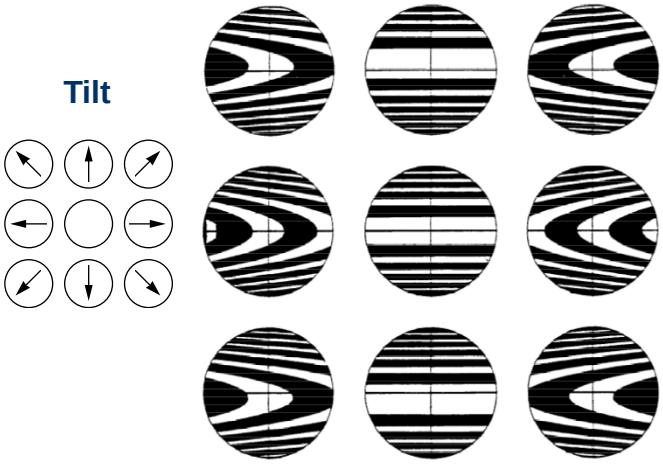
Interferograms, Large Astigmatism, Sagittal Focus, Small Tilt



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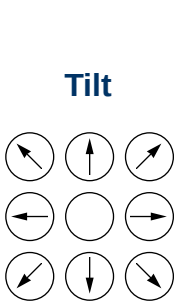
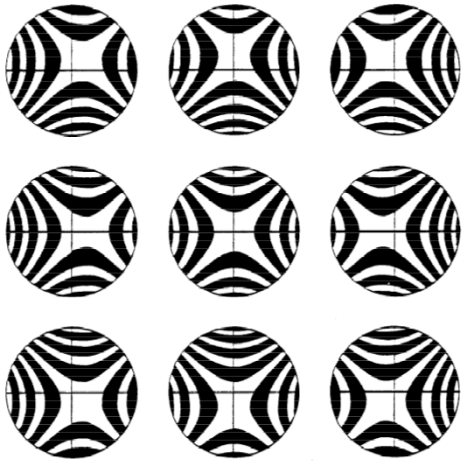
Interferograms, Large Astigmatism, Medial Focus, Small Tilt





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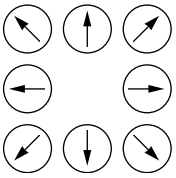
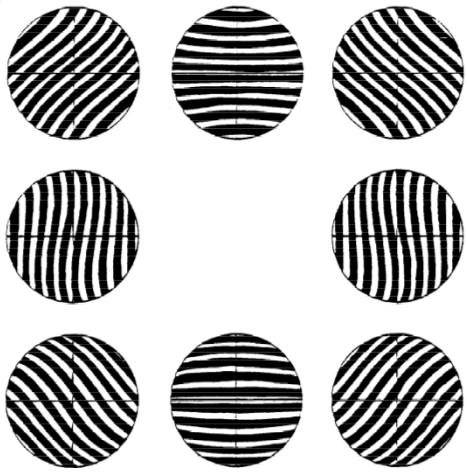
Interferograms Small Coma, Large Tilt





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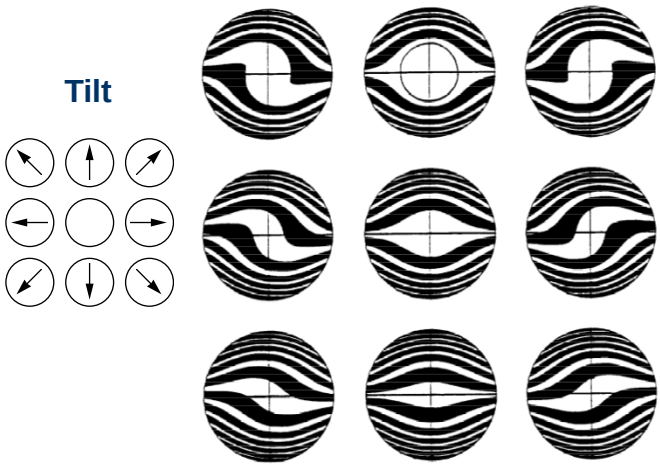
Interferograms
Large Coma, Small Tilt



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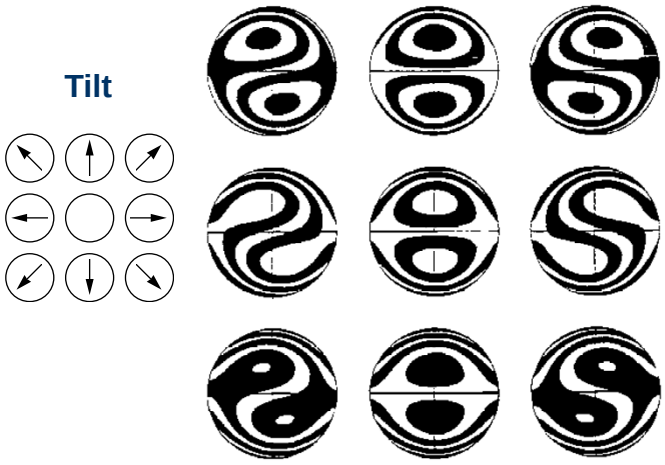
Interferograms
Large Coma, Large Tilt



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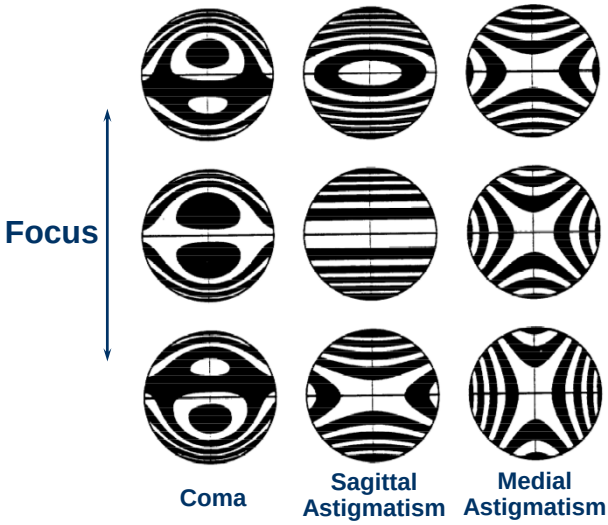
Interferograms - Small Focal Shift



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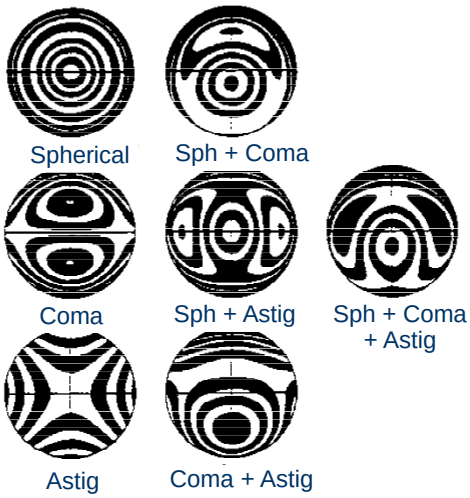
Interferograms - Combined Aberrations



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

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