8.2.15) Lateral Shear Test

In a lateral shear interferometer the wavefront to be tested, ΔW(x,y), is interfered with a shifted version of itself. Let the shift, or shear, between the two interfering wavefronts be Δx in the x direction, then a bright fringe is obtained whenever

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

where m is an integer. The left-hand side of the above equation can be thought of as the average of the wavefront slope over the shear distance times the shear distance. That is, the above equation can be written as

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

It is of interest to compare the above result with the result obtained using the Ronchi test. If the Ronchi ruling has sufficiently high spatial frequency that only two orders overlap at once, the result is a lateral shear interferogram. Let d be the line spacing of the Ronchi ruling; then for small diffraction angles the first order diffraction angle can be approximated as

$$\theta=\frac{\lambda}{d}$$

Thus, the shear, Δx, in normalized units, between the first and zero order is

$$\Delta x=\frac{R\theta}{h}=\frac{R\lambda}{hd}$$

Thus, we have

$$\frac{R}{h}\frac{\partial\Delta W(x,y)}{\partial x}_{\text{Avg. over shear distance}}=md$$

This is the same result as obtained for the Ronchi test, except now the partial derivative is averaged over the shear distance. However, this is not really different from the Ronchi test, since the Ronchi is the limit where the shear is equal to zero, in which case the average partial derivative is equal to the instantaneous partial derivative. Therefore, the equations given above for the shadows for the Ronchi test also describe the fringe positions for the lateral shear interferometer test.

There are many different lateral shear interferometers, of which two are shown in Fig. 8.2.15-1 and Fig. 8.2.15-2. The Murty plane-plate lateral shear interferometer shown in Fig. 8.2.15-1 is useful for working with collimated light that has a temporal coherence length long compared with the plate thickness. The thickness and tilt of the plate control the amount of lateral shear.

The double frequency grating lateral shear interferometer shown in Fig. 8.2.15-2 is similar to the Ronchi ruling except it can give any amount of lateral shear and still have only two diffraction orders overlapping. The grating, which can be made holographically, has two different line spacings. Hence, two different first diffraction orders are produced to give two shear images of the exit pupil of the system under test. A double-frequency-crossed grating can be used to obtain two interferograms having shear in orthogonal directions.

Two crossed gratings having the same spatial frequency can also be put together to form a lateral shear interferometer. As the two gratings are rotated with respect to one another, the first diffraction orders produced by the two gratings move across one another to give two lateral shear interferograms having shear in orthogonal directions. The ability to easily vary the shear is very important in testing wavefronts having much aberration.

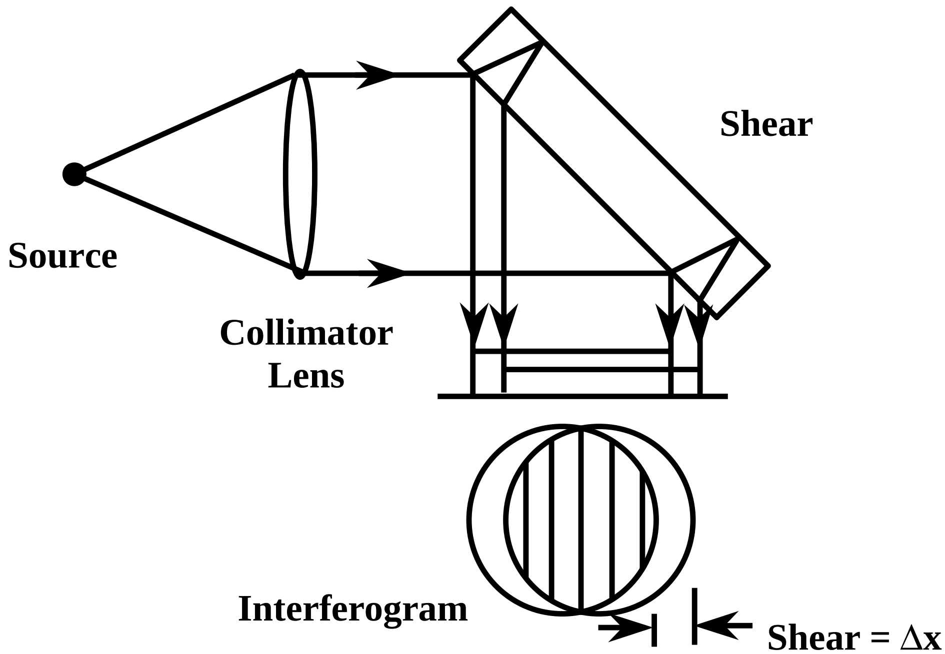


Fig. 8.2.15-1 Murty Plane-plate lateral shear interferometer.

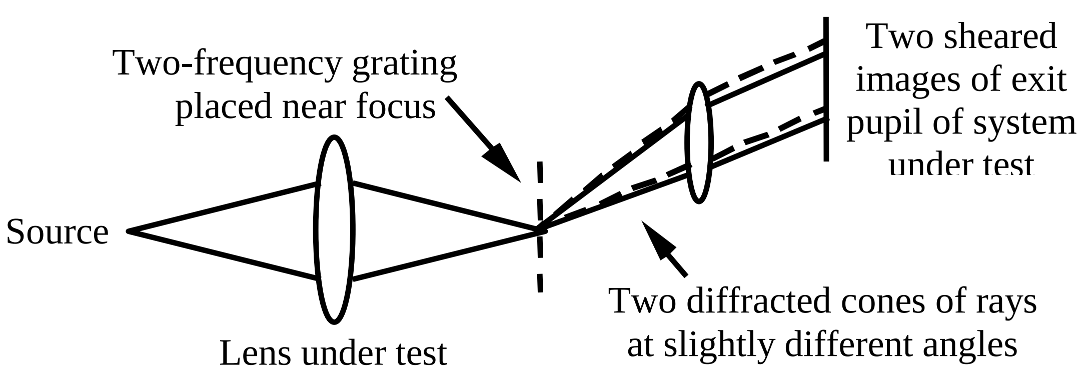
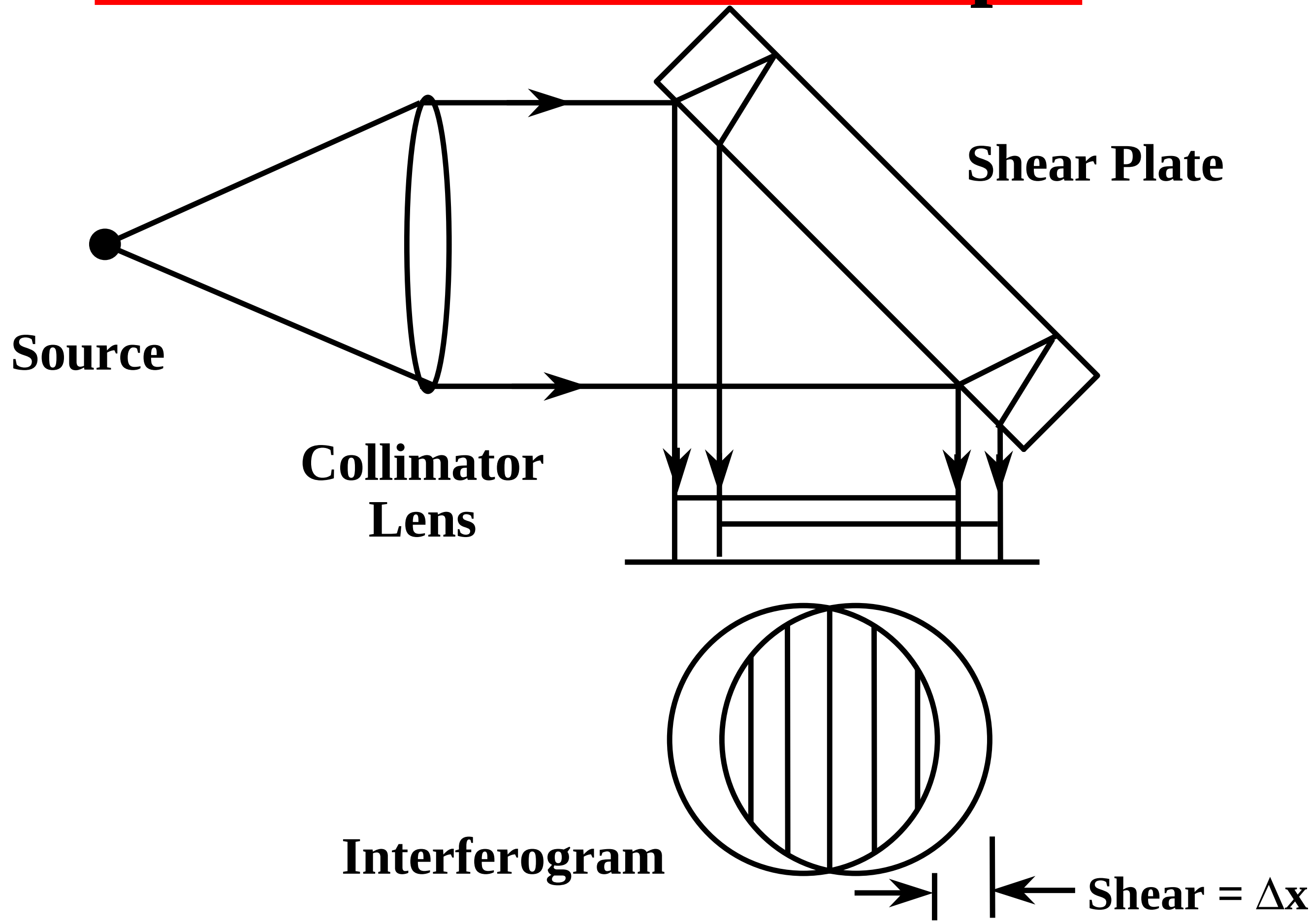


Fig. 8.2.15-2 Double-frequency-grating lateral shear interferometer.

Lateral Shear Interferometry

Measures wavefront slope



Lateral Shear Fringes

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

Bright fringe obtained when

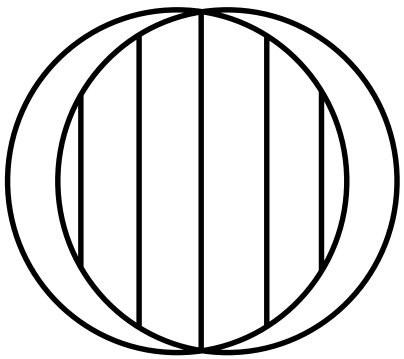
$$\Delta W(x+\Delta x,y)-\Delta W(x,y)=m\lambda$$

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

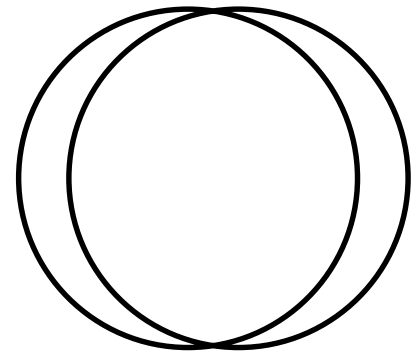
Measures average value of slope over shear distance

Collimation Measurement

No wedge in shear plate

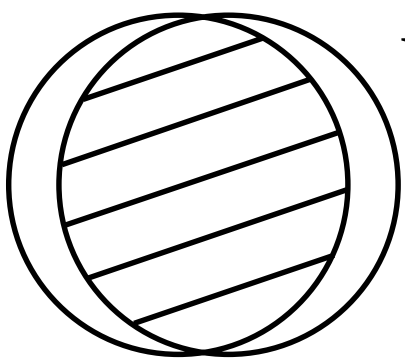


Not collimated

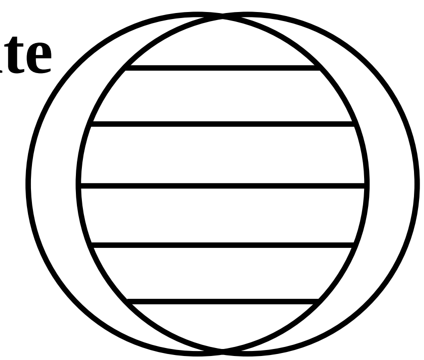


Collimated (one fringe)

Vertical wedge in shear plate

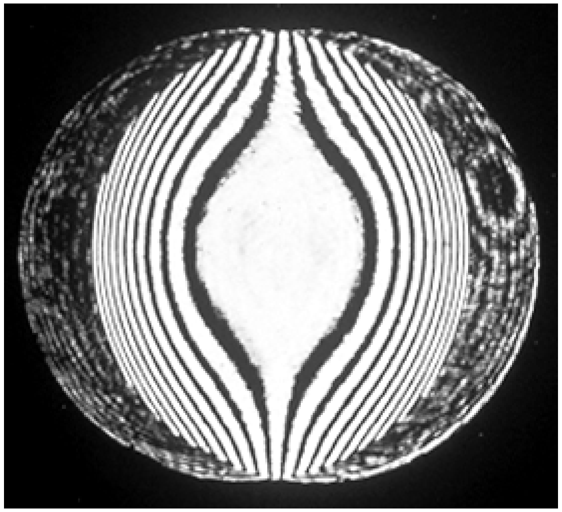


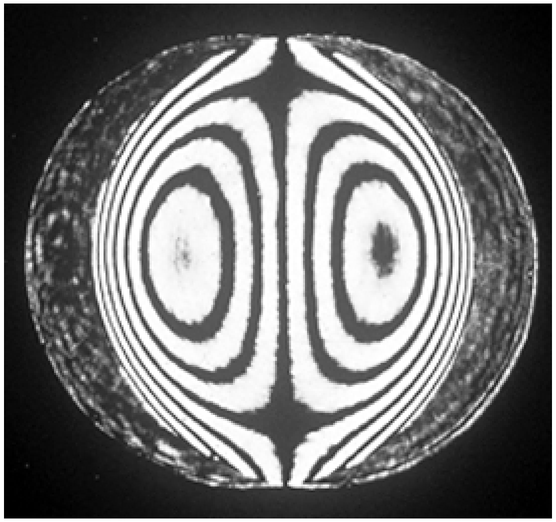
Not collimated



Collimated

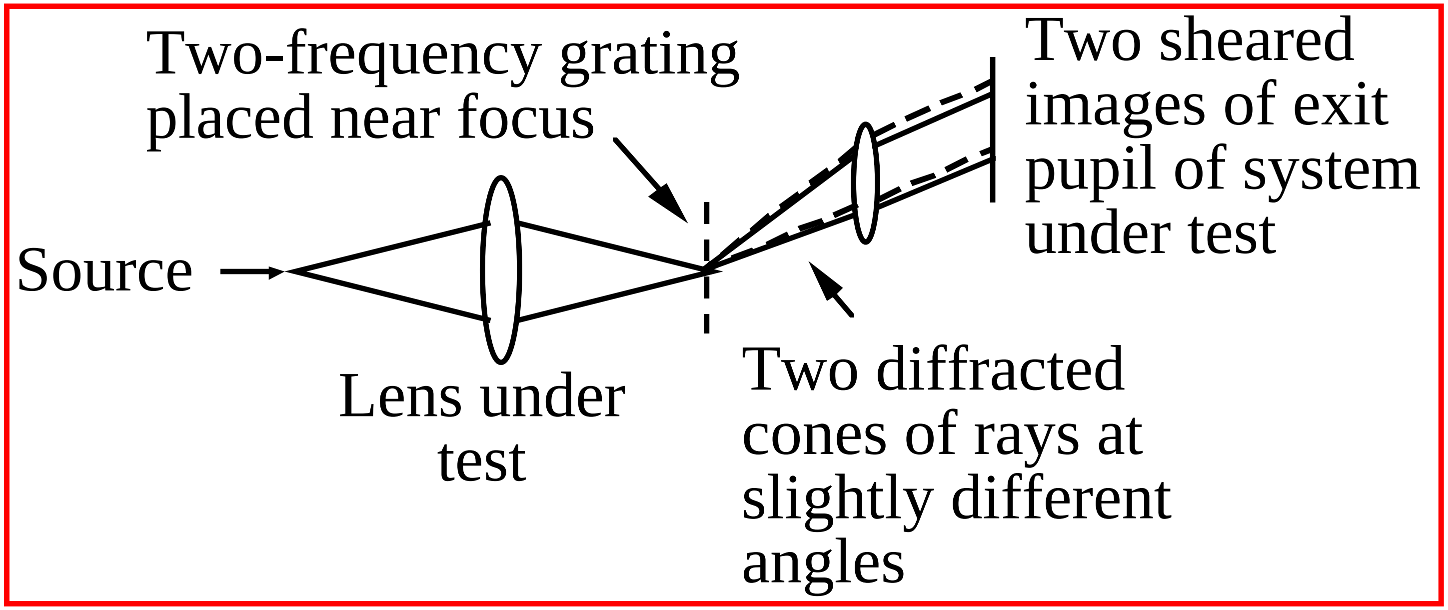
Typical Lateral Shear Interferograms





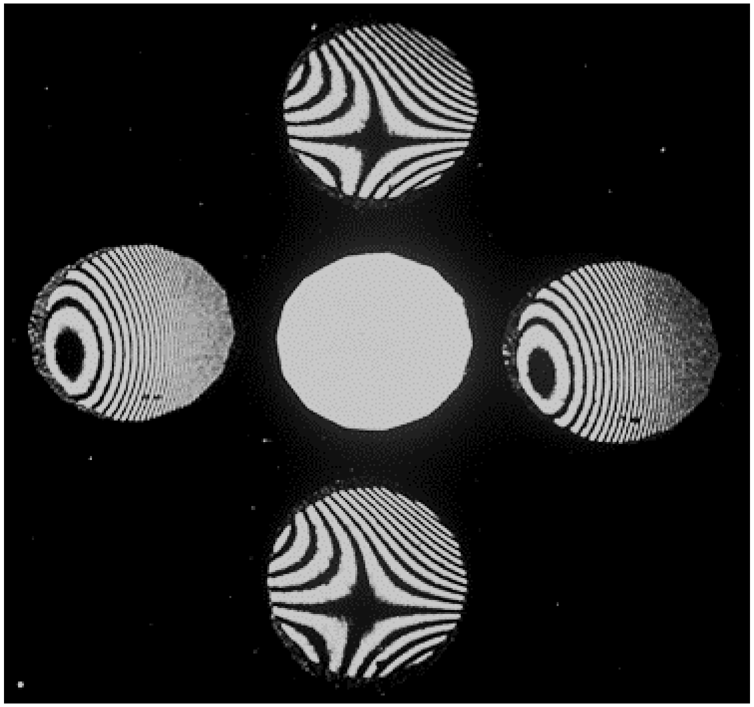
James C. Wyant

Lateral Shear Interferometer

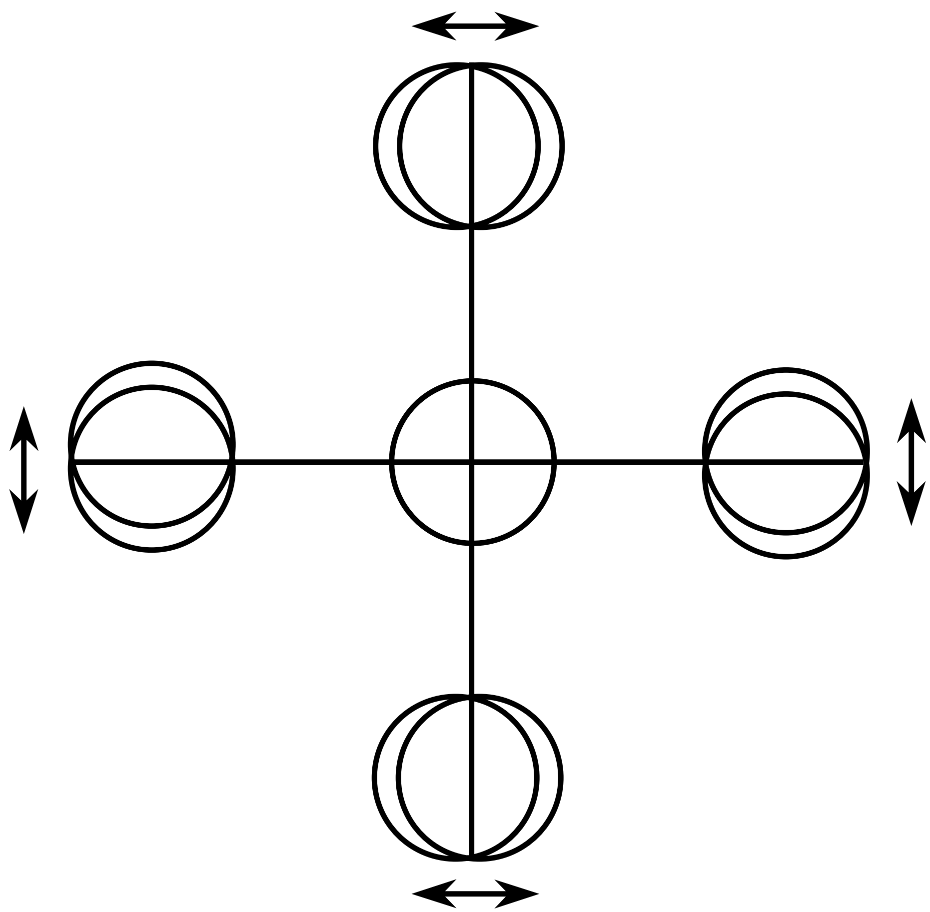


Measures slope of wavefront, not wavefront shape.

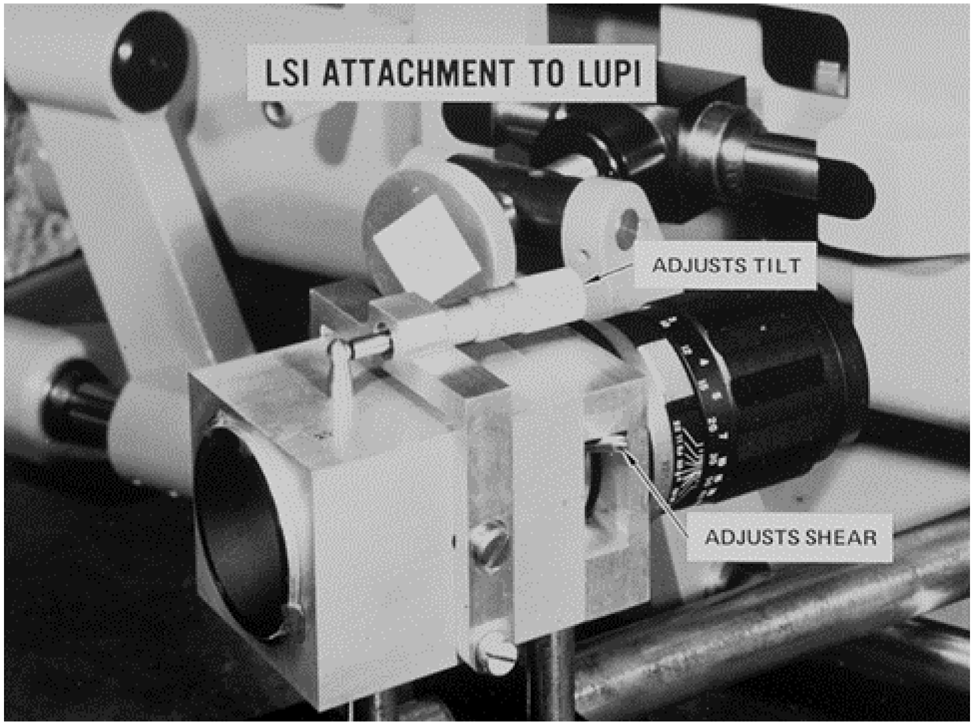
Interferogram Obtained using Grating Lateral Shear Interferometer



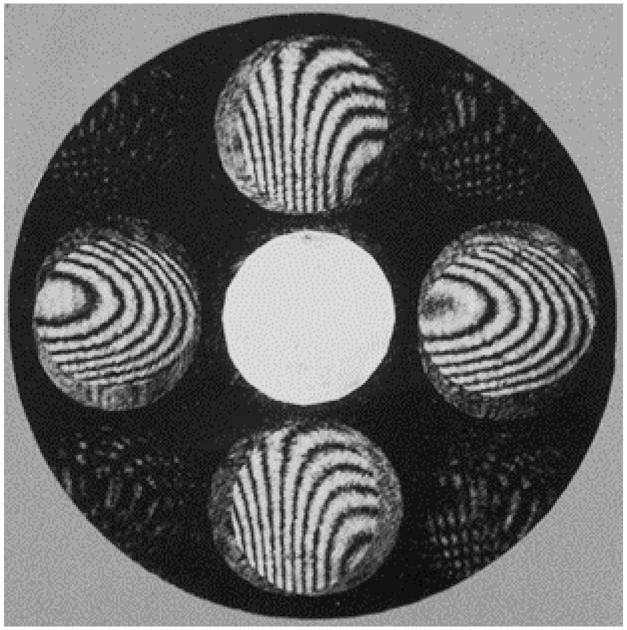
Rotating Grating LSI
(Variable Shear)

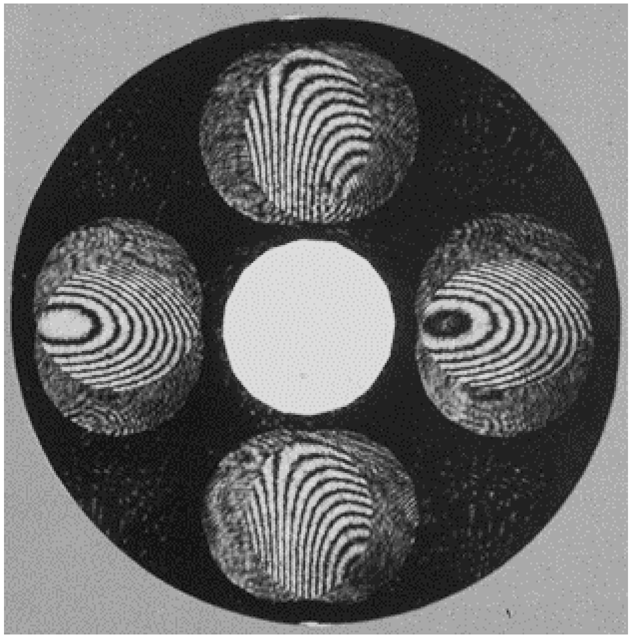


Rotating Grating LSI



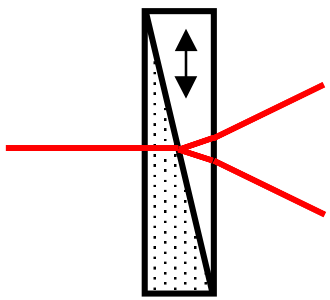
Shearing Interferograms (Different Shear)





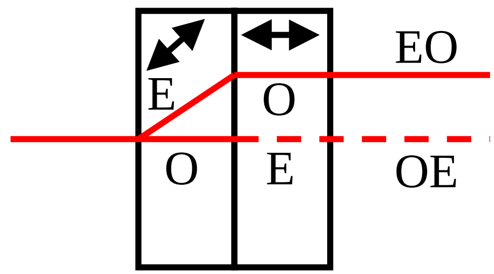
Polarization Interferometers

Angular Shear

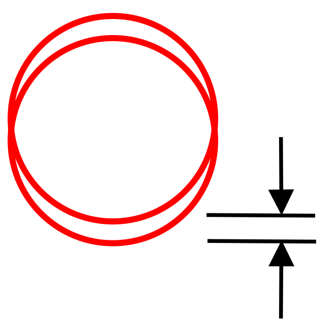


Wollaston Prism

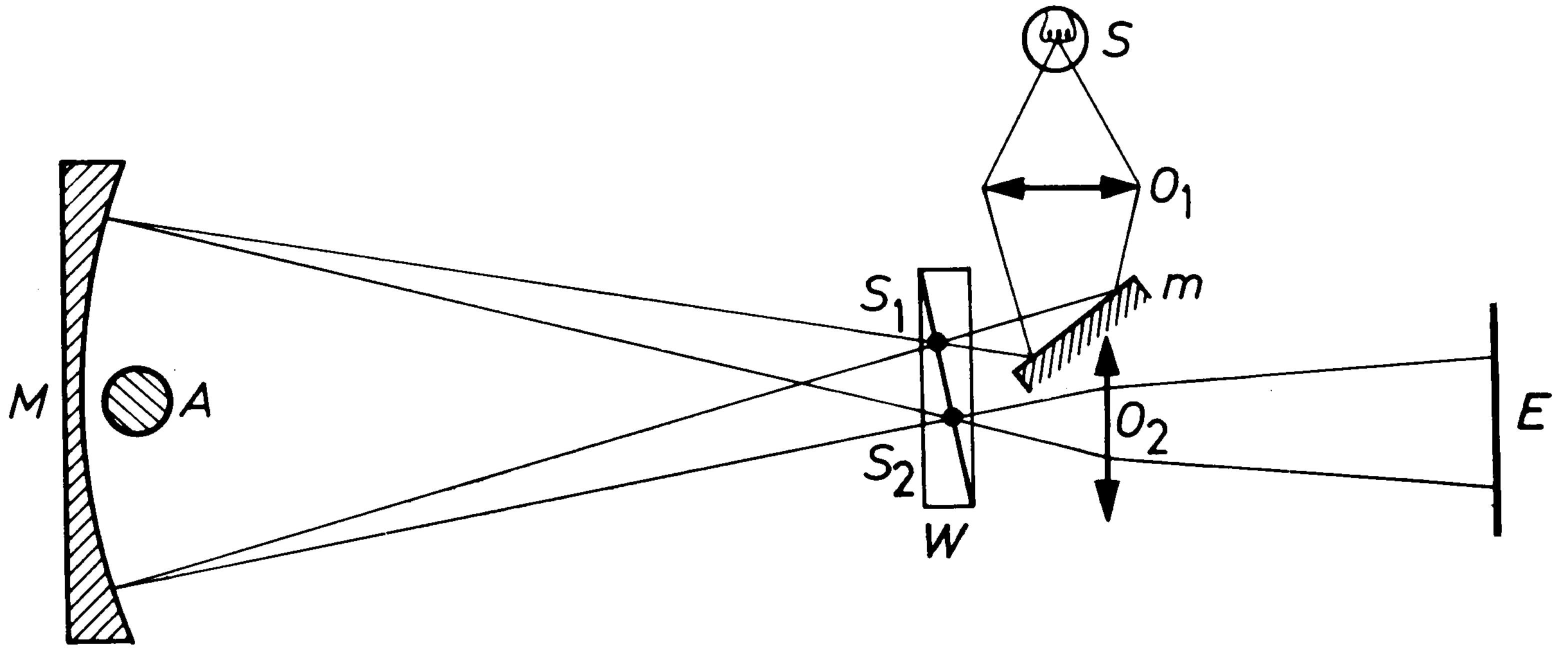
Lateral Shear



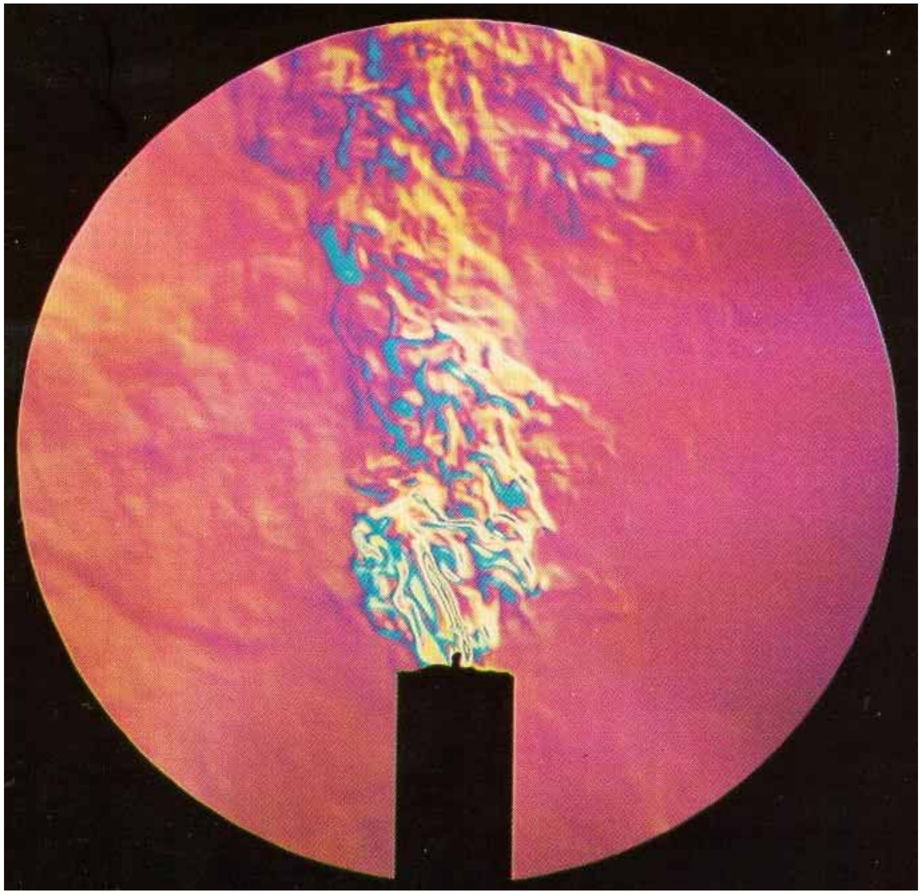
Savart Plate



Polarization Lateral Shear Interferometer



Convection currents in vicinity of candle flame observed with polarization interferometer



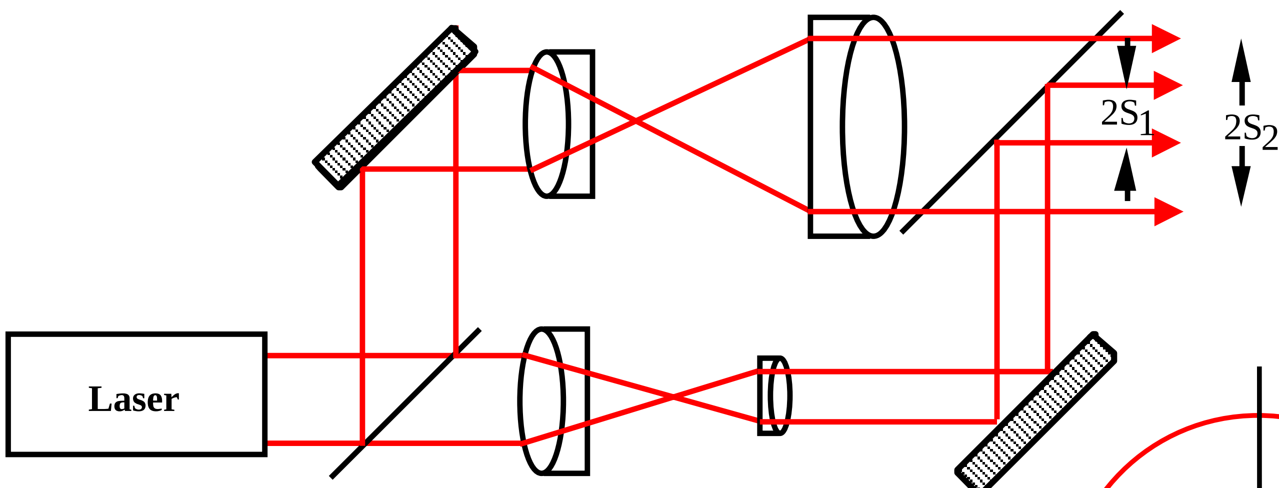
Convection currents in vicinity of candle flame observed with polarization interferometer

Defects of glass plate observed with polarization interferometer

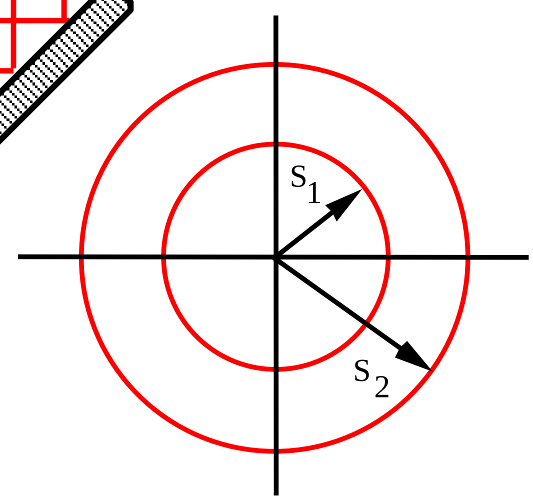
8.2.16) Radial Shear Test

Radial Shear Interferometry

Wavefront is interfered with expanded version of itself



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



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**