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## Wavefront Distortion

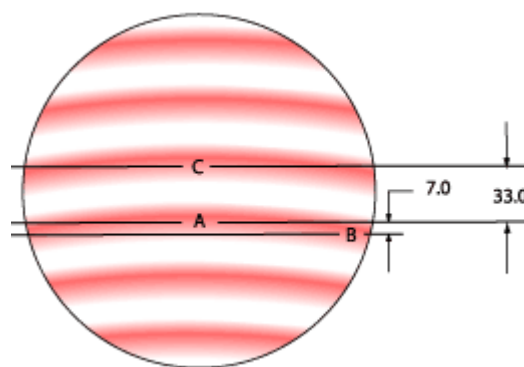
### Interferometer Measurements

Melles Griot measures wavefront distortion with a laser interferometer. The wavefront from a helium neon laser ( $\lambda = 632.8 \text{ nm}$ ) is expanded and then divided into a reference wavefront and a test wavefront by using a partially transmitting reference surface. The reference wavefront is reflected back to the interferometer, and the test wavefront is transmitted through the surfaces to the test element. The reference surface is a known flat or spherical surface whose surface error is on the order of  $\lambda/20$ .

When the test wavefront is reflected back to the interferometer, either from the surface being tested or from another  $\lambda/20$  reference surface, the reference and test wavefronts recombine at the interferometer. Constructive and destructive interference occurs between the two wavefronts. A difference in the optical paths of the two wavefronts is caused by any error present in the test element and any tilt of one wavefront relative to the other. The fringe pattern is projected onto a viewing screen or camera system.

A slight tilt of the test wavefront to the reference wavefront produces a set of fringes whose parallelism and straightness depend on the element under test. The distance between successive fringes (usually measured from dark band to dark band) represents one wavelength difference in the optical path traveled by the two wavefronts. In surface and transmitted wavefront testing, the test wavefront travels through an error in the test piece twice. Therefore, one fringe spacing represents one half wavelength of surface error or transmission error of the test element.

An example of the interferometric fringes produced by a nearly flat optical sample is shown in the figure below.



Interferometric fringes

If the sample were perfectly flat, the fringes would be straight and parallel. In this case, the fringes are curved, indicating a high or low point in the test area. The degree of surface error can be determined by comparing the distance between the center of a fringe at its highest point (line A) and the center of the fringe at its edges (line B) to the distance between the center of two successive fringes (lines A and C). Assuming the light source is a helium neon laser operating at 633 nm, the flatness error is given by

$$\text{Deviation} = \frac{AB}{AC} \left( \frac{\lambda}{2} \right) = \frac{7}{33} \left( \frac{633 \times 10^{-9}}{2} \right) = 0.07 \mu\text{m} = 2.6 \text{ microinch}$$

where AB and AC are the fringe distances in arbitrary units.

A determination of the convexity or concavity of the error in the test element can be made if the zero-order direction of the interference cavity (the space between the reference and test surfaces) is known. The zero-order direction is the direction of the center of tilt between the reference and test wavefronts.

Fringes that curve around the center of tilt (zero-order) are convex, as a result of a high area on the test surface. Conversely, fringes that curve away from the center of tilt (zero-order) are concave, as a result of a low area on the test surface.

By using a known tilt and zero-order direction, the amount and direction (convex or concave) of the error in the test element can be determined from the fringe pattern. Six fringes of tilt are introduced for typical examinations. Melles Griot uses wavefront distortion measurements to characterize achromats, windows, filters, beam-splitters, prisms, and many other optical elements. This testing method is consistent with the way in which these components are normally used.

### Interferogram Interpretation

Melles Griot tests lenses with a noncontact phase-measuring interferometer. The interferometer has a zoom feature to increase resolution of the optic under test. The interferometric cavity length is modulated, and a computerized data analysis program is used to interpret the interferogram. This computerized analysis increases the accuracy and repeatability of each measurement and eliminates subjective operator interpretation.

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