Test Plates and their use in Optical Testing

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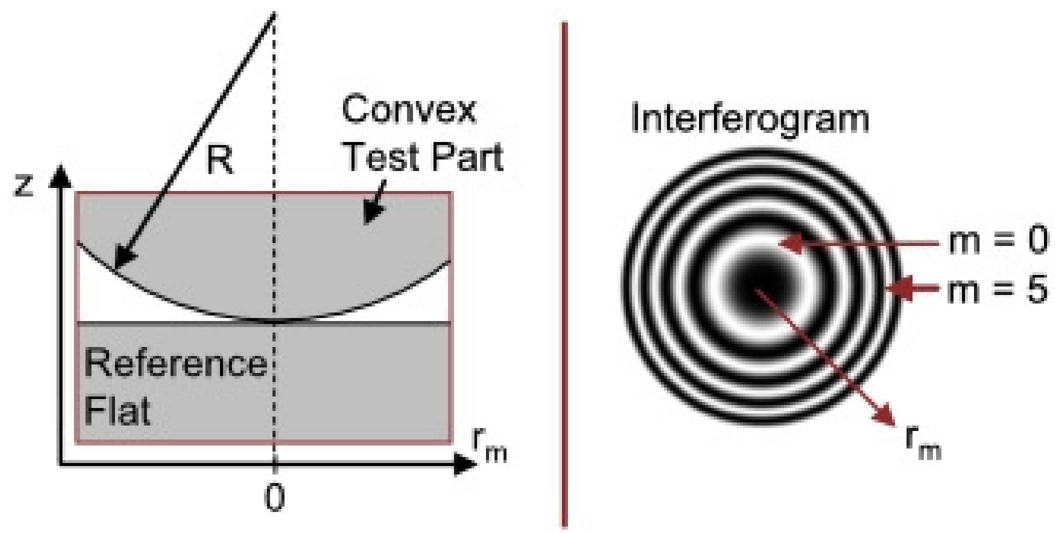
Test Plate Testing

- Test plate testing is the oldest, simplest and most common method used to verify the flatness or sphericity of an optical surface during fabrication.

- It uses the interference effect known as Newton's rings or Fizeau fringes.

Newton's Rings

When a convex test surface is placed on top of a reference flat, circular interference fringes called Newton's rings will result.

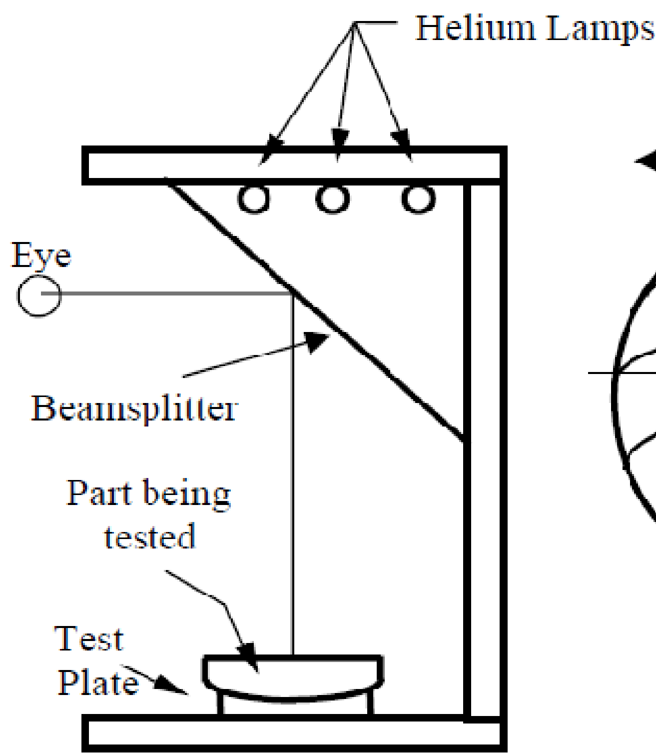


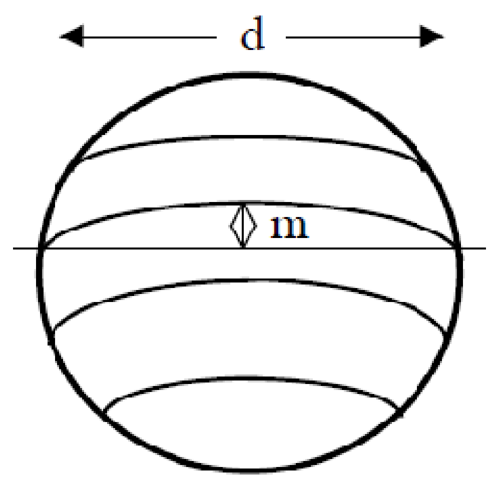
$$R = \frac{{r_m}^2}{\lambda(m + \frac{1}{2})} \quad for\ bright\ fringes$$

$$R = \frac{{r_m}^2}{m\lambda} \quad for\ dark\ fringes$$

Classical Fizeau Interferometer

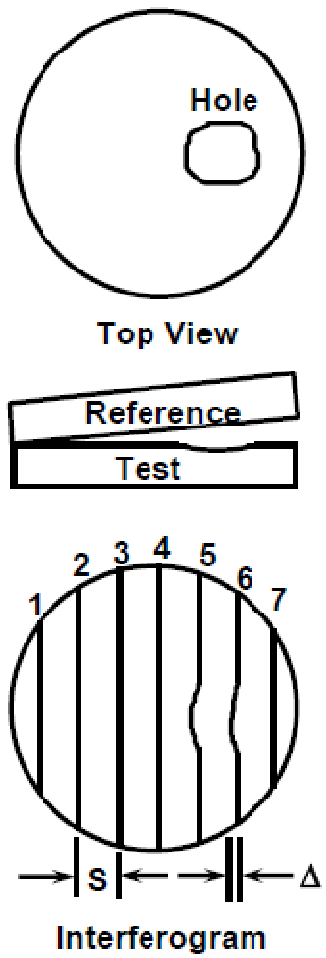
Concave or convex surfaces with smaller radii can be measured by placing them on top of a spherical test plate with approximately the same radius of curvature (but opposite inflection)





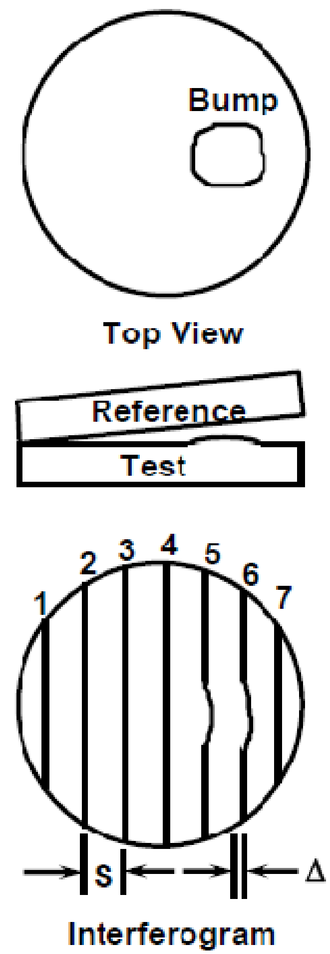
$$\Delta R = \frac{4m\lambda R^2}{d^2}$$

Fizeau Fringes



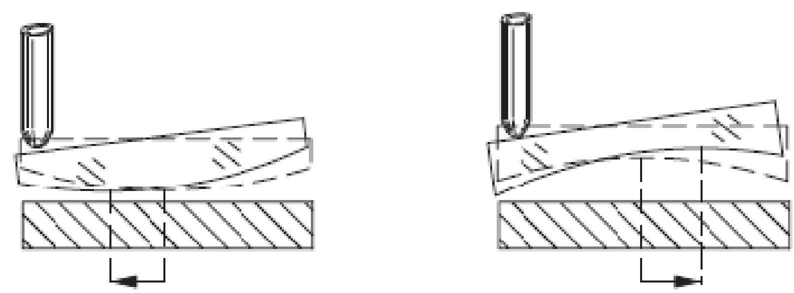
Straight fringes, called Fizeau fringes, are formed in an air wedge between two flat, transparent surfaces.

$$h = \frac{\lambda}{2} \cdot \frac{\Delta}{s}$$

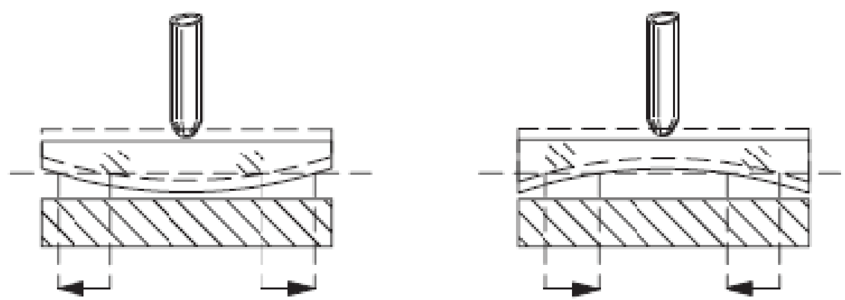


Convex or Concave?

The direction in which curved fringes move when pressure is applied shows whether the test surface is concave or convex.

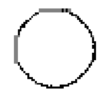
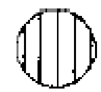
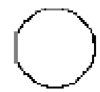
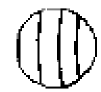
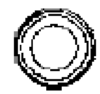
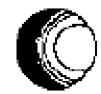
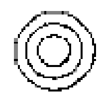
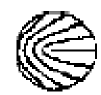
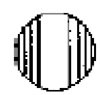
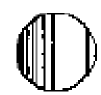
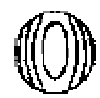
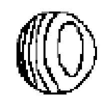
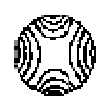
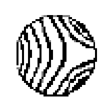
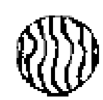


(a) Displacement of the center of rings



(b) Enlargement or contraction of rings

Newton Fringes for different surfaces

		Appearance of the Newton fringes	
S. No.	Surface type	Without tilt	With tilt
1	Plane		
2	Almost plane		
3	Spherical		
4	Conical		
5	Cylindrical		
6	Astigmatic (curvatures of same sign)		
7	Astigmatic (curvatures of opposite sign)		
8	Highly irregular		

Light Sources

- Test plates can be used with white light.

- If fringe definition is more important, an extended mono-chromatic source should be used.

- Common monochromatic light sources for test plate testing:

Source	Color	Wavelength [nm]
Sodium D	Bright orange	589.3
Mercury	Dull green	546.1
Helium	Pale orange	587.6

Test Plate Materials

- BK7:
  - Rarely used anymore (soft, high coefficient of expansion).
  - Low cost, excellent optical properties and easy availability.
  - Good for working plates for noncritical applications.
  - Easy to polish, but precise figure is difficult to control.
- Pyrex:
  - Good for general quality optical flats and test plates.
  - Most popular material for standard or working test plates.
  - Commonly available, low expansion material.
  - Optical transparency and homogeneity not very good.
  - Excellent for large plano test plates.

Test Plate Materials

- Fused silica:
  - Generally the best material for optical flats.
  - Very hard, wear-resistant and very low coefficient of expansion.
  - Optical properties depend on the grade.
  - Polishes well and holds a precise figure over a wide temperature range.
  - Expensive.
- Cervit:
  - Low-expansion glass ceramic.
  - Good wear resistance.
  - Undesirable optical properties (yellow coloration and material inhomogeneities).
  - Excellent choice for large reference quality flats.
- Zerodur and ULE:
  - High cost.
  - Large diameters not readily available.

Matching to Vendor Test Plates

- Test plates are very expensive – typically several hundred dollars or more – and take a long time to manufacture.
- The lens designer should strive to match all radii to existing vendor test plates.
- Vendor test plate lists can be found in most lens design software packages.
- Packages often have automatic test plate fitting routines.

Performance and Accuracy

- Most optical shops still depend on test plate testing as the only practical in-process testing method, because of easy availability of the test plate at the machine and the speed with which the test can be performed.
- Accuracy limited to about a ¼ fringe (1/8 wave).
- If no curvature is detected in the fringes, the test is at least 1/10 wave - an interferometer test must be performed to get a more accurate measurement.
- Accuracy can be limited by:
  - Partial fringes that cannot be accounted for with accuracy.
  - Dirt particles trapped between surfaces.
  - Distortions caused by thermal effects.
  - Optical effects caused by viewing the fringes at oblique angles.
  - Distortions caused by material inhomogeneities.
- When the test specification permits a few fringes, these effects can often be ignored.
- Follow accepted test plate testing practice for best accuracy.
- Test plate testing should be restricted to the shop floor, while interferometers should be used for final quality control.

References

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5. OPTI 513R Class Notes.