# Specifying And Measuring Spherical Surface Irregularity©

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This paper will define surface irregularity for spherical surfaces, offer information on measurement methods for testing surface irregularities, and some specification guidelines.

## SURFACE IRREGULARITY FOR SPHERICAL SURFACES

Irregularity is error in surface form relative to an ideal form. For spherical surfaces, irregularity is how much the actual surface deviates from the radius of curvature of an ideal or perfect best fit sphere (BFS), and accordingly may be called asphericity[1]. BFS is chosen at minimum Root Mean Square (RMS) irregularity[2]. Figure 1 shows a 2-D example of the relationship between ideal form and the actual surface.

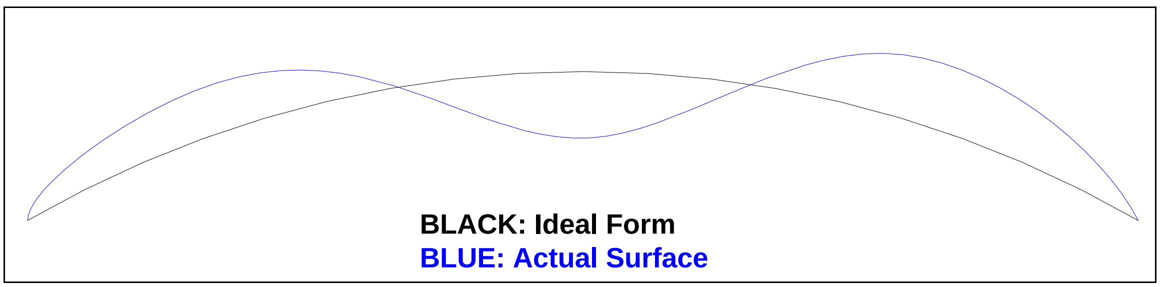


**Figure 1 - Ideal Form and Actual Surface**

Typically, irregularity is represented as form error. Differences between the actual and ideal surface positions are plotted relative to a horizontal line representing an ideal surface[3]. Figure 2 shows the information presented in Figure 1 in this form error convention.

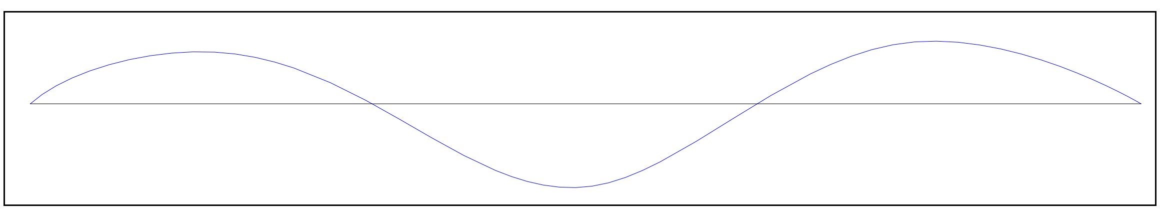

**Figure 2 - Representation of Form Error**

## MEASUREMENT METHODS FOR TESTING SURFACE IRREGULARITIES

### Traditional Method - Test Plate

The traditional tool for form measurement of spherical and flat optical surfaces was the test plate[4]. Bringing the test plate and the surface under test into close contact formed interference fringes known as Newton Rings. The quantity and nature of these fringes indicated the form accuracy of the surface under test relative to the test plate, and what was seen using a test plate was a combined power and irregularity[5]. Radius and irregularity were appraised using the test plate using fringe counting[6].

With test plate based metrology, power was held in proportion to allowable irregularity. Power masks irregularity[7], and to guarantee irregularity detection the power tolerance (~4x specified irregularity[8]) was have been kept smaller than required for the desired optical performance.

**Current Methods – Non-Contact Interferometric Testing**

Non-Contact interferometers like a Fizeau or Twyman-Green use laser light to illuminate a surface under test. Interference between the reflected wavefront and the reference wavefront forms a fringe pattern. This isn't much different than traditional testplating under a monochromatic light source, except the part and reference are not brought into contact. Interferometers are found in most shops, often located directly in the manufacturing area.

Interferometers combined with a 5-axis mount tied to a radius rail or a distance measuring interferometers (DMIs) allow accurate positioning of the part at an approximate null position, and power can be separated from irregularity[9]. During the test, the fringe pattern is analyzed using fringe analysis software, and the errors present can be apportioned based on errors in null position (power) and errors present in the surface under test (irregularity) [10].

Test results are shown in a 3-D representation, with the Z-axis representing the axis of the measuring instrument[11]. Different heights are represented by different colors or, in a one color plot, as different shades. The 2-D information in Figure 3 can be transformed into the 3-D plot Figure 4 shows.

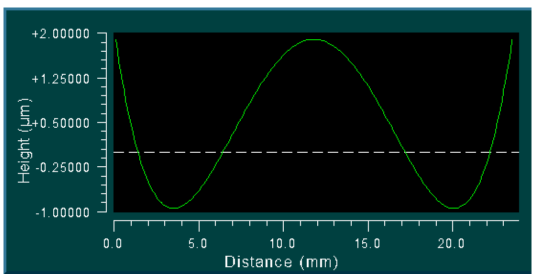


**Figure 3 – 2 Dimensional Form Error Data**

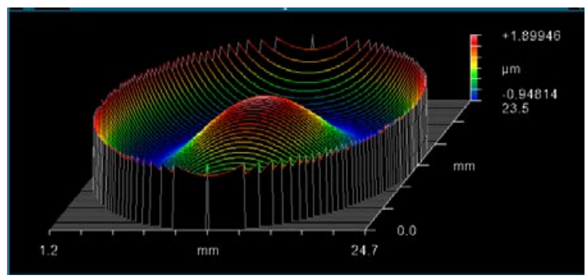


**Figure 4 – 3 Dimensional Form Error Data**

The data generated can be handled using standard statistical functions, typically calculating a Peak-To-Valley (P-V) and RMS value for irregularity[12]. Calculations are preformed over a specific area[13], usually equal to or larger than the clear aperture.

## SPECIFICATION GUIDELINES

Peak-To-Valley error is still the primary quantity specified for irregularity or asphericity. There are practical reasons for this. An optician using test plating can only assess PV error. Additionally, the contributors to PV can be targeted directly during the polishing process.

For many applications PV alone is not enough [14]. Depending on the testing options available for the surface to be made, the items that can be specified can change. If the spherical surface has good coverage on an interferometer and the fringe analysis software supports quantification, virtually any means of specifying asphericity can be used.

## CONCLUSIONS

- Irregularity is error in surface form relative to an ideal form
- Irregularity is graphically expressed as form error relative to a horizontal line (2-D) or plane (3-D) representing an ideal surface
- Irregularity is measured using interferometry, with qualitative fringe interpretation during test plating or electronic analysis of fringe pattern in non-contact interferometry

- Specify irregularity tolerances relative to capabilities of planned testing

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[9] Ibid, Pg 662
[10] Ibid
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