Sample Imaging with a Compact Twyman-Green Interferometer

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Introduction

Sample illumination properties of interferometers utilized for surface and transmitted wavefront testing of precision components and optical assemblies are well known. This paper addresses the sometimes overlooked aspect of proper sample imaging.

The Twyman-Green interferometer

A test set-up of a Twyman-Green interferometer for measurement of a concave surface is shown below. The sample is adjusted axially until its center of curvature coincides with the front focus of the interferometer objective. This position is also referred to as the confocal condition.

The sample is illuminated is this way to cause the light in the test arm to precisely reflect back upon itself. This arrangement illustrates the illumination property of the interferometer.

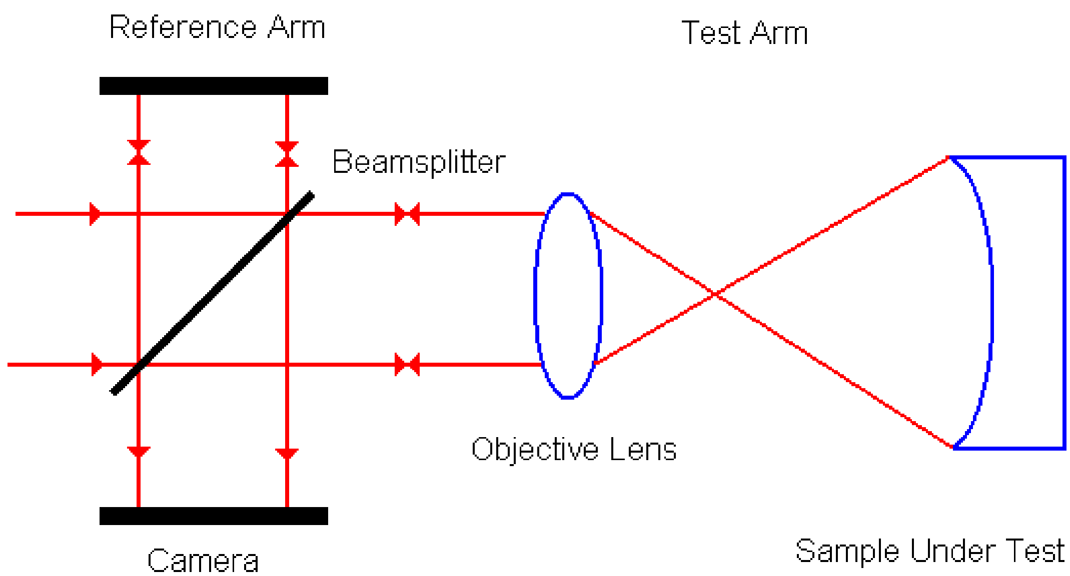

Figure 1
Illumination property of a Twyman-Green interferometer

Sample Imaging

Next, we consider the imaging of the sample. In some instruments, this is accomplished by adjustment of an auxiliary lens in the imaging arm of the interferometer. In other instances, the sample imaging is fixed.

Irrespective of the sample imaging features of a particular interferometer, some samples may not be well imaged. To help understand this aspect of interferometers, we first review the imaging property of a simple thin lens.

Adopting the convention so light travels from left to right, the concave mirror now appears as an object in figure 2. As long as the concave mirror satisfies the confocal condition, a real image is formed. If the mirror were convex, the resulting image would be virtual. That is, the image of a convex mirror would be located to the left of the interferometer objective.

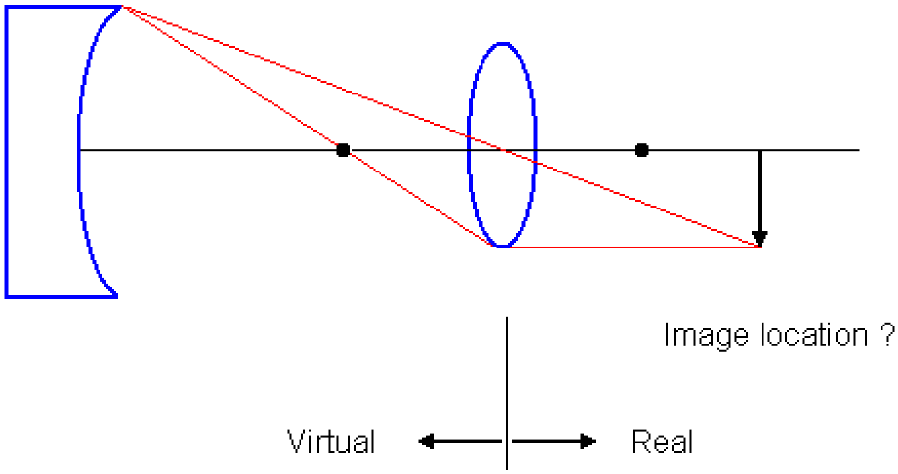

Figure 2
Imaging formation in a Twyman Green interferometer

The illumination (confocal) condition constrains the distance of the sample with respect to the interferometer objective. Treating the interferometer objective as a thin lens, object distance is the sum of the objective focal length (f) plus the radius of curvature (x) of the concave mirror.

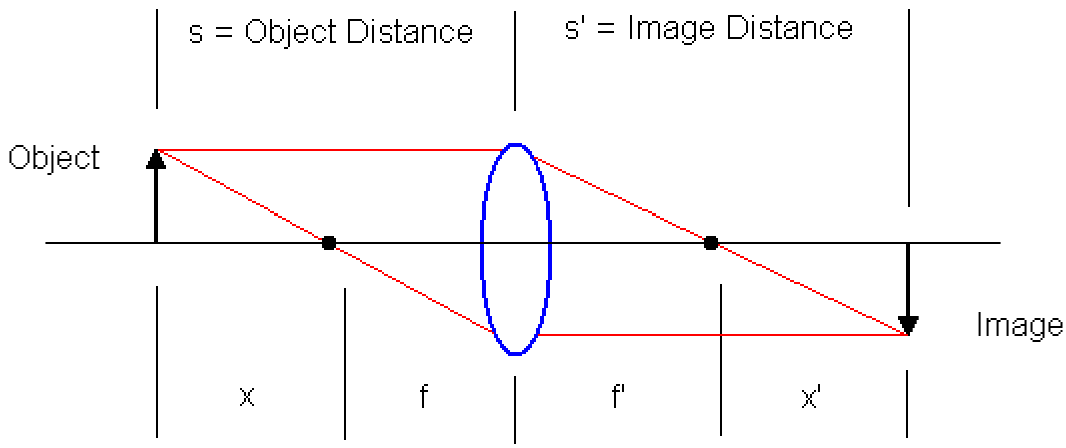

Figure 3
Parameters in determining image location

Newtonian form of imaging equation
By rearranging the Newtonian form of the thin lens equation, we can calculate x' which is the image location relative to the back focus f' of the interferometer. Mindful of sign convention, please note that x is negative (left of f) and x' is positive (right of f'); as illustrated in figure 3.

$$x' = -f^2 / x$$

For f = 100 mm and x = -500 mm (concave), we find x' is +20 mm; to the right of the 100 mm back focus (f') of the interferometer objective. For concave mirrors with radii approaching infinity, x' approaches 0. That is, an object at infinity will have an image located at the back focus (f') of a simple imaging lens.

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Sample Imaging Example
A Fisba Optik μPhase® 2 interferometer with 10 mm diameter collimating lens was used to measure a concave mirror with 1270 mm (50”) radius of curvature. To make full use of the 1,000 x 1,000 pixel sensor, a custom 100 mm focal length f/10 objective was produced.

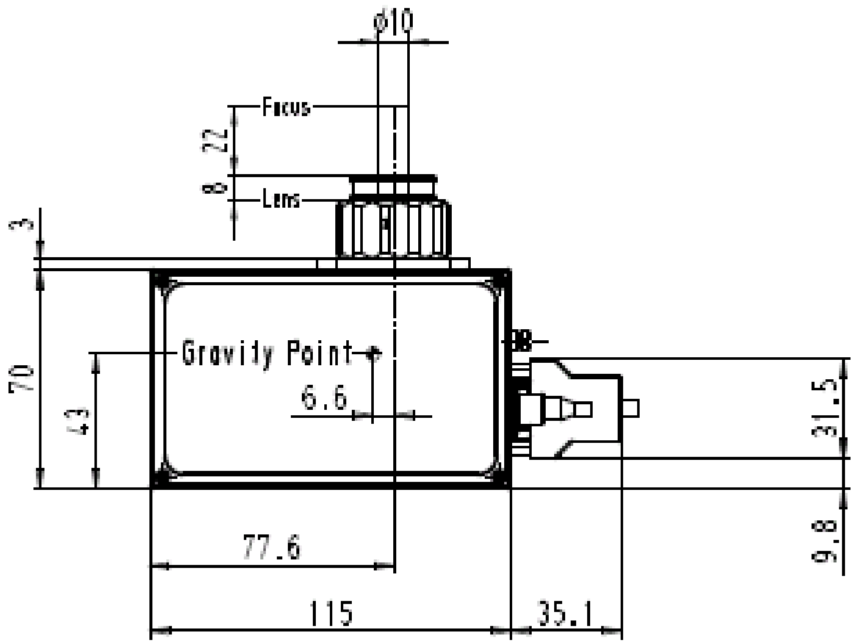
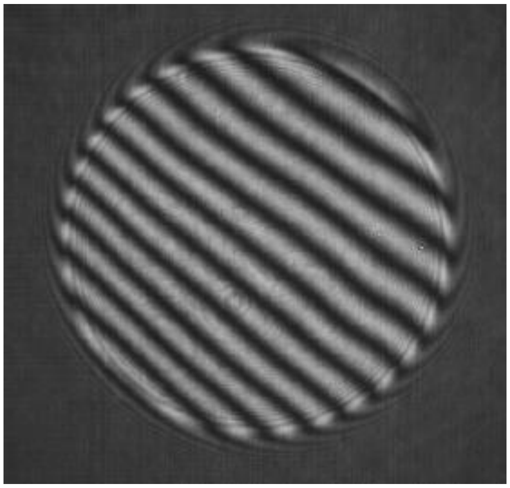
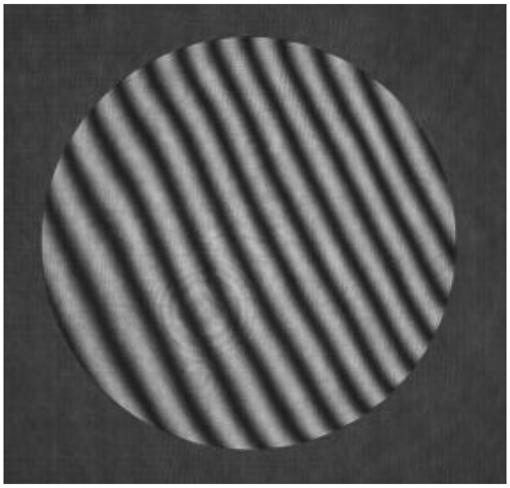


Figure 4
Fisba interferometer dimensions, including sample focus plane

To determine the correct lens position, we first calculate x’ according to the Newtonian equation. For 1270 mm radius of curvature and 100 mm focal length, x’ is ~ 8 mm. Fisba reports the nominal focus plane of their 10 mm collimator as 22 mm; so ideal sample focus would be achieved at 130 mm.

For added flexibility, a mechanical focusing component was included in our custom f/10 objective to allow optimal sample imaging over the range of 250 mm to ∞. Below, the left image below represents a 25 mm shift from optimal image position; while the image on the right has been set for optimal sample focus.





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