Interferometric Testing of Objective Lenses

PRECISION-OPTICAL ENGINEERING

IF 001

Application Note

Objective lenses may be tested interferometrically in two ways; -

By focussing the interferometer beam down to the lens focal plane with a lens (referred to as a Transmission Sphere).

By using the lens under test to focus a plane wavefront to the centre of curvature of a spherical mirror (commonly called a Reference Sphere).

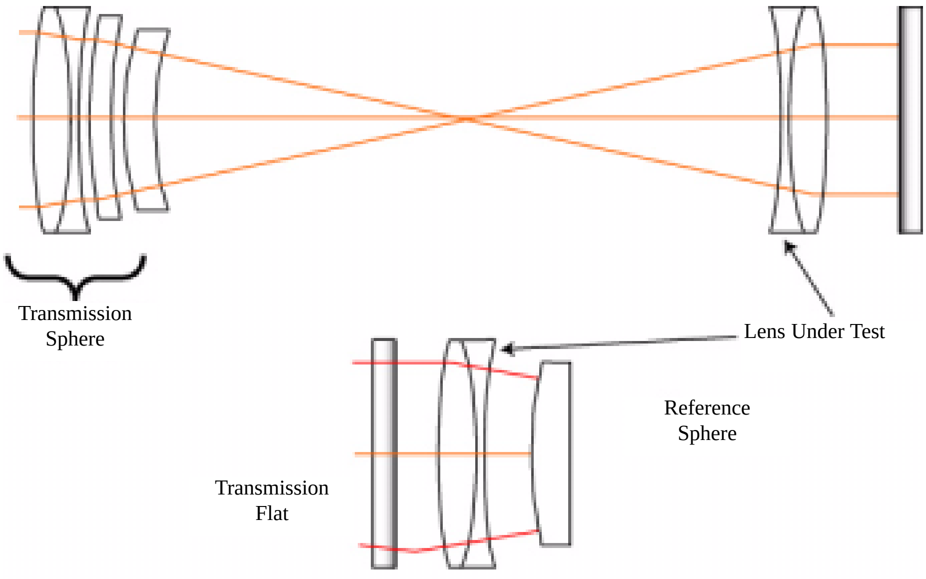

Figure 1: Test arrangements for lenses

In principle the techniques appear simple to use. The method using the Transmission Flat and spherical Reference Sphere would appear to be the simplest to use and the most cost effective, since it does not require the relatively expensive Transmission sphere, which for fast lenses may itself be a 5 or 6 element lens.

Increasingly interferometers are being used in the infra-red, where materials are more expensive. This increases the cost of Transmission Spheres yet further, as they may be manufactured from germanium or zinc sulphide, whereas the reference sphere can be aluminium or aluminised glass.

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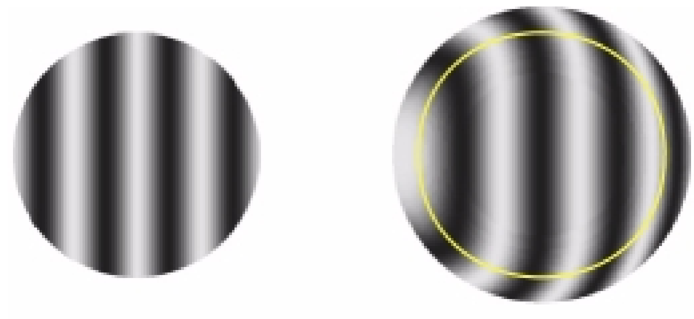
When choosing the method of test, the most important criterion is the value of the information received from the interferogram. In infra-red interferometry especially, the quality of the interferogram is highly dependent on the reduction of diffraction effects. The lens will have a defining aperture, which forms the optical pupil. The edge of this aperture will diffract the light incident upon it so that if for instance a plane wavefront is incident, the edges of the wavefront will curve away from the main beam. This diffracted light can interfere with the interferometer's reference beam to give a fringe pattern, which appears to indicate a rapid roll-off at the edge of the pupil. The appearance of this is not unlike the patterns seen in the presence of Spherical Aberration and can cause some concern especially to the designer. The solution to this is to focus the optical aperture onto the camera sensitive plane in the interferometer. Figure 2 shows idealised fringes from 'in-focus' and 'out-of-focus' interferometers. This, however, is not as simple as it may seem in that the optical aperture is 'seen' twice, once directly and once reflected off the Reference Sphere or Reference Flat and it suffers diffraction in both directions. In order to remove diffraction effects, these two planes must be at best conjugate to one another or, more usually, close together. For instance in Figure 1 the reference surfaces are shown physically close to the lens under test, which helps to reduce this effect.



In Focus Pupil

Out of Focus Pupil

Figure 2: Effect of focus defect in an Interferometer

However, it is not always possible to arrange for such configurations, especially if the lens is mounted in a housing that precludes close approach to the pupil plane. For simple lenses where the pupil is close to the front lens, then the method employing the transmission sphere and Reference Flat should be adequate. If the diffracting pupil is buried deep within the lens then some problems may be seen at long wavelengths. In the absence of a Transmission Sphere then the second method is the only alternative.

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If it is not possible to get the ideal configuration, a small radius Reference Sphere is used (see Figure 3) which precludes any attempt at pupil focussing, but does have the advantage of separating the two sources of diffraction so that some spatial filtering of the pupil is performed on the return path. Indeed interferometry can be performed on ball bearings and in one extreme situation the tip of a ballpoint pen (previously unused of course). Under such circumstances it is often impossible to make any other than a qualitative assessment of performance. If the presence of diffraction can be demonstrated to be the cause of the fringe shape, it is often best to find some way of determining the correct aperture diameter on the camera faceplate and then ignoring the shape of any fringes outside this aperture. The pattern on the right in Figure 2 shows this, in that the pupil has been superimposed on the fringe pattern. This may be done by effectively calibrating the camera output so that the required pupil diameter is known in pixels. The fringes can then be masked in software to remove extraneous effects.

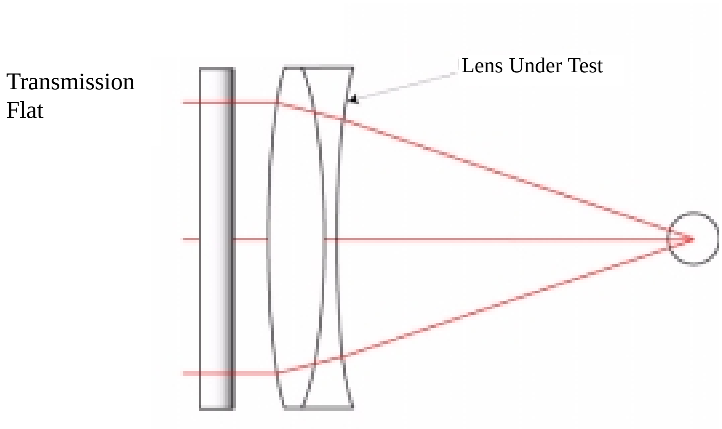

Figure 3. Using a Small Sphere

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