12.5. MOIRÉ INTERFEROMETRY

Moiré interferometry, which can be regarded as a form of holographic interferometry, is a complement to conventional holographic interferometry, especially for testing optics to be used at long wavelengths. Although TWH can be used to contour surfaces at any longer-than-visible wavelength, visible interferometric environmental conditions are required. Moiré interferometry can be used to contour surfaces at any wavelength longer than 10 µm (with difficulty) or 100 µm with reduced environmental requirements and no intermediate photographic recording setup. For nondestructive testing, holographic interferometry has a precision of a small fraction of a micrometer and is useful over a deformation amplitude of a few micrometers, whereas moire interferometry has a precision ranging from 10-100 µm to millimeters, with a correspondingly increased useful range of deformation amplitude.

125.1. Basic Principles

Although moiré techniques have been used for many years, only recently has the full potential of moiré interferometry been realized (Brooks and Heflinger 1969, Takaski, 1970, 1973, MacGovern 1972, Benoit et al. 1975). If parallel equispaced planes or fringes are projected onto a nonplanar

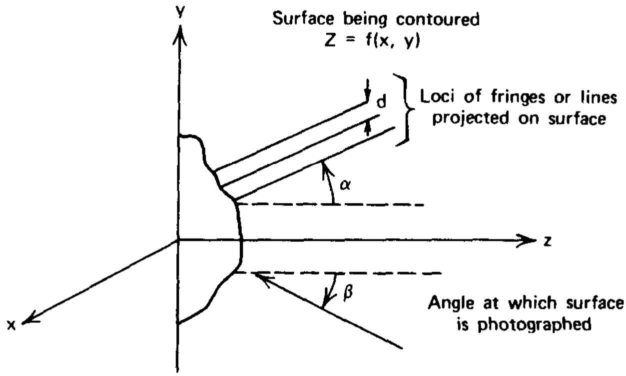


Figure 12.14. Fringes projected on surface Z =f(x, y) at angle a **and viewed at angle** b.

surface and the surface is viewed at an angle different from that at which the fringes are projected, curved fringes are seen. It can be shown that a photograph of these fringes is equivalent to a hologram made of the surface using a long wavelength light source (MacGovern 1972). If a surface described by the function Z=f(x,y) is illuminated and viewed as shown in Fig. 12.14, a photograph of the projected fringes shows contour lines of the surface relative to a plane surface, where the contour interval C is given by

$$C = \frac{d}{\tan\alpha + \tan\beta} . \tag{12.7}$$

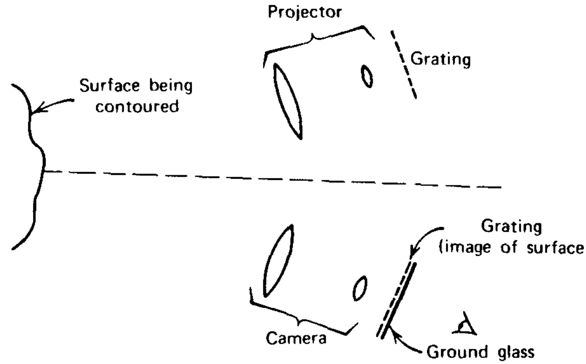
The sign convention used for the angles is shown in the figure.

The moire pattern of the photograph of the projected fringes, as compared with a straight line pattern, is equivalent to changing the tilt of the reference surface. The moiré pattern of two photographs of projected fringes for two different objects gives the difference between the two objects, for example, a master optical surface and another supposedly identical optical surface. Likewise, deformation measurements can be made.

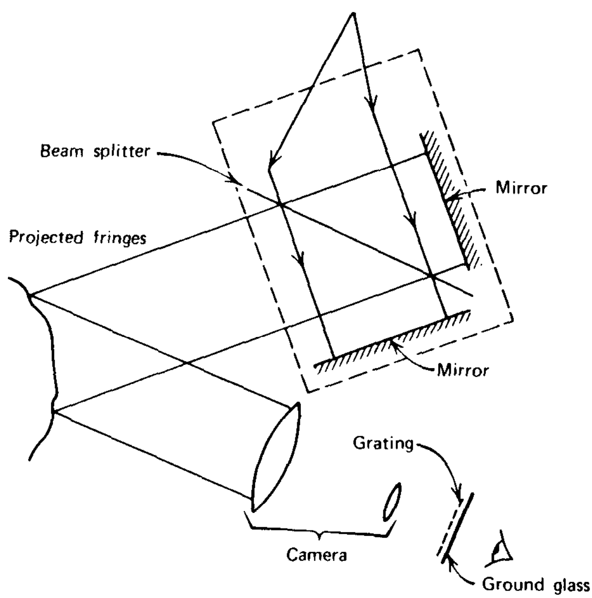
12.52. Experimental Setups

Several experimental setups can be used to perform moire interferometry, of which three are illustrated in Figs. 12.15 to 12.17.

In Fig. 12.15a a grating is projected onto the surface being contoured. There is no requirement that the light be coherent or even monochromatic. Both the camera and the grating projector should be telecentric systems so that the angles of projection and view are well defined. The surface being



(a)



(b)

Figure 12.15. Experimental setups for moiré interferometry. (a) Projecting grating on surface. (6) Projecting fringes on surface.

contoured is imaged onto a grating so as to select the desired tilt of the reference plane. If ground glass is placed next to the second grating, the moire pattern can be viewed directly. The moire pattern can be photographed by replacing the ground glass with a sheet of film. This technique has the disadvantage that the relatively high frequency fringes must be transferred through an optical system with attendant loss of contrast. In addition, the projector has a limited depth of focus.

To meet this objection, the grating projector can be replaced with an interferometer, as shown in Fig. 12.15b. In this case a coherent laser beam is used, and a beam splitter with one mirror slightly tilted produces nonlocalized interference fringes, which fall on the surface to be contoured. This method has the advantage that, since the lines projected on the surface are nonlocalized fringes resulting from the interference of two collimated beams, there are no depth-of-focus problems in the projection system.

The higher frequency (carrier frequency) will be displayed on the final photograph unless some effort is made to avoid it. One technique to eliminate the carrier frequency is to use spatial filtering, as illustrated in Fig. 12.16. A second technique is to raise the carrier frequency above the resolution limit of the film. For instance, Polaroid film has a resolution limit of 22 to 28 line pairs per millimeter; since the moire pattern is created before the film plane, only the relatively coarse moire will be recorded if the carrier frequency exceeds about 22 line pairs per millimeter.

A third possible setup is shown in Fig. 12.17. In this case the same grating is used for both projecting and viewing. This setup has the advantage that the camera does not have to resolve the higher frequency grating lines, and must be capable of resolving only the moiré. This, in principle, yields a higher contrast moire pattern. Another advantage is that the grating may be freely translated (but not rotated) in its plane without changing the perceived moire pattern. If the grating is slowly moved during the recording exposure, it will not appear on the photograph; only the stationary moire pattern will be recorded. The perceived sensitivity (fringes per unit deformation) may be varied easily by rotating the grating; it goes to zero when the grating lines lie parallel to the light source-camera

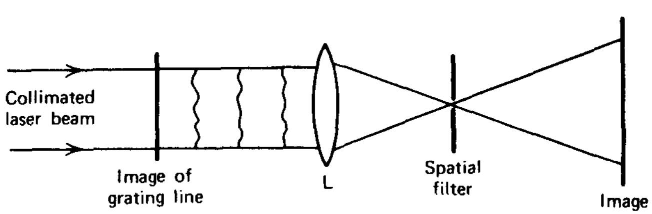


Figure 12.16. Use of spatial filtering to eliminate carrier frequency.

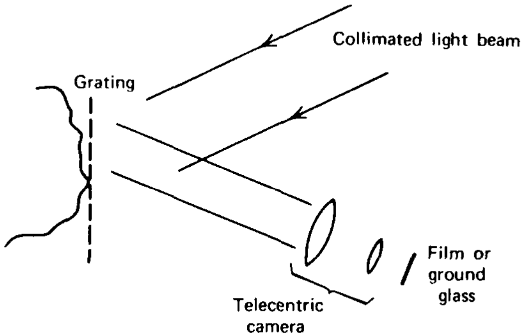


Figure 12.17. Use of single grating for projection and viewing.

plane. Finally, the contouring may be performed with white light, where projector and camera are telecentric and have a large relative aperture. This technique has the disadvantage that the grating must be reasonably near the surface being contoured. This requirement is relaxed, however, as the light source becomes better collimated, the camera lens goes to larger f numbers, and the carrier frequency decreases.

12.53. Experimental Results

Figure 12.18 shows results obtained testing a spherical surface in the setup shown in Fig. 12.17. The equivalent wavelength in this instance was 200 µm. As stated above, moire interferometry is definitely a complement to conventional holography and should be of particular use in testing components for longer wavelength optical systems.

Figure 12.18. Moiré interferogram obtained when testing *a* spherical mirror (λ_{eq} = 200 µm).