

# Holographic Interferometry

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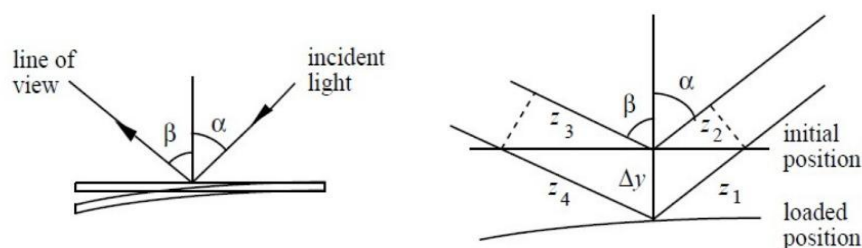
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**ABSTRACT :**Optical interferometry is a powerful tool for measuring displacements of the order of a wavelength of light. One significant limitation of common interferometric methods is that they require specular reflectors, so that one is limited to measuring the displacement of a mirror. This limitation can be removed by utilizing holography, allowing very small motions of arbitrary, diffusely reflecting, objects to be detected.

**KEYWORDS:** holographic, wavefront, coherent, reconstruction, interference

## I. INTRODUCTION

Holography, or wavefront reconstruction, is a process by which the amplitude and phase variation across a wavefront may be recorded and subsequently reproduced. If monochromatic, coherent light enters the eye or any other optical instrument, the only information furnished is the amplitude and phase variation across the input aperture. It follows, therefore, that the holographically reconstructed wavefront is completely equivalent to the original optical wave. Any measurement that could be made on the original optical signal can also be made with the reconstruction. In double-exposure holographic interferometry this principle is applied to obtain an interference pattern between two reconstructed images of the same object. A holographic recording is first made with the object in some reference state. The object is then moved or deformed as desired and a second hologram is made on the same photographic film. During reconstruction two waves are created and interfere in the space beyond the hologram. The resulting interference fringes record the local displacement of the surface of the object. Making and viewing a plane transmission hologram, as described above, demands excellent stability of all the components and fairly careful placement of the reconstruction beam. By going to the geometry shown in Figure 2a, both these problems are eased. The reference and object beams now mix in such a way that interference fringes are formed in the volume of the photographic emulsion, more or less parallel to the surfaces. The hologram is therefore a three-dimensional grating, more like a crystal than the familiar flat pattern. Since there are fewer components and they can be closer together, alignment and vibration during hologram exposure are less critical. During reconstruction, as shown in Figure 2b, the hologram is viewed by reflected light, which need not be coherent or even monochromatic. Like a crystal, the three-dimensional grating will only reflect wavelengths that meet the Bragg condition, so it acts as a monochromator at the same time as it forms the (Figure 1) image. Finally, it is noted that the photographic process can be further manipulated to enhance the hologram. Exposure to light sensitizes some of the silver halide grains in the



**FIGURE 1 : Fringe shift**

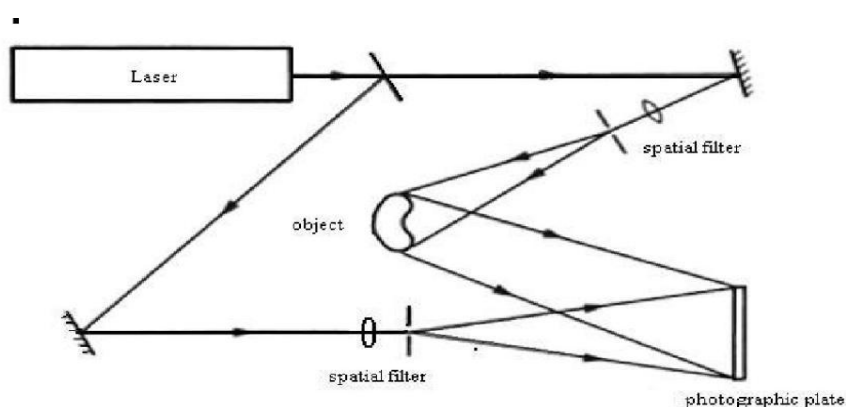
emulsion in such a way that they can be chemically reduced to metallic silver. This process is called “development”, and yields the familiar black photographic image. (Small grains of silver appear black, not shiny.) For a hologram the blackened regions absorb light, and serve as the barriers of a grating, but it would obviously be more efficient to use all

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the incident light. This can be accomplished by converting the metallic silver to a different silver halide compound. The new compound formed in the exposed and developed regions has a different index of refraction than the original silver halide left in the unexposed areas, so there is a differential phase shift for light which traverses different parts of the emulsion. Interference still occurs as it does in the absorptive grating, but with greater intensity because no light is actually lost.



**Figure 2a : Recording setup Double-exposure interferometry**

In double-exposure interferometry, one makes two successive holograms on the same film. For the first exposure the object is in some reference state, and for the second it is moved or deformed. During reconstruction, the two images interfere as though there were two copies of the object present. Where the displacement between the two “copies” is such that the reflected light would be shifted by an integral multiple of half wavelengths there will be a dark fringe in the combined image. Conversely, bright fringes occur when the displacement is an integral number of wavelengths.

### II. METHOD

Several steps were needed to construct the holographic interferogram and measure the beam deflection. A laser beam must be expanded and directed to uniformly illuminate the object. The photographic film must be positioned and exposed to record the holograms of the bar with and without load. The latent image in the film must then be developed and viewed under appropriate conditions to visualize the interference fringes. The fringe positions can then be measured, the deflection as a function of position deduced, and a comparison made with the expected variation. The holographic material is most sensitive to red light, so a dim green “safe light” can be used to facilitate handling. Even this will eventually fog the emulsion, however, so limit total exposure to a few minutes. Keep the plate at least three feet from the safe light whenever it is out of the box. It is essential that the plate not move a significant fraction of a wavelength during exposure. To accomplish this, it is held between two glass plates with heavy paper clamps. When ready for an exposure, simply center the plate on the lower glass and then gently hold down the upper glass while positioning the clamps. To minimize loss of object beam by reflection on glass surfaces, the emulsion side of the plate should face the object. This helps in identifying the emulsion side of the material. After making any disturbance on the optical table is allow several seconds for vibrations to damp out before starting an exposure. Processing consists of development, a rinse to stop the process, bleaching to convert the metallic silver, and a final rinse to remove residual chemicals. Detailed instructions are posted in the darkroom. At this stage, water has expanded the emulsion so much that the grating is not effective at visible wavelengths. After several hours of drying it should return to its original dimensions, and the hologram will be visible. To speed the drying a fan is used to blow air across the plate.

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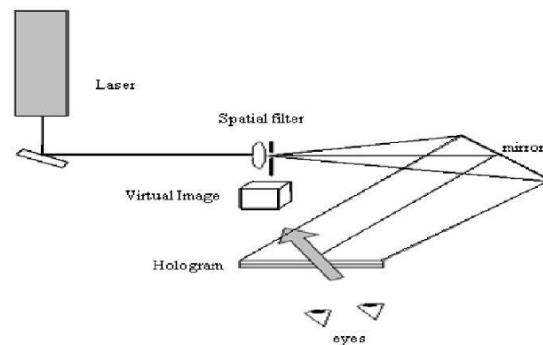


Figure 2b : Reconstruction setup of double exposure holographic interferometry

### III. PATTERN FORMATION

Sincethe need to expose the plate twice, each interval should be about  $\frac{2}{3}$  of the optimum time estimated. This will be long enough to give a good image without grossly over exposing the plate. To get the interference pattern, the lead weight on the end of the cantilever, and put a plate in the holder. Allow the vibrations to die out and expose for the needed time. Using the string, gently remove the weight, while creating minimal disturbance to the table. Let the vibrations die out for a few seconds, and then do the second exposure. If everything works, the finished hologram will show a series of straight dark fringes across the invisibly-bent bar. To analyze the fringe pattern, set up the hologram for viewing as explained above. A ruler is laid on top of the plate, and estimate the centre of each dark fringe, relative to the edge of the clamp. Note that there will be some parallax because the ruler is not in the plane of the fringes. Alternatively, support the plate above the viewing surface and hold the ruler in the plane of the cantilever. In either case, it is probably most convenient to look straight down on the image.

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