

MAS 450/854: Holographic Imaging Lab Notes

#3: IN-LINE HOLOGRAPHIC OPTICAL ELEMENTS

Introduction:

When a diffraction grating has a constant groove spacing, or spatial frequency, it deviates an incident beam by a constant angle (which varies with the wavelength of the light). If the spatial frequency varies smoothly with location, the deviation angle also varies smoothly. Thus rays passing through different areas of the grating will no longer be parallel to each other, but may be converging toward each other, or diverging, separating from each other. If the spatial variation of spatial frequency is just right, light from everywhere on the grating will converge at exactly the same point downstream, so that the grating behaves like a perfect “positive” lens. Or, the rays might appear to be diverging from a single common point (or both at the same time). It might be possible to generate such a groove pattern mechanically, after much computation, but it is much easier to do it holographically, by recording the interference pattern produced by two point sources at different distances. Often, one of these sources is a point focus produced by a lens, and the resulting hologram will mimic some of the focusing properties of that lens. One might consider it as a hologram of the lens itself, a sort of “optical clone” of the original lens.

In this lab, you will make and study an in-line hologram of a lens that has been chosen to produce interference fringes that are, in places, coarse enough to be seen with a simple magnifier, and in other places, fine enough to produce significant angles of diffraction. While this may seem to be a very simple type of hologram, it is also one of the most subtle, and most difficult to execute flawlessly. Here our approach will be deliberately crude, but these holographic optical elements will contain all the elements of much more sophisticated image holograms to follow.

Experimental Topics:

1. Turn on the He-Ne laser, pass the beam through a shutter, and diverge the beam so that it covers half a 4”x5” plate fairly uniformly at about 2 meters away. Install the “split-lens” between the diverging lens and the plate holder so that the plate is illuminated by “straight through” light, and by the focused beam that has gone on to diverge. Position the “split-lens” so that the shadow cast by the lens is roughly the same size as the light focused by the lens. Look from the plate’s location toward the laser (through a dark filter, please!) and see that there are TWO point sources at different distances, and that the angular separation between them varies with location of your eye (i.e., location on the plate).
2. Measure the distances of the two “sources,” D1 and D2, from the plate. Calculate the maximum spatial frequency at the edge of the pattern. Measure the intensity of the two beams at the exposure plane. Calculate the beam ratio, the fringe contrast, and the exposure time required to give an exposure “dose” of 600 ergs/cm² to the plate.
3. Learn how to open (and close tightly!) the plate box, locate the emulsion surface, position the plate, and expose it for the proper time. Develop with a simple process: development in D-19, stop bath, fixer, and water wash. Dry in air, with an alcohol rinse to speed things along.
4. Check the overall plate density, which should be around ND 0.6 (compare to the standard density filter in the lab). Adjust the exposure time and reshoot if the plate is hopelessly dark or thin. Examine the dried plate with a magnifier to locate the coarsely fringed center of the pattern. Note the increase of fringe spatial frequency as you move toward the edge.
5. Examine the hologram in He-Ne light diverging from the distance of the farther exposure source (D2). Diagram and explain the various images that you see. Measure the distances from the plate of the “first-order” virtual and real images. Move the hologram to half and double D2, and comment on how the diffracted images change.
6. Examine the hologram with the Gre-Ne laser, with a beam again diverging from the distance of the farther exposure source (D2). Measure the distances from the plate of the “first-order” virtual and real images. Describe your procedure for determining the distance in both cases.
7. Examine the hologram in white light from a point-like source (tensor lamp, slide projector, sunlight, etc.), and diagram and explain what you see.

Note: To conserve time and holographic plates (they cost about \$5.00 each!), several people are expected to share the same holographic lens.