MAS.450/854: Holographic Imaging Lab Notes

#2: DIFFRACTION

Introduction-

The process that is, in many senses, complementary to “interference,” and is the basis for the second “reconstruction” or viewing step of holography, is termed “diffraction.” Broadly speaking, diffraction refers to effects due to the “spreading” of light waves around the edges of opaque obstacles, so that light falls into what we ordinarily think of as “shadow” areas. We are especially interested in what happens when light is diffracted by regularly-spaced holes or slits, so that several spread-out waves overlap and interfere to produce complex “diffraction patterns.”

Coherent-optical effects are not often observed in everyday life, and diffraction effects even less so than interference effects. Life with lasers is much more “diffraction active,” and this laboratory is designed to give you some preliminary experience with some of the diffraction phenomena that underlie holographic practice.

This is a very full lab, so resist the temptation to linger over details of the first sections. Come back to them if there is time at the end!

Multi-Slit Diffraction-

When light passes through a single narrow slit, it diverges as a cylindrical wave. The narrower the slit, the wider the angle over which the beam is spread. The intensity of the light that gets through the slit also decreases with the width of the slit, so the spreading effect can be hard to see. In this lab we have to compromise by using fairly wide slits to begin investigating diffraction.

When light passes through two nearby parallel slits, it is spread by each to become two cylindrical waves. Where those beams overlap, they interfere (much like differently inclined plane waves) to produce a smooth sinusoidally-varying interference pattern of parallel “fringes.” If a third slit that is separated by the same distance is opened up, the bright fringes become sharper, and some dimmer in-between fringes appear. As more slits are opened, the bright fringes become increasingly well defined, and the spaces between become increasingly darker, until the beam seems to be split up into only a few diffracted beams that are no wider than the original beam. Such an array of many equally spaced slits is what we usually mean by a “diffraction grating.” In this lab we will observe this build-up of diffraction grating behavior from an increasing number of slits that are recorded in the “Cornell Interference and Diffraction Slitfilm Demonstrator,” a glass lantern slide your TA will provide you.

Procedure:

1) Find the corner of the lantern slide that has the letters *“CAL”* and a winged shape in a circle about a quarter-inch across. This logo should be in the upper right-hand corner. The second column from the left is, in its bottom half, a slit of continuously decreasing width. Shine an undiverged He-Ne laser beam through it and onto a white screen. By carefully moving the slide up and down, see that the width of the diffracted beam increases with decreasing slit width. The slit is on a piece of photo film sandwiched in glass, so there are plenty of internal reflections to confuse things. Try to pick out the relevant patterns amongst the junk!

2) The second column from the right consists of a single slit on top, and below it are two, three, four, and then ten identical slits, side by side. The spacing between the slits is twice the slit width in all cases.

With the same setup as part one, place the 1-, 2-, 3-, 4- and 10-slit gratings in front of the laser, and observe the changes in the diffraction pattern. Sketch them roughly in your notebook, with what you consider to be important observations. Estimate the number of slits per millimeter in the Slitfilm.

3) Confirm your observations by looking through the Slitfilm at a point source (laser light or bare-filament bulb).

4) There are several other interesting patterns on the Slitfilm, which you may want to investigate after you finish the rest of the lab.

Studies of Transmission and Reflection Gratings-

We will now examine a variety of diffraction gratings to try to estimate their “spatial frequencies” (inter-groove spacing, lines per millimeter, etc.), number and orientations of multiple grating structures, etc. The setup will again be as in part 1, but the patterns will sometimes have to be reflected onto a white card for measurement.

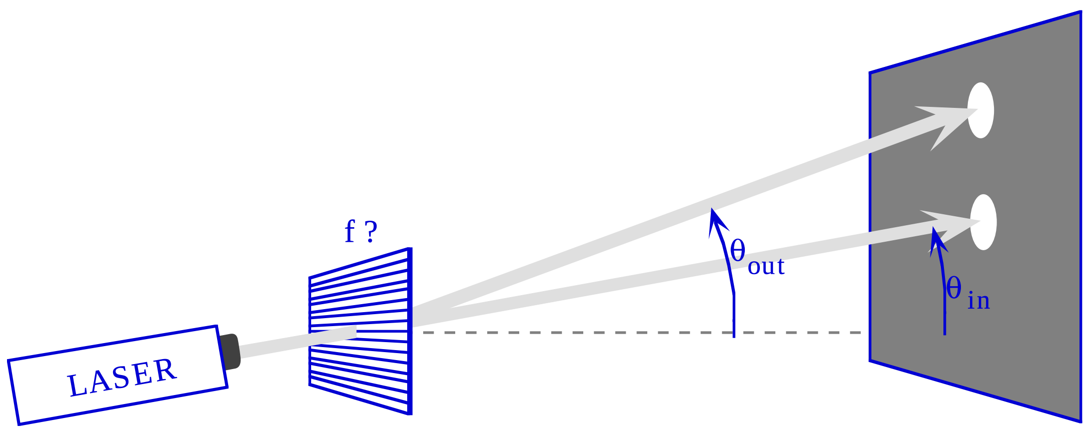
Procedure:

1) Place the grating you made in the previous lab into the undiverged beam, and confirm that one of the diffracted beams is deviated by the same angle as you set up between the exposing beams. Infer the grating’s lines/millimeter from the diffracted beam angle using the $m\lambda f = (\sin\theta_{out} - \sin\theta_{in})$ diffraction equation. Compare the diffraction patterns of differently exposed gratings, and describe their differences. Which exposure produced the brightest diffracted beam? Twist the grating so that the laser beam is incident at 30 degrees to the perpendicular to the plate. Measure the angles of the diffracted beams, and confirm that they correspond to the predictions of the diffraction equation.

2) Repeat part #1 using the “Gre-Ne” laser beam, which has a wavelength of **543.4** nm. This is simply a helium-neon laser with special green-reflecting mirrors and a gas mixture optimized for this strange new wavelength.

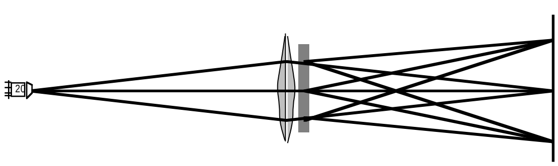
3) Put the laser beams through some of the commercial gratings that may be in the lab (”spectra-glasses,” camera filters, etc.), and describe the important features of their diffraction patterns. Determine the spatial frequencies and orientations of their component gratings, if possible.

4) Even though the adjacent grooves of a videodisc and compact audio disc are different in detail (they hold different data), they are similar enough to produce vivid diffraction effects. Reflect the laser beam from such discs, measure the diffracted beam angles, and determine the inter-track spacing (progressive difference of radius) for the discs. Discuss the directions of the diffraction of light by the discs.

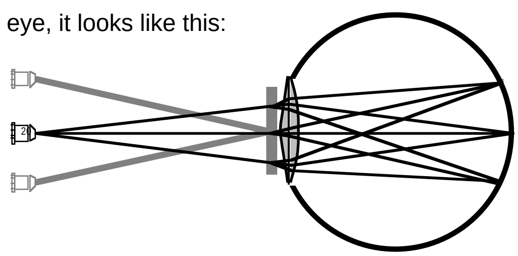


$$m\ \lambda\ f = \left(\sin\theta_{out} - \sin\theta_{in}\right)$$

in the lab, it looks like this:



in the eye, it looks like this:



numbers alongside the patterns are:

15 = number of lines

1 = line width (44 µm/unit)

3 = line separation (44 µm/unit)

numbers at the pattern bottoms are the distances between centers of slits (in millimeters)

CAL