MAS450/854 Lab #2: Interference and diffraction
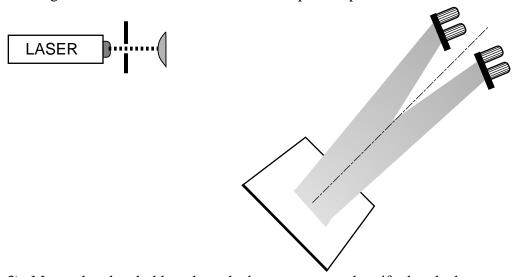
This is a very full lab; resist the temptation to dwell on any one topic for very long!

Two-Beam Interference

Here you will cause two expanded beams (approximately plane waves) to overlap at a small angle, producing finer interference fringes than the Michelson interferometer does. The fringes will be coarse enough to see with a simple microscope, and yet fine enough to produce noticeable diffraction grating effects. To keep things simple, you will deviate parts of a single expanded laser beam with two small mirrors that are angled so as to overlap the two small beams.

Procedure

1) Calculate the angle between the beams needed to produce a grating frequency of 100 cycles per millimeter. With your TA, work out an optical system that will produce this angle for exposure.

2) Set up the optical components to produce the two beams, following the directions of your TA. Determine the distances of the mirrors, etc., so as to accurately match path lengths when their reflected beams overlap at the plate holder.
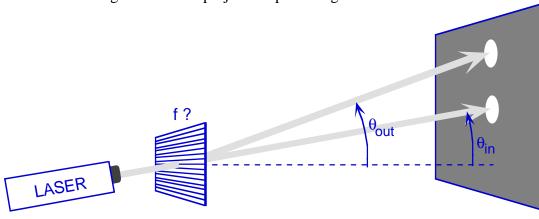

3) Mount the plate holder where the beams cross, and verify that the beams overlap nicely and have roughly equal intensities. The perpendicular to the plate should bisect the angle between the beams.

4) Prepare to record the interference fringe pattern:

a. Fasten the plate holder to the table at the desired location and orientation.

b. Measure the laser light intensity in the overlap area, and calculate a shutter time to give an average exposure of 60 micro-joules per square centimeter (600 ergs/cm^2; this should give a processed "density" of around 0.6). Each student team should shoot a different exposure, bracketing the center exposure by a square root of two ("half a stop"). Close the shutter and pre-check its operation with the squeeze-bulb.

c. Your TA will give you a small plate (roughly half of a 4"x5" inch plate). Note which is the emulsion side (there are three tests to find the emulsion side!), and place the plate in the holder with the emulsion facing the laser. Expose the plate for the required time. Develop your plate as your TA instructs.

5) After the plate has dried, you should examine it carefully. Find the fringe area. Measure the number of fringes per millimeter (the spatial frequency) as best you can with a microscope and reticle, verifying that it came out near 100 cy/mm.
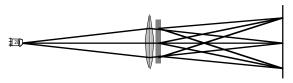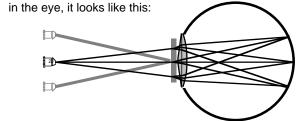
Diffraction and grating analysis

1) Using a new optical setup, place the grating you made in the previous part of the lab into the undiverged beam and project the pattern against a wall or other surface.

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

in the lab, it looks like this: in the eye, it looks like this:

2) 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 spatial frequency from the diffracted beam angle using the $m\lambda f = (\sin \theta_{out} - \sin \theta_{in})$ diffraction equation.
3) Compare the diffraction patterns of differently exposed gratings, and describe their differences. Which exposure produced the brightest diffracted beam?
4) 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.
5) 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.

Multi-Slit 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

We have examines the "CAL" plate during lecture. In this part of the lab, you will do some quantitative observation of a small set of the CAL plate patterns.

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. Observe and sketch a relevant subset of the patterns caused by these slits. Using your measurements, 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).

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 2, but the patterns will sometimes have to be reflected onto a white card for measurement.

1)   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.

2)   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.

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

1
32
-

1
16
-

1
8
-

1
4
-

1
2
-

variable spacing
constant width

parallel slits
varying width

single slit
varying width

1
2
-

2
2
6

2
2
12

1
16
-

1
1

-

15
1
3
0.176

30
1
1
0.088

80
1/4
1/4
0.033

40
1/2
1
0.066

20
1
2
0.132

1
1
-

2
1
2
0.132

3
1
2
0.132

4
1
2
0.132

10
1
2
0.132

1
2
-

2
2
2
0.176

2
2
6
0.35

2
2
14
0.70

2
2
30
1.40

4