MAS 450/854: Holographic Imaging Lab Notes

Lab #1: INTERFERENCE

Introduction -

The constructive and destructive overlap of light waves to form "interference fringes" is the central mechanism of holographic recording. This laboratory will explore interference in two contexts: coarse fringes in the Michelson interferometer, and moderately fine fringes in an overlapping-beam experiment that mimics holographic recording. In both cases, you will observe (and in the second, record) high contrast fringes formed in laser light, and thus you will also be introduced to laser operation and optical hardware, and the related safety issues.

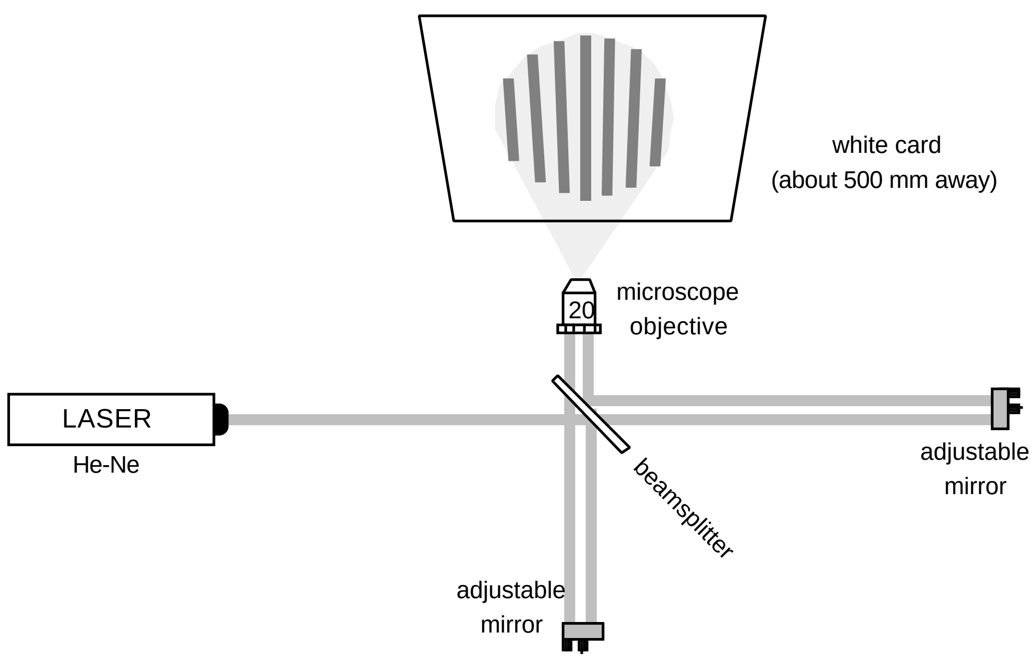
These notes will describe the experiments involved with only a little background, and a few comments on specific setups. They will also request that you make some observations, and occasionally remark on the results. You should enter these responses into your laboratory notebook—the teaching staff will review them during the term. Entries should include raw data as well as sketches, and it is best to do as much notebook work as possible while still in the lab. If you clean up your data later, do not obliterate the original entries! Remember, it must be possible for someone else to understand and repeat all of your experiments from your notebook entries, to understand what you saw, and the conclusions you drew. We intend the labs to be as open-ended as possible, and to gently suggest further topics for you to study. You should also enter these ideas in your notebook.

Laser Safety -

If this is your first experience with a laser, you probably have a few questions about its safest use. We are using a low-power helium-neon continuous-wave gas laser. The output power is only a few milliwatts, not enough to damage your eyes if you are careful **not to look down the undiverged beam**, or any reflection of it by a shiny surface. Review the Laser Safety Guide pamphlet in the lab, and ask your Teaching Assistant if you have any questions about safe use of these lasers. Mike Klug will give a review lecture in class.

The Michelson Interferometer -

Invented by A.A. Michelson[1] in 1881 to study theories of the aether, this simple and robust optical design is now finding a new life as a diagnostic tool for holography tables, and here as an interference demonstration. The setup is roughly as shown on the accompanying sketch, although it can be tricky to align. If you take care to keep the beams parallel to the table top, and to adjust each mirror to return the laser beam to the spot where it first passes through the beamsplitter, you should find good fringes with only minor twiddling.



Procedure:

1) Set up the interferometer with mirror legs of roughly equal length, perhaps 150 mm (6 inches). Successful alignment requires keeping the beams at a uniform height above the table surface; this should be 200 mm (8 inches) for these labs.

2) Adjust the mirrors to give broad (perhaps 10 mm wide) vertical fringes on the screen. Note the sensitivity of the fringe pattern to disturbances on the table, especially nudges to the components, warm air drafts in either leg, stresses on the table (which should not be floating for this lab), and so forth. Try to arrange things so that the entire screen is as dark as possible. The screen will light up when you block either beam, but is dark when both legs are open! Discuss where the energy has gone.

3) Increase the length of one of the legs by 100 or 150 mm and observe any change of the contrast of the interference fringes. Interpret this and find the approximate "coherence length" of the laser you are using.

4) Further increase the length of one of the legs until it is one laser cavity length longer than the other leg; observe the interference fringe contrast, and discuss the results. The interferometer is much more sensitive with longer legs, and can be used to judge the stability of the table, the vibration state of the room, the maximum practical exposure time, and other useful factors. Comment on a few of these effects in your notes.

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. Your TA (Teaching Assistant) will explain about the various concepts of laser power, energy, flux, and exposure that you will need.

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. Return the plate to the TA and observe the processing procedure (you will process your own plates in subsequent labs—this is your tutorial).

d. After it has dried, you should examine the processed plate carefully, and find the fringe area. Measure the number of fringes per millimeter (the spatial frequency) with a microscope and reticle, verifying that it came out near 100 cy/mm. Save the plate carefully for analysis in the next lab (that is, wrap it in tissue, don't scratch it, keep it dry, etc.), but do not hesitate to make casual optical experiments with it at home during the week! Be sure to write your observations in your notebook, per the handout on "Lab Notebook Formatting."

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[1]. Michelson (mí'kél sén), Albert Abraham, 1852-1931, American physicist; b. Prussia (now Poland). He designed the modern interferometer, with which he measured the speed of light to an unequaled degree of accuracy. With Edward Morley he conducted the Michelson-Morley experiment, which led to the refutation of the a*ether* hypothesis and was eventually explained by Einstein's theory of relativity. In 1907, Michelson became the first American to win the Nobel Prize in physics.