Student Name _____ Date _____

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science

6.161 Modern Optics Project Laboratory

Laboratory Exercise No. 4 **Fall 2011**

Holography: An Example of Diffraction

The Pre-Lab Exercises must be completed BEFORE entering the Lab. In your lab notebook record data, explain phenomena you observe, and answer the questions asked. Remember to answer all questions in your lab notebook in a neat and orderly fashion. No data are to be taken on these laboratory sheets. Tables provided herein are simply examples of how to record data into your laboratory notebooks. Expect the in-lab portion of this exercise to take about 3 hours. **Please note that a formal written report is required for this Laboratory Exercise.**

PRE-LAB EXERCISES

PL 4.1 – Get Prepared to Start the Laboratory Exercises

Read the **entire** laboratory handout, and be prepared to answer questions before, during and after the lab session. Determine all the equations and constants that may be needed in order to perform all the laboratory exercises. **Write** them all down in your laboratory notebook before entering the Lab. This will ensure that you take all necessary data while in the Lab in order to complete the lab write-up. This preparatory work will also count toward your Lab Exercise grade.

PL 4.2 Preparation for Making Holograms

In Lab Exercise 4.2, your group will be making one type of hologram. You will have the option of making: (a) a Denisyuk single-beam white-light reflection hologram (simplest), (b) a two-beam or multiple beam reflection hologram, (c) a two-beam transmission hologram (must be viewed with a laser) or (d) a rainbow hologram (pseudo-color – but it takes quite a while to setup and develop). For those with little or no experience with optics or holography, this is a great opportunity to get your feet wet (pun intended).

For this section of the Pre-Lab it is your job to find out more about these types of holograms - everything about exposure of the holographic film, its development, and processing will be explained on lab day However, before coming to the Lab you are advised to do some outside research on how to configure the holographic recording and readout setups for each of the four types of holograms listed above.

After you have decided which hologram you want to make, make a detailed sketch of the recording system you will use. – This includes placement of the object, lenses, laser, mirrors, beam splitters, holographic plate, and any other items you might need (e.g., slits, wave plates, irises, etc…).

Here are some useful tips to consider before coming to the MOL to make holograms:

(1) You should bring some *interesting* objects from which we can make holograms. Such objects should not be dark in color, nor should they exceed a volume of 3"x3"x3".

(2) Those students whose objects we use will be able to take home a copy of their hologram. Otherwise, holograms made in the MOL will be archived for demonstration to future students. You will need your own laser to view the transmission holograms at home. Reflection holograms will be viewable in white light.

(3) Make sure to wear clothes that can handle stains. Also, you will not be able to leave to go to the bathroom while the plates are developing, so be sure to go beforehand.

(4) Be aware that it will be extremely dark at times in the laboratory, and that it can be fairly time-consuming depending on the complexity of the hologram you choose to make.

"'By-the bye, what became of the baby?' said the Cat. 'I'd nearly forgotten to ask.' 'It turned into a pig,' Alice answered."

– Lewis Carroll, *Alice in Wonderland*

IN-LAB EXERCISES

In the first holography lab session you will observe several holograms and participate in making one (or more) simple holograms. In the second session, you will have the opportunity to design and make a more difficult type of hologram. Some options are listed below. Your report (not more than 4 pages) for this section of the laboratory exercise will be graded by both the writing and laboratory staff. For this assignment assume your audience is a fellow 6.161 student. The Writing Coordinator will be looking at your grammar, at your sentence construction, for critical thinking on your part, and to see how clearly you can express your ideas in writing.

4.1 Viewing of Transmission, Reflection, White-Light and Computer-Generated Holograms

A collimated laser beam and a white-light source have been set up for viewing of four types of holograms.

(a) Illuminate the given laser-made **transmission holograms** with the divergent laser beam (remove the large collimating lens). For each hologram, find the direction of propagation of the virtual image, and view it directly (i.e., no lens or screen is to be used to view this image). Move your head around and tilt the hologram to get the best view of the image.

For the **hologram of the clock or the hologram of the lion**, draw a diagram of the setup that gives a virtual image with the best fidelity. In your diagram, show the location of the virtual image and any other beams that exit the hologram. Use this information to infer the geometry of the setup that was used to record the hologram (reverse engineering).

(b) Illuminate the **reflection hologram of the coins** with the divergent laser beam and view the image through the hologram in reflection. Is the image you see real or virtual? Draw a diagram of the setup showing the location of the image and any other beams that exit the hologram. Use this information to infer the geometry of the setup used to record the hologram.

(c) Illuminate the **white-light hologram of the owl** with white-light from the overhead lights in the Laboratory such that the light strikes the hologram and then reflects an image into your eye. Tip the hologram from side to side and up and down. Draw a diagram of your readout configuration showing the location of the image or images. Describe your observations from tipping the hologram in the beam. Re-illuminate the white light hologram with the divergent He-Ne laser beam. What differences do you observe? Explain these differences. Use your observations to infer the geometry of the setup used to record this hologram.

(c) Put the collimating lens back into the system so as to generate a collimated laser beam. Illuminate the **first computer-generated transmission hologram** (written on a 4"x5" plate) with the collimated laser beam, and view the real image (it will spell a familiar acronym) on a distant screen. Draw a diagram of the setup showing the location of the real image and any other beams that exit the hologram. Use this information to infer the geometry of the setup used to record the hologram.

(d) Place the **second computer-generated hologram** (written on 2"x2" film) into the collimated laser beam. Now relocate the screen close to second computer-generated hologram. Move the

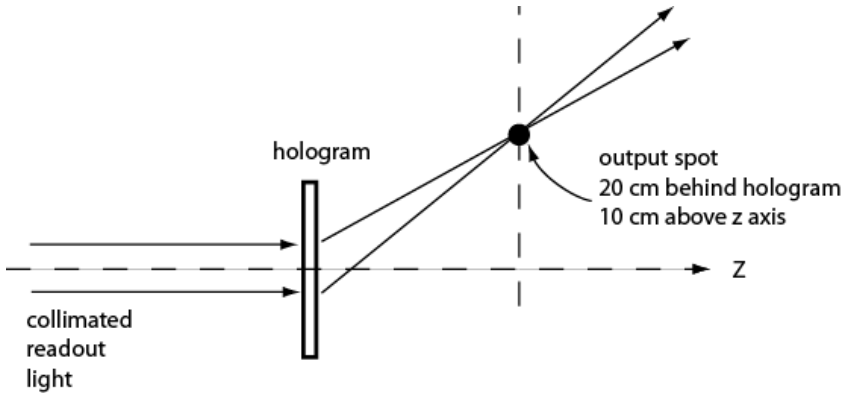
screen away from the hologram slowly. What do you observe on the screen? How do you explain what you see on the screen with respect to what you see on the actual hologram? Ask the TA or LA to show you how this hologram was made.

4.2 Designing and Making Holograms

Hologram Options

(a) Make a Holographic Optical Element
In this session you will see an example of a holographic optical element. The element was designed to act as a reflection hologram, taking collimated light and producing a focused off axis beam. For this writing project you will use what you know about holography and the holographic writing process to design a Holographic Optical Element (HOE) with the following characteristics:

Goal: Focus a collimated beam to an off-axis spot
Read Wavelength: 514nm (Argon-ion laser green line)
Write Wavelength: 632.8 nm
A diagram of the desired system is shown below.



The most interesting aspect of this project is the complication introduced by using a different wavelength light to write the hologram than is used to readout the hologram. Detailing how you addressed this complication should be a major focus of your report.

(b) Make a hologram of a magnifying glass in front of an object
For this option you will make a multiple beam hologram of an object located beyond a magnifying glass. For the purposes of this assignment the position of the glass and object should be set to generate a virtual image of the object when observed from the location of the hologram plate.

An interesting question to ask about this system is what happens when you read out with a conjugate of the reference beam without the magnifying glass in the system? For a hologram made without a magnifying glass when the hologram is read out with a conjugate of the reference a real image forms at the location of the object. In the system described for this option do you form a real image when using a conjugate readout? What about when you return the magnifying glass to the system? Addressing these questions should be a major focus of your report.

(c) Make a more complicated hologram

Most of the more interesting examples of art holography, at least from a technical point of view, are made using systems significantly more complicated than the two beam hologram made in class. For this option you will design and make a more complicated hologram. Some examples include multi-beam reflection or transmission holograms (more than two beams), rainbow holograms, white light transmission holograms, multiplexed holograms, multiple exposure holograms, and pseudo-color holograms.

More complicated hologram geometries can result in more interesting holograms. In your report you should address why you chose the hologram geometry used to make your hologram. In particular, what does this hologram geometry allow you to achieve, either in readout or writing, that you cannot duplicate with a simpler hologram. You should also present a brief summary of the history of the type of hologram you choose to make.

Further Instructions for your Report

For all options, your report should include:

(1) A brief (1-2 paragraph) discussion of holography in general

(2) A discussion of the design of your hologram including diagrams of the systems used to write and readout your holograms

(3) Experimental details of the exposures, beam intensities, and recording material

(4) Details of experiments you used to answer the questions posed by your chosen topic

The Lab will be set up for holography for a full week after the holography lab session ends to give you time to design and build the hologram recording system for experiment 4.2. Recording holograms can be difficult, and it is possible you will not make a successful hologram with your system. In this case, your paper should address why you think the system you built did not work.