Holograms

In this lab you will explore the phenomenon of holography, a process whereby optical interference patterns create images. **Bring some small, hard objects (keys, toy cars, coins) to use as objects.** We will be using a method that has been designed to make holograms in a teaching lab setting. The process has high rate of success provided the procedures are carefully followed. You will use a red diode laser with a much longer coherence length than the usual HeNe lasers. **Q1.** What is the definition of coherence length? How long must it be for the present experiment to work?

You will use photographic plates optimized for 633 nm light. A small amount of white light will not affect the plates but they are sensitive to the laser wavelength. Each group will receive a darkroom bag with 6 plates. It is important that the bag be kept closed at all times to avoid fogging the plates. Each of you will make a hologram to keep as a souvenir. You do **not** need to hand in a hologram with your report. However, you should accurately describe your procedures and results.

Each setup has a laser attached to a clip, a battery pack, beam blocks, a lab jack, a mouse pad and a darkroom bag with photographic plates. All of the components should be placed in sand to minimize vibrations. **Q2.** Why do large vibrations ruin a hologram? You will be making two types of holograms, a reflection hologram, which can be viewed with white light and a transmission hologram which requires a laser for viewing.

Reflection Holograms

A. Place the laser and battery pack in the cup of sand on the lab jack. The diode laser diverges more in one direction than the other so you should see a large ellipse of light within a foot or so. Orient the light to illuminate the mouse pad in the sand box. Place small, fairly flat objects on the mouse pad in a 2 inch area. Make sure they can hold a glass plate without shifting. Now place the beam block between the laser and the object. Draw a diagram of how the light hits the plate. Make sure the laser stabilizes for at least 5 minutes before making an exposure.
B. Using your body to block the room light, remove a plate from the bag. The emulsion side will feel sticky to a wet finger. Place the plate on the objects with the emulsion side up (towards the laser). When everything is ready, remove the beam block from the sand, but hold in place to block the beam for 10 seconds (this lets all vibrations settle). Unblock the beam for 10 seconds, then replace.
C. There are two developing setups, each with 5 trays. Development moves from left to right – do not move the plates from one tray backwards to an earlier tray. **You must use gloves when developing the plates – the developer and bleach can hurt your skin!** Hold the plate by the sides and agitate slowly in the solutions. Try not to spill!! If the plate sits on the bottom it may not develop properly. The protocol for development is as follows:
    - **a.** Place in the developer for 30 seconds – the plate will turn black.
    - **b.** Wash in the first large tray for 3 minutes
    - **c.** Bleach for 30 seconds – the plate will turn clear

- **d.** Wash in the second large tray for 3 minutes
- **e.** Rinse in the wetting solution for 30 seconds
- **f.** Wipe edges with a Kimwipe to remove large drips
- **g.** Place in foam block in front of blower for a few minutes

D. You may look at your hologram after development but the images may not be visible until it is fully dry. To see the hologram shine a strong white light on the plate and look at it from the same side. You may need to tilt the light and/or the plate until you see the image in the glass. **Q3.** Can you see multicolored stripes in the hologram as well as your object? What is causing this?

E. Now generate a hologram with the laser in the sand box shining horizontally at the object. Place the plate upright a few inches in front of the object (to give some depth to the image). Repeat steps B and C.

Transmission Holograms

F. Traditional transmission holograms have used a beamsplitter to create two separate light paths, one of which is reflected off the object, then recombined on a photographic plate to create an interference pattern. However, a beamsplitter is unnecessary as long as some of the light can hit the plate directly. Therefore change your setup so the plate stands vertically behind the object in the sand box. Use an old plate to check that your plate and object are both well illuminated by the laser. You may have better success by placing the laser back on the lab jack and using fairly flat objects on the mouse pad. Repeat Steps B and C.

G. To view this hologram, shine a laser through the plate and look on the opposite side. **Avoid looking directly into the laser!** Alternatively, put the laser and plate back into their original positions and look for the image where the object used to be. If you dare, try breaking the plate into pieces and viewing the hologram of each piece.

Optional Things to Try:

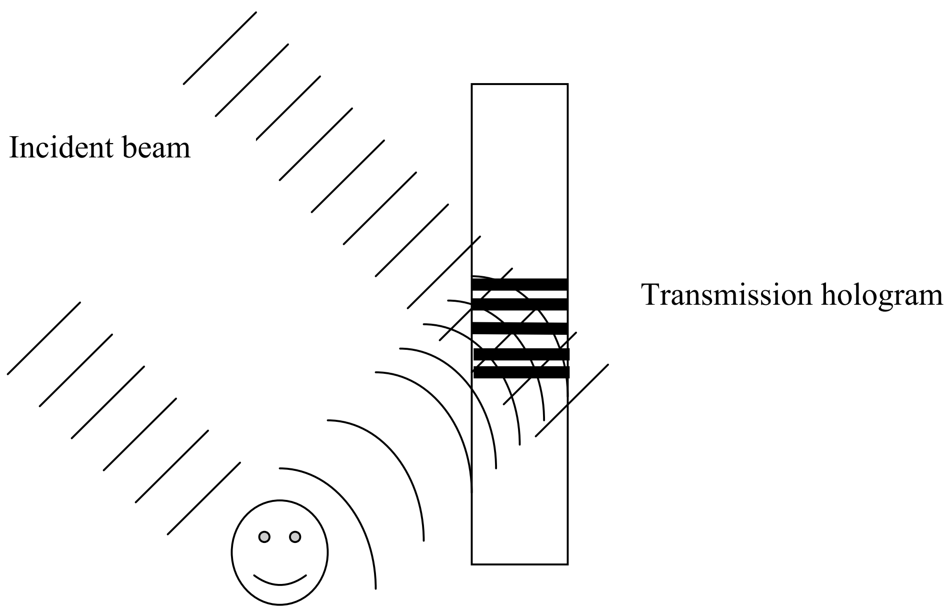
- Try making a hologram with two views of the same object. Expose the plate for 5 seconds in one position. Block the beam and move the plate to another position (make sure it is still in the path of the laser). Expose again for 5 seconds. Develop normally.
- Use a good transmission hologram to project an image, then place an unexposed plate in the middle of the image. Expose and develop normally. Try viewing as a transmission and reflection hologram.

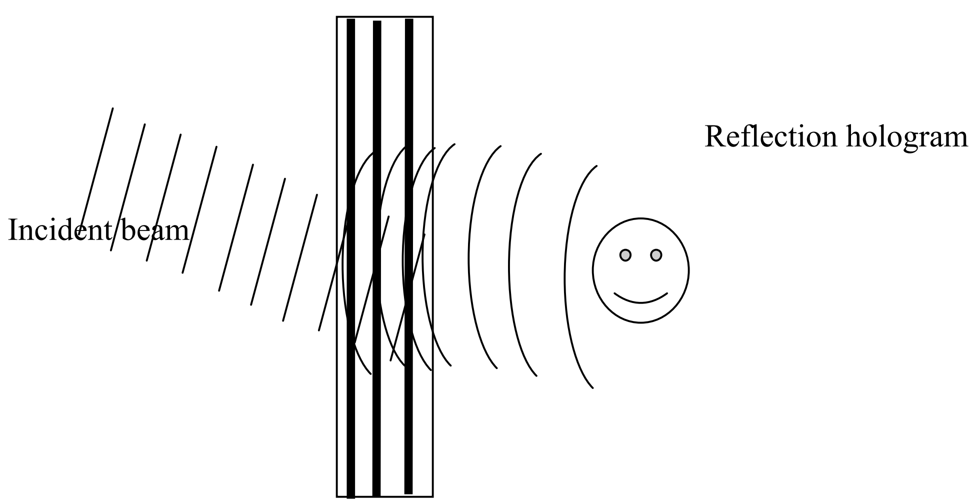
Examine the diagrams in the Appendix to answer the following questions

Q4. Why can transmission holograms be broken up and still make a whole image? Why doesn't this work for reflection holograms?
Q5. Why can reflection holograms be viewed with white light?

Appendix

A hologram is recorded pattern that results from the interference of two coherent beams of light, one of which is reflected from an object. The main difference between reflection and transmission holograms is the orientation of the interference fringes with respect to the photographic plate. In the transmission setup, the fringes lie in planes perpendicular to the plate, while in the reflection setup the fringes lie in planes parallel to the plate.





Reflection of light off one of these planes follows the Bragg equation $\lambda = 2d\sin\theta$ where d is the spacing between planes, λ is the wavelength and θ is the angle of incident light for viewing. The emulsion on the plates is much thicker (~7 microns) than the wavelength so multiple planes of fringes are created in the reflection hologram.

For more information on holograms, these websites are good places to look:

http://nobelprize.org/nobel_prizes/physics/articles/biedermann/index.html
http://www.holokits.com/holography_tutorials.htm