ECEN 4606, UNDERGRADUATE OPTICS LAB

Lab 7: Holography

SUMMARY:
In this lab you will record and develop your own holograms including a double-exposure hologram that will reveal sub-micron perturbations between the two exposures.

PRELAB:

HOMEWORK PROBLEM 1: Pedrotti\textsuperscript{3} 16-5.
HOMEWORK PROBLEM 2: Pedrotti\textsuperscript{3} 16-9, parts a and b. You can omit part c.

\begin{figure}
\centering
\includegraphics[width=0.5\textwidth]{figure.png}
\caption{Figure for problem.}
\end{figure}

HOMEWORK PROBLEM 3: Pedrotti\textsuperscript{3} 16-12.
HOMEWORK PROBLEM 4: Pedrotti\textsuperscript{3} 16-10.

DESIGN PROBLEM: None this week.

TECHNICAL RESOURCES:

TEXTBOOK: Chapter 16
LECTURE NOTES: Lecture 7, Holography.

EQUIPMENT AVAILABLE:
- A JDS Uniphase 1103P-3020 helium neon laser.
- Various objectives to create an expanding beam. Various lenses and mirrors are available for the “extra credit” section.
- Slavich PFG-03M\textsuperscript{1} 2.5” x 2.5” holographic film plates. The active layer is a 7.00 ± 0.01 micron thick suspension of silver bromide (n=2.25) in gelatin (n=1.52) on BK7 glass. Optical properties at 633 nm\textsuperscript{2}: \(n_{BK7}=1.5151\), \(n_{emulsion}=(1.569 \pm 0.002)+j(0.00099 \pm 0.00011)\). Ultra-fine grained emulsion with 10 nm grain diameter.
- JD-4 holographic developer kit\textsuperscript{3}
- Chemical safety goggles and gloves – use them.
- Film plate box for storing exposed but undeveloped films.
• Optical power meter with 1 cm\(^2\) active area
• Hard reflective objects attached to a stiff, flexible surface. Bring in your own objects if you’d like to try them, but they should be shiny and hard (metal is good).

**LAB PROCEDURE:**

**STEP 1: RECORD SIMPLE REFLECTION HOLOGRAM**

• Figure 1 shows the basic setup. We will use an expanding red beam to record a reflection hologram. The film should be placed as close as possible to the objects to minimize any vibration that can occur between them. The next question is distance from the objective to the film.

• The developer we are using increases the film sensitivity an order of magnitude. Thus the sensitivity quoted by Slavich of 1.5 to 2 mJ/cm\(^2\) is improved to 0.15 to 0.2 mJ / cm\(^2\). For a fixed laser power, this reduces the exposure time by a factor of 10 which in turn reduces the chances of vibration destroying your recording. We will be using stop watches and manual shutters to time the exposures, so in order to be accurate we need at least several seconds of exposure. Calculate the intensity you need and select an objective and distance to 1) expose the entire hologram with moderately uniform intensity and 2) require as short an exposure as possible with a lower bound of several seconds.

![Figure 1. Reflection hologram recording configuration. The hologram can be slightly tilted so that during reconstruction the light source does not have to be directly behind the observer.](image)

• Block the beam with your “shutter”. Hang the “DO NOT ENTER” sign on the outside of your door. Locate the film container and your stopwatch. Turn off all lights except the green night-light. The light should be positioned to provide only indirect light on the table. You may want to wait a moment to let your eyes adjust to the darkness. Open the film container and remove one plate. Tightly close the box. Identify which side has the emulsion by touching it in a corner with a damp finger – it should feel slightly sticky. Place the film in its mount with the...
emulsion facing the object. Place the cover over the recording area to shield it from air currents and room lights.

- Move as far away as possible from the recording area and prepare your stopwatch. Then hold completely still to let the air currents settle. Lift the shutter slightly off of the table while keeping the beam blocked. Wait 10 seconds for any table vibrations to settle. Lift the shutter just out of the beam path and start the stopwatch. When it reaches your exposure time, smoothly move the shutter back into the beam and set it back on the table.
- Place the exposed film in your exposed film container and make sure it is closed.
- Repeat the procedure with half and twice the calculated exposure time, placing the films in the box in order so you know which is which.
- Remove the “DO NOT ENTER” sign from the door.

_In your lab book:_

1. Record your setup, exposure times and any notes on procedure.

**STEP 2: DEVELOP YOUR HOLOGRAM**

- Read and understand the development procedure shown in Figure 2. The various liquids should be laid out, left to right, in the order shown and clearly labeled. You need to do this procedure in near darkness, so familiarize yourself with the arrangement.
- Put on your chemical goggles even if you wear glasses (they will fit over them). Put on one latex glove and use that hand exclusively to hold the film until you dry it. Place a clean paper towel on your bench near a wall – this will be your drying rack.
- Turn the room lights off and make sure your “DO NOT ENTER” sign is again on the door.
- Open your exposed film box and remove one film. Place it glass side down in the developer trays to avoid scratching the soft emulsion.
- Use your stopwatch to time the process. Once you reach the wetting stage, you may wish to turn the room lights on so you can see the surface of the hologram. Try to remove it smoothly from the solution avoiding any drips or runs on the surface.
- To dry the holograms, set them nearly vertically on the paper towel with the glass leaning on the wall.
- Repeat for all exposures. If you turn the lights on after the bleaching step, remember to turn them back off again before you open the exposed film container.
- Once all films are developed, remove the “DO NOT ENTER” sign. You can use the hair drier to speed the drying process, but be careful not to heat the films – stay well back from them.
Use a sharpie pen to number the holograms on the glass side and note which is which in your notebook. Label them in a corner in such a way that you can tell front (glass side) from back (emulsion side).

View your holograms with various light sources.

In your lab book:
Note your observations. Which side do you need to observe from? Which holograms were brightest, most clear, etc. What light sources work best and why? What color do you see and why? What is the impact of tilting the hologram?

STEP 3: HOLOGRAPHIC INTERFEROMETRY

- Place the micrometer behind the object plane and adjust it until it is touching but putting very little force on the object. Examine the scale on the micrometer and practice moving it 5 microns farther into the object. You will need to do this in the dark without bumping the setup, so practice it several times including memorizing how far you have to turn. Record the starting position.
- Repeat the recording procedure that yielded the best results using HALF the total exposure time.
- Without turning the lights on, move the micrometer as you practiced. Do not bump anything on the table, particularly in the recording area.
- Repeat the recording procedure with the same film, again using half the total exposure time.
- Record the actual amount you moved the micrometer by reading it once the room lights can be safely on.
- Develop the film as in step 2.
- View the hologram using the best setup you found in step 2. You should see the object painted with an interference pattern.

In your lab book:
Quantitatively explain the interference pattern. If possible, take a photograph of the reconstructed image and label the fringes.

STEP 4: EXTRA-CREDIT – FUN WITH HOLOGRAMS
If you have time, play. Suggestions:

Presoak
DI water
20-30 sec

Develop
10 sec
Hologram will turn black

Rinse
DI water
3 min
with agitation

Bleach
Agitate until clear (up to 1 min) + 10 sec

Rinse
DI water
1 min

Wetting
DI water
20 sec
Avoid streaks or runs

Dry

Figure 2. Summary of development procedure.
1. Try different objects.
2. Repeat step 3 but use temperature to deform the object.
3. Record multiple images, tilting the hologram between exposures.
4. Make a diffraction grating by intersecting two collimated beams and recording a transmission hologram.
5. Make a transmission image hologram as described here: http://www.holokits.com/a-simple_holography_2.htm

REFERENCES

1 http://www.slavich.com/pfg03m.htm
Grading Expectations

Lab Report 7: Holography (100 total points)

Name  Name and group members.
Abstract (10 points).
Introduction (10 points)
Methods (35 points)
   1. RECORD HOLOGRAM, 12 pts
       a. Figure of setup, 6 pts
       b. Description, 6 pts
   2. DEVELOP HOLOGRAM, 11 pts
       a. Description of method, 11 pts
   3. HOLOGRAPHIC INTERFERENCE, 12 pts
       a. Figure of setup, 6 pts
       b. Description, 6 pts
   4. FUN WITH HOLOGRAMS - EXTRA CREDIT! 5 pts
       a. Figure, 3 pts
       b. Description, 2 pts
Results and Analysis (35 points)
   1. RECORD HOLOGRAM, 7 pts
       a. Record of exposure times, 2 pts
       b. Analysis/comments on procedure, 5 pts
   2. DEVELOP HOLOGRAM, 16 pts
       a. Figure showing how holograms were viewed, 6 pts
       b. Discussion/analysis (what happened and theoretical reason)
          which side need to observe from?, 2 pts
          which holograms were brightest/most clear?, 2 pts
          what light sources work best?, 2 pts
          what color do you see?, 2 pts
what is impact of tilting hologram?, 2 pts

3. **HOLOGRAPHIC INTERFERENCE**, 12 pts
   a. Figure/picture of reconstructed image with fringes labeled, 6 pts
   b. Explanation, 6 pts

4. **FUN WITH HOLOGRAMS - EXTRA CREDIT!**, 5 pts
   a. Figure or figures, 3 pts
   b. Explanation, 2 pts

e. **Conclusion (10 points)** Summary of lab report

f. **References** Include any references that you used.