PHY324 - Holography Lab Report

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Abstract

In this experiment, we operated an optical setup involving a laser to create a hologram of a chess queen by recording its image on a photographic plate. The 3-D image was created by recording the interference pattern of the incoming laser and that reflected by the object (the queen) behind the photographic plate. The plate was developed and the quality of the image analyzed.

1 Introduction

Holography is a technique of using a laser (or any other monochromatic light source) to produce an 3-D image on a prepared glass plate. A 3-D image is seen in the glass plate as it contains all the information carried by the wavefront, and by viewing the plate from different view points (parallax), one can observe a complete 3-D image.

We encode the spatial features of an object in a wavefront by placing the object in a Michelson interferometer variant optical setup. It involves a magnified laser beam, called the reference beam, incident on a photograhic plate behind which the object to be holographed is positioned. The reference beam is transmitted through the plate and is then reflected back from the object. The relative phase shifts between the wavefronts of the reference beam and those of the beam reflected from the object encodes the shape and structure of the object. As these two beams combine at the photographic plate, an interference pattern forms. This entire process is called single-beam reflection based holography.

The interference pattern is recorded on the photographic plate by the emulsion film on it. Moreover, since the entire glass plate is exposed to the wave-fronts, one can use any smaller piece to regain all of the spatial information of the object. That is, if the hologram is broken into smaller pieces then each piece contains all the information to see the original hologram (assuming there are no internal fractures in the glass). Given a hologram, we can see the 3-D image by shining a light on the plate and viewing the plate from different view-points. This external light is forced to follow the the interference pattern encoded in the plate, thus recreating the wavefront of the original object, which one can see and interpret as a 3-D image of the object. Going back to a shattered hologram, since each piece contains all the the information to recreate the original wavefront, shining a light on any piece of the hologram, allows one to see a smaller (with less details) portion of the original 3-D image.

1.1 Materials & Apparatus

For the laser source, we used *Thor Labs'* Helium Neon Laser of wavelength 632.8 ± 0.01 nm and 5 mW power[1]. Our optical setup also included a round silvered mirror, a Newport 846 shutter with a time control setup, a circular iris to narrow the input beam, a lens to magnify the central part of the interference pattern, and a pinhole to allow only the centre of the beam to be projected to the screen. The lens and the pinhole were mounted on a carriage with three knobs to adjust the spacing between them and their position in the plane of the setup. Finally, we used a white chess queen as our model object which was held behind the photographic plate which had an emulsion on the side facing the queen. We also had access to photographic plate developing chemicals like the developer, fixer, and a dryer.

1.2 Method

Optical Methods: We first setup the optical equipment as seen in Figure 1 without the 10x magnifying lens and pinhole and a temporary un-prepared plate, and ensured the shutter was off to allow the laser to pass through and reflect off the mirror. Since the laser is a 5mW laser, we avoid direct contact with it and use a white paper whenever needed. We then adjusted the mirror via the two control knobs to center the laser such that it would pass through the magnifying lens holder and shine on the dummy plate. Moreover, we orientate the plate holder such that the angle between the laser and the normal to the plate is in between $60° - 80°$. At this point we noticed countless swirls and tiny interference pattern at the plate. We also made a light intensity measurement at the

[1] "Thorlabs - HNL050LB HeNe Laser, 632.8 Nm, 5 MW, Polarized, 100 - 240 VAC Power Supply Included." Www.thorlabs.com, www.thorlabs.com/thorproduct.cfm?partnumber=HNL050LB. Accessed 21 Mar. 2023.

center of the diffraction pattern and found it to be 1.61 ± 0.01 Lux.

We then placed the 10x magnifying lens and 25μm pinhole in the location seen in Figure 1. We ensured that when handling the pinhole, we did not touch the center to avoid introducing dust/debris in the laser's path. At this point we noticed enlarged diffraction fringes on the dummy plate and significant background "noise" which we reduced by placing a circular aperture as seen in Figure 1. We varied the aperture size until the visible "noise" on the dummy plate was reduced. This "noise" was caused by part of the laser bouncing off the edge of the pinhole reflecting back from the mirror. Placing the aperture removes the scattered beam.

Then we use the three knobs (only vertical labeled in the figure provided) to control the vertical, horizontal and lateral displacement of the pinhole to enlarge the central bright spot of the diffraction pattern to fill the majority of the dummy screen. We vary the vertical and horizontal knobs to center the central bring spot on the plate and use the lateral knob to enlarge the central spot, repeating this process until the majority of the plate is filled by the central bright spot. Once a desired central spot is reached, we recorded the intensity to be 0.61 ± 0.01 Lux. For best results we want the change in intensity with and without the pinhole to be approximately 60% to 70%. Our change in intensity was 62 ± 2 %. We confirmed the best central spot by noticing that any slight change in the vertical or horizontal knobs results in major distortions of the central spot on the dummy plate.

We turned on the shutter and set it to 1 second and removed the dummy plate, noting its relative location in the holder. Next we turned off all light except the safety lights and removed the prepared plate from its box and placed it in the holder (emulsion side towards the object and clear side towards the laser[2]) and positioned the desired object[3] as close as possible behind the plate. Pressing the shutter trigger, we exposed the plate to the laser for 1 second, and placed the exposed plate in a dark box.

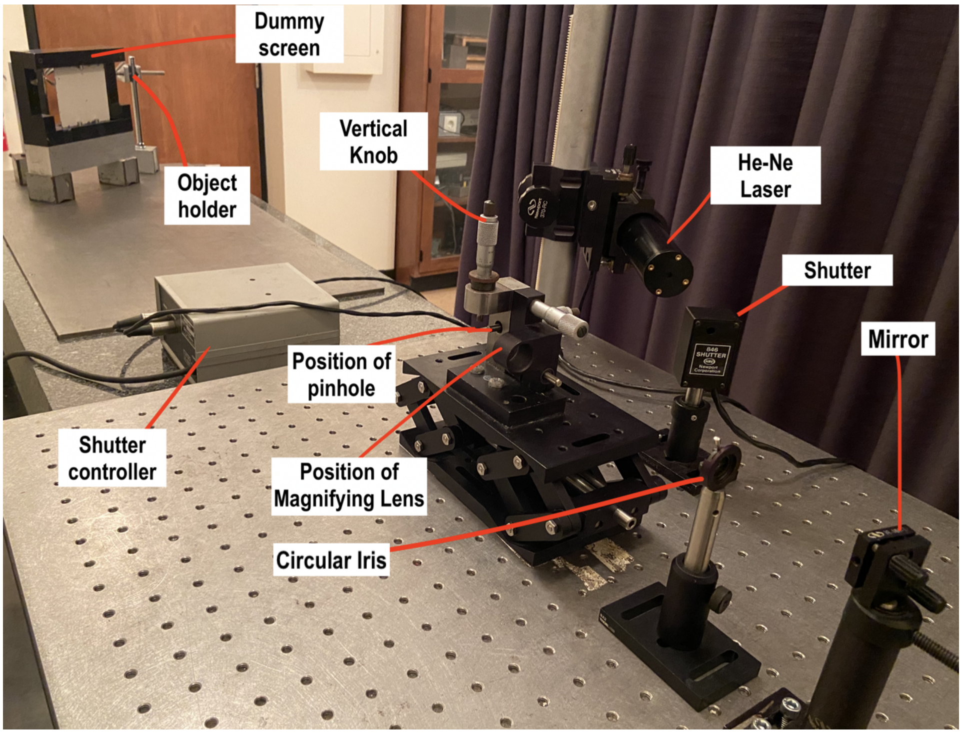

Figure 1: Experimental Setup for making a single beam hologram. The object is placed behind the dummy screen shown above. The procedure is entirely carried out in a dark room with only safety lights on. The laser exposure time to the photographic plate was kept at 1.0 s. Horizontal Knob and Lateral Knob are not labeled. All components are magnetically attached or screwed into the table to ensure components remain free of vibrations.

[2]Breathing hot air on the plate, we can identify the glass side as it will fog up, while the emulsion side will not.
[3]For best result, use a white or bright object.

Plate Development Method: We then took the plate to the development room which was again dark except safety lights. We first inserted the plate in a metal carriage that was submerged into a developer liquid (Kodak D-19 (1:1) developer), was slowly moved back and forth for 5 minutes. Then, the plate was washed with cold water on both sides to remove any leftover chemical. It was then submerged into a container holding the fixer chemical. Here, it was moved back and forth for 10 minutes. It was then removed, cleaned with cold water and allowed to sit in running cold water for 5 more minutes. Now, the plate can be exposed to light without the plate reacting to it. After removing it from the cold water bath, we observed a big dark spot in the plate. This was the latent image formed on the photographic negative before it was put into the dryer. We could not see any kind of image on the plate. It was then put into the dryer for 15 minutes so that the image can be seen. Afterwards, it was removed, the room was darkened and white light was shined on the finished plate. Then, we were able to observe the 3D hologram of the chess queen piece.

2 Results & Discussion

In Figure 2 we see the resulting Hologram of a white chess queen piece that we obtained.

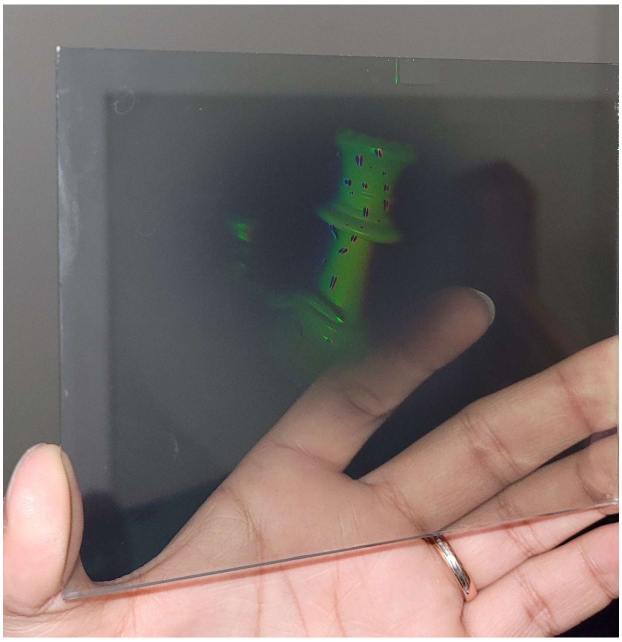

Figure 2: The developed hologram generated from an exposure time of 1 second. Notice the slight green tint in the image and the dark "spots" on the image, believe to be caused by left-over chemicals during the developing procedure. Although, not visible in the image, the plate contains physical wavelike patterns in the region of the hologram. We noticed that the the 3D image was visible for an approximately $-40°$ to $40°$ (relative to the normal of the plate) angle. Outside this range, the object gets largely distorted and hard to view.

To view the hologram more accurately, we would have to view it with a point sized white light source angled at $45°$ between the hologram and the observer as shown in Figure 3

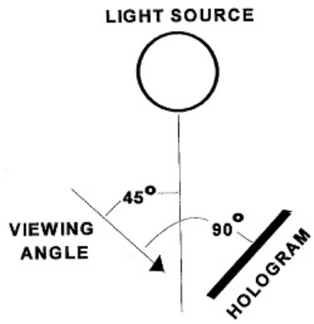

Figure 3: Schematic for the ideal viewing setup to be employed to best view the hologram image and its spatial nature. Image courtesy of PHY324 faculty [4]

As can be seen from Figure 2, although the image resembles the white color of the white chess queen as expected, it seems to have a green tinge in its color. This is caused by the shrinking of the emulsion film when the plate is developed[5]. This lowers the peak reflection wavelength and hence the hologram image appears to be green which has a wavelength of around 500 nm whereas the laser's wavelength used to create the image was 632.9 nm. Moreover, the hologram only showed the portions of the queen and the holder holding it which were facing the screen as these parts reflect the laser beam's light. We can also see some spots reflecting all light colors in the film. These can result from not cleaning the developing and fixer chemicals properly with water. More importantly, although we made sure the central bright fringe of the interference pattern on the screen was large enough to cover the full length of the queen, the bottom of the chess piece was fainter than its top. This seems to happen because the centre of the dark spot on the plate is centred at the middle of the chess piece where the intensity of the reference laser beam is higher. The top of the queen is more clear because it was tilted towards the plate to bring more spatial part of the queen in the hologram. Overall, the image quality was quite acceptable.

3 Conclusion

In this experiment, we used a single beam reflection method of holography via a Michelson interferometer to develop the 3D hologram of a white queen chess piece. We developed the hologram on a photographic plate using photograph developing methods and were able to clearly see the the white queen's hologram. We exposed the piece to the laser for 1 second with a calculated change in intensity of $62 \pm 2\%$. This lets us conclude that the exposure time and intensity difference is within the range that produces the good results.

[4] Holography. www.physics.utoronto.ca/ phy224_324/experiments/hologram/HOLIG.pdf.
[5] See footnote 4