Holography: A Swan of One Color

Alex Saines

5/05/2010

Abstract

Using a helium laser and several mirrors I constructed an apparatus such that when a laser is shined through it in a specific way it would create two beams of light that would take different paths both ending in the same place; on a light sensitive glass plate. By placing an object in the way of one of the beams so that the light from that beam was reflected off the object onto the glass plate I was able to observe the light interfering with itself. The result of this interference was a single color hologram captured on the light sensitive plate. The image was then viewable by shining a laser through the glass plate. This projected the holographic image onto the surface beyond the light sensitive plate. Using the same method twice in a row on the same plate I created a double exposure hologram of an aluminum can; once with a rubber band around it and once without. The resulting hologram showed fringes that took the form of ovals and allowed me to measure how much the rubber band deformed the can. I found that my rubber band caused an indentation of $1.1 * 10^{-6}$ m.

1 Introduction

Holography was first discovered by Dennis Gabor in 1947. The first holograms that Gabor created were done using a Mercury lamp and did not have well defined figures within them. These dim figures aroused little interest until 1960 when after the invention of the laser holograms became much clearer rekindling research into Holography. This resurgence of research resulted in several new methods of hologram creation eventually resulting in the discovery of multi color holograms, or white light holograms. These new holograms are made using multiple colors of light and can be viewed under normal non-intense light.

2 Theory

The key to understanding the creation of holograms is to understand that light can interfere with itself. This is achieved when two beams of light with similar wavelengths travel different distances from one place to another. When the two beams intersect at the end point they interfere with each other creating a composite light with a different phase than the originals. This new composite light shows the difference in the distances that the two beams traveled and shows up as fringes, or circles/ovals of brighter and darker hues. Each fringe represents a complete cycle of interference between the two beams of light (one full wavelength of interference); the darker hue corresponds to a the cancellation of the two interfering waves. Because each of the fringes that are created represent one wavelength, one light to dark progression, we can actually measure the difference in distance that the light has traveled between the two beams using [2]

$$d = \lambda * f \quad (1)$$

where d is the difference in distance traveled, λ is the wavelength of the light, and f is the number of fringes seen.

Fringes are nice and have a clear meaning, but the same principal can be used to make $3D$ pictures known as holograms as well. A hologram can be made using any object. This can be done in the same manner as described before but one of the beams of light has to reflect off of the chosen object towards the end point. The interference pattern that appears when the object is used does not take the form of fringes. This is because all of the rays of light which make up the beam are traveling slightly different distances than all of those around them as they are reflected off the object and towards the end point. All of the slightly different wavelengths that are then seen make up a gradient which gives the image the illusion of depth as your eyes view the result of the interference.

3 Procedure

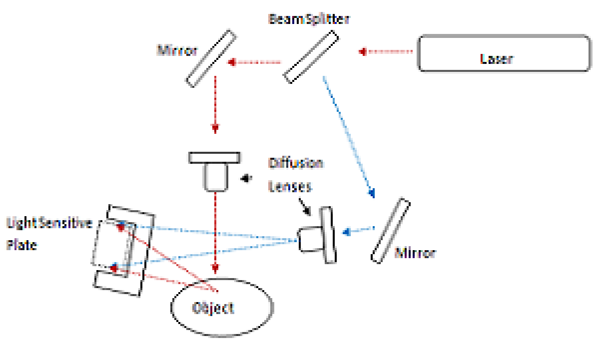

Figure 1: This diagram shows the setup that I used and the path that the laser travels to create the hologram. Path A is red and is called the object beam while path B is blue and is referred to as the reference beam.

Figure 2 shows the setup that I used to create my holograms. The laser that I used was a Helium-Neon laser which has a wavelength of $3.7 * 10^{-7}$ m. Path A is the red path or the object beam, and the blue beam is path B and is referred to as the reference beam. For this setup I required a dark room as the plates that I was using to capture the holograms on were sensitive to red light and would be unusable if exposed to white light. I used lenses to diffuse the light so that I would get more of the object in the image instead of just a small part of it.

I began by turning off all of the lights within the dark room, then I turned on a green light and let my eyes acclimate, after which I removed an exposure plate from light proof case and placed it in the spot marked as the Light Sensitive Plate in figure 1. Once this was accomplished, and the case from whence it came was closed again to protect the unused exposure plates, I switched on the laser. The exposure time for each plate is not set and can be varied between 6 and 15 seconds, I used an 8-9 second exposure time. After the plate was exposed I turned the laser off and began the development process with the lights still off.

Development is a five step process; the first step is a two minute bath in a one gram of Cartechol, 0.5g Assorbic Acid, 0.5g Sodium Sulfite, 3.75g Urea, and three grams of Sodium Carbonate per 50 ml. As the slide soaked in the bath I slowly moved it back and forth then turned it over every half minute or so (I did this for all of the steps during this process), this should turn the exposed slide black, or at least dark. Then three minutes under running water followed by a bath in a diluted bleach solution until the slide was clear, then another three minutes under running water. The final bath was Form-a-Flow for three minutes, no rinse afterwards. Once all of the baths were completed I set the exposed slide on the counter to air dry for roughly 15 minutes. At this point the exposed slide was no longer light sensitive and I was able to turn the lights back on.

Using this process I first made a hologram of a swan to make sure that my methods were correct and to iron out any possible errors that might occur. The second object I did required a double exposure. Using the same exposure procedure I exposed a plate once to the object, then I turned the laser off, modified the object, and exposed the slide again. I did this to an empty aluminum pop/soda can so that I could test equation 1. I modified the can by placing a loose rubber band around it on the second exposure, planning to calculate the the depth to which the can was deformed by the rubber band.

4 Results/Analysis

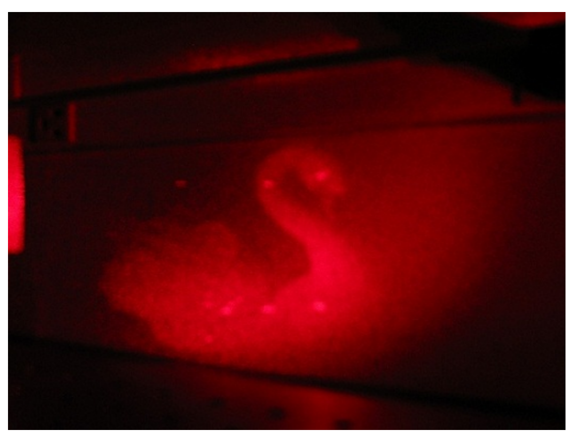

Figure 2: This is a picture of the best Swan hologram that I created being projected on the wall of the darkroom with the same laser used to create it.

My best test hologram, as shown in figure 2, was of a porcelain swan. The bright points that are seen on the swans projection were caused by highly reflective areas on the swans surface. The neck and bill of the swan are clearly visible as are the tail feathers;

however the bottom of the swan is excluded because it was sitting on a wooden base that was wider than it was, and thus the wood blocked a good bit of the light that was reflecting off of the bottom of the swan. Figure 2 shows that I was able to successfully create a hologram using my setup, knowing this I moved on to testing the theory using the pop/soda can double exposure.

Figure 3 is a picture of my fourth hologram on which I did a double exposure. The cylindrical object in the foreground is the can which I used to create the projected hologram. It is present simply because of the angle at which I was taking the pictures of my projected double exposure.

I was able to discern three fringes using the projected hologram, which if connected across the rubber band create oval-like shapes. So in accordance with the theory and procedure sections I multiplied the wavelength of the laser light ($3.7 * 10^{-7}$ m) that I used by the number of fringes counted (three) and received $1.1 * 10^{-6}$ m.

Figure 3: I was able to count three fringes using the pictured hologram. The ovals are not easily discernable as they merge in several areas. But if you look at the central band on the cans projection three general ovals can be found.

5 Conclusion

I tested the theory that holograms work off of the principles of basic light interference. Using a setup based on this idea was able to create a fuzzy hologram of a small porcelain swan figurine. To test equation 1 I used a double exposure method on a pop can with a rubber band to deform said pop can. This created a hologram with apparent fringes on it of which I counted three. I then used equation 1 with $3.7 * 10^{-7}$ m as the value of λ to find that the rubber band caused an indent of $1.1 * 10^{-6}$ m on the can.

6 References

1) Wooster Physics Staff, *Junior I.S. Manual*, 2010

2) Hans C. Ohanian John T. Markert, *Physics for Engineers and Scientists*, Norton Compnay [2007], Third Edition, pages 1169-1174

3) Wikipedia, *Holography*, modified 3/1/2010 [http://en.wikipedia.org/wiki/Holography]