Beginning Holography

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Abstract:

Holography is a unique process to capture an image on film. This paper will define what holography is and the process to create holograms. It will show how a person who knows nothing about holography can render a hologram from start to finish.

Introduction

Holography, like photography, is a technique that produces an image on film.[1] The method by which a hologram records and produces an image is very different from conventional photography. Standard photography creates on film the two-dimensional image of an object. The film image is called a negative; it is a two-dimensional image on the film is of a single, unchangeable viewpoint. Holography captures the third dimensional aspect of the image; the third dimension of the image is collapsed onto the plane of the film. Instead of capturing the image by the reflection of light on an object, the interference pattern of an object is captured. Since the interference pattern has a higher resolution, holography is suitable to more specific applications such as medical imaging or scanning electron microscopes where a higher degree of resolution is required.[2] While the technology of holography can be complex, the basic process for making holograms is not.

What is a hologram?

A hologram is a light wave interference pattern, recorded on a photographic plate, that can produce a 3-dimensional image when illuminated properly. An interference pattern is

required to create a hologram; a source of coherent waves is needed to accomplish this. A laser emits light in a coherent pattern—of the same wavelength and phase—and a hologram is made by splitting the emitted light into two components. Figure 1 shows the typical configuration for shooting holograms:

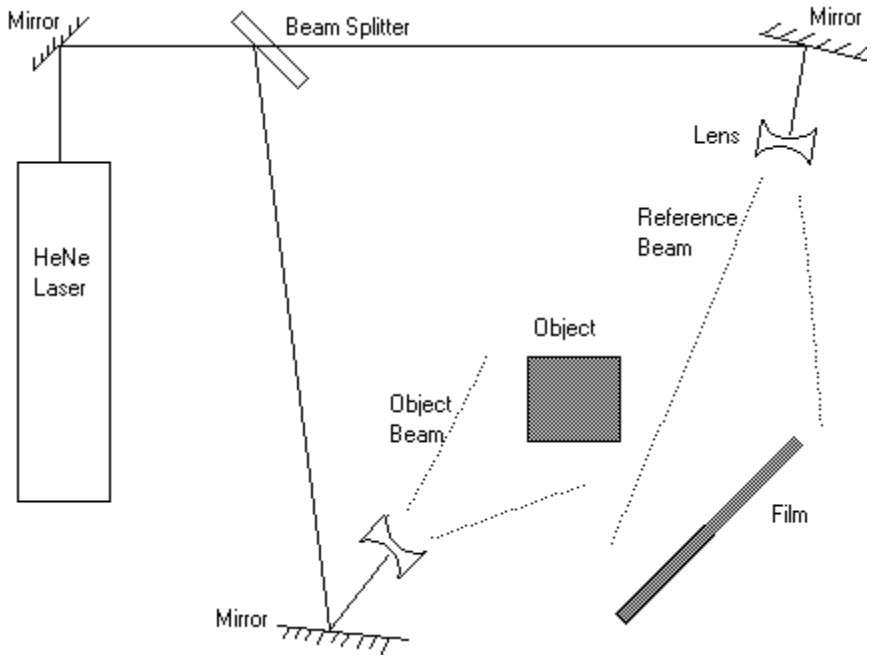

Figure 1: General arrangement of how a hologram is rendered from an object.

The laser emits a beam that is split and reflected off two full-silvered mirrors. Each beam is focused by a lens, but each beam serves different functions. The reference beam is aimed and spread at the film plate. The object beam is spread and aimed at the object. The object interferes with the light in the object beam and the pattern this interference creates is imprinted on the film plate. This is the hologram.

A hologram is viewed by illuminating it from the original direction of the reference beam. The angle is illustrated in Figure 1. A 3-dimensional image of the object appears at the original location of the object. Some holograms must be viewed with laser light while others can be viewed with white light. The main types of holograms are:

1. *Transmission Holograms*—These are viewable only with laser light. They are made with two laser beams approaching the film from the same side.
2. *Reflection Holograms*—These are viewable with white light from a suitable source such as a flashlight or the sun. They are made with the two beams approaching the holographic plate from opposite sides. This is the type of hologram most often made by beginners.
3. *Multiple channel holograms*—These are two or more images are visible from different angles. There are different types of multiple channel holograms which include:
    a. Simple: Contains two or three images viewed from different angles.
    b. Multiplex: A large number of "flat" pictures of a subject viewed from different angles are combined into a single, 3-dimensional image of the object.
    c. Rainbow holograms: The same image appears in a different color when viewed from different angles.
4. *Real Image Holograms*—These are usually reflection holograms made from a transmission original. The image projects dramatically in front of the plate toward the viewer. Most holograms seen in museums and at amusement park settings, such as the

rides in Disneyland, are of this type. The procedure for making them is elaborate and demands precise control of angles.

5. *Mass-Produced Holograms*—There are three types commercially manufactured. These are:
    a. Embossed—made by stamping on foil-backed Mylar film and using a metal master.
    b. Polymer—made from light sensitive plastic. The Polaroid Corporation mass produces holograms by this method. Credit card holograms are of this type.
    c. Dichromate—holograms on jewelry and watches. They are recorded on a light sensitive coating of gel that contains dichromate.[3]

Making holograms

The easiest kind of hologram for the beginner to make is the reflection hologram. The process outlined below is for this kind of hologram. Here are the things needed:

1. A helium-neon or 632 nm diode[4] laser. Helium-neon lasers, which are more expensive, have been recommended because of their better TEM (Transverse Electromagnetic Mode)[5]. The TEM refers to the degree of fineness of the beam's spread across a surface. The lower the designation, the less divergence the beam has at a distance. For holography, a laser emitting a beam of TEM_{00} is required. In the past few years semiconductor lasers have demonstrated a capacity to emit the needed TEM_{00} required for holography. The semiconductor laser is cheaper and easier to set up; it requires fewer external components and is smaller. Whichever method is

chosen, the laser should also be selected for its power output. The higher the output, the shorter the exposure time which reduces the effects of vibration. A 20-35 milliwatt laser works best for clean exposure.

2. Safety goggles that block light in the 632.8 nm band. When using a laser, be sure to wear safety goggles. Because of the coherent waves emitted by the laser, the light can damage the eyes and could cause blindness.
3. A 10x to 20x lens.
4. An object to be rendered.
5. A holographic plate. A Slavich PFG-01M is a good choice. A 2.5 in by 2.5 in glass plate would be best.
6. A sturdy table and mounts for the laser, optical components, model, and holographic plate. It is best to make your own table out of a 12" by 48" by 1½" piece of sturdy lumber. Get four 12" square by ⅛" pieces of steel plate. Purchase four small tire inner tubes, the ones used for lawn tractors work well. Use old cinder blocks for the bases and place the inflated inner tubes between the blocks and table for cushion. Additionally using a carpet remnant will help to eliminate vibration.
7. A room that can be darkened without too much air movement or vibration. It should be kept at a stable temperature. When ready to create holograms, turn the heater or air-conditioning system off.
8. One or more green safe-lights—25 watts or less.

9. Developer. Solution A: 20 grams pyrogallic acid in one liter of distilled water. Solution B: 60 grams sodium carbonate in one liter of distilled water. The A and B solutions should be mixed just before development is started.
10. Bleach: 4 grams potassium dichromate and 4 ml sulfuric acid per liter.
11. Kodak photo-flow solution to keep the plate from spotting when drying.
12. Darkroom utensils: Four 5 in by 7 in white plastic trays. Disposable gloves. Small plastic tongs. Green safe-lights.
13. A hair drier. It should be cautiously used to dry the hologram without scorching it.[6]

Setting up

Begin by constructing the isolation table. The cinder blocks are used to support the table at its corners. Place the carpet remnant, cut to size, on top of the cinder block. Place the inner tubes on the blocks. Place the steel plates on top of the tubes before mounting the table on top of the legs. There should be no fastening of the table to the legs, it should sit firmly on them without tipping. Check the level of the table with a bubble gauge and shim between the steel plate and the inner tube. Do not place the shim between the tube and the carpet remnant.

The key to making quality holograms is removing any possible vibration on the table. Vibrations will cause destructive interference in the laser beams which will yield a distorted image imprinted on the film. Air currents, changes in temperature, walking, or making any contact with the table will cause destructive interference. The optical components that are used—beam splitters, lenses, and mirrors—will increase the destructive effects of vibrations. All

optical components should be mounted on steel shafts placed in square metal bases for additional stability.

If there is concern about the magnitude of the vibration on the table, check the level of destructive interference with a Michelson interferometer.[7] The typical set up is illustrated in Figure 2.

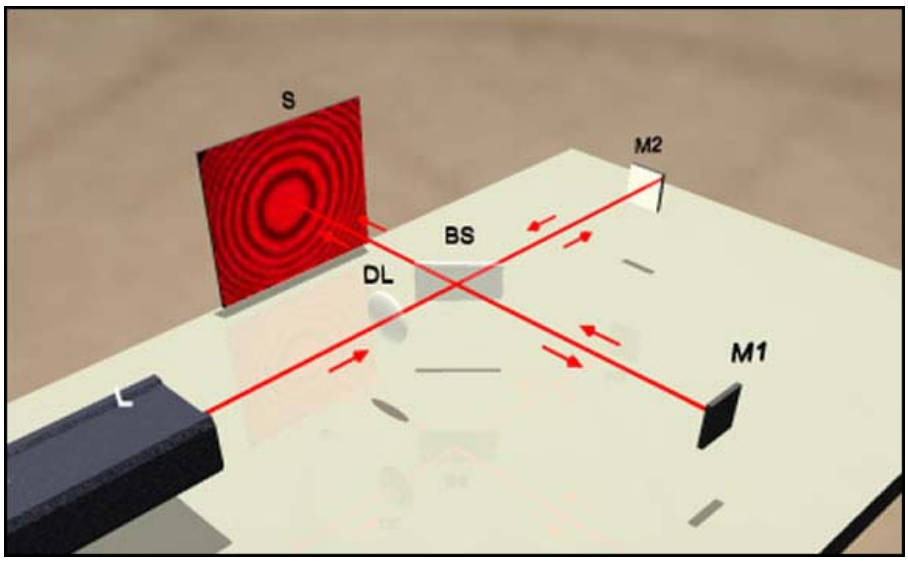

Figure 2: Using a Michelson Interferometer to check the level of destructive interference.

The laser beam is split into two components and upon reflecting back, creates an interference pattern captured on the film plate (S). If the circular interference pattern is smooth and regular, there is minimal destructive interference.

Exposure

Set up the apparatus according to Figure 1. Do the alignments in green light. Align the beams as to get a smooth interference pattern. Use a piece of discarded holographic plate to

assure a good coverage of the beam on the plate. Use a small white card to trace the path of the beam and block it.

Replace the discarded plate carefully with a good unused holographic plate; the emulsion (sticky) side of the plate should face the object. Feel the edges for firm seating. Secure any unused plates in the original box. Wait a few minutes for the temperature to stabilize from contact with the apparatus.

Make no unnecessary motion. Be absolutely certain there is no contact of body parts or clothing with the table. Lift the beam blocking card off its support, still blocking the beam. Wait without moving 30 seconds to one minute. Gently lift the card off the beam for 6 to 10 seconds, then put it in its original position to block the beam again.

Development

Now the plate is ready for development. Set up four 5 by 7 trays labeled *developer, water, bleach, and photo-flow* under the safe-light. Use gloves when handling chemicals. Place 200 ml distilled water in the water tray, 100 ml bleach in the bleach tray, and mix the photo-flow solution according to the instructions on the bottle. Do not mix the developer ahead of time as its shelf-life is about 15 minutes, instead, wait until the exposed plate is ready for development.

1. In tray #1, mix 50 ml solution A and 50 ml solution B with and 100 ml distilled water. Place the plate in the tray emulsion side up. Lift one end of the tray gently every few seconds for agitation. In about 2 minutes the exposed surface will be dark.

2. Wash the plate for the first time by placing it into the water tray for three minutes to remove the developer. Keep the plate vertical as to prevent the solution from pooling.

3. Place the developed plate in the bleach tray face-up and agitate gently. Continue until all the silver coating is gone.

4. Return the plate to the water tray. Repeat steps 2 through 4.

5. Dip the plate in a photo-flow solution, drain well, and blot lightly with lint-free cloth. Do not wipe. Finish drying with warm air from a hair drier, using a rapid sweeping motion.

6. View with a penlight to see if any pattern is there.

The viewing direction is approximately the opposite of the direction of the light reflected off the object when the hologram was made (Figure 3). In other words, the angle between the line of sight towards the image and the line of illumination should be the same as the angle between the reference beam and the object beam.[8]

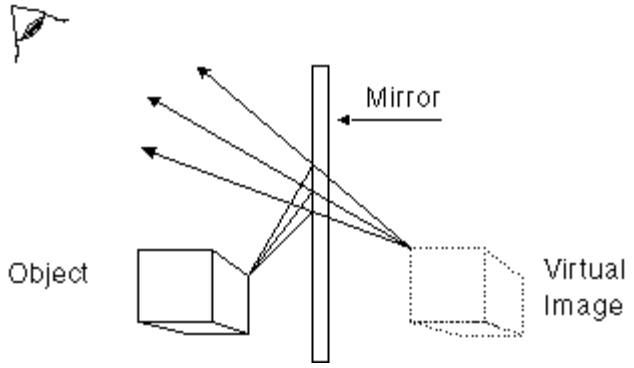

Figure 3: Viewing the hologram.

Once the hologram is completed, it should be wrapped in tissue paper and placed in a small padded envelope for storage. The envelope should be kept in a cool, dry place. By making a reflection hologram, the beginner can display it using a laser, a flashlight, or the sun as a light source. This makes the hologram easily transportable where it can be shown at home, school, or parties.

Conclusion

This paper has outlined the process of creating holograms. The beginner can make some great holograms after the first few tries if vibration can be eliminated from the table. If vibration continues to be an issue, try using a higher powered diode laser. These lasers can shorten exposure times lessening the reliance on the types of cushion supports used for the table.

References/Endnotes

[1] Smith, Howard, *The Principles of Holography*. (Wiley, New York, 1969), p.2.

[2] Ibid., p.3.

[3] Saxby, Graham, *Holograms, How to Make and Display Them*. (Focal Press Limited, London, 1980), pp.38-4, 66-72, 113-4.

[4] Hecht, Jeff, *The Laser Guidebook*. (McGraw-Hill, New York, 1992), p.97.

[5] *T*ransverse *e*lectric and *m*agnetic mode. A TEM mode represents the electric and magnetic field vectors across the diameter of the lasing surface. A designation of TEM_{00} indicates the smoothest energy distribution of the laser across the beam's diameter, minimum diffraction losses, minimum beam divergence, with focusing to the smallest possible spot.

[6] Ibid., pp.55-60.

[7] Ibid., pp.20-2.

[8] Ibid., pp.55-60.