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Holography: Capturing the Third Dimension

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HOLOGRAPHY: CAPTURING THE THIRD DIMENSION

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Introduction

Holography, the three-dimensional recording of interference patterns on film, has unlimited possibilities in the fields of science, art, technology, and media. Three types of holograms, the "flat" or plane, circular, and white light, are presently being produced successfully and inexpensively in the high school situation. The novelty of holography arouses curiosity while allowing the student to experience the application of interference phenomenon.

Purpose

The intention of this article is to give the reader the information necessary to produce the "flat" hologram. This type is the most practical for a high school since it provides a maximum effect at a minimum expense.

Equipment

I. Commerically Available from Edmund Scientific, Edscorp Building, Barrington, New Jersey 08007.

1. 2 half-silvered, front-surfaced mirrors, 2 cm x 4 cm
2. 2 full-silvered, front-surfaced mirrors, 2 cm x 4 cm
3. 1 full-silvered, front-surfaced mirror, 10 cm x 10 cm
4. 20 sticks of modeling clay used for mirror and lens supports
5. Holographic film or other film of equally high resolution
6. Miscellaneous diverging lenses with small diameters and short focal lengths, approximately 8 to 10 mm focal length and a 1 cm aperature
7. Helium-neon laser, 1.0 mw or greater
8. Dark room chemicals may be obtained from your high school dark room. The chemicals needed are common developer (Dektal), stop bath, and fixer.

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II. Constructed Equipment.

1. A work table made either of a concrete slab 24" x 30" x 4" or an equal sized sand box. Either one should be rested on rubber (inner tubes work well) to diminish room vibrations.

2. A dark room may be improvised with black plastic and scrap wood.

3. Six pieces of wood 1" x 2" x 8" with narrow slits cut ½" longitudinally on the 8" side. These are used as film holders and holders for light shields.

Preparation

I. Equipment Set-up

1. Arrange the apparatus similar to Fig. 1 and Diagram 1. The geometry may differ, but the two beams should strike the film nearly normal to its surface. Also it is important that the length of the object beam and the reference beam be approximately the same.

2. Success is easiest to obtain if the object chosen has a high reflectivity (*i.e.*, coins, keys, jewelry, etc.).

3. Since the film is recording the interference pattern produced by wavelengths of approximately 1/100,000 of an inch, the vibrations caused by the holographer must be damped out. The specially designed table and a "quiet time", during which no unnecessary motion or sound is produced, are used for this purpose.

II. Beam Ratios

Place a small piece of construction paper in the film holder to adjust and align the beams. The intensity of the beam passing directly from the laser to the film, the reference beam, should be approximately equal to that of the object beam. To alter the intensity, change the placement of the lenses or discard a portion of the appropriate beam with a half-silvered mirror.

III. Final Preparations

Prepare the photographic chemicals and remove all extra equipment from the work area. Prior to the removal of the paper from the film holder, make a final check of alignment and ratios. Place a shutter (*i.e.*, foam rubber or construction paper) directly in front of the laser.

Figure 1.

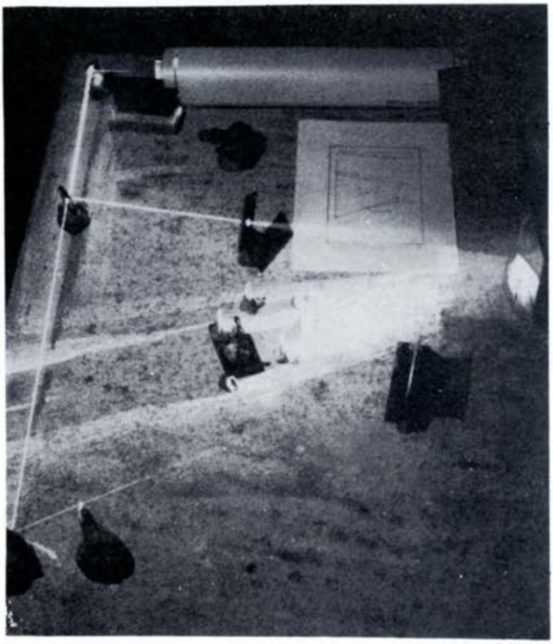
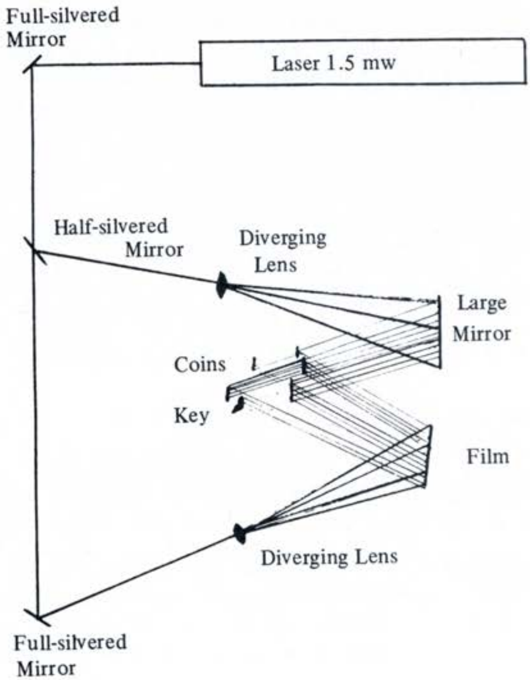


Diagram 1.



Procedure

I. Exposure

Darken the room, and block any stray light with light shields. Place a piece of film securely in the film holder. At least a one minute "quiet time" period should be allowed for the vibrations in the table to cease.

The length of the actual exposure period will vary significantly depending on the strength of the laser and the characteristics of the objects. A two-second exposure period is successful with a 1.5 mw laser and several coins that are adjusted for maximum reflection. To expose the film simply remove the shutter carefully and replace it after the predetermined time.

II. Developing

The developing times are the same as those used in most dark rooms. Suggested times: developer, 2 minutes; stop bath, 30 seconds; fixer, 2 minutes. Following these treatments rinse the film thoroughly in running water. Allow the film to drip dry. Pat drying the film results in small scratches that affect the hologram's quality.

III. Viewing

View the hologram with great care. Always use a diverging lens with the laser for direct observation both for safety and improved viewing. The observer should hold the film between himself and the diverged beam of the laser. Several different orientations of the film may be necessary to find the best image.

CAUTION: THE OPERATOR SHOULD AVOID, AND CAUTION OTHERS TO AVOID, LOOKING DIRECTLY INTO THE BEAM OR ITS REFLECTIONS. ALTHOUGH THE BEAM IS NOT NECESSARILY PAINFUL OR HARMFUL, PARTIAL OR TOTAL BLINDNESS MAY RESULT FROM SUFFICIENTLY STRONG LASERS.

A well-made hologram may be projected on a screen using the beam directly from the laser. The three-dimensional effect is only noticed when the orientation of the film is changed. This is true because the hologram is being projected onto a two-dimensional surface, the screen. A typical result is shown in Fig. 2.

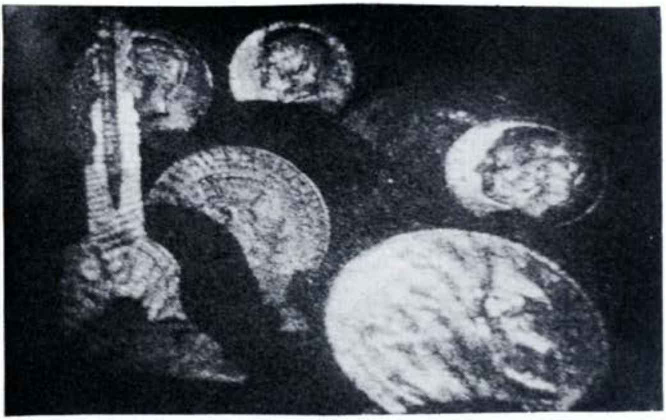


Figure 2. A flat hologram of coins and a key.

Discussion

Data recording is essential because time and materials may be conserved by avoiding duplication of error. Information to be recorded after each trial includes: beam intensity ratios, diagram of set-up, objects used, exposure times, "quiet time", and miscellaneous data which may be pertinent (Fig. 3).

HOLOGRAPHY DATA SHEET

Date_______________ Time_______________ Number_______________

Results: Good Fair Poor No Image

Exposure Time = ________ Fixer Time = 2 min.

Developing Time = ________ Beam Ratio = $\frac{O}{R}$ = ________

Stop Bath = 30 secs. Objects used:

Diagram of set up: Comments and conclusion:

Figure 3.

The vibrations must be limited to less than one-half the wave-length of the laser light or no interference patterns can be recorded. "Quiet time" is important, but like many of the variables it may be changed after successful trials are accomplished.

Different experimental variations, (*i.e.*, of geometries, objects, and exposure times) produce better than 60 percent success rates. After following the specified procedures success is normally achieved on the second trial. Subsequently, an 80 percent success rate can be achieved.

Holography does not lend itself to a typical classroom situation due to the limited space available in a dark room. To utilize holography with all its variations, either a special short course may be implemented or an established time after school can be arranged.

Unlike photography the film used for holography can be nearly clear after development and still produce a sharp image. (This is true because the actual pattern desired is too small to see. The visible lines are produced by dust particles in the air.) If the experimenter obtains a very dark film after development, the exposure time should be decreased. If the film ends up gray and no image results, the area should be checked for sources of vibrations, such as a refrigerator or pop machine.

A gray film with no image may indicate a poor beam ratio. Usually the object beam will be weak. The operator may diffuse some of the reference beam using another lens or by inserting glass plates in the beam's path. This, in turn, will increase the relative strength of the object beam.

After the reader has experienced success with these methods, he may wish to refine these techniques. Basic dark room procedures used for cleaning film, such as soap solutions, photo flo, and bleaches will increase the clarity of the hologram. Also, a film holder made of glass plates will help hold the film perpendicular to the beam paths.

References

1. Jeong, T. H. 1976. *Study Guide on Holography*. (Available from INTEGRAF, P. O. Box 586, Lake Forest, Illinois 60045).

2. Kock, W. E. 1976. *Lasers and Holography*. (Science Study Series) Doubleday Anchor.

Editorial Note: Holography is a method of recording three dimensional information about an object on film. When the developed film is viewed under proper conditions, a three dimensional image can be seen. The developed image is called a *hologram*. (The word *hologram* is derived from the Greek words *holos* and *gramma* which mean, "the graphic whole".) This technique of recording image information was introduced by Gabor in 1948. However, it was not until the invention of the laser in the 1960's that the technique could be completely developed.

In the last ten years, holography has been applied to many areas of human endeavor. Holography has been used in information storage, information transmission, production of three dimensional motion pictures, investigation of architectual structures and non-destructive testing of mechanical devices. Holography has also been used as a commercial display technique and an art form, but these latter applications have received little consideration.

Holography has not yet been applied specifically to the field of education, but it is expected that it will be developed into an educational medium in the future. Exploration of chemical models, of families of mathematical curves, of geometrical designs and of plant growth are a few of the fields currently being considered for educational development.