THE APPLICATION OF HOLOGRAPHY TO TRAINING DEVICES

ALFRED H. RODEMANN
Physical Sciences Laboratory
Naval Training Device Center

Holography has been one of the most exciting scientific developments in recent times. During its short history it has created more interest than almost any other scientific phenomenon, with the exception of the Laser, which has played such a great role in the development of holography. The list of interested groups continues to grow and includes such fields as data storage, quality control, and even medicine.

What does holography have to offer to training devices? It is the only means of presenting a true three-dimensional image from a two-dimensional medium without the use of lenses or other optical aids. For true visual simulation it has no equal. The three-dimensional image possesses all of the properties attributed to actual real-world scenes or objects. Parallax, aspect, and focus are all present and practically indistinguishable from the real world. One can view an image which can be turned around to the other side. Objects hidden from view can be seen by moving around just as in the real world. The limitation of the two-dimensional visual simulation world are overcome without discarding the two-dimensional medium.

What is a hologram? A great deal has been written describing the physics of and the necessary parameters for the making of holograms. This afternoon, however, I would like to present to you a simple explanation of how a hologram is made.

To begin with, in conventional photography, if we expose an object directly to a photographic plate we do not get anything but a fogged plate (Figure 20). This is because the photographic emulsion only has the ability to record amplitude or intensity of the light falling upon it. Since the whole object facing the photographic plate scatters light over the whole plate we end up with a fairly even illumination across the plate and nothing else.

Therefore in photography we have to insert a lens in between the object and the photographic plate. The function of this lens is to direct the light from point A on the object to point A^1 on the photographic plate (Figure 21). The same goes for point B and so on. In this way the object intensities are transferred or imaged onto the photographic plate, point by point over the entire object. But we have lost some information by this process, namely the depth of the object. The image on the plate is only two-dimensional.

In holography we can use the coherent properties of laser light to provide more information on the photographic plate which will give the third dimension to the scene. We start out with the same object and photographic plate set-up as we did before (Figure 22). We now illuminate the object with laser light (beam #1) and split off part of the laser light and shine it directly onto the photographic plate at an angle (beam #2). This second beam we call the reference beam. The object reflects or scatters the light in the direction of the plate and this scattered light combines with or modulates the reference beam and forms an interference pattern. This pattern is one of lights and darks caused by the constructive or destructive interference between the two beams. Where they are in phase they will add and give a larger amplitude and where they are out of phase they will subtract and give a smaller amplitude and so on in between. In this manner we have added phase information to the photographic plate in the form of amplitude. The plate is now developed in a standard photographic fashion. The resulting interference pattern is called a hologram. To read-out the phase and amplitude information or in other words

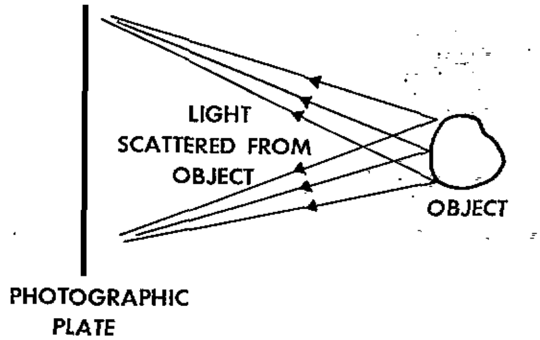

Figure 20.

PHOTOGRAPHIC RECORDING

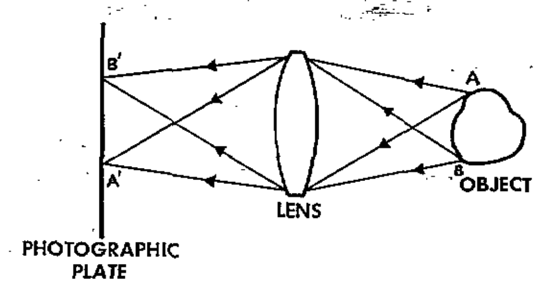

Figure 21.

HOLOGRAPHIC RECORDING

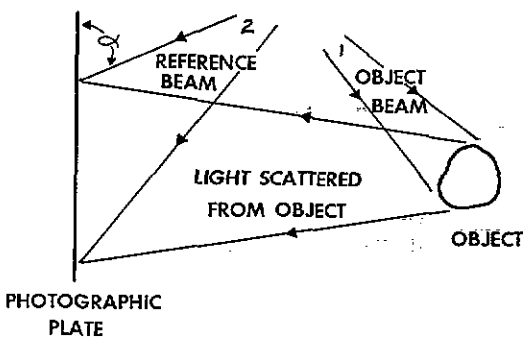

Figure 22.

HOLOGRAPHIC RECONSTRUCTION

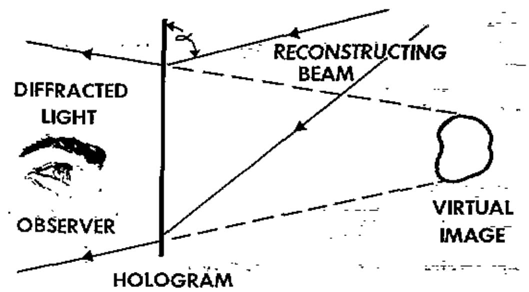

Figure 23.

HOLOGRAPHIC IMAGES

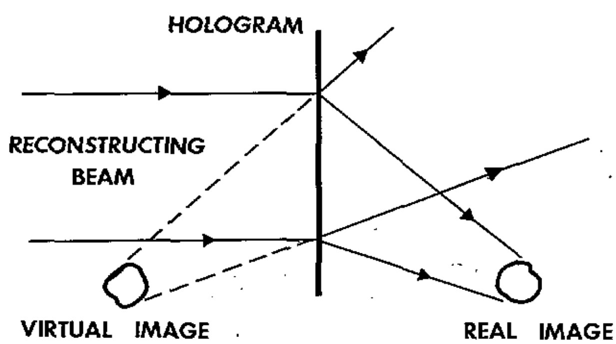

Figure 24.

MULTIPLE IMAGE HOLOGRAM

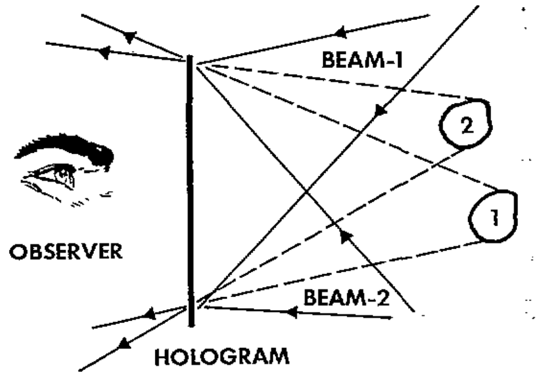

Figure 25.

CONTOUR HOLOGRAM

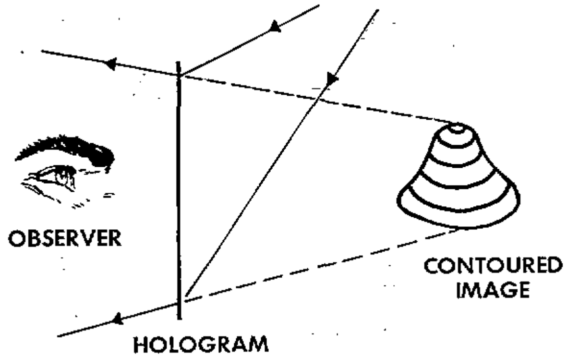

Figure 26.

RANGE RECONSTRUCTION

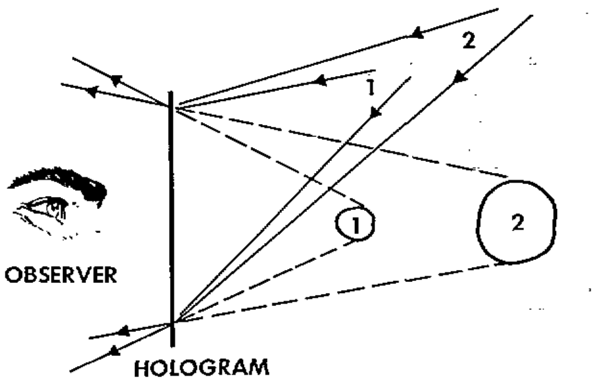

Figure 27.

HOLOGRAPHIC ZONE-PLATE DISPLAY

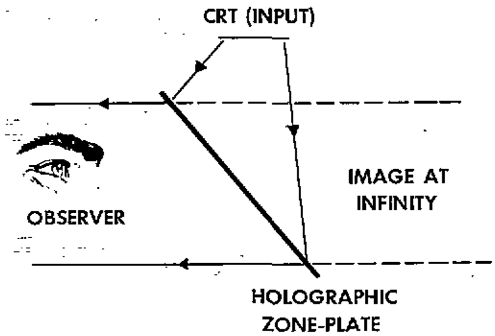

Figure 28.

REAL IMAGE RECONSTRUCTION

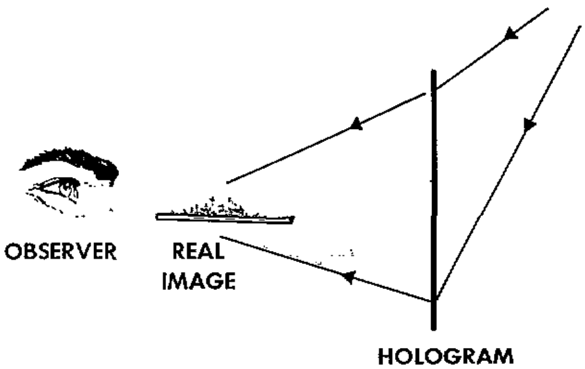

Figure 29.

to create the three-dimensional image, the hologram is illuminated by laser light or any monochromatic point-source of light at the same angle which the reference beam originally impinged upon the plate during the recording of the hologram (Figure 23).

The hologram now acts like a diffraction grating and bends the light in such a manner as to recreate the object wavefront which originally combined with the reference beam. This diffracted wavefront or beam looks to an observer exactly like it came from the original object itself. It shows all of the three-dimensional properties of the object. As mentioned before, it has parallax, aspect, and focus. It is a true three-dimensional virtual image (Figure 24).

This virtual image, however, is not the only image created by the hologram. The hologram diffracts the illuminating beam into two beams of light. One is a divergent beam creating the virtual image and the other is a convergent beam creating a real image. This real image is actually formed in the space out in front of the hologram and it also displays three-dimensional properties.

In addition to these unique three-dimensional properties of the hologram, it also possesses other attributes which are currently being investigated in our laboratory and which may become the basis for application of holography in training devices. These are the following:

1. The hologram is capable of storing more than one three-dimensional image on the same two-dimensional medium (Figure 25). Here it is possible to show a sequence of operations, flow diagrams, or built-up skeleton views all in the same visual presentation. These views can be shown separately or in sequence as desired, giving a very versatile motion picture to the trainee.
2. The hologram can be made to have accurate contours positioned on the three-dimensional image where no contours existed on the original object (Figure 26). These contours can be spaced at any desired interval over the object, even down to less than the resolution of the eye if required. By utilizing these contours on a terrain model image in a training device, more information can be transmitted to the trainee.
3. The hologram image can be made to change size by moving the light source used in the reconstruction (Figure 27). This can be applied to a simulated approach to an object or scene. The movement can be completely nonprogrammed and under the control of the trainee, providing him with a simulation of his own approach maneuver.
4. Within limits, the hologram can be made to act as an off-axis optical element to project a scene in any given direction, and at the same time acting as a fairly clear window for viewing (Figure 28). This application gives rise to the windshield type displays which can superimpose a generated scene upon an actual scene or lack of it. The hologram in this case is cleared up by a bleaching technique, thereby providing a good see-through capability. By using these windshield displays a trainee can be shown additional information as to where he should be at all times with respect to where he actually is during his training problem.
5. A real holographic image is created in the space out in front of the recording medium (Figure 29). This is an image and, of course, has no substance and therefore presents no problems for objects, such as an optical probe, to pass right through it. By using these images such trainers as landing simulators could get right down onto the deck without any physical constraints associated with a solid model.

One of the missions of the Naval Training Device Center is to develop new and more effective training devices for the Armed Services' Schools and Personnel. In keeping with this goal, the Physical Sciences Laboratory of NTDC undertook a study of holography to explore its unique properties as applied to visual simulation in training devices. This program has been active for the past three years and many new ideas and concepts such as multi-imaging techniques and contour generation have been explored and developed.

What is in the future concerning holograms and training devices? NTDC feels sure that there is great promise in applying holography to visual simulation. The work here will continue to expand, covering the many aspects of holography. Some of the future possibilities which are foreseen in training devices include the utilization of three-dimensional holographic, large screen, motion pictures and television, 360° holograms to be viewable from all directions, and complete landing and docking simulators using holograms as the visual display. As holography grows out of its infancy, many new and better ideas will develop. These ideas will become the basis for future work making "Better Training Devices through Holography."

LASER DISPLAY

A. H. MARSHALL
Physical Sciences Laboratory
Naval Training Device Center

I. INTRODUCTION

The development of the laser has made possible a new approach to a large-screen, high-brightness, high-resolution, real-time display for training device applications. This paper will describe efforts by the Naval Training Device Center and others who are striving to improve methods of display by utilizing the laser.

A large screen laser display would be useful in rapidly communicating information from a computer to a trainee and allowing him to interact with this information. A large screen real-time laser display would also be of value in presenting larger, faster, brighter, real-time tactical data to a large audience at a control center in an undarkened room.

The laser display is essentially an "open air" cathode ray tube. In a laser display system the beam is not maintained in a vacuum as in a CRT, therefore, the previous physical limits on screen size and brightness have been removed and the resolution capabilities are determined by physical optics instead of electron optics. Therefore, it is expected that the laser will provide the key to larger, brighter and higher resolution displays. The crucial areas of research are the development of efficient higher power lasers and better methods of both light deflection and modulation. Present lasers are not compact, require maintenance and lack the desired reliability for field use. A single multi-color emitting laser would also reduce the required equipment for color displays. At the present time light cannot be deflected as easily as the electron stream in a CRT, therefore, high speed, large angle deflectors must be developed.

We feel these problems will be solved and the laser will eventually be utilized in large screen displays.