

# A BASIC UNDERSTANDING OF HOLOGRAPHY

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## INTRODUCTION

Holography, or wavefront reconstruction, is a process by which the amplitude and phase variation across an optical wavefront may be recorded photographically and subsequently reproduced so that a complete three dimensional image of the original object emitting this wavefront can be seen.

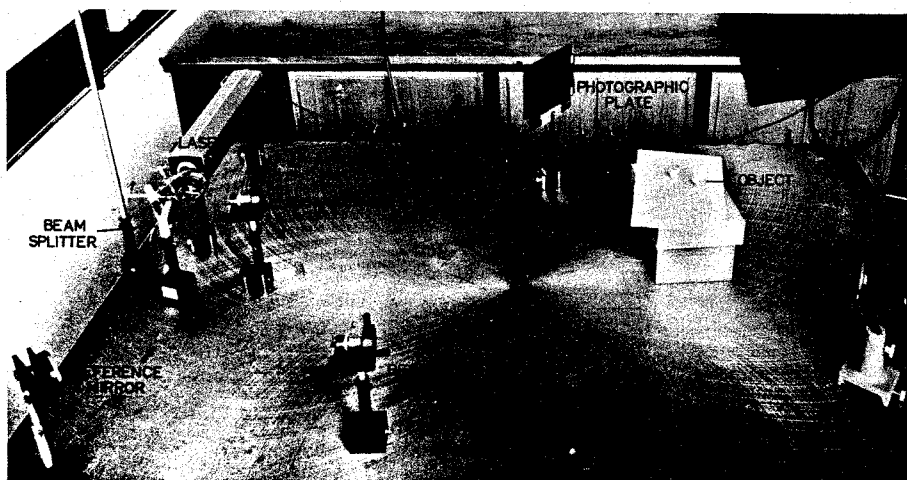
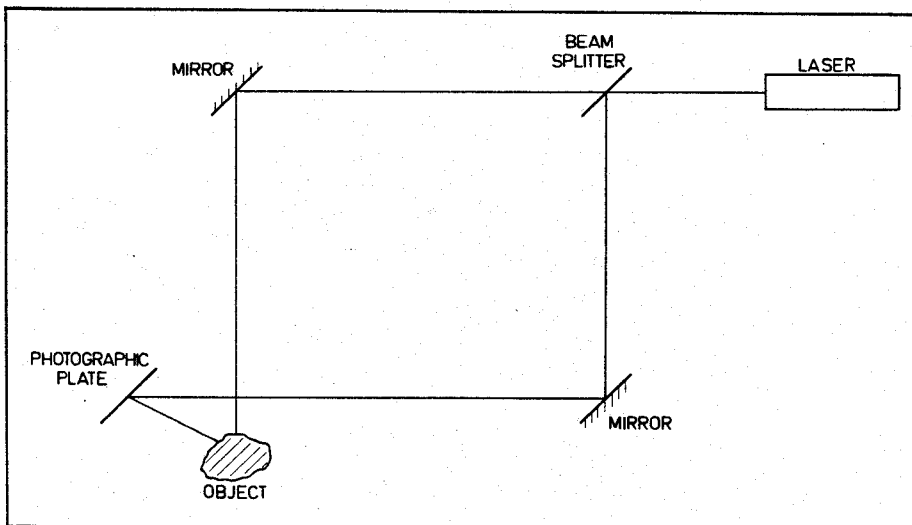
## PROPERTIES OF HOLOGRAMS

The basic optics of wavefront reconstruction photography differ from those of ordinary photography in three ways.

1. In a similar way to photography the object is illuminated and the scattered light is recorded by a photographic emulsion. However, in holography no lens or image forming device is used, and therefore no imaging of the usual type is performed. Instead, each point in the photographic emulsion re-

ceives light from each point on the object.

- Another departure from ordinary photography is that of using a second optical wave to illuminate the photographic plate. This second wave, combined with the object wave, gives a resultant interference pattern which is recorded by the emulsion.
- The third difference is the necessity to use coherent light for illuminating the object and plate. Basically, two separate wavefronts are required to record both phase and amplitude variations on a photograph. Generally, photographic emulsions only register intensity distributions. This is shown for a single wavefront where the phase of the wave is not recorded, giving a two dimensional image as observed in a normal photographic transpar-



ency. However, on using two wavefronts, interference takes place when they are superimposed onto the emulsion, and is recorded in the form of an intensity distribution. The coherence requirements on both of these light beams is that they both must be spatially and temporally coherent. That is each point of one wave must be capable of interference with every point of the other wave. Laser light meets these requirements and a He-Ne laser of wavelength  $6328\text{\AA}$  is most commonly used. To produce a hologram it is necessary to reflect one of the beams (object beam) from the object to be photographed, and onto the photographic emulsion. The other beam (reference beam) passes directly onto the same material (Fig. 1). The former wavefront is generally of a complex nature due to reflection from the object whereas the latter is generally a plane or spherical wavefront. On the surface of the emulsion the two light beams interfere and hence the resultant interference pattern is recorded. The developed hologram does not resemble the object at all, as does a transparency or normal photograph, but appears as an apparently random set of lines and dots (Fig. 3). This pattern acts as a diffraction grating, which when illuminated by the original reference beam, reproduces the original object wave. The emerging light gives a complete three-dimensional image of the original object. This three-dimensionality is due to the reproduction of the amplitude and phase variations of the original object wave. One great advantage that arises is that a three-dimensional object can be reconstructed without the use of any lenses. Also since a hologram contains all the information about the object over the entire plate, any section of the hologram taken separately will give a reconstruction of the object. That is, the entire object can be seen even if the hologram is cut into, say, ten pieces.

## REQUIREMENTS OF HOLOGRAM PRODUCING:

Although the basic idea of hologram producing is simple, there are several very rigid conditions which need to be

fulfilled in the recording process. The most important is the equipment stability. The average fringe spacing of the interference pattern is about 2 microns. Therefore, during exposure, a successful hologram will only be produced if the movement of the fringes is less than about 1 micron. It is general procedure to have all apparatus mounted rigidly on a heavy table, supported on some type of damping system to eliminate vibrations through the floor. The apparatus is extremely sensitive to air currents and temperature fluctuations and these also need to be eliminated to stop fringe movement.

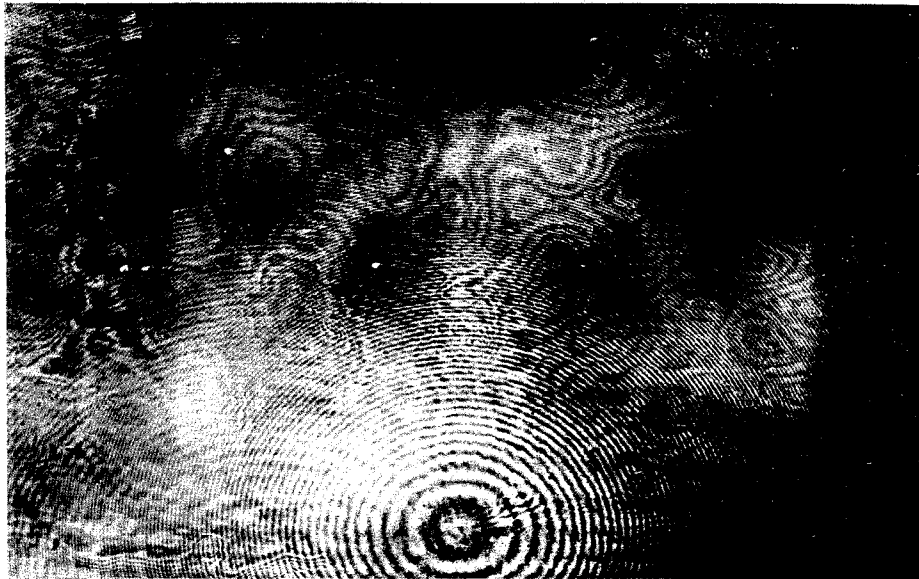
As mentioned earlier, the fringe spacing is about 2 microns which implies that a very high resolution emulsion must be used to record these fringes. The most commonly used is Kodak Spectroscopic plate-type 649F which has a resolution greater than 2000 lines per millimeter. However, due to the high resolution and therefore, very small grain size, this plate has a very slow speed. This stresses the need for a vibrationless system since the exposure times are usually in the order of minutes. As with all emulsions exposed in the visible region of the spectrum, it must be used in the linear region of the D-log E curve. In addition the intensity ratio of reference beam to object beam must be between 2 to 1 and 10 to 1. This latter requirement is most easily explained in the mathematical analysis of the holographic process (2).

(2) See Ref. 2.

Processing of the photographed hologram is no different from the normal procedure. Developer D19 is used for about 4 minutes at 20°C. Random emulsion shrinkage and buckling does occur, but these are not very important unless an extremely accurate hologram is required as in "stress-holo-interferometry".

#### APPLICATIONS OF HOLOGRAPHY

The most advanced use of holography is in the above mentioned field of stress-holo-interferometry. This technique is used to determine strain in metals and machinery. Its application requires placing the processed hologram back in the original position in which it was exposed and viewing light from both the object and the hologram. The superposition of the actual object and the virtual image of the object



from the hologram then occurs and by distorting the object slightly (by a few microns) another interference pattern consisting of light and dark bars appears across the object. This shows the relative displacement of the object in terms of fringe spacing. Using this method, movements of less than 1 micron can easily be measured (3). Colour holograms have also been produced using two lasers namely the He-Ne laser with red light of wavelength 6328Å and the argon laser having blue and green light of wavelengths 4880Å and 5145Å respectively. Such holograms are used commercially for advertising purposes.

(3) See Ref. 3.

#### ACKNOWLEDGEMENT

Grateful acknowledgement is made to the staff of the Photographic Laboratory, Mr. R. L. Bryant and Mr. R. Brazill.

#### REFERENCES

Further references have been included for those interested in broadening their knowledge of holography.

1. Principles of holography by Howard M. Smith.
2. Introduction to Fourier Optics by J. W. Goodman, Chapter 8.
3. The engineering uses of holography, edited by E. R. Robertson and J. M. Harvey.