HOLOGRAPHY

Deema Najjar, Israa Shlaldah, Waad Awad, Ayman Sweiti.

Applied Physics, College of Applied Sciences

PPU

Hebron, Palestine

Abstract- **Holography is a way of recording and reconstructing waves to produce a hologram. The hologram that produced depend on physical principle i.e interference and diffraction, it have many characteristic and type. To make a successful hologram there must be a coherent and monochromatic light as laser. The most important applications of holography is producing three dimensions image can see it without using glasses and use it in many fields like TV. The other important application is holographic interferometery, that used in vibration and modal analysis. There are other applications such that holographic microscopy, holographic filters and data storage.**

keywords; hologram, interference, diffraction, interferometery.

I. INTRODUCTION

Holography is a way of recording and then reconstructing waves to produce a hologram. In conventional photography, only the distribution of the amplitude is recorded in a two-dimensional projection of an object onto the plane of the photograph . For this reason when examining a photograph from various directions ,we do not obtain new angles of approach , and we cannot see , for instance , what is happing behind objects in the foreground. The physical foundation of holography is the science of waves, their interference and diffraction.

Holography can be summarized by two-step process: 1) writing the hologram, which involves recording on film the amplitude and phase information and 2) reading the hologram, by which the hologram is illuminated with reference field similar[1]. D. Gabor (1900–1979) realized the basic ideas of holography. The origin of holography was at first connected to problems in optics of electrons. Gabor showed the applicability of this new process of wavefront recording by using a mercury discharge lamp and taking collinear object and reference beams[2].It was not simple until the coming up of laser technology when developments in holography experienced a significant upturn[2]. So 23 years after his experiments Gabor was awarded the Nobel prize in 1971. In 1962 the theoretical aspects of this methods were refined by E.Leith and J. UpatnieksLeith and Upatnieks this methods which made it possible to make holography not complicated way .This paper includes four components: (1) fundamental principal of holography, (2) properties and type of hologram, (3)holographic experiments, (4) applications of holography.

II. PHYSICAL PRINCIPLE OF HOLOGRAPHY

The hologram represent interference pattern that is created by the superposition of object wave (o) and reference wave (r) .the phenomenon will now be described in more detail[3] .

1) *Interference of light*

The object wave (the wave scattered by the object) and the reference wave are superimposed within holographic experiment[3] .The wave equation for the object wave and reference wave respectively:

$$O = |O| e^{-i\Phi} \tag{1}$$

$$r = |r| e^{-i\Psi} \tag{2}$$

The intensity I is the square of the sum of the complex amplitudes:

$$I = |r + O|^2 \tag{3}$$

$$I = r \cdot r^* + O \cdot O^* + O \cdot r^* + r \cdot O^*$$

$$I = r^2 + O^2 + 2|r||O|\cos(\Phi - \Psi)$$

r^2: the square of amplitude of reference wave .

o^2: the square of amplitude of object wave .

$2 \cdot r \cdot o \cdot \cos(\Phi - \Psi)$: interference term .

If the wave object and reference wave are have not parallel polarization ,if the angle between the polaraization vector ψ ,the intensity will be :

$$I = r^2 + O^2 + 2|r||O|\cos(\Phi - \Psi)\cos\psi \tag{4}$$

2) *Diffraction grating*

In this part the interference of two plane coherent waves will be calculated. This procedure can be thought of as holography of a plane object and reference wave. The angles of incidence are denoted as $\boldsymbol{\delta_0}$ and $\boldsymbol{\delta}$ (in this case both of them are positive!). Two points P_1 and P_2 are chosen that correspond to the location of two neighboring maxima (or minima) with the spacing dg (=1/spatial frequency σ). The difference in optical path lengths $(\Delta_0 + \Delta)$ according to Fig1. Is

$$\Delta = dg \sin \delta$$

and

$$\Delta_0 = dg \sin \delta_0 \tag{5}$$

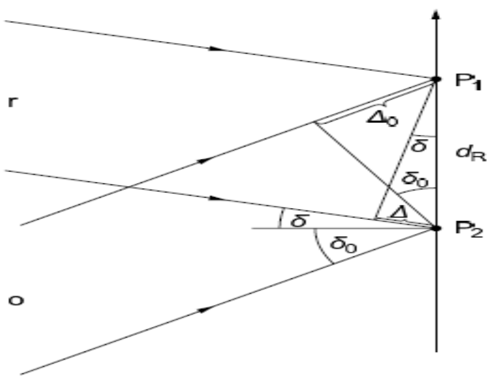

Fig1. Formation of a holographic diffraction grating[3].

Using $\Delta_0 + \Delta = \lambda$ the fringe spacing dg and the spatial frequency σ become

$$dg = 1/\sigma = \lambda/(\sin\delta + \sin\delta_0). \tag{6}$$

A diffraction grating with the spacing dg shall be illuminated with a light wave impinging with an angle α . The maxima of the diffracted light occur at an angle β according to

$$dg = (N \cdot \lambda)/(\sin\alpha + \sin\beta) \tag{7}$$

where N denotes the order of the spectrum. When illuminating it at an angle of $\alpha = \beta$ the first diffraction order is formed at $\beta = \delta_0$. This means that the object waves reconstructed.

3) The holographic recording and reconstruction (mathematical approach)

Recording :the intensity in the plane of photographic layer is given by;

$$\begin{aligned} I(x,y) &= r^2 + O^2(x,y) \\ &+ 2|r||O(x,y)|\cos[2\pi\sigma_r x + 2\pi\sigma_O x]. \end{aligned} \tag{8}$$

Where σ_r and σ_O are the spatial frequency of the reference wave object wave respectively.

The transmission decreases proportional to the exposure intensity I and the exposure time τ. The transmission without any exposure is given by t_0:

$$t = t_0 + \beta\tau I = t_0 + \beta E \tag{9}$$

The term E = Iτ describes the energy density of the light, commonly called the "exposure." The parameter β is negative and is represented by the slope of the curve between the optical density and the exposure .The amplitude transmission(t) then given by:

$$\begin{aligned} t(x,y) &= t_0 + \beta\tau r^2 \\ &+ \beta\tau r O^2(x,y) \\ &+ \beta\tau r O(x,y) e^{-i2\pi\sigma_r x} e^{i2\pi\sigma_O x} \\ &+ \beta\tau r O(x,y) e^{i2\pi\sigma_r x} e^{-i2\pi\sigma_O x} \end{aligned} \tag{10}$$

then by using euler's equation :

$$t(x) = \bar{t} + t_1 \cos(kx) \tag{11}$$

$$k = 2\pi(\sigma_r + \sigma_o) \tag{12}$$

$$t = t_0 + \beta\tau(r^2 + o^2(x, y)) \tag{13}$$

$$t_1 = \beta\tau ro. \tag{14}$$

The amplitude transmission t of a hologram formed by two plane waves r and o is therefore a cosine-like diffraction grating. Hence the intensity transmission $T = t^2$ is proportional to a $\cos^2$-function[3].

Reconstruction:The hologram is again illuminated with the reference wave. The hologram acts like a filter and the wave field directly behind the photographic layer is given by :

$$u(x,y) = r(x,y)t(x,y)$$

$$\begin{aligned} u(x,y) &= (t_0 + \beta\tau r^2) r(x,y) \\ &+ \beta\tau O^2(x,y) r(x,y) \\ &+ \beta\tau r^2 O(x,y) \\ &+ \beta\tau r^2 O^*(x,y) e^{i4\pi\sigma_r x} \end{aligned} \tag{15}$$

u_0: zeroth diffraction order consisting from two terms, the first refers to reduction of the reconstruction wave and the second is halo around it .

u_{+1}: the+1st diffraction order represent the virtual image.

u_{-1}: the-1st diffraction order represent the real image.

III. PROPERTIES AND TYPES OF HOLOGRAM

A. Properties of Holograms

The three-dimensional imagery produced by hologram quite pronounced and a viewer quickly realizes that much more information about the object is furnished by a hologram than by any other form of 3-D process such as stereophotography, so it has some unique characteristics :

- The light from a reconstructed image from a hologram reaching to the observer's eye is the same as that would come from the original object[4].
- The hologram of a diffuse object can be reconstructed by a small portion of the hologram[4].
- An image reconstructed has all the visual properties of the original object and no visual test that can distinguish the two[5].
- Two images, usually a real and a virtual can be reconstructed from a hologram[4].
- More than one independent scenes can be stored in the same photographic plate which can be viewed one at a time[4].

B. Holographic Emulsions

The emulsion is a kind of photographic plates and it has has some properties that characterized it such as:

- Transmission and Phase Curves:

The amplitude and the phase of a light wave passing the emulsion are influenced by the optical properties of holographic emulsions change during exposure and subsequent chemical development[3].

- Resolution and Diffraction Efficiency:

Information on the resolution is contained in the visibility transfer function ,which is given by :

$$M = \frac{V'}{V} \tag{16}$$

and the diffraction efficiency is given by :

$$\epsilon = \frac{1}{16}(0.43\,\Gamma M V)^2 \tag{17}$$

The equation means that the diffraction efficiency is proportional to the sensitivity of the layer given by Γ and also to visibility of the grating V , and to the visibility transfer function M [3].

- Noise of Emulsion Layers :

Due to the granularity of photosensitive layers diffraction and scattering of light occur, which in holography leads to so-called noise. These disturbances are especially important for holograms with low diffraction efficiency and for multiple recordings of holograms on top of each other[3].

C. Types of holograms

A hologram is a recording in a two- or three-dimensional medium of the interference pattern formed when a point source of light (the reference beam) of fixed wavelength encounters light of the same fixed wavelength arriving from an object (the object beam).

When the hologram is illuminated by the reference beam alone, the diffraction pattern recreates the wave fronts of light from the original object. Thus, the viewer sees an image indistinguishable from the original object, and there are many types of holograms:

- Transmission hologram

The typical transmission hologram is viewed with laser light, usually of the same type used to make the recording and it's produced when the reference and object waves traverse the emulsion from the same side[6].

- Reflection hologram

One differentiates between transmission and reflection holograms depending on whether the hologram is to be viewed in transmitted or in reflected light, so it's produced when the reference and object waves traverse the emulsion from opposite sides[6] .

- Thin holograms

A hologram is considered “thin” when the separation between successive hyperboloidal surfaces exceeds the thickness of the recording medium[6].

- Thick Holograms

If the thickness of the recording medium is larger than the average spacing of the fringes, then it’s considered to be thick hologram[6].

IV. Holographic experiments

To make a hologram you need a laser, beamsplitter, lenses, mirrors and recording material . Lasers are devices that amplify or increase the intensity of light to produce a highly directional, high-intensity beam that typically has a very pure frequency or wavelength. The word LASER is an acronym for Light Amplification by Stimulated Emission of Radiation. Stimulated emission of radiation is a natural process first identified by Einstein. For a simple holographic system, the helium–neon (He–Ne) laser is the usual choice[7]. It is inexpensive and operates on a single spectral line at 633 nm which is well matched to the peak sensitivity of many photographic emulsions[7].

In order to maximize the visibility of the interference fringes formed by the object and reference beams, while recording a hologram, it is essential to use coherent illumination[8]. In addition to being spatially coherent. Spatial coherence can be defined as a strong correlation (fixed phase relationship) between the electric fields at different locations across the beam profile. And the coherence length is roughly the maximum path difference two beams can have and still be coherent. to obtain a satisfactory hologram, the light used must be spatially coherent and its coherence length must be much greater than the maximum optical path difference between the object and reference beams in the recording system. After produced spatially coherent light we need beam splitters that is a device that uses mirrors and prisms to split one beam of light into two beams one of them go’s to the object and other beam called reference beam[9], during this process we use lenses to spread out the beam and we use mirrors to direct the beams of light to the correct locations. Along with the lenses and beam splitter[9].

After that the interference between two beams occurs on recorded material, that in hologram may be recorded in a medium as a variation of absorption or phase or both. The recording material must respond to incident light pattern causing a change in its optical properties. In the absorption or amplitude modulating materials, the absorption constant changes as a result of exposure, while the thickness or the refractive index changes due to the exposure in phase modulating materials[10]. In the phase modulating materials there is no absorption of light and all the incident light is available for image formation, while the incident light is significantly absorbed in an amplitude modulating medium. Holograms have been recorded in a vast number of different materials during the history of holography[10]. The first is Silver Halide Emulsions then Photopolymer Films, Photorefractive crystals, Photoresists and finely Dichromated Gelatin[10].

V. SELECTED APPLICATIONS OF HOLOGRAPHY

By holography we can produce three dimensional image that can use it in many fields and testing for stresses, strains and surface deformations by holographic interferometry. There are many other applications like holographic filters, holographic microscopy and information storage .

a) Three-Dimensional Image

Holograms are true three-dimensional images. This is evidenced by the fact that you can move your head while viewing the image and see it in a different perspective. This includes revealing part of the image which was hidden at another viewing angle[11].

3D image holographic can be made not only with the light waves of a laser, but also with sound waves and other waves in the electromagnetic spectrum. It would also be very useful in medicine to be able to obtain a direct three-dimensional image of, say, a fractured hip joint with a single exposure. But the image would have to be played back by X-rays too, so some kind of three-dimensional fluorescent screen technique would be needed[11].

3D image holographic can be use in television .Transmission of holograms via television has been a natural desire of holographers due to its possible impact in the field of entertainment. The main difficulty has been due to the enormous information content of the holograms which cannot be handled by TV channels. The techniques can be employed to reduce the information content of the hologram. The transmission of holograms via TV was executed in 1966 but the actual holographic TV could not be realized in the absence of a suitable recording material[11].

b) Holographic Interferometry

In essence a hologram can be considered as a device to store a complicated wave pattern. That the stored wave pattern can be retrieved for reconstruction at a later time offers the unique possibility to compare two complicated wave patterns that have albeit existed at different times. This statement is fundamental to the understanding of holographic interferometry as it makes it feasible to compare the shape of a diffusely reflecting object with the shape of the same object after it has been deformed[12].

Holographic interferometry is used in vibration and modal analysis, structural analysis and strain evaluation. All these applications derive from one or more of the three basic methods of applied holographic interferometry: double-exposure,real-time, and time-average holography.

Double-exposure creates a hologram by using two or sometimes more exposures. The first exposure shows an object in an undisturbed state. Subsequent exposures, recorded on the same image, are made while the object is subjected to some stress. The resulting image depicts the difference between the two states[3].

real-time illuminated object is viewed through a hologram which was made from the undisturbed object before the experiment and that is replaced to its original position during the recording. Consequently, our eye is hit by the reconstructed object wave o as well as the scattered object wave o' . shows the imagined path of the object waves o and o' to the right of the hologram. The difference is exaggerated here. On the left side only the objectwave o' exists, i.e., the scattered light from the deformed object [3].

Time Average, involves creating a hologram while the object is subjected to some periodic forcing function. This yields a dramatic visual image of the vibration pattern. time-average interferometry is comparatively easy to set up, there are difficulties associated with the quantitative analysis of the fringes. However, it is easy to spot the parts of the object that are stationary (the nodes of vibration), as they are the brightest parts of the image. This type of hologram is best used for visual judgments. For analytical purposes it is preferable to use shear Interferograms[3][12].

c) Other applications

The first application is holographic filters that used as notch filters that has been use for eye protection against laser radiation, while maintaining high visual transmittance . Holographic notch filters are also used in Raman spectroscopy, to suppress the Rayleigh line while freely transmitting the Stokes region [13].

The other applications is a holographic microscope has an appreciable split into two beam. One beam is passing through the specimen and through the microscope ; the other beam is led around it . The two beams recombine , producing The hologram . The reconstructed image can be viewed in any cross section desired .The observer merely looks at the cross section wishes to see, moving back and forth throughout the depth of the image , without the object being present anymore at all [13].

The final application is information storage can be stored and retrieved more efficiently in the form of holograms than in the form of real images .Perhaps this is how information , then called engrams , is stored in the brain ;at least it would help explain why attempts to locate certain “centers” in the brain have never met with much success and why major brain injury often does not lead to predictable, circumscribed defects. Similar considerations apply to technical information storage .Storing images on microfilm is subject to errors because of misfocusing and contamination . Information storage by holography, either on photographic film or in single crystals of lithium niobate , LiNbO3,does not have these problems[13].

VI. CONCLUSION

Holography as mentioned is a way of recording (science of the interference) and Reconstructing wave (science of the diffraction), to make a hologram coherent source of light and recording material is needed which arrange in a way depends on the type of hologram and its characteristics.

Holography is the only technique which forms an image, that there is no optical test can distinguish it from the original object, but holography exceeded this field (formation of the image) to many applications as interferometry, filtration, microscopy and storage.

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