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Topic:

Holography: Holography, Difference between Photography & Holography, Recording of Hologram & Reconstruction of Image.

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HOLOGRAPHY

1. Objective& Relevance of the unit

In recent years, the 3 dimensional image of an object, called "hologram" are being used in banknotes, identity cards and credit cards, etc. to improve the security of these valuable things. Hologram is produced by holography technique. In this chapter, we shall discuss about the holography technique, construction and reconstruction of image by holography technique.

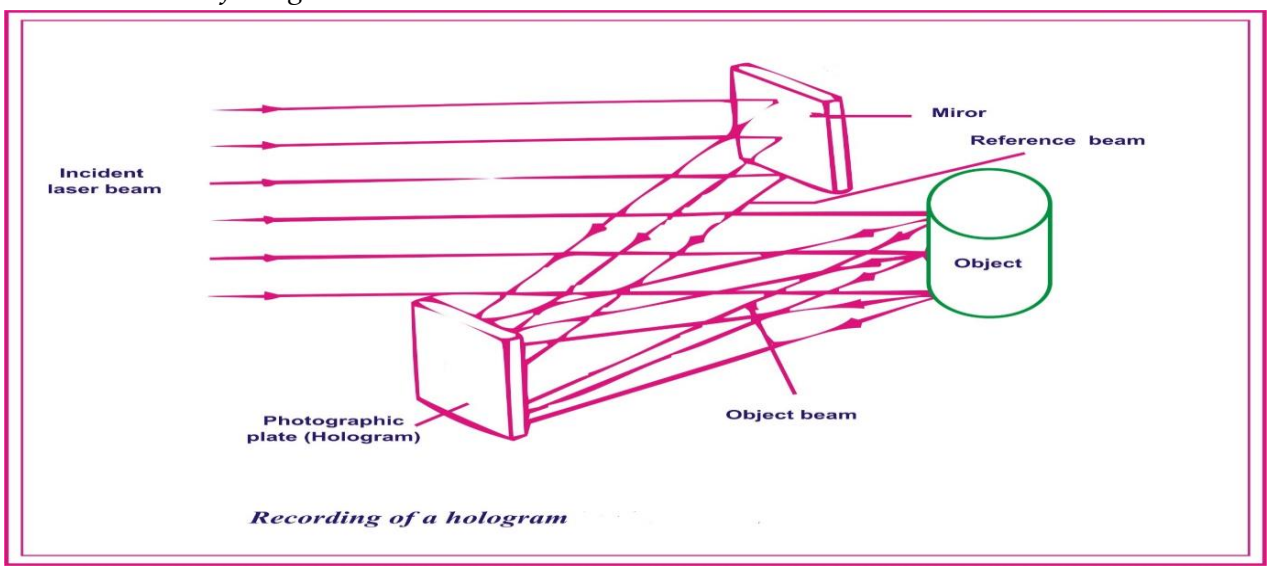
2. **Introduction**

In 2 dimensional (D) photography, only the difference in intensity from the different parts of the object recorded. Therefore, the outlook of the image does not change if it viewed from different angle due to not recording of phase of light. In 1948, Dennis Gabor first recorded the both the amplitude and phase of reflected coherent light from object and constructed the three dimensional image of an object, called hologram. The difference between conventional photography and holography are-

Conventional Photography	*Holography*
Photography is constructed by the recording the variation of intensity of light from the object.	Holography is constructed by interference of reference and transmitted coherence beam of light
It produces 2 dimensional image	It produces three dimensional image
In photography, the coherence light source is not necessary.	It needs coherent light source.
Only, amplitude is noted.	Amplitude and phase both of wave are recorded.
It produces photograph	It produces hologram

3. Recording and reconstruction of wave front

The principle of holography is explained in two parts-*i) Recording of hologram* and *ii) Reconstruction of image.*



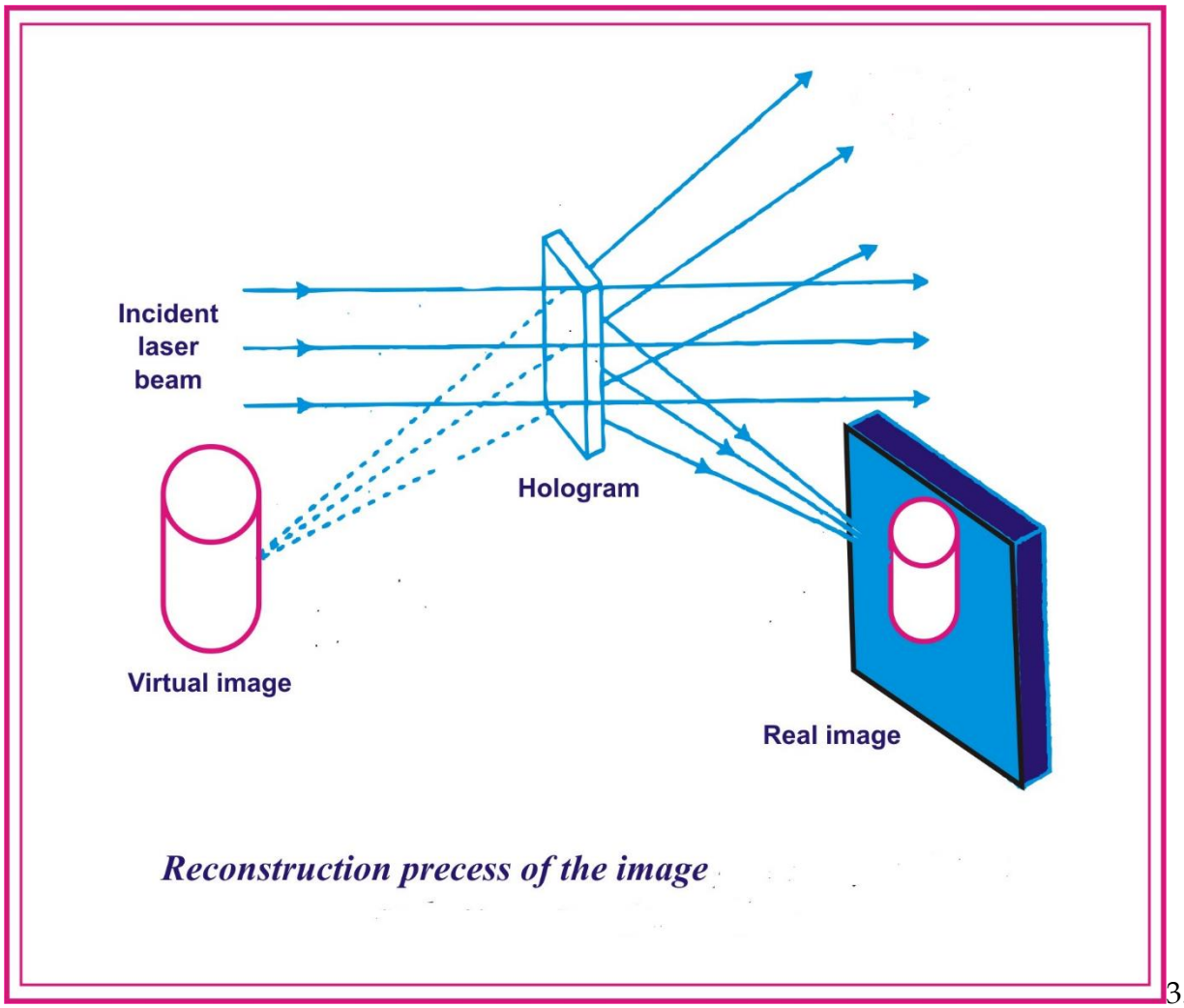
Recording of a hologram

i) Recording of hologram

The basic principle of holography is interference of coherence light waves. Here, a highly coherent laser beam is taken at first. Next, the beam is splitter in two parts- the reference beam and the object beam. The object is illuminated by an object beam. Each point of the object scatters the object beam. Finally, the scattered beam having all information about phase and amplitude is fall on photographic plate. Here, the reference beam is also fallen. The interference between, scattered beam and reference beam produce hologram

ii) Reconstruction of Image

Herein, the hologram is illuminated by a collimated laser beam which may be the matching to the reference beam. This beam undergoes the diffraction phenomena on hologram. One of the diffracted beam from the hologram when projected back, it appears to diverge form an apparent object as well as yield virtual image. Instead, the other beam produces real image. The different perception of the object can be realized in the real image by moving the position of eye.



Reconstruction precess of the image

3.

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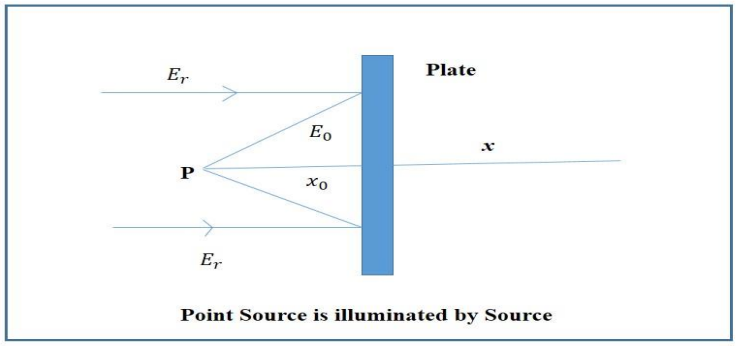
Theory of Hologram

Here we consider, a small object P is illuminated by light as well as most of the light falls on photographic plate. The scattered light from P interfere with direct beam.

Here, $E = E_r + E_o$ (1), where, E_o is the electric field from the scattered wave from object and E_r is the electric field from the reference beam.



Let us consider,

$E_r = A_r e^{i(kz-\omega t)}$(2), where r =$z_0$ is the perpendicular distance between photographic plate and the object

$E_o = \frac{A_o}{r} e^{i(kr-\omega t)}$ (3)

Intensity at photographic plate becomes-

$$I = |E_r + E_o|^2$$

$$= \left|A_r e^{i(kz-\omega t)} + \frac{A_o}{r} e^{i(kr-\omega t)}\right|^2$$

$$= |A_r|^2 + \left|\frac{A_o}{r}\right|^2 + \frac{A_o}{r} A_r e^{i(kz-\omega t)} e^{-i(kr-\omega t)} + \frac{A_o}{r} A_r e^{-i(kz-\omega t)} e^{i(kr-\omega t)}$$

$$= |A_r|^2 + \left|\frac{A_o}{r}\right|^2 + \frac{A_o}{r} A_r e^{ik(z-r)} + \frac{A_o}{r} A_r e^{-ik(z-r)}$$

$$= |A_r|^2 + \left|\frac{A_o}{r}\right|^2 + \frac{A_o}{r} A_r \left[e^{ik(z-r)} + e^{-ik(z-r)}\right]$$

$$= |A_r|^2 + \left|\frac{A_o}{r}\right|^2 + \frac{A_o}{r} A_r [\cos k(z-r) + i \sin k(z-r) + \cos k(z-r) - i \sin k(z-r)]$$

$$= |A_r|^2 + \left|\frac{A_o}{r}\right|^2 + \frac{A_o}{r} A_r 2 \cos k(z-r) \quad (4)$$

Let, the hologram is illuminated by reference beam and the expression of electric field of transmitted wave is to be-

$E = TE_r$ (5), where, $T = \left(1 - \frac{\alpha}{2} I\right)$

I = intensity of beam on the photographic plate and α = constant

Therefore, $E = \left(1 - \frac{\alpha}{2} I\right) E_r$

$$= \left(1 - \frac{\alpha}{2}\left\{|A_r|^2 + \left|\frac{A_o}{r}\right|^2 + \frac{A_o}{r} A_r\left[e^{ik(z-r)} + e^{-ik(z-r)}\right]\right\}\right) A_r e^{i(kz-\omega t)}$$

$$= \left(1 - \frac{\alpha}{2}|A_r|^2 - \frac{\alpha}{2}\left|\frac{A_o}{r}\right|^2\right) A_r e^{i(kz-\omega t)} - \frac{\alpha}{2}\frac{A_o}{r} {A_r}^2 e^{ik(z-r)} e^{i(kz-\omega t)}$$
$$- \frac{\alpha}{2}\frac{A_o}{r} {A_r}^2 e^{-ik(z-r)} e^{i(kz-\omega t)}$$

$$= \left(1 - \frac{\alpha}{2}|A_r|^2 - \frac{\alpha}{2}\left|\frac{A_o}{r}\right|^2\right) A_r e^{i(kz-\omega t)} - \frac{\alpha}{2}\frac{A_o}{r} {A_r}^2 e^{i(kz-kr+kz-\omega t)}$$
$$- \frac{\alpha}{2}\frac{A_o}{r} {A_r}^2 e^{-i(-kz+krkz-\omega t)}$$

$$= \left(1 - \frac{\alpha}{2}|A_r|^2 - \frac{\alpha}{2}\left|\frac{A_o}{r}\right|^2\right) A_r e^{i(kz-\omega t)} - \frac{\alpha}{2}\frac{A_o}{r} {A_r}^2 e^{i(2kz-kr-\omega t)} + \frac{\alpha}{2}\frac{A_o}{r} {A_r}^2 e^{-i(kr-\omega t)} \quad (6)$$

Therefore, the first term of the above expression represents *the attenuated reference wave* as well as the second term of the expression which represents *a spherical wave surface, the replica of original wave*. Along with, the third term which represent *the diverging spherical wave surface, produces the virtual image of the object, when projected backward*.

4. Summary

In 1948, Dennis Gabor first recorded the both the amplitude and phase of reflected coherent light from object and constructed the three dimensional image of an object, called hologram. Holography is a technique which produce three dimensional image of an object using coherent light sources through the technique of interference.

Frequently Asked Questions (FAQ)

i) What is holography? Write down its basic principle.
ii) What is the difference between holography and photography?
iii) What are the importance of holography?
iv) Explain the recording and reconstruction of hologram.
v) Write down the characteristics of hologram.

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