Holography

Dr. Deepa Khatik
Asstt. Professor, Physics
Government Autonomous Girl's P.G. College of Excellence, Sagar (M.P.)

Abstract :

If you're carrying money, a drivers license, or credit cards, you're carrying around holograms. The dove hologram on a Visa card may be the most familiar. The rainbow-colored bird changes colors and appears to move as you tilt the card. Unlike a bird in a traditional photograph, a holographic bird is a three- dimensional image. Holograms are formed by interference of light beams. Holograms are made using lasers because laser light is "coherent". What this means is that all of the photons of laser light have exactly the same frequency and phase difference. Splitting a laser beam produces two beams that are the same color as each other (monochromatic). In contrast, regular white light consists of many different frequencies of light. When white light is diffracted, the Frequencies split to form a rainbow of colors. In conventional photography, the light reflected off an object strikes a strip of film that contains a chemical (i.e., silver bromide) that reacts to light. This produces a two-dimensional representation of the subject. A hologram forms a three-dimensional image because reflected on an object strikes a strip of film that contains a chemical (i.e., silver bromide) that reacts to light. This produces a two-dimensional representation of the subject. A hologram forms a three - dimensional image because light interference patterns are recorded, not just reflected light. In this paper we will discuss about construction of hologram, holography it's types and it's applications in physics.

Keywords : Holography, Holograms, coherent, monochromatic, diffraction, interference patterns.

Introduction :

Holography is a technique which can lead to the information of optical images and often uses photographic materials. In some respects it is similar to photography. In other respects, however, it is fundamentally different. The two techniques should be seen as complementary rather than competing process.

In conventional photography we record the two dimensional irradiance distribution of the image of an 'object scene', which may be regarded as consisting of a large number of reflecting or radiating points. The waves from these points all contribute to a complex resultant wave, which we call the object wave. This wave is then transformed by a lens into an image of the object which is recorded in photographic emulsion.

In holography, on the other hand, we record the object wave itself rather than the image of the object. The object wave is recorded in such a way that on subsequently illuminating the record the original object wave front is reconstructed, even in the absence of the original object. Holography, in fact, is often referred to as wave front reconstruction. Visual observation of the reconstructed wave front gives a view of the object which is indistinguishable from the original object. That is, the image generated in holography possesses the depth and parallax properties normally associated with the real objects.

The fundamental difference between photography and holography is that in photography we record only the amplitude of the resultant wave from the object (strictly speaking about photographic plate records irradiance, which is proportional to the square of the amplitude), while in holography we record both the amplitude and phase of the wave. We may see in simple terms, how this is achieved, as follows.

Principle of Hologram:

To record the phase of the object wave we use a beam of monochromatic light originating from a small source so that the light is coherent. By this we mean that the temporal and spatial variations of the phase of the light beam are regular and predictable. If light beams are coherent then interference effects which are stable in time can be obtained. The monochromatic beam splits into two parts, one of which is used to illuminate the objet, while the other which we call the reference wave, is directed towards a photographic plate. The light directed towards the object is scattered and some of it, the object wave, also falls of the photographic plate. If the original monochromatic light has a sufficiently high degree of coherence, then the reference and object waves will be mutually coherent and will form a stable interference pattern in the photographic emulsion. The interference pattern, in general, is a complicated system of interference fringes due to the range of amplitudes and phases of the various components of the light scattered from the object. This interference pattern, which is unique to a particular object, is stored in the photographic emulsion when the plate is developed. This record is called a hologram.

The hologram consists of a complicated distribution of clear and opaque areas corresponding to dark and bright interference fringes. When it is illuminated with a beam of light similar to the original reference wave, light is transmitted only through the clear areas, resulting in a complex transmitted wave. The hologram behaves rather like a diffraction grating. Because of the action of the recorded interference fringes the transmitted wave divided into three separate components, one of which duplicates the original object wave. In viewing this reconstructed wave front we see an exact replica of the original object even though the object is no longer present. Holography then is a two-step process. Firstly, an interference pattern is recorded to form the hologram. Secondly, the hologram is illuminated in such a way that part of light transmitted by it is a replica of the original object wave. Holography was in fact invented before lasers became available. It will be appreciated, however, that as light with a high degree of coherence is required its developed has proceeded most rapidly since the advent of the laser.

The science of holography was initiated by Gabor in 1948 when trying to improve the performance of transmission electron microscopes. He realized that if a hologram were formed by light of one wavelength and then viewed by a similar beam of another wavelength then the reconstructed object would be magnified by the ratio of the wavelengths of the reconstructing and forming waves. Thus if the hologram could be created using electron waves and viewed using visible light waves, then a magnification of about 105 should be expected. For a number of technical reasons the method did not succeed. The most serious of these, however, was that the three components transmitted by the hologram mentioned above were coincident. These three components are the undiffracted transmitted beam, the virtual image, and the real image.

Arrangement of Hologram :

***Optical Arrangement :**

The optical arrangement the so called off-axis geometry developed by Leith and Upatnieks, avoid this problem by physically separating the two images which may be regarded as the two first orders of the diffraction pattern produced by the hologram. At about the same time that Leith and Upatnieks introduced the off-axis method lasers became more widely available. The intense, coherent and mono-chromatic nature of laser radiation makes it ideal for holography and enables high resolution holograms of much larger objects to be made than was previously possible.

During the last years many additional geometrical arrangements and methods for producing holograms have been introduced. These include plane and volume holograms. In turns plane and volume holograms can be either of the absorption or phase type. In parallel with the advances in the optical arrangements for holography improved photosensitivity materials for recording the holograms have been introduced. These need to have a high resolution with the grain size less than about 50 nm as the interference fringes are typically one wavelength apart. In addition, for some purposes, the photosensitivity should be high to reduce exposure times, though the high irradiance available from lasers often components for this. Thus, while the high sensitivity of silver halide emulsion makes it attractive in some application, gelatin films.

A typical holographic arrangement have two parts that is (a) making the hologram by recording the interference pattern produced by the interference of the reference and object wave fronts; (b) reconstruction of the object wave front. The reconstruction produces two images, a virtual (orthoscopic) image and a real (pseudoscopic) image.

***Holographic optical components :**

We have seen that a hologram is essentially a pattern of interference fringes which diffract the light transmitted by or reflected from it. Thus a suitable pattern of fringes can perform a variety of tasks which are normally performed by conventional optical components. An obvious example of this is the production of diffraction gratings by holograph. Plane object and reference beams will interfere to give a series of straight-line parallel fringes which, if the beams are of equal irradiance, will have a cosine squared irradiance distribution. Although the first transmission gratings were produced some twenty-five years ago the most successful gratings are formed in photo resist layers coated onto optical blanks . Photo resists are light-sensitive organic films which yield a relief image after exposure to light. The relief image is coated with an evaporated metal film to form a reflection grating of high quality for spectrographic applications.Holographic gratings have several advantages over diamond ruled gratings. For example, they are simpler and therefore cheaper to produce, they are free from the periodic and random errors in line spacing of ruled gratings, and they produce less scattered light. In addition it is possible to produce larger gratings with narrower line spacing then by conventional ruling techniques, which are limited by were of the diamond cutter. On the other hand, to reduce high-quality gratings the hologram optics must produce wave fronts which are plane to about ?/10 and the fringe pattern must be kept very stable as photo resists are photographically 'slow' and require long exposures.

Another holographic optical component which is being increasingly used in such applications as point-of-sale bar-chart readers and laser printer is the holographic scanner. A simple disk has up to 20 or so separate holograms recorded on it. Each hologram is recorded with a point source as the object and a collimated reference beam. When the hologram is re-illuminated with the conjugate of the reference beam a point image is formed. If now the disk is rotated about an axis perpendicular to its plane, the reconstructed image point scans out a fine line.

The main problem is that the scanning line is curved and thus not suitable for many applications such as printing. A straight-line scan can quite easily be produced, however, by the use of subsidiary optics.

Holographic scanners are replacing multifaceted mirror (or polygon)Scanners not only because they are cheaper but also because the optical system can be made simpler in virtue of the holographic element being able to combine multiple functions as mentioned above. In this case the hologram can combine diffraction, focusing and spectral filtering functions, in which case it may be referred to as a holographic optical element.

Holographic Optical Elements (HOE) :

Holographic optical elements have a grating structure which may be used to transform optical wave fronts in the same way as do lenses. The unique characteristics and capabilities of HOEs include the follow. HOEs can serve several functions, for example an HOE may act as a combined lens, beam splitter and spectral filter. Also several HOEs may be formed in the same area of the emulsion so that several lenses can exist simultaneously. Another very important point is that the fabrication and replication of HOEs are essentially photographic and therefore much simpler than for conventional optical components which require laborious grinding and polishing processes. Finally as they can be produced on quite thin substrates HOEs can be very light in weight even for large-aperture devices.

In principle HOEs are able to duplicate most of the function of conventional optical elements, ranging from simple beam splitters (or combiners) to complex instruments. It seems, however, that apart from applications where their unique features are important, HOEs will not in general replace conventional optics. A typical example of an application which requires the unique features of HOEs is in providing beam combiners for display purposes such as head-up displays.

Head-up displays (HUD) are essentially reflectors arranged so that cathode ray tube (CRT) information displays may be viewed at infinity superimposed over an air pilot's normal field of view. The need for such displays originated from problems of piloting high-performance aircraft. If the pilot were to look down at the CRT display or move his head whilst executing a tight turn it would be all too easy for him to lose equilibrium and control of the aircraft. The HUD allows the pilot to have a complete and continuous view of the CRT information without the need for him to move his head.

In a typical HUD the beam combiner must not restrict the pilot's forward vision by significantly attenuating the light passing through it. Hence its reflectance must be low. If this is the case, however, the CRT display must be very bright, significantly shortening its life time.

Holographic beam combiners can be very efficient reflectors over a narrow spectral range and have a very low reflectance outside of this range. They can also be made to be physically large. Thus, by matching the spectral range to that of the CRT phosphor output, we can produce an HUD with a large unimpeded field of view with the CRT information brightly superimposed upon it. Using dichromate gelatin holographic beam combiners a bandwidth of about 25 nm can be achieved matched to the phosphor peak output at a wavelength of about .525 nm. Furthermore, if the display requires a very large field of view, then curved-beam combiners, which incorporate magnification, can be produced.

References :

1. D.Gabor, 'A New Microscopic Principle', Nature, 161, 777-778,1948.
2. E.N.Leith and J.Upatnieks, 'Reconstructed Wavefronts and Communications Theory', J.Opt. Soc. Am. , 52, 1123-1130, 1962.
3. (a) H.M. Smith, Principles of Holography (2nd edn), Wiley-Interscience,New Yoek,1975,Chapters 2-5.

   (b) P. Hariharan, Optical Holography - Principles, Techniques and Applications, Cambridge University Press, Cambridge 1984, Chapter 4.

   (c) R. J. Collier et al., Optical Holography, Academic Press, New York,1971,Chapters 8-9.
4. (a) Yu N. Denisyuk 'Photographic Reconstruction of the Optical Properties of an Object in its own Scattered Radiation Field' , Sovier Physics -Doklady, 7,543-545,1962.

   (b) Yu N.Denisyuk 'On the Reproduction of the Optical Properties of an Object by the Wave Field of its Scattered Radiation' , Part I Optics and Spectroscopy, 15,279-284, 1963; Part II Optics and Spectroscopy, 18,152-157,1965.
5. S.A. Benton , 'Hologram Reconstructions with Extended Incoherent Sources', J. Opt. Soc. Am. , 59,1545-1546, 1969.