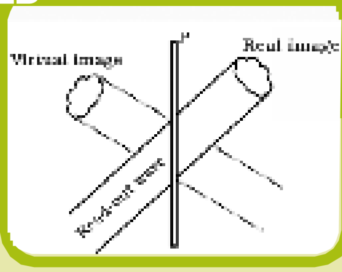
HOLOGRAPHY– THE FASCINATING WORLD OF 3-D VIEWING



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Memories of people, events etc. are better stored in the form of photographs. In fact, the technology of photography has been with us for a long time. Regular photograph "freezes" a two-dimensional image of the three-dimensional world, thereby enabling only a two-dimensional view of reality. Standard photographic film registers the total light intensity (which is square of amplitude of light wave) falling on each point of the film during exposure i.e. when the shutter is open. The resulting image is a two-dimensional mapping which contains only the intensity attributes of the wave. The phase attributes of the wave related to the depth of the field are therefore lost. An ordinary photography, therefore, loses the phase completely. It records only the intensities. However, if both the intensity and the phase attributes of the wave are recorded, one can get a three-dimensional image of the object. This is achieved by using the principles of what is known as holography.

History

The technique of holography was developed by the Hungarian physicist Dennis Gabor in 1948 when he was working in the Research laboratory of the British Thomson-Houstan Company in Rugby, England. This discovery won him the 1971 Nobel Prize in Physics.

In fact Gabor's interest was to improve the resolving power of the electron microscope. He used a two-step lensless imaging process that involved interference between an object wave (emanating from the object) and a coherent background wave (called reference wave). The resulting interference pattern was called a "hologram", after the Greek word *holos,* meaning whole as it contained the whole information. This is known as the recording process. Recorded in the interference pattern is not only the amplitude distribution but also the phase of the object wave.

The hologram has,however, little resemblance to the object. It has in it a coded form of the object wave. The second step in Gabor's process, called reconstruction process, involved reproduction of the image. The hologram was illuminated by an appropriate light beam which formed the reconstructed image of the object in its true three-dimensional form.

Although the principle of holography was laid down by Gabor in 1948, it attained practical importance in 1960 only after the advent of lasers. In 1962 Emmett N. Leith and Juris Upatnieks, working in the Radar Laboratory of the University of Michigan, succeeded in developing good quality holograms using laser light.

In 1962, Yuri Nikolayevitch Denisyuk of Russia introduced a scheme for generating holograms that was conceptually similar to the early colour photographic process of Gabriel Lippmann. He succeeded in producing a white light reflection hologram which, for the first time, could be viewed in light from an ordinary incandescent light bulb.

Another significant development in holography took place in 1969 when Stephen A.Benton of Polaroid Research Laboratories, Cambridge,Massachusetts, U.S.A.succeeded in creating white light holograms. Depending on the viewing angle these holograms show all the seven colours constituting white light and are called "rainbow" or Benton holograms. In fact, such holograms are used on credit cards, magazines and other commercial products to prevent forgery. They find extensive use in the field of advertising, publishing and banking industries.

In 1972, Lloyd Cross developed a technique that combined white light transmission holography with the conventional cinematography. In this way he was able to develop integral holograms, called "integrams" Looking through a transparent cylindrical drum, the three-dimensional images can be seen in motion. Such holograms describing motion find applications in science fiction movies.

In 2008, optical scientists under leadership of Tay Peyghambariam working at the University of Arizona College of Optical Sciences in collaboration with Nitto Denko Technical Corporation, Oceanside, California, U.S.A. could make 3-D holographic displays that could be erased and re-written in a matter of minutes. Their device consisted of a special plastic film sandwiched between two pieces of glass each coated with a transparent electrode. In this device the images are "written" with the help of laser beams and an externally applied electric field into the light-sensitive plastic called 'photorefractive' polymer. The holographic displays in this new technique are capable of showing a new image every few minutes.

Principle of Holography

Holography is actually a two stage process which involves:

(i) Recording the hologram; and

(ii) Reconstruction of the image from the hologram.

For recording the hologram, a highly coherent laser beam is divided by a beam splitter into two beams, A and B. The beam A, known as the reference beam, hits the photographic plate

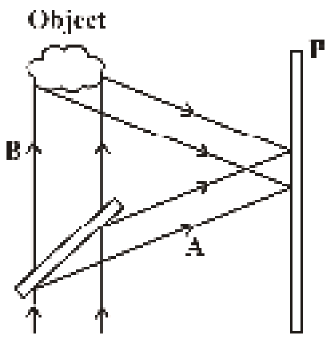

Fig. 1: Reading of a hologram

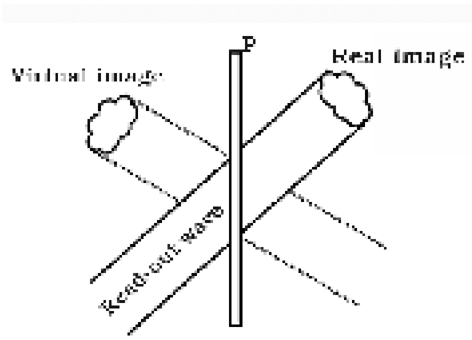

Fig. 2: Reconstruction of the image

directly. The beam B illuminates the object whose hologram is to be recorded .This gets scattered by the object.The scattered beam, called the object beam, impinges on the photographic plate. The superposition of the object beam and reference beam produces an interference pattern which is recorded on the photographic plate. The hologram thus recorded is quite unintelligible and gives no idea about the image embedded in it. However, it contains all the information about the object.

For viewing or reconstructing the image, the hologram is illuminated by the laser beam, which is called the read-out beam. This beam is identical with the reference beam used during the formation of hologram. The points on the hologram act as diffraction grating. The waves diffracted through the hologram carry the phases and amplitudes of the waves originally diffracted from the object during the formation of hologram. The diffracted beam in general, gives rise to two images–one virtual and the other real. The virtual image has all the characteristics of the object and can be seen on looking through the hologram. The real image, called pseudoscopic image, can be photographed directly without using a lens.

Instead of a conventional photographic film, holograms can also be recorded by using a digital device, e.g. a charged-coupled device (CCD) camera. Known as digital holography, the reconstruction process in this case can be carried out by digital processing of the recorded hologram using a standard computer. A three-dimensional image of the object can later be visualized on a computer screen or TV set.

Applications of Holography

Holography has wide range of applications in diverse fields. We shall mention here some of the important applications of holography in science and technology.

An important application of holography is in the field of information or data storage. The ability to store large amount of information is of great importance, as many electronic products incorporate storage devices. The advantage of holographic data storage is that the entire volume of the recording media is used instead of just the surface. Producing holographic CD storage is under intense research and it is estimated that lTB (terarbite) data can be stored on a holographic CD. Certainly, holographic data storage seems to have the potential of becoming the next generation of popular storage media.

Another major application of holography is in the coding of information for security purposes and in preventing forgery. Holograms having security features are often used in credit and bank cards, books, DVDs, branded products, etc. Some Indian and foreign currency notes too carry the security holograms.

Holographic microscopy is another potential application of holography. As is known, a conventional microscope has a small depth of field (the range of depth over which an object is in focus at any microscopic setting). Biological specimens, generally suspended in a fluid, move about making them sometimes in and sometimes out of focus of the microscope. However, this motion can be "freezed" in a hologram taken through the microscope. The reconstructed 3-D image can then be studied at leisure.

Holographic interferometry is yet another significant application of holography. It can be used for testing stresses, strains and surface deformations in objects. Holographic interferometry was actually a chance discovery made in 1965 by a number of groups working around the world. R. L. Powell and K. A. Stetson at the University of Michigan, Ann Arbor, made an interesting discovery in that year. They found that the holographic images of moving objects are washed out. However, if double exposure is used, first with the object at rest and then in vibration, fringes will appear indicating the lines where the displacement amounted to multiples of a half wavelength. In this way, Powell and Stetson could reconstruct vibrational modes of a loudspeaker membrane and a guitar. The principle of holographic interferometry by double exposure was discovered simultaneously and independently in 1965 by Haines and Hildebrand of the University of Michigan, Ann Arbor and also by J.M. Burch in England and by G.W. Stroke and A. Lebeyrie in Ann Arbor, Michigan.

Non-destructive testing by holographic interferometry is a very important industrial application of holography. The technique is able to detect even smallest defects. Applications of holographic interferometry have, therefore, resulted in the improvement and reliability of products.

Medical diagnostics is a new and emerging field of the applications of holography. Some of the prominent fields of medical sciences in which holographic technology is used are radiology, dentistry, urology, ophthalmology, orthopedics, pathology and so on. In the field of ophthalmology, for instance, any retinal detachment or foreign body can easily be detected.

Although holography has applications in diverse fields it still is a relatively expensive procedure. However it is expected that with time we would be able to get over the cost factor and holography will then have many more applications even in everyday life. There is no gainsaying the fact that potential for holographic technology is indeed limitless.