What is Holography? Describe the recording and reconstruction of Holography.

Describe the basic principles of Holography.

Holography:

Holography is a technique that enables a wavefront to be recorded and later re-constructed. Holography is best known as a method of generating real three-dimensional images, but it also has a wide range of other applications. In principle, it is possible to make a hologram for any type of wave.

A hologram is made by superimposing a second wavefront (normally called the reference beam) on the wavefront of interest, thereby generating an interference pattern which is recorded on a physical medium. When only the second wavefront illuminates the interference pattern, it is diffracted to recreate the original wavefront. Holograms can also be computer-generated by modelling the two wavefronts and adding them together digitally. The resulting digital image is then printed onto a suitable mask or film and illuminated by a suitable source to reconstruct the wavefront of interest.

Recorder or reconstruction/Basic principles of holography:

Holography is a technique that enables a light field (which is generally the result of a light source scattered off objects) to be recorded and later reconstructed when the original light field is no longer present, due to the absence of the original objects. Holography can be thought of as somewhat similar to sound recording, whereby a sound field created by vibrating matter like musical instruments or vocal cords, is encoded in such a way that it can be reproduced later, without the presence of the original vibrating matter. However, it is even more similar to Ambisonic sound recording in which any listening angle of a sound field can be reproduced in the reproduction.

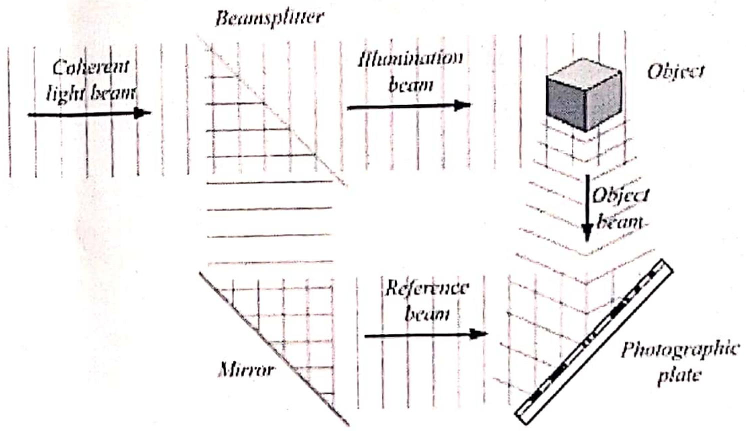


Figure 1: Recording a Hologram

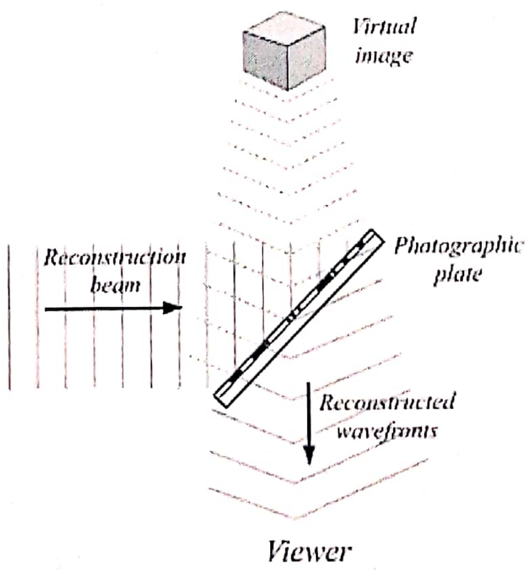


Figure 2: Reconstruction a Hologram

 # What is the basic principle of holography?

In the holographic plate, both the beams combine and interference pattern will be formed. This interference pattern is recorded on the holographic plate. The three-dimensional image of the object can be seen by exposing the recorded holographic plate [hologram] to coherent light. This is the principle of holography.

Distinguish between Holography and Photography

Holography may be better understood via an examination of its differences from ordinary photography:

- A hologram represents a recording of information regarding the light that came from the original scene as scattered in a range of directions rather than from only one direction, as in a photograph. This allows the scene to be viewed from a range of different angles, as if it were still present.
- A photograph can be recorded using normal light sources (sunlight or electric lighting) whereas a laser is required to record a hologram.
- A lens is required in photography to record the image, whereas in holography, the light from the object is scattered directly onto the recording medium.
- A holographic recording requires a second light beam (the reference beam) to be directed onto the recording medium.
- A photograph can be viewed in a wide range of lighting conditions, whereas holograms can only be viewed with very specific forms of illumination.
- When a photograph is cut in half, each piece shows half of the scene. When a hologram is cut in half, the whole scene can still be seen in each piece. This is because, whereas each point in a photograph only represents light scattered from a single point in the scene, *each point* on a holographic recording includes information about light scattered from *every point* in the scene. It can be thought of as viewing a street outside a house through a 120 cm × 120 cm (4 ft × 4 ft) window, then through a 60 cm × 120 cm (2 ft × 4 ft) window. One can see all of the same things through the smaller window (by moving the head to change the viewing angle), but the viewer can see more *at once* through the 120 cm (4 ft) window.
- A photograph is a two-dimensional representation that can only reproduce a rudimentary three-dimensional effect, whereas the reproduced viewing range of a hologram adds many more depth perception cues that were present in the original scene. These cues are recognized by the human brain and translated into the same perception of a three-dimensional image as when the original scene might have been viewed.
- A photograph clearly maps out the light field of the original scene. The developed hologram's surface consists of a very fine, seemingly random pattern, which appears to bear no relationship to the scene it recorded.

Write down the application of Holography

1. **Art**

Early on, artists saw the potential of holography as a medium and gained access to science laboratories to create their work. Holographic art is often the result of collaborations between scientists and artists, although some holographers would regard themselves as both an artist and a scientist.

Salvador Dalí claimed to have been the first to employ holography artistically. He was certainly the first and best-known surrealist to do so, but the 1972 New York exhibit of Dalí holograms had been preceded by the holographic art exhibition that was held at the Cranbrook Academy of Art in

Michigan in 1968 and by the one at the Finch College gallery in New York in 1970, which attracted national media attention. In Great Britain, Margaret Benyon began using holography as an artistic medium in the late 1960s and had a solo exhibition at the University of Nottingham art gallery in 1969. This was followed in 1970 by a solo show at the Lisson Gallery in London, which was billed as the "first London expo of holograms and stereoscopic paintings".

During the 1970s, a number of art studios and schools were established, each with their particular approach to holography. Notably, there was the San Francisco School of Holography established by Lloyd Cross, The Museum of Holography in New York founded by Rosemary (Posy) H. Jackson, the Royal College of Art in London and the Lake Forest College Symposiums organised by Tung Jeong. None of these studios still exist; however, there is the Center for the Holographic Arts in New York and the HOLOcenter in Seoul, which offers artists a place to create and exhibit work.

During the 1980s, many artists who worked with holography helped the diffusion of this so-called "new medium" in the art world, such as Harriet Casdin-Silver of the United States, Dieter Jung of Germany, and Moysés Baumstein of Brazil, each one searching for a proper "language" to use with the three-dimensional work, avoiding the simple holographic reproduction of a sculpture or object. For instance, in Brazil, many concrete poets (Augusto de Campos, Décio Pignatari, Julio Plaza and José Wagner Garcia, associated with Moysés Baumstein) found in holography a way to express themselves and to renew Concrete Poetry.

A small but active group of artists still integrate holographic elements into their work. Some are associated with novel holographic techniques; for example, artist Matt Brand employed computational mirror design to eliminate image distortion from specular holography.

The MIT Museum and Jonathan Ross both have extensive collections of holography and on-line catalogues of art holograms.

2. Data storage

Holographic data storage is a technique that can store information at high density inside crystals or photopolymers. The ability to store large amounts of information in some kind of medium is of great importance, as many electronic products incorporate storage devices. As current storage techniques such as Blu-ray Disc reach the limit of possible data density (due to the diffraction-limited size of the writing beams), holographic storage has the potential to become the next generation of popular storage media. The advantage of this type of data storage is that the volume of the recording media is used instead of just the surface. Currently available SLMs can produce about 1000 different images a second at 1024×1024-bit resolution which would result in about one-gigabit-per-second writing speed.

In 2005, companies such as Optware and Maxell produced a 120 mm disc that uses a holographic layer to store data to a potential 3.9 TB, a format called Holographic Versatile Disc. As of September 2014, no commercial product has been released.

Another company, InPhase Technologies, was developing a competing format, but went bankrupt in 2011 and all its assets were sold to Akonia Holographics, LLC.

While many holographic data storage models have used "page-based" storage, where each recorded hologram holds a large amount of data, more recent research into using submicrometre-sized "microholograms" has resulted in several potential 3D optical data storage solutions. While this approach to data storage can not attain the high data rates of page-based storage, the tolerances, technological hurdles, and cost of producing a commercial product are significantly lower.

3. Dynamic holography

In static holography, recording, developing and reconstructing occur sequentially, and a permanent hologram is produced.

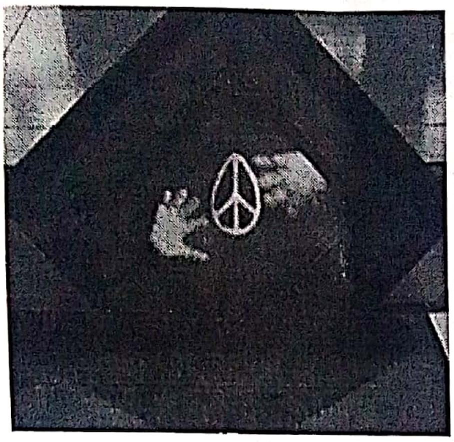
There also exist holographic materials that do not need the developing process and can record a hologram in a very short time. This allows one to use holography to perform some simple operations in an all-optical way. Examples of applications of such real-time holograms include phase-conjugate mirrors ("time-reversal" of light), optical cache memories, image processing (pattern recognition of time-varying images), and optical computing.

The amount of processed information can be very high (terabits/s), since the operation is performed in parallel on a whole image. This compensates for the fact that the recording time, which is in the order of a microsecond, is still very long compared to the processing time of an electronic computer. The optical processing performed by a dynamic hologram is also much less flexible than electronic processing. On one side, one has to perform the operation always on the whole image, and on the other side, the operation a hologram can perform is basically either a multiplication or a phase conjugation. In optics, addition and Fourier transform are already easily performed in linear materials, the latter simply by a lens. This enables some applications, such as a device that compares images in an optical way.

The search for novel nonlinear optical materials for dynamic holography is an active area of research. The most common materials are photorefractive crystals, but in semiconductors or semiconductor heterostructures (such as quantum wells), atomic vapors and gases, plasmas and even liquids, it was possible to generate holograms.

A particularly promising application is optical phase conjugation. It allows the removal of the wavefront distortions a light beam receives when passing through an aberrating medium, by sending it back through the same aberrating medium with a conjugated phase. This is useful, for example, in free-space optical communications to compensate for atmospheric turbulence (the phenomenon that gives rise to the twinkling of starlight).

4. Hobbyist use



Since the beginning of holography, amateur experimenters have explored its uses.

In 1971, Lloyd Cross opened the San Francisco School of Holography and taught amateurs how to make holograms using only a small (typically 5 mW) helium-neon laser and inexpensive home-made equipment. Holography had been supposed to require a very expensive metal optical table set-up to lock all the involved elements down in place and damp any vibrations that could blur the interference fringes and ruin the hologram. Cross's home-brew alternative was a sandbox made of a cinder block retaining wall on a plywood base, supported on stacks of old tires to isolate it from ground vibrations, and filled with sand that had been washed to remove dust. The laser was securely mounted atop the cinder block wall. The mirrors and simple lenses needed for directing, splitting and expanding the laser beam were affixed to short lengths of PVC pipe, which were stuck into the sand at the desired locations. The subject and the photographic plate holder were similarly supported within the sandbox. The holographer turned off the room light, blocked the laser beam near its source using a small relay-controlled shutter, loaded a plate into the holder in the dark, left the room, waited a few minutes to let everything settle, then made the exposure by remotely operating the laser shutter.

Many of these holographers would go on to produce art holograms. In 1983, Fred Unterseher, a co-founder of the San Francisco School of Holography and a well-known holographic artist, published the *Holography Handbook*, an easy-to-read guide to making holograms at home. This brought in a new wave of holographers and provided simple methods for using the then-available AGFA silver halide recording materials.

In 2000, Frank DeFreitas published the *Shoebox Holography Book* and introduced the use of inexpensive laser pointers to countless hobbyists. For many years, it had been assumed that certain characteristics of semiconductor laser diodes made them virtually useless for creating holograms, but when they were eventually put to the test of practical experiment, it was found that not only was this untrue, but that some actually provided a coherence length much greater than that of traditional helium-neon gas lasers. This was a very important development for amateurs, as the price of red laser diodes had dropped from hundreds of dollars in the early 1980s to about $5 after they entered the mass market as a component of DVD players in the late 1990s. Now, there are thousands of amateur holographers worldwide.

By late 2000, holography kits with inexpensive laser pointer diodes entered the mainstream consumer market. These kits enabled students, teachers, and hobbyists to make several kinds of holograms without specialized equipment, and became popular gift items by 2005.[27] The introduction of holography kits with self-developing plates in 2003 made it possible for hobbyists to create holograms without the bother of wet chemical processing.

In 2006, a large number of surplus holography-quality green lasers (Coherent C315) became available and put dichromated gelatin (DCG) holography within the reach of the amateur holographer. The holography community was surprised at the amazing sensitivity of DCG to green light. It had been assumed that this sensitivity would be uselessly slight or non-existent. Jeff Blyth responded with the G307 formulation of DCG to increase the speed and sensitivity to these new lasers.

Kodak and Agfa, the former major suppliers of holography-quality silver halide plates and films, are no longer in the market. While other manufacturers have helped fill the void, many amateurs are now making their own materials. The favorite formulations are dichromated gelatin, Methylene-Blue-sensitised dichromated gelatin, and diffusion method silver halide preparations. Jeff Blyth has published very accurate methods for making these in a small lab or garage.

A small group of amateurs are even constructing their own pulsed lasers to make holograms of living subjects and other unsteady or moving objects.

5. Holographic interferometry

Holographic interferometry (HI) is a technique that enables static and dynamic displacements of objects with optically rough surfaces to be measured to optical interferometric precision (i.e. to fractions of a wavelength of light). It can also be used to detect optical-path-length variations in transparent media, which enables, for example, fluid flow to be visualized and analyzed. It can also be used to generate contours representing the form of the surface or the isodose regions in radiation dosimetry.

It has been widely used to measure stress, strain, and vibration in engineering structures.

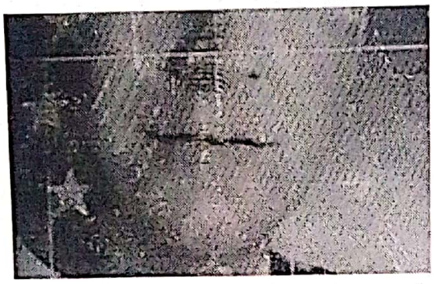
6. Interferometric microscopy

The hologram keeps the information on the amplitude and phase of the field. Several holograms may keep information about the same distribution of light, emitted to various directions. The numerical analysis of such holograms allows one to emulate large numerical aperture, which, in turn, enables enhancement of the resolution of optical microscopy. The corresponding technique is called interferometric microscopy. Recent achievements of interferometric microscopy allow one to approach the quarter-wavelength limit of resolution.

7. Sensors or biosensors

The hologram is made with a modified material that interacts with certain molecules generating a change in the fringe periodicity or refractive index, therefore, the color of the holographic reflection.[36][37]

8. Security



Identigram as a security element in a German identity card

Holograms are commonly used for security, as they are replicated from a master hologram that requires expensive, specialized and technologically advanced equipment, and are thus difficult to forge. They are used widely in many currencies, such as the Brazilian 20, 50, and 100-reais notes; British 5, 10, and 20-pound notes; South Korean 5000, 10,000, and 50,000-won notes; Japanese 5000 and 10,000 yen notes, Indian 50, 100, 500, and 2000 rupee notes; and all the currently-circulating banknotes of the Canadian dollar, Croatian kuna, Danish krone, and Euro. They can also be found in credit and bank cards as well as passports, ID cards, books, food packaging, DVDs, and sports equipment. Such holograms come in a variety of forms, from adhesive strips that are laminated on packaging for fast-moving consumer goods to holographic tags on electronic products. They often contain textual or pictorial elements to protect identities and separate genuine articles from counterfeits.

Holographic scanners are in use in post offices, larger shipping firms, and automated conveyor systems to determine the three-dimensional size of a package. They are often used in tandem with checkweighers to allow automated pre-packing of given volumes, such as a truck or pallet for bulk shipment of goods. Holograms produced in elastomers can be used as stress-strain reporters due to its elasticity and compressibility, the pressure and force applied are correlated to the reflected wavelength, therefore its color. Holography technique can also be effectively used for radiation dosimetry.

9. High security registration plates

High-security holograms can be used on license plates for vehicles such as cars and motorcycles. As of April 2019, holographic license plates are required on vehicles in parts of India to aid in identification and security, especially in cases of car theft. Such number plates hold electronic data of vehicles, and have a unique ID number and a sticker to indicate authenticity.