Holograms

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> "In a Boston hotel suite recently, few dozen normally sedated scientist and engineers were playing with a toy locomotive, a toy train conductor and other such items. The train wasn't really there at all. But if you stood in exactly the right place and look into a piece of equipment you would have seen it, real as life. The toy has being reconstructed by technique that looks simple, yet is one of the most sophisticated developments in modern science. The reconstruction was done with a laser made by Perkin-Elmer Corp., and a "hologram", a special photographic plate made by researchers at the University of Michigan." (4)

That's the first practical hologram ever built. That's the first prototype that catapulted the world's interest in holography. Began in 1947, the process took almost 2 decades to understand. In the modern day world, holography serves many purposes. Holograms are also used in art, security, and entertainment. Mankind has always found way to record anything his or her eye can perceive. Beginning in the 1900's photography has continually being perfected. New uses have immerged for this two dimensional image. It's only a matter of time until a technique to create a 3D image will be discovered. In many ways, one might think holography share similarity with photography, but they are in-fact fundamentality different. Photography is a process to record two-dimensional light distribution of an image.

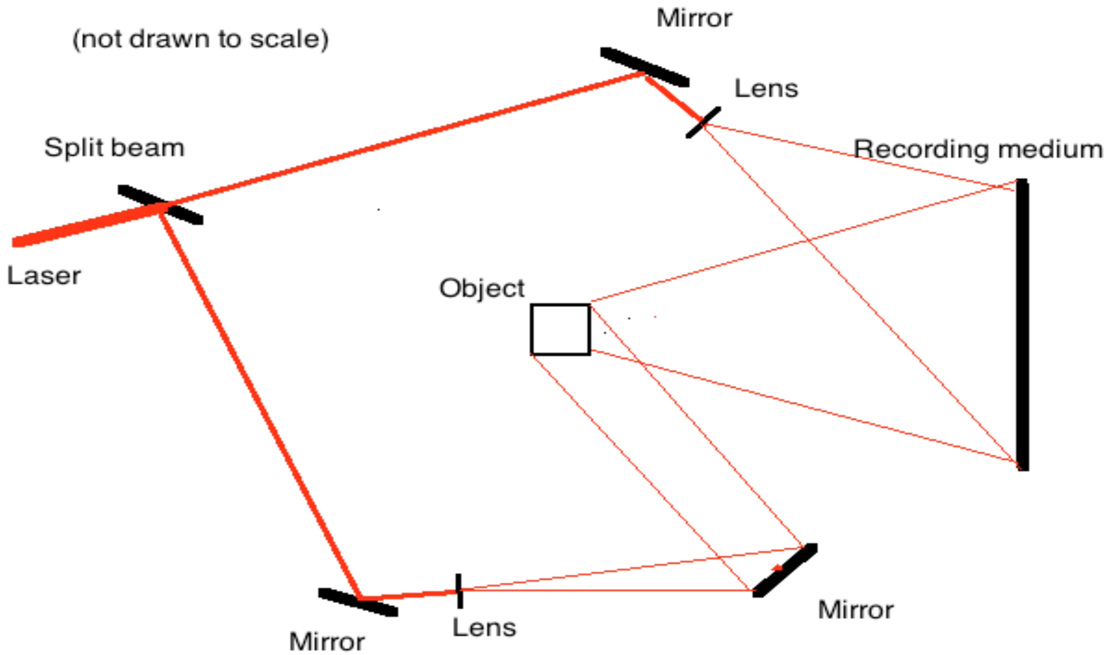
For example, let the image be that of a tree. Let the sun shine lights on a tree. The designated tree will reflect lights from all angles from the top leave to the bottom trunk. These random light rays will be emitted in all directions. A lens will then focus those scattering light into an image. This image will be collected onto a recording medium. That will become the 2D image of the tree. Holography on the other hand doesn't record that focused image, it instead record the light waves emitted by the image. The waves are recorded in a way that it reconstructs the original object even with the absence of the object, therefore creating this virtual image. Even with the absence of the original tree, one can look onto the image and view as if a real tree was there. If one moves while still looking at the tree the image will appear different than that at the original because the light wave at that point was different comparing to the originally position the person was standing on. (6)

Holography, also known as wavefront reconstruction, is a technique that uses to record light dispersed by an object. Dennis Gabor first introduced the idea to the world in 1947 and because of his contribution to optics; he won a Noble Prize in 1971 for his endeavor. (2). Although he never built a practical hologram, many use the same principle passed down by him. Gabor borrowed a dual-stage imaging process (Optical transformation, followed by a second transformation to form an image) from scientists such as Sir Lawrence Bragg and Miecislav Wolfke. (5) Gabor's original intention was to improve on the electron microscope built by Bragg, because of that, the original setup is very similar. Much of holography can be explain using the properties of light. Sinusoidal light wave consist of a distinct wavelength and a distinct frequency. Wavelength is the distance from any one point to another point on the wave with the same phase. Frequency in general is defined as a number of occurrences over time. (3) Both of these properties affect one another. Since Light travels through air at a constant speed, the numeral values of changes inversely proportional with each other. For example, when wavelength decreases, frequency increases and vice versa. A problem arise when Gabor began his experiment was that he was unable to find light sources that are coherent. Light coherence is defined as if light waves have the same phase and frequency. (5) As physicist Adolf Lohmann simply stated, "coherence is something that describes how well two partner are willing and able to cooperate."(2) Lights with similar frequency were difficult to isolate back in the 1950's. For example, tungsten light bulb emits different frequency of light depending on the atom that was being heated. Another example is the sunlight, sunlight splits into different colors when put into a prism because the lights in the white lights are actually a rainbow of colored light of different frequency that a traveling together so that they appeared "white". Simply put, they needed monochromatic lights or light with similar frequency. For lights to have the same phase they need to be in similar orientations. Because waves interfere differently depending on their position, this too was difficult to come by. Some interference might create a wave stronger than the original, (constructive interference) while other cancels out each other's energy. (destructive interference) (3) The purpose of making coherent light was to create a well-defined interference fringe. An interference fringe is the edge of the part where lights interfere. A "coherent" light produce a sharper interference fringe, therefore producing a clearer image. In the beginning Gabor used light filtered from a mercury arc to produce monochromatic light and a pinhole to achieve spatial coherence. Even with this, there wasn't enough electronic or mechanical stability within his system to produce the result he wanted. Gabor later tried the experiment again with electrons to make the holograms and the light to reconstruct the image, which also did not succeed. (5) Back then Gabor uses zone plate (acts as a lens that focus light) to diffract light. (2) Diffraction describes the bending of light from a small opening. One major problem that Gabor encountered was that the diffracted light from zone plates creates two images, one from the zone plate itself (reference wave), and other a virtual image that appear behind the zone plate (diffracted wave). (2) This "twin image" proves troubling in creating a hologram because they interfere with each other. Another problem with the optical component was the slightest amount of airborne particle landed on a lens or plate would greatly alter the image of the hologram. The dust itself will create a hologram and therefore reducing the effectiveness of the final image. (5) Because lasers wasn't develop at the time, the light source used by Gabor and other researchers limited the amount of progress done by him during his time researching holograms. At the same time near the end of 1950's the interest for holography reduced greatly.

With the invention of laser (acronym for Light Amplification through Stimulated Emission of Radiation.) In the 1960, many of the obstacles were remove and building a better hologram became possible. Resurgence in interest of holography peaked around this time due to many factors. (2) First, lasers are known far their high degree of temporal and spatial coherence. (2) Not only that, a laser provide a powerful light source from a greater area. Now holograms can be made from much larger materials and still can be made out clearly. Not only that the laser will also provide a clearer fringe pattern because they are coherent. With a near perfect light source, all that need to be fixed was the design. Second, Emmett N. Leith and Juris Upatnieks came up with a revolutionary design that eliminated some flaws that associate with the older design made by Gabor. They realized that a light beam can be split into two waves and each can travel on their own path and both end on the same photographic film plate (5). A "splitter" is use to separate the main wave to two smaller ones. One of them is the reference wave and the other wave will be the original "twin wave." The known notorious "twin image" that messed with the older model were no longer unwanted; instead, it became a useful addition to the holographic process. In addition to that, the separation of the two waves resulted in the elimination of self-interference. Earlier model's interference resulted in a boundary glare around the image. (2) In addition to creating an off axis beam method, Leith and Upatnieks create the concept of diffuse illumination holography. Sometime only parts of the holograms can be observed because a light spreads unevenly through the holograms. By placing a diffuser behind the object, the entire object becomes illuminated and any imperfection due to dust and other small particles will be smear out. (2) After a period of time of tweaking, the final design of the holograph seems complete.

The basic concept of creating a modern holograph:

- Light emits from a light source, preferably a laser
- Light is split into the diffracted wave and reference wave
- Reference wave hits the recording medium
- Diffracted wave travels through a medium until it hits the designated object
- Light hits the designated object and reflect off of the object
- The reflected light hits the recording film and creates an interference pattern
- This pattern is record as the hologram
- A reconstruction beam is pass through at the same angle
- Light is refracted off of the hologram into a observer's eye
- A virtual image appears behind the hologram.


(not drawn to scale)
Mirror
Lens
Split beam
Recording medium
Laser
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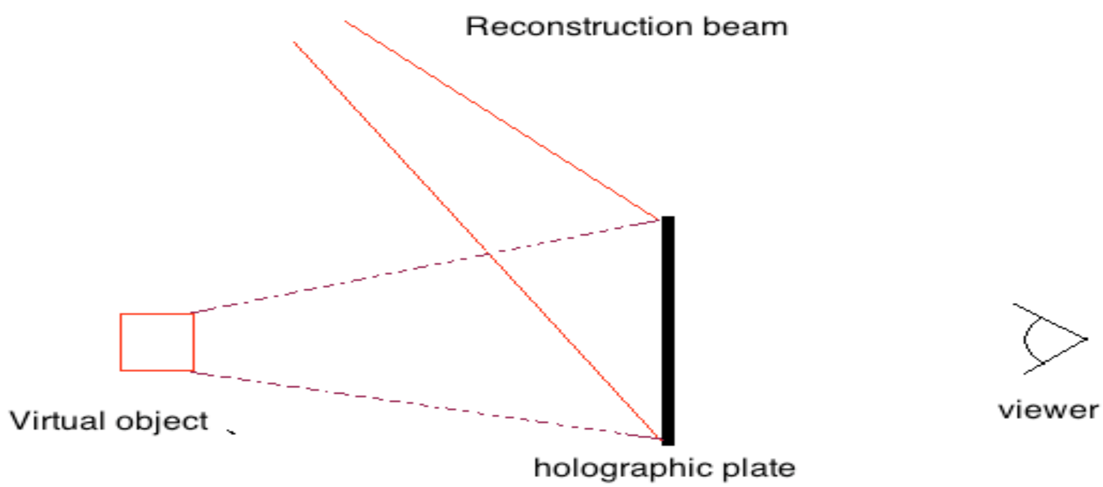
Reconstruction beam
Virtual object
viewer
holographic plate

(1)

One cannot mention holograms without their modern-day applications. For one, modern artists often use holograms as a form of expression. After all, the driving force for much of the research within the field comes from curiosity of the human eye. Modern artists such Andy Warhol is known to cooperate with scientist to create a piece of holographic art. (5) With the surge in counterfeiting goods on the rise, manufacturers also began to holograph a small portion of their merchandise to counter-act that. Holograms gave counterfeiters an obstacle that they haven't encountered in the past. This three dimensional art is tough to duplicate, in part due to it's complexity and in part due to it's general unavailability. VISA cards for example, began to print a hologram of an eagle on all of its cards back in the 1980's. (5) It became a proof of authenticity for its customers. Not only that, the hologram also act as a visual stimulator. Also, many of the world's currency began to holograph some part of their currency in order to reduce counterfeiting. The most well known holographic currency is the Euro. (5) Third, researchers began using holographs as a way to store memories. Memory storage began simply as applying a picture onto a screen then it evolves into more complicated ones. Holographic designers learned that they could store a great bit of information in three-dimensional polymers. The technology they use to create a hologram further advanced by the invention of disc. This later continued to be a vital source of coding information. The recently marketed “blu-ray” disc uses such techniques.

Popular misconception about hologram arises from our media and from hologram promoters. Many of the misconceptions are continually repeated that they become a persistent idea that’s tough to erase from the mass’s memory. One of these ideas states that if one cute a hologram in half, each half would retain the original image as a whole. For example, if one cuts a VISA card’s eagle in half, one would expect the original image of the eagle to appear exactly the same on both side of the hologram. But this is not true, as Jason Sapan from holographic studios states it:

> “Think of a hologram as a window. Anywhere you look through a window you see what's on the other side. If you were to paint the window black and scratch a hole in the paint on the left side of that window just big enough to look through, you would see everything on the other side of the window. Like looking through a peephole. “(6)

The image that was preserved was the image from that specific angle, not the exact image. Another misconception arisen when Star Wars trilogy came out and began talking with “hologram projections”. The truth is that holograms are not projection;

they are merely a film that reflects light much the same way as the original object. (6) There never was a projector that projects light to create any sort of image.

Ever since the invention of holography in 1947, the world's fascination with holography never ceased. Movies and cinematic romanticize holograms and make the world more futuristic. Although mankind's progress is nowhere near that point, the possibility of holography is still great. Ranging from art to science, every field has its uses for holograms. Only the future generation can improve what we have today and make the impossible possible.

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