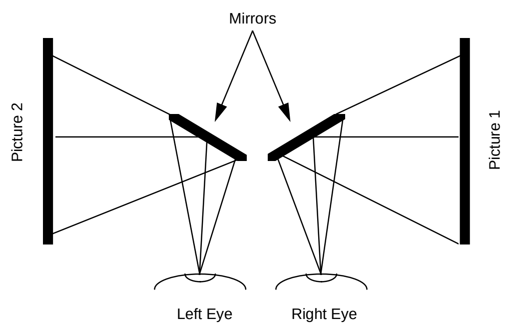
Comparing the Quantum Optics Holophoto™ Three-Dimensional Process to Other Existing Processes

by Stanley H. Kremen

Stereo Photography

Three-dimensional stereoscopic imaging was developed during the first half of the nineteenth century. In 1838, Sir Charles Wheatstone proposed a stereoscopic viewer. It became known as the Wheatstone stereoscope.



A Wheatstone Stereoscope

The principle of the stereoscope is to present each eye with a two-dimensional picture from a stereoscopic pair. A stereoscopic pair of pictures is formed from two pictures, each one of the same scene, but viewed from a slightly different perspective. The pictures can be photographs or drawings. If the pictures are identical, the scene appears two-dimensional. But, because the pictures are slightly different, the human brain merges them into a single pseudo three-dimensional scene.

The stereoscope evolved over the years into a device where a barrier separated the left and right pictures of the stereoscopic pair, and where a pair of lenses magnified the pictures.

An Early Wooden Stereoscope

The stereoscope shown in the above photograph is seen from the rear. The device was handheld using a long handle (foreground), and viewed through a pair of lenses (background). A wooden barrier is positioned between the lenses perpendicular to the plane of the lenses. A stereoscopic pair of images is mounted on the crossbar. The images may be photographs or drawings.

Initially, the stereoscopic pictures were artistic drawings. However, sixteen years before Wheatstone proposed the stereoscope, Niepce was the first to produce photographs.

A Stereoscopic Photograph To Be Used With a Stereoscope (circa. 1900)

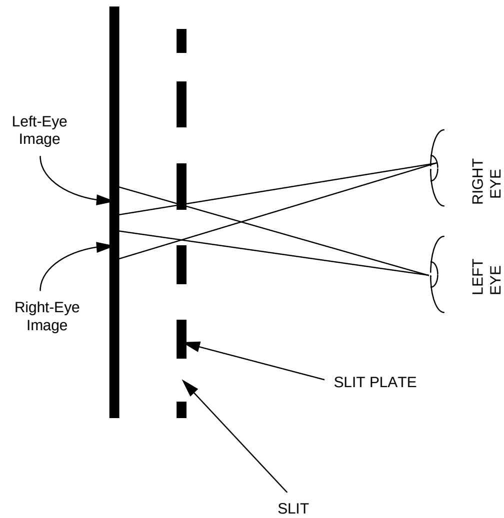
Stereoscopic photographs are created by one of three methods of photography:

- the two pictures are taken successively by a single camera;
- the two pictures are taken simultaneously using two synchronized cameras; or
- the two pictures are taken simultaneously using a single, special stereo camera.

Kodak Stereo Camera

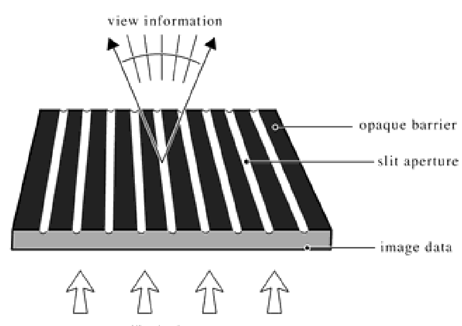
Parallax Stereograms

The parallax stereogram was invented by F.E. Ives in 1903. A stereoscopic pair of photographs was taken. A glass plate having vertical parallel lines (a slit barrier plate) was positioned between the lenses and the photographic plate. The left-eye and right-eye pictures are printed in fine stripes alternatively with the same pitch as the slits in the slit barrier plate. Once the photograph is printed, a geometrically congruent slit barrier plate was positioned between the developed photograph and the viewer. Both the left-eye and right-eye photographs are visible through each slit. However, when positioned properly, the slit barrier plate separates the images for each eye.



Viewing a Parallax Stereogram

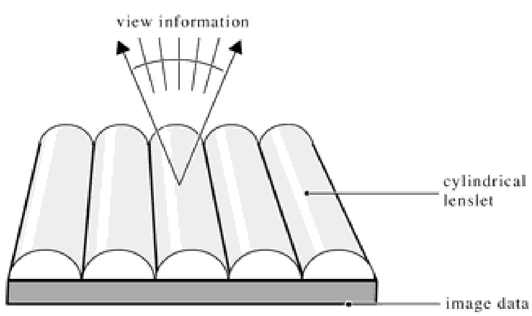
The stereoscopic pair of pictures can be viewed in three-dimensions by a number of viewers simultaneously.



Viewing A Photograph Through A Slit Barrier Plate

Slit barrier plates have several drawbacks. The first difficulty is that the three-dimensional pictures suffer from lack of brightness. The second difficulty is that the pitch of the slits creates a Moiré pattern, which is annoying. Many people experience vertigo and dizziness while viewing these photographs. The third difficulty is that the pitch of the slits can create diffraction pattern artifacts.

The parallax stereogram evolved over the years where the slit barrier plate was replaced by a lenticular lens plate. A lenticular lens plate consists of an indefinite number of parallel vertical cylindrical lenses.



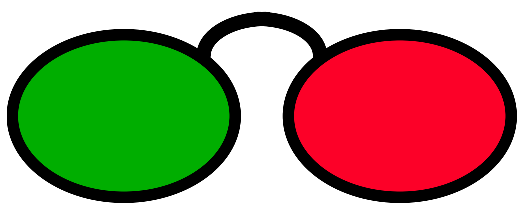
Viewing A Photograph Through A Lenticular Lens Plate

Parallax stereograms are easier to manufacture in large quantities where lenticular lens plates are used.

The pictures stored on a parallax stereogram are only binocular. This medium is a form of stereoscopic photography that may be viewed without special viewing aids. It is compatible with motion picture technology, and the images may be transmitted digitally. This technology is presently used in 3D computer monitors, 3D gaming devices and 3D smart phones to capture and view three-dimensional images without glasses. However, the pictures have a very poor quality. People and objects look like cardboard cutouts positioned in a three-dimensional volume that does not have very much depth.

Anaglyphic 3-D

Parallax stereograms lack significant depth because of the fine pitch of the slit barrier plate or the lenticular lens plate. The depth problem is solved by magnifying the stereoscopic pair of photographs. For example, the depth problem is absent when viewing a three-dimensional picture through a two lens stereoscope. Magnification of stereoscopic pairs can be done using ordinary projection methods. However, the magnification must be accompanied by a means of separating the left-eye image from the right-eye image, and directing it to the appropriate eye for viewing.



Red and Green Glasses to be Used With Anaglyphic 3-D Pictures

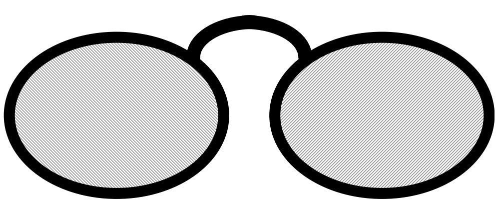
Anaglyphic 3-D became popular during the 1930's, and the process produced photographic stills and motion pictures. Initially, the movies were photographed in black and white. One of the stereo pair photographs is projected in red and the other is projected in green. Sometimes, a blue lens is used instead of green. The red photograph cannot be seen with the green lens, and the green photograph cannot be seen with the red lens. Therefore, the glasses provide the stereo pair separation.

Viewing anaglyphic 3-D movies can be very annoying. The picture suffers from brightness, the red and green superimposed colors are unnatural, and prolonged viewing causes eyestrain and head aches. This will be discussed later.

Until the 1970's, production of full color anaglyphic 3-D movies was impractical. At that time, some full color 3-D movies were presented to television audiences. The anaglyphic 3-D images were superimposed on a full color two-dimensional image of the same scene. Although these movies appeared in full color, viewing them through the red and green glasses proved very annoying.

3-D Viewing With Polarizing Lenses

During the 1950's, 3-D movies viewed with polarizing lenses became very popular. These movies were viewable in full color. The polarizing lenses have a neutral color.



3-D Glasses With Polarizing Lenses

Polarization of light is a state in which rays of light exhibit different properties in different directions. Ordinary light is randomly polarized. A polarizing filter only allows light having a specific polarization to pass. The 3-D glasses comprise two pieces of polarizing material. The two lenses are physically oriented so that the left-eye lens allows light having a given polarization to pass, and the right-eye lens only allows light having a polarization perpendicular to the right-eye lens to pass. In that specific orientation, if the left-eye lens is positioned directly in front of the right-eye lens (or *vice versa*), no light will pass. The two-lens combination will be opaque. Therefore, if a stereo pair of pictures is projected onto a screen, with each picture having an opposite polarization, the left-eye lens will not allow the right-eye picture to pass, and *vice versa*. Thus, picture separation is accomplished.

During the 1950's, 3-D movies were projected onto the screen using a projector with two polarizing lenses. The images from the two lenses were superimposed upon one another. In this way, polarized 3-D movies were similar to their anaglyphic 3-D counterparts. But they were less objectionable because their color was more natural.

When polarized light is projected onto an ordinary screen, the light reflected into the audience loses its specific polarization. An ordinary screen serves to randomize the reflected polarization. To overcome this difficulty, an aluminized screen is used. Such a screen can reflect the original polarization.

Single Lens 3-D Projection

Vectography

3-D vectography utilizes a special type of film. Both sides of the film (front and back) have a photographic emulsion. The emulsion is able to retain the correct polarization of its image. One image of the stereo pair is recorded on one side of the film, and the other image is recorded on the other side of the film. Most of the resulting superimposed image has a neutral polarization. However, the edges of objects retain their specific polarizations. When the vectograph is projected onto an aluminized screen with a single unpolarized lens, a person can view the three-dimensional image when he wears polarizing glasses.

The two disadvantages of vectography are that the film is expensive, and color film is not available. The three-dimensional pictures are in black and white.

Shutter Lens 3-D

Until the 1990's, the only type of 3-D movies that could be broadcast on television used the anaglyphic process. However, a method for broadcasting 3-D television programs emerged. Television pictures are broadcast with a synchronization pulse for each frame. When glass CRT television tubes were in use, a special box was placed within view of the screen. This special box would rebroadcast the synch pulse using infrared light.

The viewer wears shutter glasses. Each lens comprises an electro-optic crystal and a polarizing filter. The glasses are battery operated. When a voltage is applied to an electro-optic crystal, the crystal rotates the plane of polarization of the light passing through it. The angle of rotation depends upon the applied voltage. The electronic circuitry of the glasses apply a voltage sufficient to rotate the plane of polarization by 90 degrees.

When no voltage is applied to the crystal, the polarizing filter permits the light to pass. However, when the appropriate voltage is applied, the plane of polarization is crossed perpendicular to that of the polarizing filter, and no light passes. The circuitry of the shutter glasses causes the appropriate voltage to apply to alternate lenses. First it is applied to the left lens, and then to the right lens. This is repeated thirty times each second. The glasses also have a photocell that detects infrared light. The sequence is controlled by the infrared synch pulse that emanates from the special box.

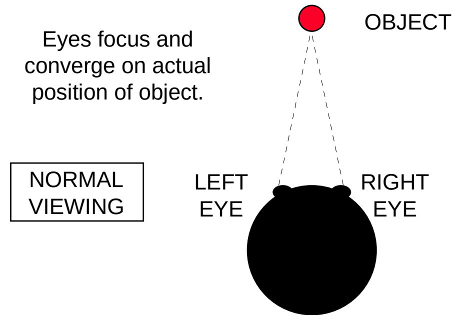
Special DVD's were made upon which were recorded many of the 3-D movies of the 1950's. When shown on ordinary television sets, the left and right stereo pair of pictures appeared alternatively on the screen. The synch pulse indicated to the glasses which eye needed to see the picture on the screen. The screen no longer needed to retain the polarization of the images. An aluminized screen was not necessary. Separation was accomplished by synchronizing the correct stereo pair image with the unshuttered lens. Thus, we have 3-D television.

Glass CRT television screens are no longer being manufactured for consumer use. Instead, television monitors comprise LCD or plasma screens. Neither of these devices requires a synch pulse, and video frames appear on them independent of the synch pulse. With the CRT television, the special box was connected to the TV set, and the synch pulse was rebroadcast. However, the special box that broadcasts the infrared synch pulse is useless with modern television sets. Therefore, in order to have 3-D television, a new special box must detect and rebroadcast the synch pulse independent of the television set.

Many movie theaters have instituted this type of 3-D projection to show 3-D movies. Glasses distributed to viewers are shutter type glasses, and an infrared synch pulse is broadcast in the theater and is picked up by the shutter glasses.

The shuttering that occurs thirty times each second cannot be detected by most viewers due to persistence of vision. However, some viewers complain of annoying flicker. As with viewing most polarizing 3-D movies, the pictures lose half of their brightness. And then, there is the eyestrain and headaches inherent in 3-D.

3-D Viewing Discomfort

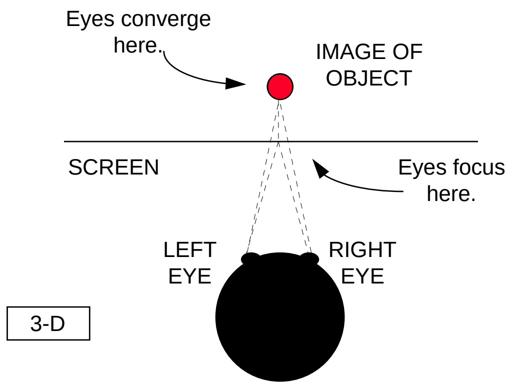


Normal Viewing of a Live Three-Dimensional Scene

When we view a live three-dimensional scene, each eye sees a separate two-dimensional image, each from a slightly different viewpoint. This binocular vision is interpreted similarly to the way we interpret a stereoscopic pair of images. The brain gets the impression of three-dimensional depth.

There are two major differences. Parallax is the ability to look around objects to see what is behind. This is completely absent in stereoscopic 3-D viewing. The second difference is how we focus on objects in real life. As can be seen from the above drawing, when we look at an object in real life, both eyes focus and converge on the object. Everything else is blurred out. When we change our concentration to a second object, we lose our focus and convergence on the first object.

However, when we view a scene in a 3-D movie, everything appears in focus (unless specifically blurred by the cinematographer). This makes the image look unreal. Also, while our eyes converge to the apparent position of an object, our eyes focus upon where the image of that object really exists -- on the screen. This is illustrated in the drawing below.



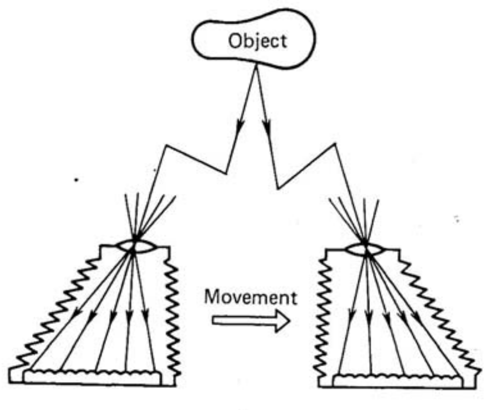
Viewing of a 3-D Scene

Observe that the viewer's eyes focus and converge at two different points in space. This unnatural viewing condition strains the eye muscles. After watching a full-length 3-D movie, our eyes are tired. Many people experience headaches.

It is not the glasses that cause the discomfort. The eyestrain is inherent in any stereoscopic three-dimensional process. During the twentieth century, many inventors have attempted to develop three-dimensional stereoscopic motion picture processes that do not require viewers to wear glasses. None of these processes was ever commercialized. The eyestrain is inherent in all of these processes. It is the unnatural viewing condition of the stereoscopic process that causes the problem.

Parallax Panoramagrams

This non-stereoscopic three-dimensional photographic technique was invented in 1928 by H.E. Ives. The parallax panoramagram is similar to the parallax stereogram (discussed earlier) in that no special glasses or viewing aids are required to view the three-dimensional scene. In fact, the two types of photographs are often confused with one another. Parallax panoramagrams are often called lenticular 3D photographs.

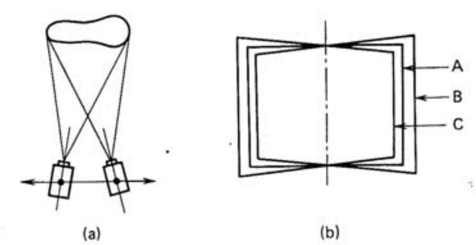


Photographing A Parallax Panoramagram

A parallax panoramagram is a specially fabricated time-lapse photograph of a three-dimensional scene. Rather than utilizing a stereoscopic pair of photographs to create the impression of three-dimensions in the brain, these photographs actually reconstruct virtual and real three-dimensional images in space. Consequently, the photographs look more realistic, and are not uncomfortable to view.

Parallax panoramagrams are usually photographed using a single camera having a large single lens. Ive's camera placed a slit barrier plate in contact with the photographic plate between it and the lens. Modernly, a lenticular lens plate replaces the slit barrier plate.

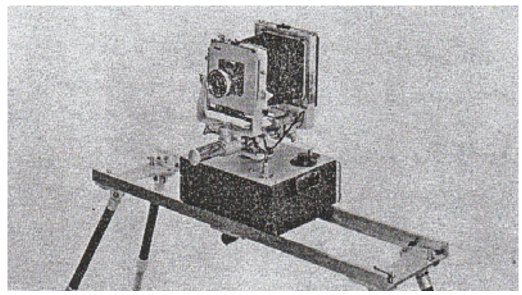
In order to create a parallax panoramagram, during a single exposure, either the camera must move relative to the scene or the scene must move relative to the camera. The case where the camera moves relative to the scene is shown in the above drawing. Here, a camera is mounted on a horizontal rail. During the exposure, the camera moves from left to right on the rail. The lens assembly is mounted to the camera using a bellows. To avoid the keystone effect, the lens travels a shorter distance than the photographic plate. The keystone effect is shown below.



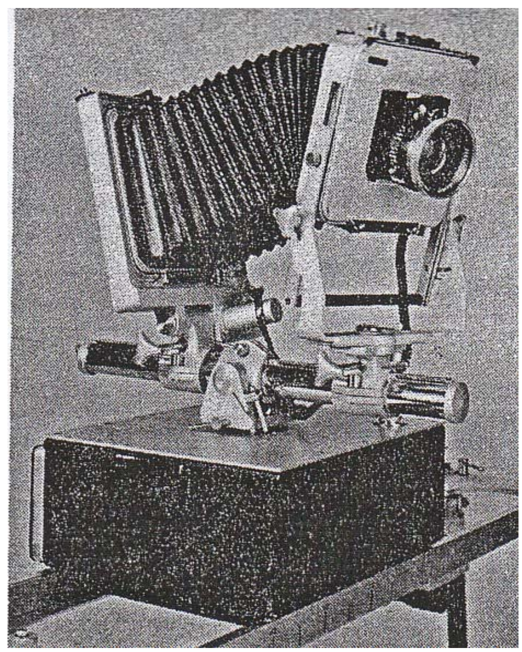
Keystone Effect

A keystone photograph is trapezoidal in shape. In the case of a parallax stereogram, if the lens were to move through the same distance relative to the scene as the photographic plate, the image will appear taller on one side of the photograph than the other will. The effect reverses with camera movement. The image is rectangular in only one position.

Movement of the camera relative to the scene is useful to produce parallax panoramagrams of outdoor scenes. Alternatively, the scene may move relative to the camera. This technique is employed in photographic studios. Here, the subjects are mounted on a turntable. The time-lapse exposure is made as the turntable moves while the camera is kept stationary. To avoid a keystone effect, the lens still moves relative to the photographic plate. The camera is shown below.



Rail-Mounted Camera



Parallax Panoramagram Camera

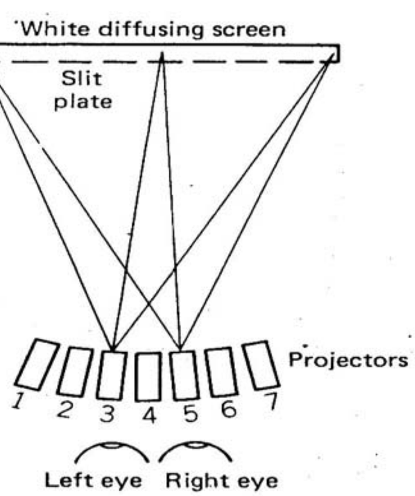
When the photograph is developed, the image is unintelligible. However, once the lenticular lens plate is placed in front of the photograph, a true three-dimensional image of the scene is reconstructed.

Parallax panoramagrams often produce spectacular three-dimensional images. However, they suffer from four disadvantages.

- Because the pitch of the lenslets is small and a single lens is used to photograph the scene, picture definition (resolution) suffers.
- Because a single lens is used, the depth of focus is poor. Objects in the foreground are clearer (more focused) than objects in the background.
- Three-dimensional images are pseudoscopic (*i.e.,* background objects appear closer than foreground objects). They must be everted for normal viewing.
- Because time-lapse photography is used to create the photograph, this technology is generally unsuitable for motion pictures.

Projection-Type Parallax Panoramagrams

In an effort to overcome the drawbacks mentioned above, Ives proposed a multi-camera multi-projector approach.



With this technique, multiple photographs are taken of the same scene from different viewing angles. This may be done with a single camera taking successive photographs or with multiple cameras taking simultaneous photographs. The multi-camera method has the advantage that all aspects of the picture are time coherent. Typically, the multiple cameras are positioned in an arc and pointed at the subject

Once developed, the multiple photographs are projected through a slit barrier plate or through a lenticular lens plate to create a parallax panoramagram photograph or to be viewed directly by people in an audience. This is shown in the above drawing.

This technique requires the same number of projectors as cameras. In the above drawing, seven cameras and projectors are used. In the drawing, Ives' original configuration is shown utilizing a slit barrier plate. People in the audience will observe a pseudo three-dimensional image reconstructed in space.

The three-dimensional images produced by this method do not exhibit the same spatial quality as those reconstructed from more traditional parallax panoramagrams. The individual projected images are discreet rather than continuous. While this three-dimensional imaging technique creates parallax, the greater the number of cameras used to photograph the scene and projectors use to reconstruct the scene, the better the three-dimensional reconstruction. Clearly, if only two projectors are used, then we have a parallax stereogram. Therefore, this method produces a picture that is a hybrid between the parallax stereogram and the parallax panoramagram. The three-dimensional image quality is better than the former and poorer than the latter. If too few cameras are used, the flipping from viewpoint to viewpoint becomes annoying. However, this technology is compatible with motion picture projection.

Yet, the image quality of these projection-type parallax panoramagrams suffers. The number of projectors that may be practically employed in a theater is limited. Consequently, the picture definition is poor and usually out of focus. Unwanted artifacts appear on the reconstructed image, thereby requiring a degraded (or slightly blurred) image to be projected to eliminate them.

Holography

When you throw a pebble into a pool of water, circular waves radiate from the point where the pebble hit the water. When you throw a handful of pebbles into the water, each pebble creates its own set of waves. The pattern is no longer clearly defined. The waves interfere with each other. Yet, the multiple waves create a characteristic pattern on the surface of the water.

Light is a wave like phenomenon. When we look at the world, it does not appear as bright as it can be, because the light is not pure. It is of many different colors and intensities. By analogy, it is as though someone threw a very large number of pebbles into the water. You cannot see the interference pattern.

However, the light generated by a laser is very pure. Every light wave has the same color. The waves are identical, in both wavelength and intensity. And they travel together, peak-to-peak and trough-to-trough. A laser beam is coherent and very bright.

When two laser beams intersect on a photographic plate, the waves interfere with each other. The resulting photograph is called an interferogram. A hologram is a special kind of interferogram. At least one of the intersecting light beams reflects off the surface of an object onto the photograph. It is called an object beam. The other light beam is standard laser light emitted from a laser. It is called a reference beam. When the reference beam and the object beam intersect at a photographic plate, a hologram is produced. The hologram is not a photograph of the object, but rather it is a two-dimensional photograph of the interference pattern caused by the reference and object beams. The photograph resembles the pattern caused by throwing pebbles into a pool of water.

Once the hologram is developed, if it is illuminated by the reference beam, it reproduces the object beam. In other words, light waves are sent into the eyes of a viewer as though the object is really there. A viewer can perform no visual test to determine whether of not the object is real. This is true three-dimensional viewing. And, no glasses are required.

If the holographed scene contains multiple objects that block each other, a viewer can look around any object to see what is behind. The image has true horizontal and vertical parallax. When he moves his head, he sees the same scene from a completely different viewing angle.

Disadvantages of Holography

Holographic movies are impractical for a number of reasons.

- It is difficult to prepare holograms. True holography requires laser light in a darkened room. This is not healthy for humans, because lasers can cause eye damage. Also, you cannot make a true hologram of an outdoor scene.
- You cannot project a hologram onto a screen to make a holographic movie. A hologram projected onto a screen will be seen as a bunch of wavy lines.
- You cannot enlarge holograms for large audiences. Holograms are usually small. Certainly, that would be the case for holograms prepared on movie film. If you try to enlarge a hologram of a three-dimensional image, you will de-magnify the image by the amount of the hologram magnification. It has the opposite effect of what you want to accomplish.

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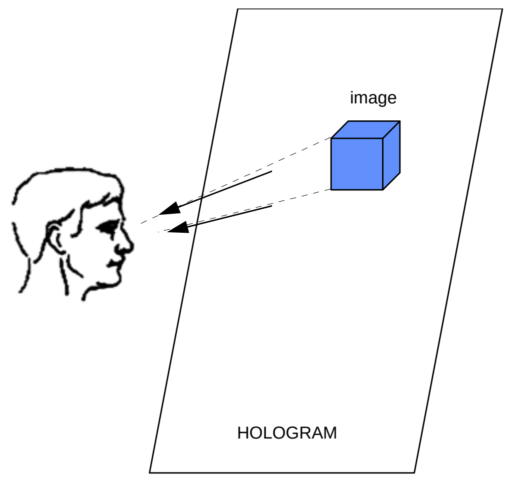
- Finally, if you try to magnify the three-dimensional image itself, the depth magnification will be so much greater than the lateral magnification that the image will look ridiculous.

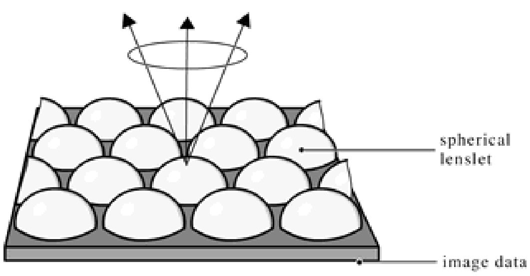


Integral Photography

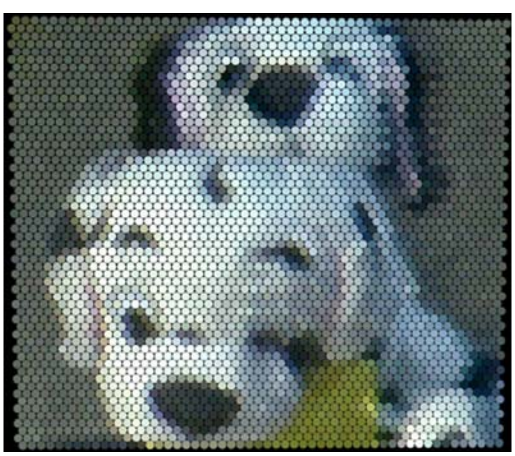
If you have an ordinary two-dimensional photograph of two people standing side-by-side, and you cut the photograph in half lengthwise, the image of each person will be in a separate half of the photo. In one hand, you hold a picture of one person, and in the other hand, you hold a picture of the other person. This is not the case with a hologram. If you have a three-dimensional hologram showing two people standing side-by-side, and you cut the hologram lengthwise, each half will reconstruct a three-dimensional image of both people. The difference is that each resulting hologram will show both people from a different viewing angle.

Similarly, if you cut a hologram into a thousand pieces, each resulting hologram will still reconstruct both people. If the pieces are small enough, a viewer will only see the scene in two-dimensions, because they are each too small to be seen by both eyes. However, if you assemble the little pieces to reassemble the hologram, the entire scene will be seen in three-dimensions as though the original hologram was never cut into pieces. This is the principle of integral photography.

An integral photograph is taken of a live scene with a fly's eye lens positioned in front of a photographic plate. When the photograph is developed, and placed behind the original fly's eye lens, a three-dimensional image of the original scene is produced. Each lenslet photographs the entire scene in two-dimensions,



but from a slightly different viewing angle.



Integral photography has the advantage in that the photographs can be made in ordinary indoor or outdoor lighting of large scenes on movie film. When viewers in the audience are far enough away from the screen so that they cannot see the individual lenslets of the fly's eye lens, the integral photograph is the equivalent of a hologram. The integral photograph itself is two-dimensional. However, with the fly's eye lens, light waves are transmitted into the eyes of the audience that tell viewers that the scene is absolutely real. Viewers can look around objects to see what is behind. Integral photographs produce absolutely real three-dimensional images. While holographic movies are impractical, integral photographic movies can be made and projected onto two-dimensional screens.

A Fly's Eye Lens

A Fly's Eye Lens Projects Light Waves At A Viewer As Though The Scene Really Exists.

The above photograph shows a three-dimensional reconstruction from an integral photograph of stuffed toy puppies. Note the appearance of the fly's eye lens in the photograph. It looks as though you are viewing the image through chicken wire.

Shown above is a three-dimensional reconstruction from an integral photograph of a person's face. Below, is a three-dimensional reconstruction of a finger.

Although the fly's eye lens is still visible in both of the integral photographs of the human subjects, the image is blurred (degraded) in order to make viewing more acceptable. In the reconstruction above, the subject's finger extends in front of the fly's eye lens.

Integral photography has three inherent problems.

1. Three-dimensional images produced from integral photographs are pseudoscopic (*i.e.,* turned inside out). Additional processing is required to evert the images to make them orthoscopic (*i.e.,* the way objects are normally viewed).
2. Integral photographs suffer from poor resolution (definition). Note that the images in Figures 2, 3, and 4 are blurry.
3. It is necessary to magnify the three-dimensional images so that they may be viewed by large audiences in a theater. However, as previously mentioned, when you magnify a three-dimensional image, the magnification is not uniform. There is great depth distortion.

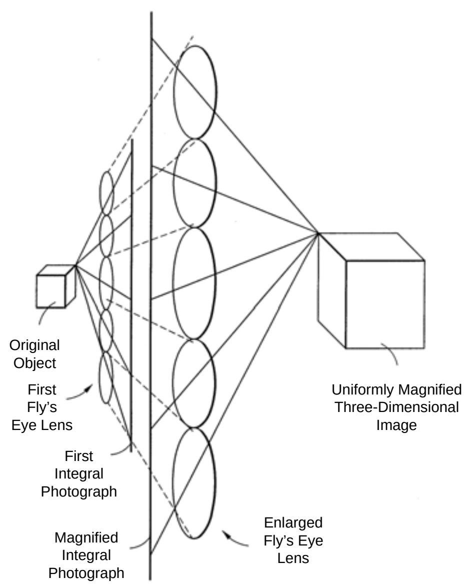
These problems have so far prevented the introduction of integral photography into three-dimensional motion pictures.

The Quantum Optics Holophoto™ 3-Dimensional Process

The Holophoto™ 3-Dimensional Process uses integral photography to produce three-dimensional images. However, the previously discussed problems with integral photography have been solved. The process is protected by eight US patents.

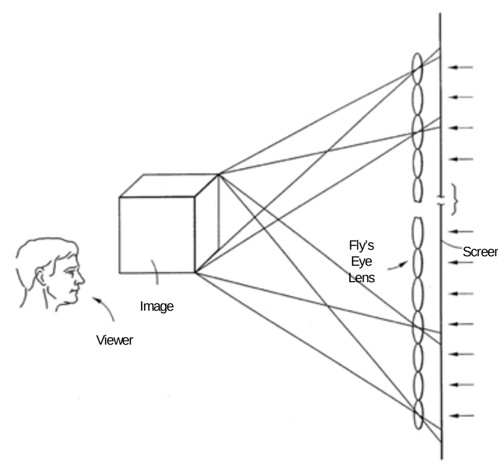
The Holophoto™ Process solves the following problems.

- The process produces realistic full-color three-dimensional images in space without the use of lasers. Photography of live actors in outdoor scenes is easily accomplished.
- The reconstructed three-dimensional pictures have very high resolution.
- The reconstructed three-dimensional pictures are magnified uniformly so that they may be viewed by large audiences.
- Pseudoscopic images are everted to orthoscopic images by a unique patented methodology.



Uniform Magnification of Three-Dimensional Images Using the Quantum Optics Holophoto™ Process

Uniform three-dimensional image magnification is accomplished in the following way. As can be seen in the drawing above, a first fly's eye lens is used to create an integral photograph of the original object. In the drawing, the object is a cube. Once created, the integral photograph is magnified using a desired magnification. This is the magnified integral photograph. The three dimensional image is reconstructed from the magnified integral photograph using an enlarged fly's eye lens. The new lens is geometrically similar to the original lens. The diameter of the individual lenslets is multiplied by the magnification, and the focal length of the lenslets is multiplied by the same magnification. In this way, the (F/#) of all the individual lenslets is the same for both fly's eye lenses. This magnification of both the integral photograph and fly's eye lens produces a uniformly magnified three-dimensional image. Therefore, it is now possible to produce three-dimensional images that may be viewed by large audiences in a theater.



Viewing a Reconstructed Three-Dimensional Picture in a Theater

The above drawing illustrates an integral photograph projected onto a rear projection screen in a theater. The three-dimensional image is reconstructed using a large fly's eye lens. In the drawing, the image is created in front of the screen. It is a true three-dimensional image. The combination of the projected integral photograph and the fly's eye lens send the same light rays into the eyes of the viewer as if the cube were actually in front of the screen. The viewer can look around the cube. He cannot perform any visual test to determine whether the cube is really there.

The Quantum Optics Holophoto Process functions with four modes of capture and display:

1. Photography on film coupled with projection onto a special theater screen.
2. Digital photography coupled with digital projection onto a special theater screen.
3. Digital photography coupled with direct digital transmission to a special active video theater screen.
4. Live direct transmission of optical images to a special theater screen.

The first methodology involving optical photography on film coupled with optical projection could prove useful for still image display. However, the currently preferred embodiment is the third methodology utilizing digital photography and direct digital transmission. This embodiment does not require projection, because the magnified integral photograph can be transmitted directly to the video theater screen.

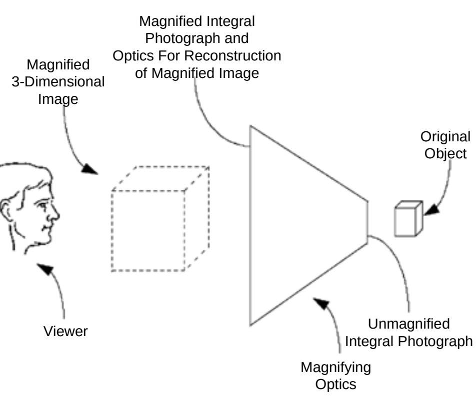
The camera is extremely simple and very inexpensive. It consists of seventy ordinary digital video cameras arranged close together in a straight line. Computer software interpolates between each adjacent pair of cameras to produce twenty-seven elemental images required for the integral photograph. Since there are seventy cameras, the computer software produces an integral photograph with 1,890 elemental images. An integral photograph with this many elemental images exhibits very high resolution.

To further deal with the resolution problem, vertical parallax is eliminated. Viewers do not need to look over or under objects in a movie theater. Yet when they move their heads from side-to-side, they can still look around objects. Viewers on the left side of the theater see the scene differently from those on the right side of the theater. This is exactly how viewers view a live stage play. Instead of a fly's eye lens, the screen consists of a large lenticular screen.

Finally, to further improve the resolution, a black-and-white screen is used. Therefore, the elemental images alternate between red, blue, and green. This is done using computer software. The image is reconstructed in full color during showing of the movie.

Theater size video monitors do not currently exist. Large video displays are created using video walls. However, in order to obtain the desired resolution, the Quantum Optics screen is a video wall consisting of a very large number of small video monitors. Each video monitor will be either one-inch or two-inches on a side.

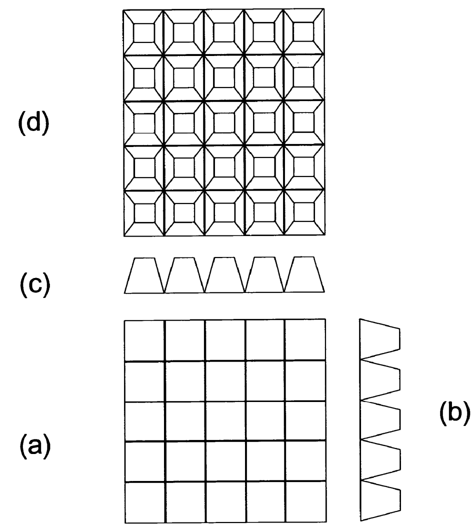
The reason for using so many small monitors is to increase screen resolution. Standard computer monitor resolution for an LCD monitor is 640 × 480 pixels (approximately one-third of one megapixel). This resolution is hardly sufficient to show integral photographic movies. By creating a video wall consisting of a matrix of a great many small monitors, and distributing the picture across all of the monitors, the screen will have sufficient resolution to show these pictures.



Modular Integral Magnifier

The principle of the modular integral magnifier is illustrated in the above drawing. An individual modular integral magnifier is shaped as the frustum of a pyramid. In the diagram, a small square faces right, and a large square faces left. An integral photograph, exhibiting only horizontal parallax, is made from an original object or scene (in this case, the small cube on the right side of the drawing). In this preferred embodiment, this unmagnified integral photograph is captured on video on the rightmost square face of the device. The integral photograph is magnified either optically or electronically to produce a magnified integral photograph on the leftmost square face of the device.

When the leftmost square face of the device is coupled with a lenticular screen, a uniformly magnified three-dimensional reconstruction of the original three-dimensional scene appears before the viewer.



A Matrix Array of Modular Integral Magnifiers Forming A Video Wall Screen

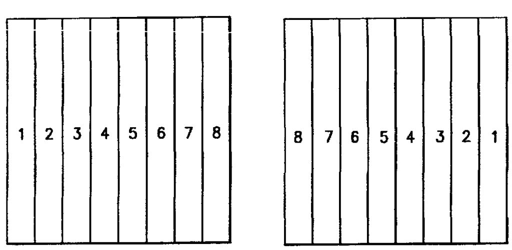
The above drawing is a schematic illustration of the modular integral magnifier screen. The drawing is divided into four sections.

(a) Front Elevation View – the side of the screen that faces the audience. It is perceived as a matrix of small squares.
(b) Right Side View – here the shape of a modular integral magnifier is clearly perceived as a frustum of a pyramid. The small square top faces right, and the large square base faces left.

(c) Top Plan View – this is similar to the right side view.
(d) Rear Elevation View – the side of the screen that faces away from the audience. The small square top contains electronics into which a transmission wire is inserted.

One of the problems with a video wall is that the junction between adjacent monitors is visible to the audience. Therefore, in a video wall, the audience will see a grid superimposed upon the plane of the screen. To overcome this effect, the brightness of the video picture at the center of each monitor will be dimmed relative to the sides of the monitor.

There remains the problem that the three-dimensional reconstruction from an integral is pseudoscopic. Most eversion techniques use a double fly's eye lens or a double lenticular sheet. This causes a drastic decrease in resolution. The Quantum Optics™ Process everts the three-dimensional image without loss of resolution.



(a) (b)

Eversion of a Pseudoscopic Image to an Orthoscopic Image

The method of eversion is illustrated in the above drawing. In drawing (a) on the left, the original integral photograph containing eight elemental images reconstructs a pseudoscopic three-dimensional image. If the positions of the elemental images are reversed as in drawing (b) without mirror reversing the elemental images themselves, the three-dimensional reconstruction will be orthoscopic.