To continue with our examination of the little-known world of 3-D in motion pictures, author Bertram starts with an explanation of holography, or photography in 3-D with lasers. Last month's installment dealt with the history of 3-D filmmaking, and the perceptual and psychological factors involved. This month, he concludes with projections on the future and reminders of many of the artistic complications of making films with an additional visual dimension.

Let the imagination run wild, and get ready for that big step into the holographic movie. And watch that first step...

film and the third dimension

(part 2)

by John Bertram

Enter the Laser

Holography, holography, holography! So much is being said about this new and complex procedure that it is difficult to put it all into perspective (no pun intended) for the purposes of this report. Nonetheless, the attempt shall be made.

Put as simply as possible (in order that I not get too confused) each microscopic point of a three dimensional object reflects light waves out in ever expanding "wavefronts". These wavefronts interact with each other and form a complex wave pattern. If this complex wave could be reproduced we would have a visual copy of the object itself, in three dimensions, and distinguishable only by touch.

Ordinary photography records only a part of this complex wave pattern: the intensity, or amplitude, of the waves. In order to have a three dimensional image, the "phase variations", or patterns of interaction between the wavefronts, must also be reproduced. But in order to record these on a photosensitive plate, they must first be converted into amplitude equivalents. This is accomplished by the technique of "interferometry", in which a photographic record is made of the interference pattern formed when a plane wave intersects with the complex wave. When this recorded "fringe" pattern is illuminated by another plane wave from the same angle, the original complex wave is reproduced, giving a three dimensional image of the original object. This technique is known as "wavefront reconstruction".

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This is the basic theory for holography; it has existed since the 1940's. It was not until the development of the laser, however, that holography became practical. This is because white light is simply too complicated – when it reflects off an object it produces a complex wave pattern with such a staggering amount of information that no way is known to record it all. Holography demanded a much simpler, pure, "coherent" light whose waves had the same frequency and would remain "in phase", or in step with one another. In 1960, as if to oblige, along came the laser with these very properties.

The basic method for producing a hologram consists in first splitting a laser beam in two. One beam is used to illuminate the object, thus producing a reflected complex wave. The other beam, the "reference beam", is precisely aimed to intersect with the complex wave where it meets the photosensitive plate, thus producing a recording of the interference pattern of the reference beam and the complex wave. No lenses are used to focus the image, thus each point on the hologram records the entire scene though with a slightly different interference pattern. When viewed normally, no images are recognizable on the hologram. But when illuminated by another coherent light beam at the proper angle, the information contained in the recorded fringe pattern in a sense impresses itself onto the new beam and a three dimensional image is seen apparently at the same distance from the hologram as was the original object.

Holograms vs. Stereograms

The effect of viewing a hologram is very much like looking through a window: you can see over, under, and around the image only to the degree allowable by the frame size of the window. Of course, no special glasses of any kind are required to view a hologram.

Holograms are also easier to view than stereograms in that they do not pit accommodation or convergence against stereopsis. The holographic image is viewed with the same cues as would be used to view the real object.

And while on the subject of depth cues another interesting comparison between holograms and stereograms should be made. It concerns the cue of motion parallax. Whereas a hologram exhibits true motion parallax (within the limits of its "window frame effect"), a stereogram does not – in fact it appears to exhibit reverse motion parallax. This is because when a viewer moves in relation to a projected stereogram the foreground objects do not change in their relationship to the background, as each eye is still being presented with the same scene from the same angle. But this is contrary to our expectations and so we tend to see the objects moving somehow in synchronization with our own movements. (The fact that contradictory motion parallax does not destroy our sense of depth is an indication of the importance of binocular disparity.) This difference between holography and stereoscopic photography is significant and I shall return to it shortly.

Holographic Cinema... (?)

Still holograms are one thing; moving holograms are something else again.

In his book **Expanded Cinema,** Gene Youngblood dates the first successful holographic motion picture as taking place in April of 1969 at the Hughes Research Laboratories in California: "... after eight months and many thousands of dollars in equipment, Jacobson produced 30 seconds of film in which one peeked through a 70mm aperture to find tropical fish swimming leisurely in three-dimensional space." But even the problems involved in producing a peepshow at this level are enormous.

First an elaborate system of mirrors, lenses, synchronous shutters, and a specially adapted camera has to be devised.

Because of the "window frame effect", the largest available film format has to be used – a comparatively small 70mm.

Holography demands film with very high resolution which means very low film speeds. But the exposures must be extremely brief as the slightest movement will blur the image, and so lasers which emit great amounts of light in the minutest fraction of a second are required. The amount of power that would be necessary for such a laser to illuminate a room-sized scene for a moving hologram is staggering. And even then the "camera" would have to remain absolutely fixed and motionless.

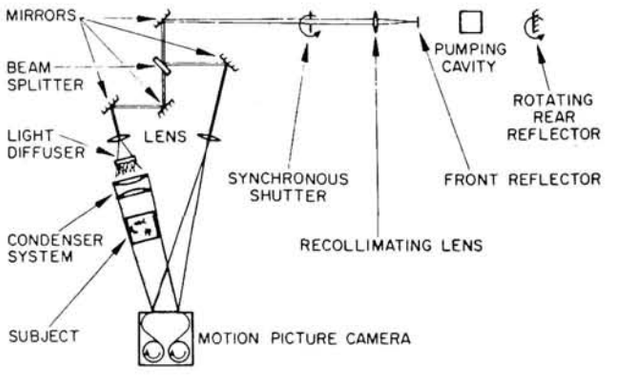
At present holography owes its existence to coherent light. But because coherent light has only one frequency holograms made from one laser are monochromatic. The only laser currently suitable for moving holograms is a pulsed ruby laser which produces a grainy red image. Colour holograms have been made by mixing two or three different lasers, but the result is still far from satisfactory.

Experts disagree on whether quality white light holograms will ever be possible. This means that at least now both outdoor and black and white holography are by definition impossible. This last point in particular would seem to place a drastic limitation on the artistic potential of moving holograms.

But let us for a moment put our faith in science, let our imaginations run wild, and say that these and many other serious problems are all solved (as no doubt most probably will be). Projecting the moving hologram would be comparatively easy, involving only special lenses and mirrors. We would then at last have holographic cinema. Or would we? I am now going to posit that "holographic cinema" is impossible, as it is a contradiction in terms. Allow me to explain.

First I must define what I mean by cinema: I consider cinema to be the selective presentation of moving images usually accompanied by an arrangement of sound. The key word is *selective.* Referring back to the differences in the motion parallax displayed by holograms and stereograms, one realizes that in an audience viewing a stereo film everyone is seeing the same 3-D image, whereas in an audience viewing a holographic film everyone would be seeing a different 3-D image (especially in the case of quite feasible 360 degrees holograms).

I may be old fashioned in saying this but I truly believe that in cinema it is the filmmaker who should decide what images the audience sees, whether in 2-D or 3-D, and not



Schematic diagram of Hughes holographic movie system. Laser is indicated as "pumping cavity"

the audience itself. For it seems to me that film's basis as an art lies in this process of the creative *selection* of images on the part of the filmmaker or makers. A 3-D person looking off at an angle just "ain't the same thing" as a 3-D person staring you right in the face. In this sense holographic film is simply too 3-D for its own good.

Having said this how do we re-classify "holographic cinema"? Electronic theater? Perhaps – it would seem to have more in common with the stage than with the screen. (Imagine **Hamlet** or **Macbeth** performed with real ghosts!) But it may just as well come to be considered as a separate medium in its own right.

Certainly moving holograms will have many applications in science and communications. No longer is it groundless to speculate on the possibility of having a sit-down face-to-face discussion with someone who is thousands of miles away. Laser-based television sets are already being developed. If and when a stereoscopic film system not requiring glasses is developed such movies could perhaps be transmitted and reproduced holographically.

But if moving holograms came to be considered the sole form of 3-D cinema, I believe that the art of film would suffer.

Stereoscopic Cinema

Stereoscopic cinema (or any film system using pairs of images to produce binocular disparity) is not new, but it is largely untouched. And yet even in its present awkward and crude form stereo film has many possibilities for expanding the film artist's potential for expression.

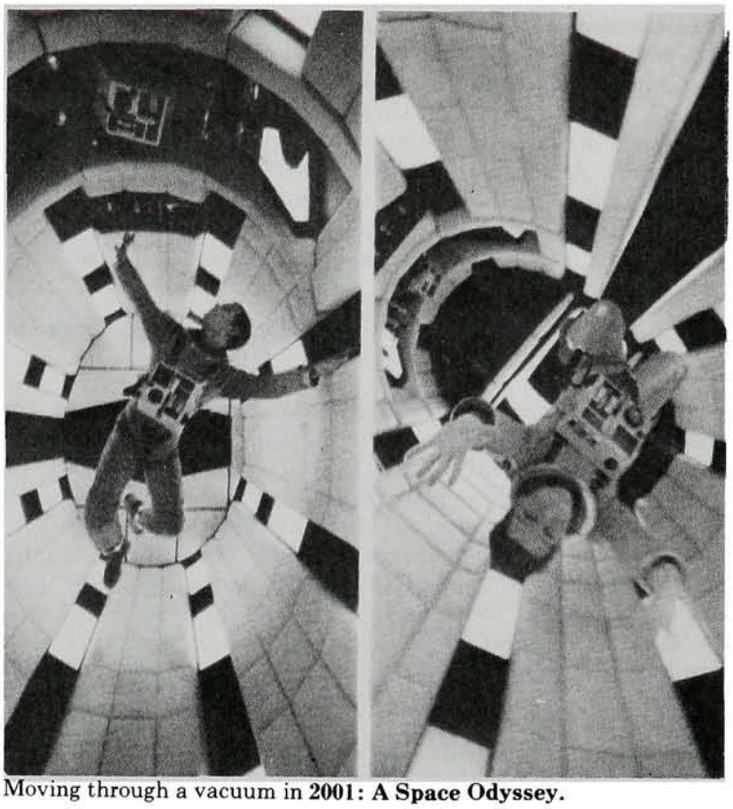
I have recently taken a large number of stereoscopic slides and based on my observations of these still pictures I have extrapolated some possibilities for film.

1) Depth quality: As a general rule the stereo scenes with the strongest sense of depth are those which already have a good sense of depth through monocular cues prior to stereopsis (such as scenes of platforms or streets, which emphasize linear perspective).

2) Viewing pyramid: When viewing any film we see through an imaginary four-sided pyramid whose apex is our eyes and whose lines extend out to the four corners of the screen and beyond to infinity. This pyramid becomes important for stereo films as the closer an object is meant to appear to the viewer the more centrally it must be located in the frame. As that same object moves towards one side of the screen the pyramid will push it back until it finally reaches the picture plane at the screen edge. When the central portion of the picture connects in some direct way with the edge, as in a linear perspective shot, the viewer will tend to see the whole scene as behind the screen.

3) Use of lenses: By bringing in more peripheral vision and exaggerating perspective, wide angle lenses produce very effective stereo shots. Telephoto lenses, which in 2-D flatten perspective, nonetheless produce interesting stereo shots – there is a sense of depth between foreground objects and background, but the objects themselves look rather like flat cardboard cut-outs. One can see how in this situation the zoom lens is invested with even greater power.

4) Separation of images: Normally pairs of stereo images are photographed from positions separated by three to four inches in order to roughly correspond to the displacement of our eyes. But this separation can be varied in order to alter the spatial relationships of the objects in the scene – the greater the separation the greater the binocular disparity and so the greater the depth. This technique can be used to photograph city-scapes where a separation of four inches would have little effect on buildings hundreds of yards away. An interesting side effect is that as the depth



Moving through a vacuum in **2001: A Space Odyssey.**

of a scene is increased by greater separation of the images the apparent size of the scene decreases. And so a city taken with image separation of a hundred feet tends to look like a miniature model of the same city viewed at close distance.

In combination with camera angles this could be used to make one person appear smaller than another. Or it could be used to show the gradual separation of two people by increasing the depth space between them. Or perhaps for special effects a model could be made to appear life size by decreasing the separation of the images.

5) Mixing 2-D and 3-D: Many interesting effects could be obtained by purposely photographing the two images "out of synch". For instance you could have a street corner in which all the buildings and sidewalks were in 3-D but where the people and cars were flat and moving through each other – transparent two dimensional ghosts who didn't really belong in the picture. Or you could have a two dimensional double exposure in which one or both of the images gradually changed (through a zoom lens and/or camera movement) so that they would eventually come together, fuse, and form a single 3-D image.

And just as many films today mix black and white and colour, so too could stereo films mix 2-D and 3-D (as well as black and white with colour) to suggest different times, locations, or states of mind.

Whether or not 3-D films will use a two-image system is not known. But no matter what system is finally developed, the possibilities for its utilization will be limited only by the artist's imagination. I have included these examples merely to suggest a few of these possibilities. The list can only grow longer.

Quo Vadis, Cinema?

> "... the film medium (besides working with the compulsive realism of photography) gives us more of physical reality than any other art. The fact that the cinema presents so comparatively complete a picture of the real world is sometimes referred to by describing cinema as a total art, and it has encouraged people to think that the way to artistic perfection lies in ap-

proaching nearer and nearer to full physical reality. It will be found that the film does, nevertheless, differ enormously from physical reality, and that it is largely in these differences that its artistic power lies. The truth of this may be illustrated by a 'reductio ad absurdum'. Advocates of 'cinéma total' consider the cinema imperfect to the extent that it falls short of complete reality; the perfect cinema they say would attain total reality. But if this dream were realized, then the cinema would *be* reality – and would cease to be art."

Ralph Stephenson and J.R. Debrix, **The Cinema as Art** (Penguin, Baltimore, 1969), p. 57.

Agreed. It was on these grounds that I questioned the validity of moving holograms as cinema.

But then why have 3-D at all?

For one thing it seems inevitable. We began with black and white "silent", went to black and white sound, then to colour, then to wider screens, then to stereophonic sound, and all the while getting technically more and more precise. This ironic trend toward realism in film is difficult to explain. Perhaps it is because so many film goers view the movies merely as an escape hatch from the day-to-day world, and thus the more realistic the fantasy the stronger is their feeling of participation and involvement in it. In this context 3-D movies would seem the logical next step.

But more importantly let us remember that whatever the reason for these technological advances may be, almost all have added to the artistic potential of the medium. **Citizen Kane** could not have been made in the silent period, just as Kubrick's **2001** could not have been made in black and white. This is not to say that recent films are better because they are more realistic, but simply that every filmmaker must first consider the technology available to him and then work within that technology.

Film after all is the technological medium, and as such its potential for artistic expression grows with every technological advance. 3-D cinema, properly used, would allow the filmmaker (if he so wished) to work with depth in the same way that he works with time, form, tone, and colour.

But if and when 3-D films begin to be widely produced, they will at first again be very sensational and commercial ("See the gorilla jump into *your* lap!"). This will probably be inevitable, due to the higher production costs. Many people will say that 2-D is dead, forgetting that colour did not kill black and white. Others will shun 3-D because of its commercial nature and refuse to see its artistic potential.

Hopefully though, cool heads will prevail in the long run. The choice of 3-D or 2-D will become much the same as the filmmaker's present choice of black and white or colour – mediated both by esthetic and financial/commercial considerations.

In short, 3-D films *will not* revolutionize the cinema. They *will* give the film artist an additional tool with which to work, create, and express. □