ON HOLOGRAPHY AND A WAY TO MAKE HOLOGRAMS

by J. Pethick

Cover drawing by Peg Bennett, based on a sculpture by J. Pethick

A BELLTOWER BOOK





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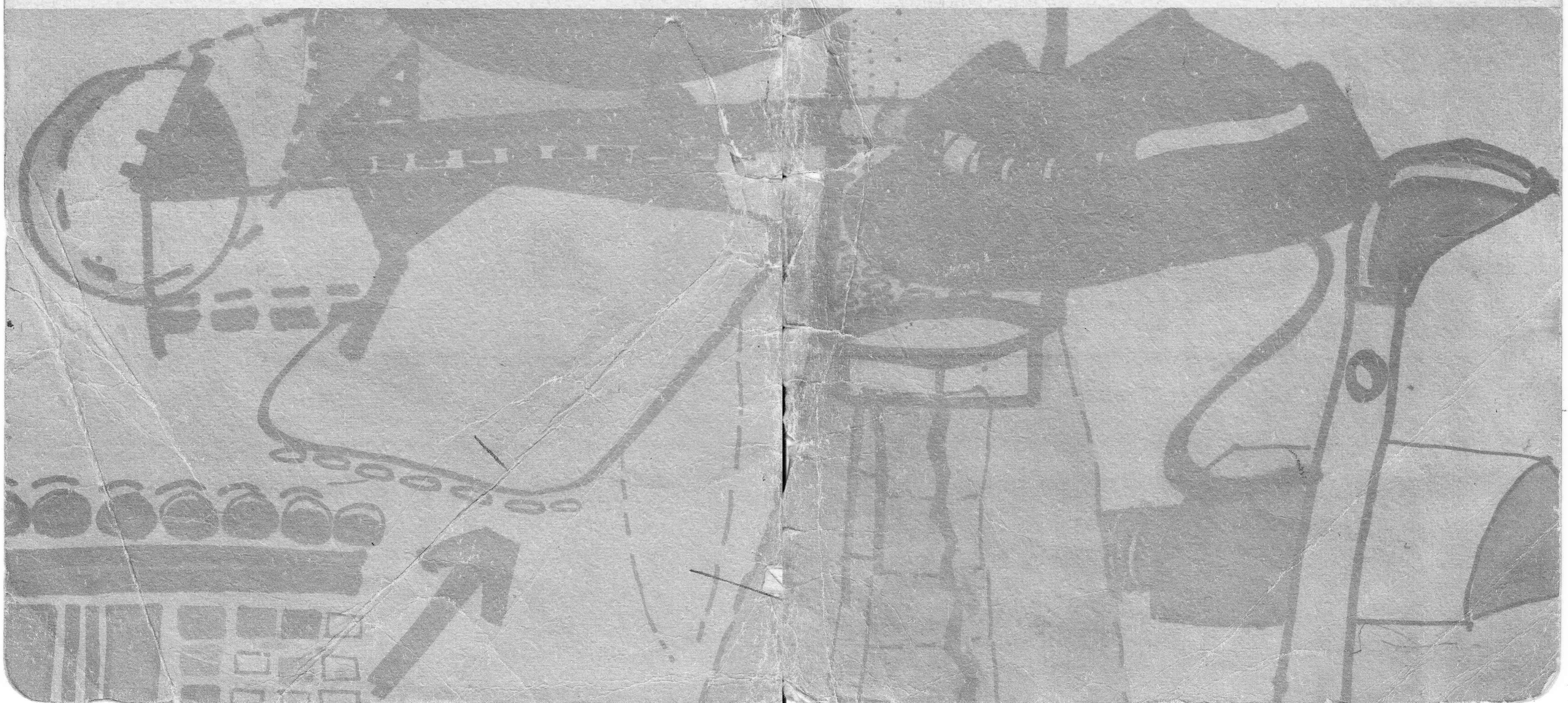
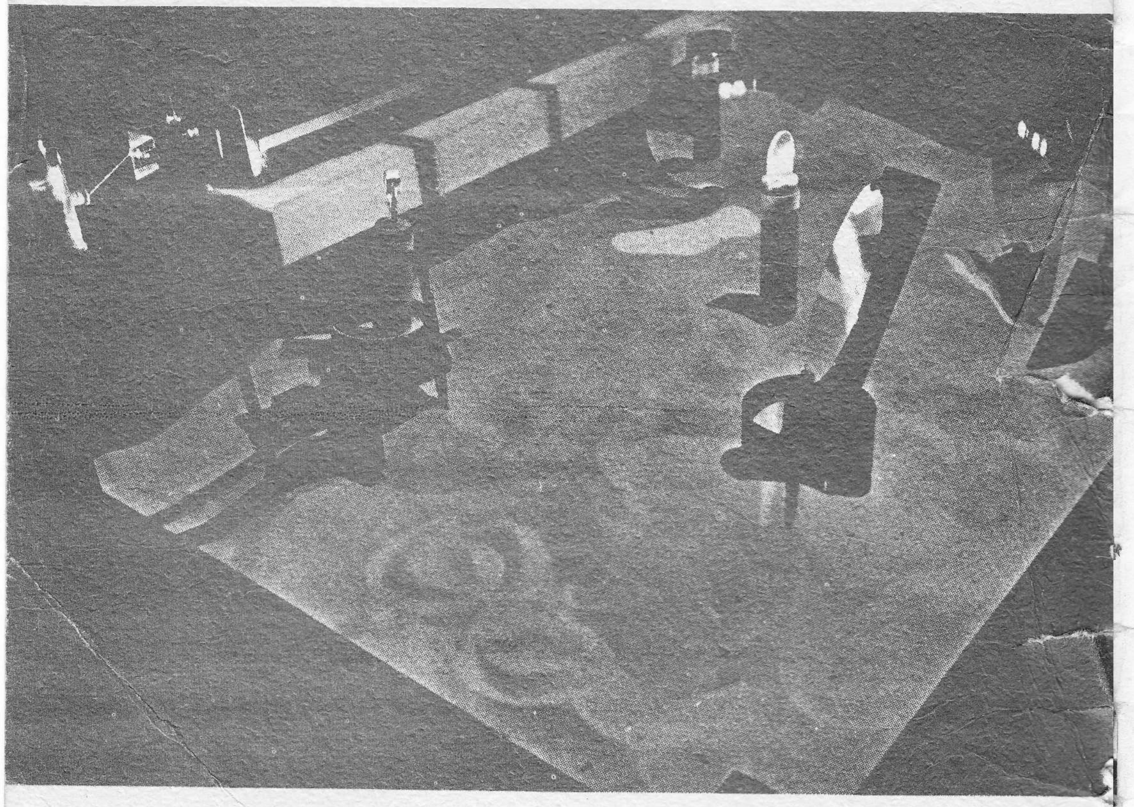


THE SAND-BASED SYSTEM FOR MAKING HOLOGRAMS.

Tube-mounted optical components inserted into washed silica sand provide a highly stable and flexible system for making holograms. The plywood box containing the sand is 'floated' on an inflated inner tube for further vibration control.



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# ON HOLOGRAPHY AND A WAY TO MAKE HOLOGRAMS

by

J. Pethick

A Belltower Book

published in cooperation with the Umbra Foundation

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Holography is in its infancy. This means that new information is continually becoming available, and huge jumps in overcoming its technical limitations are being made in short periods of time.

There is little in this booklet on pulsed holography, which seems to be a much less restricted way to work. But at present it involves a great deal of expense. The sand-based system described here, originally developed and implemented at Editions Inc. in Ann Arbor, Michigan, has been proven to be an inexpensive and efficient approach to holography.

I would like to thank and acknowledge the help of Lloyd Cross, Allyn Lite, Don Broadbent and many others who contributed towards the information and experience that have made this booklet possible. Special thanks to Margaret Southcomb and Daryl Sharp for typing and editing the material.

The way to technical and artistic advance in holography lies in the sharing of resources and information. It is hoped that the non-profit Umbra Foundation, San Francisco, will be able to assist many of those interested in the holographic process and other technical media.

J. PETHICK

## CONCERNING HOLOGRAPHY

Denis Gabor, who conceived the idea of holography, first made holograms with a complicated white light source at the Imperial Institute in London, England, in 1948. Because of the impracticability of the light source, little more was done until after the invention of the laser in 1960. The laser was to supply the ideal light source for continued research in holography.

Emmett Leith and Juris Upatnieks, working at the University of Michigan, obtained remarkable results using a laser to make holograms in 1964. Their results established holography as a medium of the future, enabling the storage or 'capturing' of three-dimensional visual information on a two-dimensional plane.

In a short time other laboratories were making holograms, but holography did not seem to serve the highly technological industries with enough economically feasible applications. Consequently, it was often treated merely as a laboratory whimsicality. The search for applications continued, while a few people, including some of the scientists working in the field, were learning more about the potential and limitations of holography simply as a visual medium.

One of the reasons for such a slow awakening is that the three-dimensional quality of holograms cannot as yet be reproduced by any of the mass media. An article and photographs published in LIFE magazine, for instance, took great care to show various views of a holographic image to demonstrate the three-dimensionality, but failed to make clear the fact that until you see an actual hologram, no manner of documentation can illustrate its unique spatial quality.

The number of holograms available for people to view between 1964 and 1968 was very limited; holography was a small and inaccessible area of research. However, the opportunities to view holograms are now more numerous. The Imperial College in London has an Open Day in May each year when the public are admitted, and in the Electrical Engineering department there are usually holograms on view. Conductron Corporation of Ann Arbor, Michigan, has several first-rate holograms on display in their lobby. An exhibition of holograms by Editions, Inc., Ann Arbor, toured in the autumn of 1970 to museums in Rochester, Syracuse and Albany, after opening at the Finch College Museum of Art, New York, and a similar exhibition was on view at the Exploratorium (Palace of Fine Arts) in San Francisco during the summer of 1971. Science museums and many electrical engineering, optical and laser exhibitions have examples of holograms.

Some of the companies currently working in holography are: Editions Inc., now located in San Francisco; Conductron Corporation, Ann Arbor; T.R.W., Redondo Beach, California; Hughes Research Centre, Malibu, California; and Bell Laboratories in Murray Hill, New Jersey. In England there are the National Physics Laboratory and the Imperial College.

Most holograms are monochromatic and viewed as though one were looking through a window - the glass photographic plate being the window. They are made with a laser emitting a continuous beam of light (continuous wave laser), using an inanimate object as the subject. For the purposes of holography, one can think of the laser as simply a special light bulb, one which emits a single color of coherent light (light waves of the same wavelength moving in the same direction).

To make a hologram, an unexposed photographic film is set up facing the object. Part of a laser beam illuminates the object, and the rest of the beam is deflected to the film. The film receives the wave pattern of both the direct laser beam and the laser light reflected from the object. The result is an 'interference pattern' recorded on the film.



When the film is developed it looks no more like a picture than a gramophone record looks like music. But when the film is illuminated by a monochromatic light source, the interference pattern causes the original photographed object to become visible in three dimensions. When you move your head, you can see 'around' the object.

The fact that one can record on the holographic film or glass plate only what is illuminated with laser light is a limitation intrinsic to the medium itself. It is a form of spotlight illumination, with the surrounding darkness being a black void. The size of the laser and the amount of coherent light it gives off determine the size of the illuminated area, but even the smallest hologram will demonstrate the medium's unique quality of three-dimensional space.

Most holograms to date have been of the transmission type. To be viewed, they need to be illuminated with either laser light or light from a white light source which has been filtered to one particular wavelength or color, and preferably from a point source (a small opening or filament that allows most of the illumination to come from one single point) so that it acquires a laser-like quality. For anything larger than a 4" by 5" hologram, a real problem occurs after the hologram has been made. To recreate the image, a light source must shine on the plate at the same angle as did the original reference beam when the plate was exposed. Since small, inexpensive lasers are inadequate, there remains the need for efficient and cheap light sources to illuminate transmission holograms.

Several general light sources are currently being used to replace the more expensive laser sources for viewing. For sharpness and clarity, the filters have to be of good quality, and the brighter the source, the more possible it is to view holograms in a normal environment, thus reducing the need for stringently light-controlled areas. The white light sources now used include tensor high-intensity bulbs, microscope illuminating lamps, quartz iodide bulbs and the more expensive arc lamps. The brightness and intensity of these sources are very important because they enable a good quality hologram to relate precisely to the original subject matter. To have good holograms not adequately viewable nullifies the whole potential of the medium.

The type of hologram that has a great many advantages is the reflection hologram, as it needs no special viewing source. A point light source illuminates it with good definition and brightness. In fact, an ordinary light bulb adequately recreates the image, and because of this it is not necessary to view reflection holograms in specially darkened areas. However, at the present time reflection holograms are somewhat difficult to make. They present problems in resolution and color smearing which restrict the degree of depth and angle of view obtainable in the hologram.

When a hologram is viewed with an ordinary filtered white light source, a color spectrum appears, spatially related to the subject matter, but without definition. The colors are bright and clear and seem to float in space. This interesting phenomenon can be used to create three-dimensional color compositions. Illumination of a hologram with an unfiltered white light source causes the holographic subject to 'smear' across the visible spectrum of color. Thus, a point of light becomes a line of light that covers the visible spectrum and, similarly, a line becomes a plane and a plane becomes a solid.

To make holograms of living matter or people, a laser is required that emits very short bursts of coherent light. This is called a pulsed laser. (The process is similar to using a flash bulb in high speed photography.) The burst of laser light occurs so rapidly that in effect it freezes all movement, and therefore greatly increases the potential subject matter for holography. Some good examples of human subject holograms have been produced by Bruce Nauman in conjunction with Conductron Corporation in Ann Arbor, Michigan.

The pulsed laser's facility for making holograms of human subjects has a bearing on the color problem in holography. Little is known about the acceptance by



the brain of images of human subjects that appear extremely real three-dimensionally and yet are unreal, i.e. monochromatic, in color content. The eye and the brain have the ability to intuitively know some of the colors of a composition by their tonal relationships, and the flesh coloring of people on some occasions seems to be 'painted' by the eye.

Pulsed lasers are expensive and generally available only in scientific laboratories. Consequently few holograms of animate objects and human portraiture have been made. Pulsed lasers for holograms with enough illuminated space to allow three-dimensional portraits of such subjects as an all-star football team, astronauts, or a pornographic group now exist in the United States only at three or four of the larger corporations. However, any marked improvement, either in photographic emulsions or the availability of pulsed lasers, will bring this facility economically within the reach of smaller companies and studios, leading to more widespread activity and realization of the full potential of holography.

At the present time, continuous beam lasers can only make holograms of inanimate subjects. There are many small, relatively cheap lasers of this type, including kits that are assembled by the purchaser, but most of these are, at the moment, inadequate for holography. They can be used, but their power is so low that exposure times must be very long. This means that a long period of stability without vibrations is necessary. Larger lasers or improved holographic emulsions could lead to a reduction in the size of lasers needed to make holograms, or an increase in the potential size of holograms using the same lasers.

Conceivably, emulsions will improve so much, both in resolution (fineness of grain) and speed, that live subjects will be susceptible to holography with a continuous wave laser. An improved emulsion's extreme sensitivity to light would so greatly reduce exposure time that the pulsed laser would not be required. Work in the photochemical field could mean a giant step towards solving these problems.

There does exist holographic film, with an obvious application in three-dimensional movies. Many of the major companies with holographic facilities are working or have worked on some of the problems involved, and some of the theoretical work has already been published. The problems are basic and difficult: a laser capable of many pulses per second is needed to do the shooting so that the motion is sufficiently convincing to avoid the 'flicker-flashback' effect of early movies. The problem of viewing, however, will require a great deal of research before any really satisfactory results are achieved. This is assuming that we conceive of and relate to moving three-dimensional holographic images on the same terms as we respond to photographic footage, in which case viewing a holographic film would be like viewing a television box in which the television screen is actually holographic film moving across that area.

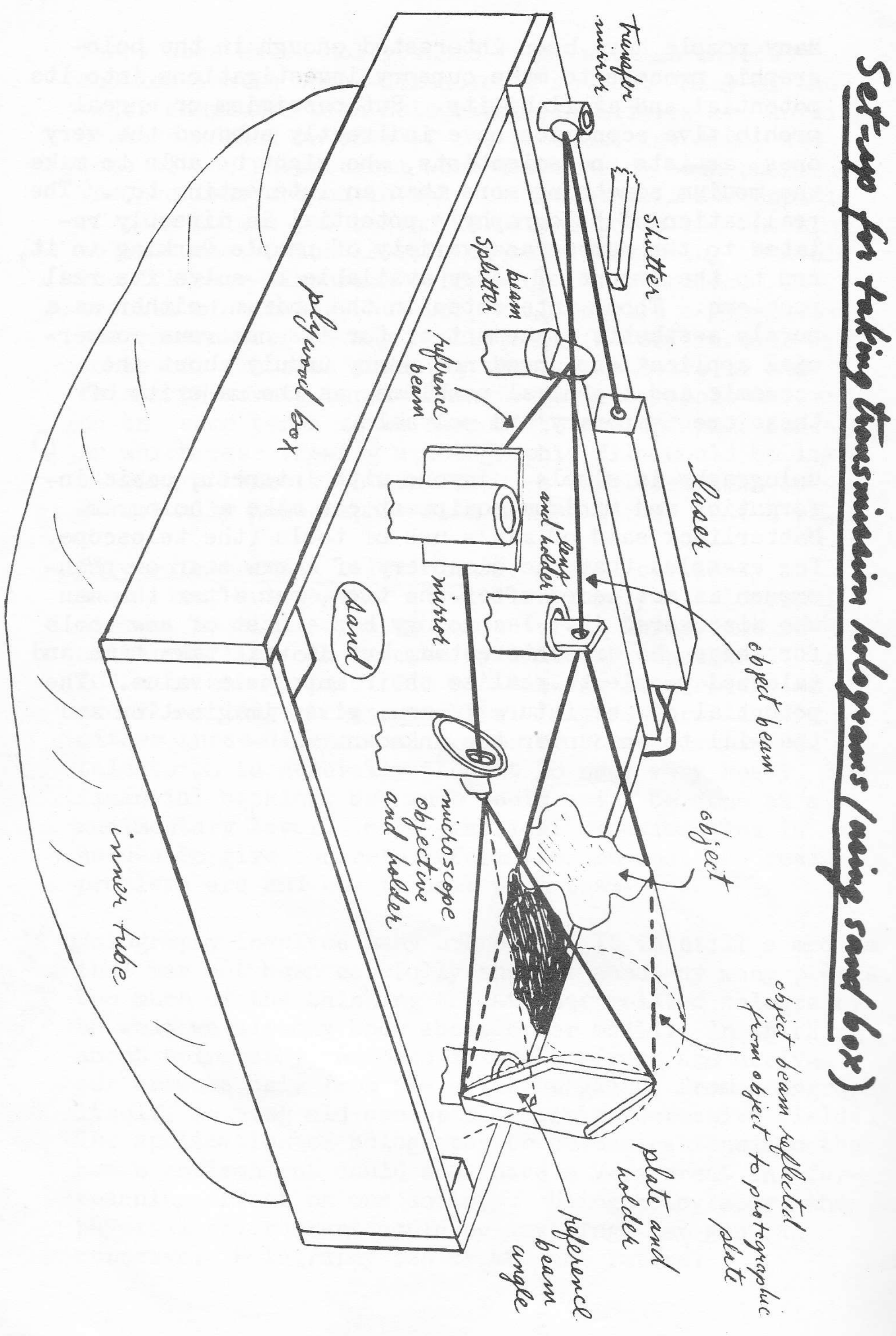
Three-dimensional television is also a certainty at some time, but whether it will be purely a holographic process is still open to conjecture. Three-dimensional animated films can be made by splicing together 5" or 10" wide holographic film and viewing it directly as one views large transparencies. Any research into either three-dimensional movies or three-dimensional television is generally thought to need very heavy financial backing, but much could still be done at a rudimentary level. More practical experimenting is needed to give concrete information on what the real problems are and how to deal with them.

Holography involves many unknowns. It is still a medium that has not been carefully thought about by many people. Too much of the thinking to date has related holography to what we already know about other media. In thinking about holography, we need to start afresh and derive our answers only from the evidence gained from holography itself, leaving old concepts to their respective fields. The application of holography to communications and the human environment could soon have a very great and far-reaching effect on our society. Using holography, the physical environment could be anything that man can conceive. Holography can create the future.



Many people have been interested enough in the holographic process to make cursory investigations into its potential and availability. But pessimism or unreal prohibitive economics have indirectly subdued the very ones, artists and scientists, who might be able to make the medium something more than an interesting toy. The realization of holography's potential is directly related to the number and variety of people working in it, and to the amount of money available to solve its real problems. Those interested in the medium, either as a purely aesthetic statement or for its numerous commercial applications, need not worry unduly about the economic and technical problems, as the majority of these are temporary and solvable.

Holography is simple. Anyone with interest, basic information and minimum equipment can make a hologram. Maeterlinck said of man's use of tools (the telescope, for example) that the discovery of a new star or phenomenon is not named after the tool, but after the man who discovered it. Technology has a host of new tools for those who are interested, but it will take time and talented people to realize their intrinsic value. The potential of the future is now, given imagination and the will to encounter the unknown.




## PROCESS, EQUIPMENT AND FACILITIES

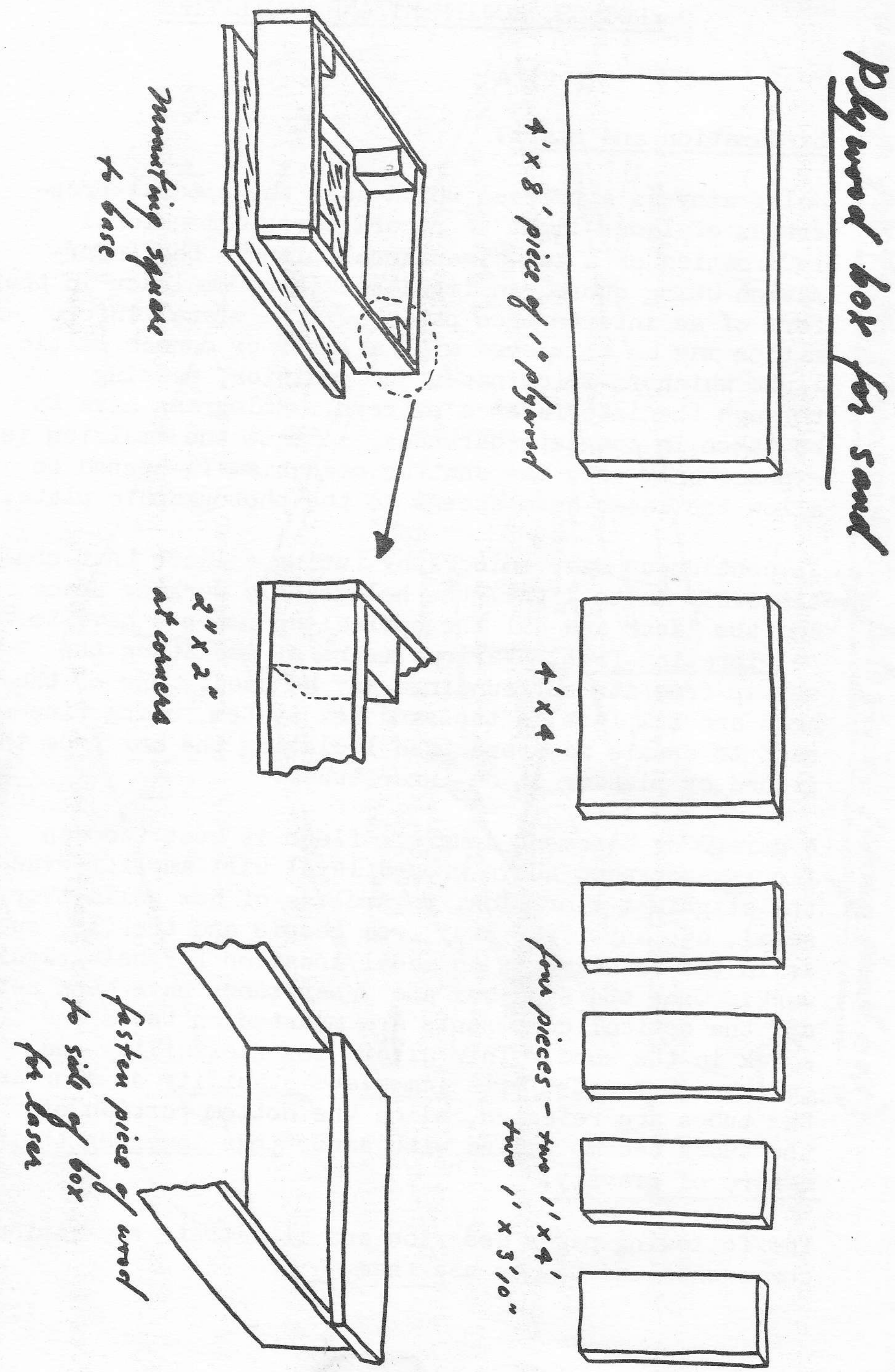
### Explanation and start.

Holography is a process which uses the special properties of laser light to record three-dimensional information on a two-dimensional plane - the information being stored on light-sensitive emulsion in the form of an interference pattern. The visual information may be retrieved with a laser or monochromatic light which re-illuminates the emulsion, passing through the interference pattern. Holograms have to be taken in complete darkness, so that the emulsion is exposed only when the shutter mechanism is opened to allow the laser beam access to the photographic plate.

In continuous wave holography (using a laser that continuously emits light) the holographic working space and the laser and all the optical components have to be vibration-free. Various means of isolating the set-up from its surroundings may be used. One of the best and simplest is the sand box system, using fine sand to create mass and then isolating the box from the ground by placing it on inner tubes.

A garage or basement concrete floor is best (wooden floors suspended above ground level will amplify even the slightest vibration, regardless of how solid they seem), but any place away from people and traffic, such as in the country, is an ideal location for holographic work. Once the sand box and inner tubes have been set up, the optical components are mounted on tubes and stuck in the sand. This allows for flexibility and quick adjustments, with immediate stability as soon as the tubes are released, since the bottom portion of the tubes become filled with sand, thus lowering their centre of gravity.

The following pages describe and illustrate the various components and how to use them.




Making the sand box.

1. Cut one sheet, 4' x 8', of one-inch plywood into one piece 4' x 4', two pieces 1' x 4' and two pieces 1' x 3'10".

2. To form a square box, put the four pieces together using 2" x 2" blocks at the corners, so that the sides are 12" high; then mount the box on the 4' x 4' base.

3. Cover the outside of the base with thin sponge or carpet material.

4. Place the box evenly and squarely on top of one large tractor tire inner tube, or four smaller inner tubes.

5. Nail a piece of wood along the box's edge, to hold the laser.

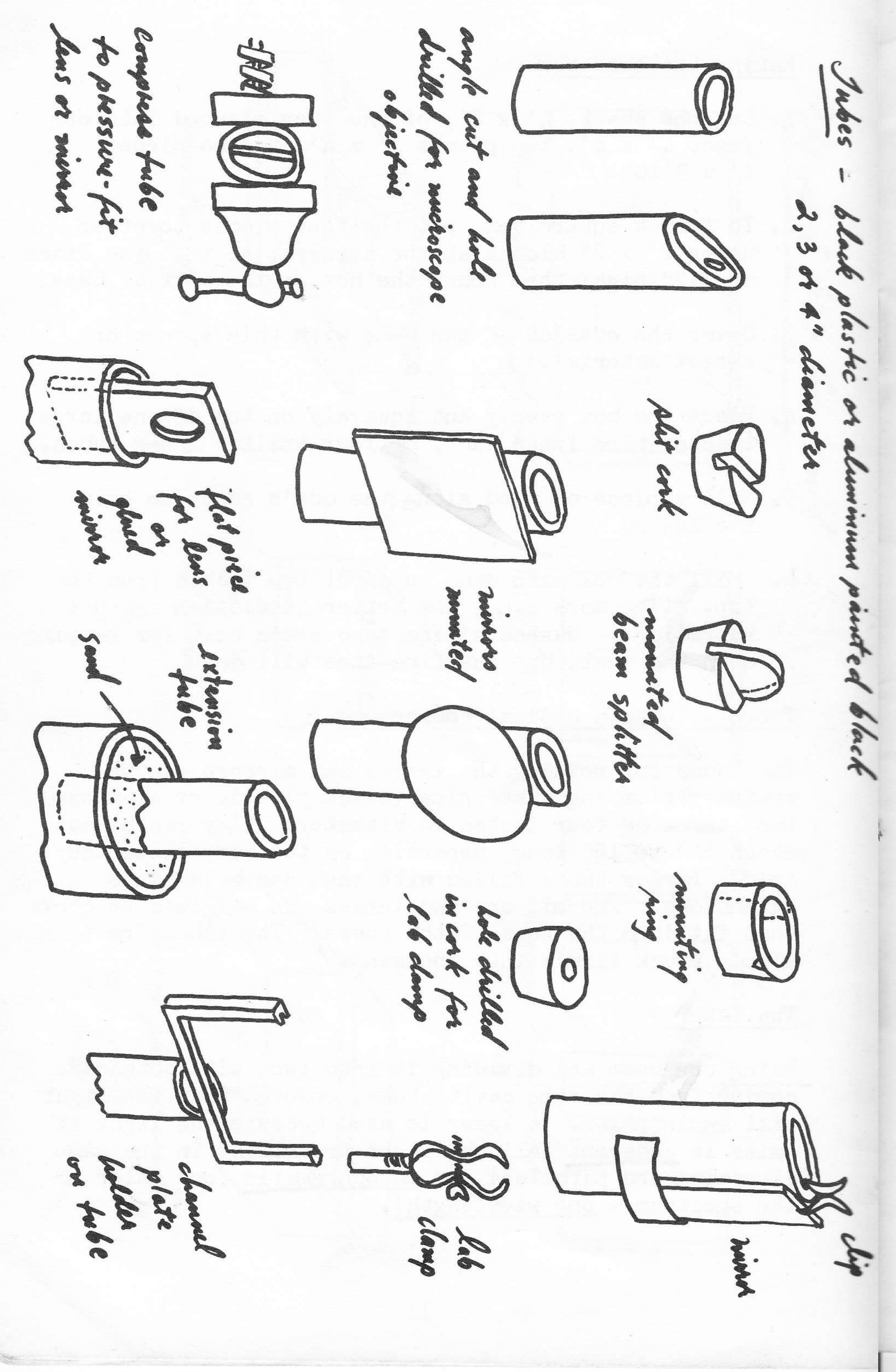
6. Fill the box with sand to about two inches from the top. (The more sand, the better insulation against vibration.) Washed silica sand seems best for keeping down the dust, but any fine sand will do.

Tubes - to hold optical components.

The tubes for holding the lenses and mirrors can be ordinary plumbing waste pipe (black plastic or aluminum) two, three or four inches in diameter. They can be cut about 14" to 18" long, depending on the components they hold. Larger tubes filled with sand can be used as extensions. The mirrors and lenses can be glued to corks that fit into the tops of the tubes. The tubes are then simply stuck firmly into the sand.

The laser.

Using one beam and dividing it into two, with both rays coming from the same cavity tube, ensures that the light will be in phase. A laser is used because the light it emits is coherent (all the light travelling in the same direction and parallel) and monochromatic (one color of the spectrum - one wavelength).




A laser takes some time to become stable and should be turned on for a few minutes prior to use. Not all lasers are coherent enough for holographic work, but some that are include the following:

Helium neon - red (most common gas laser). One-half to 100 milliwatts. Continuous wave.

Argon - green, gas laser. Pulsed or continuous wave.

Helium cadmium - blue, gas laser. Continuous wave.

Ruby - red, piece of ruby rod (cylindrical with parallel ends). Pulsed.

Krypton - white light, gas laser, water cooled. Continuous wave.

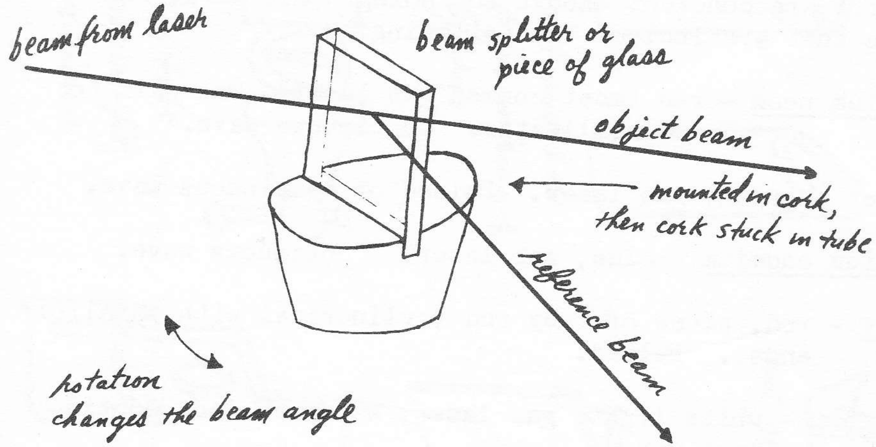
A 10 milliwatt laser is adequate for 4" x 5" plates. A 25 milliwatt laser is adequate for 8" x 10" plates. Larger holographic film gives greater flexibility in the choice of subject and the amount of illuminated space around it, but more light is needed, which means larger lasers must be used.

A prism can be set up in the path of the light, breaking it into the four primary colors, red, yellow, blue and green. With a prismatic assembly, any of the four colors can be selected by tuning the laser. This gives a very beautiful and versatile light source.

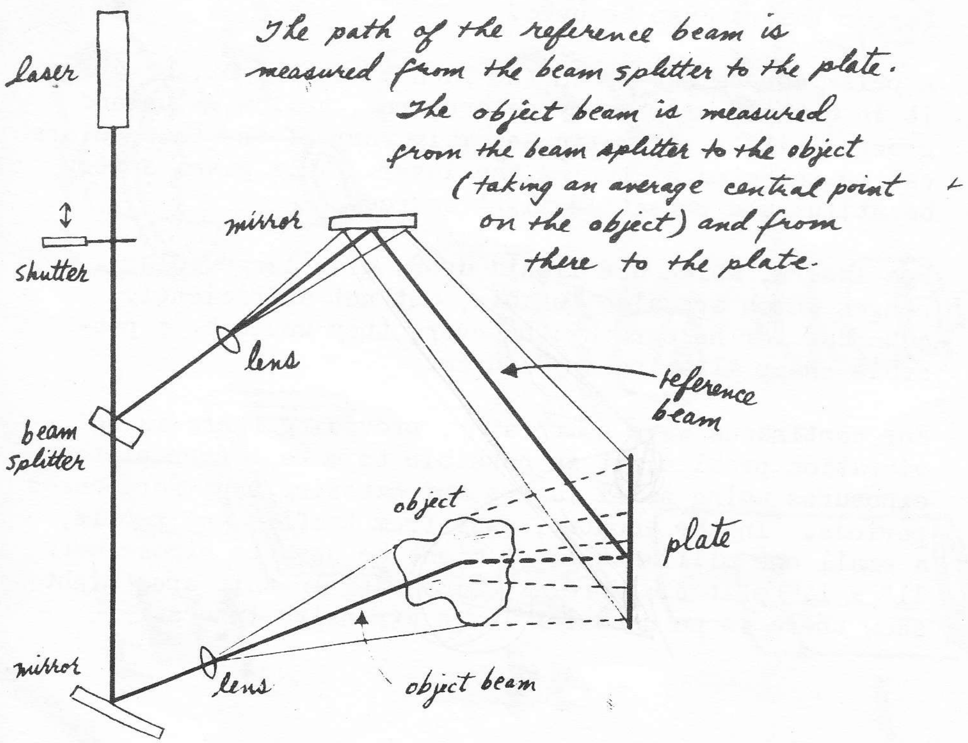
Dye lasers, which use liquid dyes, give large color ranges which are also tunable, but not sufficiently coherent for holography; however, they would be a possible cheap illuminating source.

For continuous wave holography, providing there is no vibration problem, it is possible to make larger plate exposures using small lasers and exposing them for longer periods. In the country, away from traffic and people, a small one milliwatt laser might be used to expose even 11" x 14" plates. More experimenting in this area might show there is no need for large expensive lasers.

## Beam splitter




## Equidistant paths - aerial view




The shutter.

Since exposure times vary a great deal, some kind of shutter must be used. The laser itself must not be turned on and off as this would cause vibration and affect the stability of the light. Whatever is used as the shutter should be suspended without touching the sand box, the laser or any of the components.

A mechanical device, such as a solenoid or relay switch, could move a light piece of material acting as a shutter to interrupt the beam. But it would also be quite adequate to simply hold, by hand, something which is light-absorbent in front of the beam until you want to expose the plate. The shutter mechanism must be placed somewhere between the laser and where the beam is split.

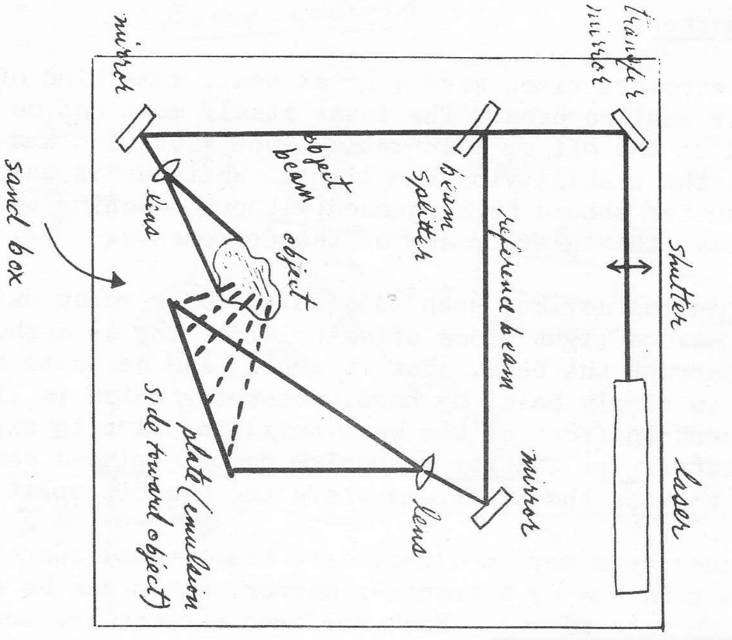
The laser beam may be directed to the optical components in the sand box by a transfer mirror, which can be any front surface mirror. Back surfaced mirrors are not suitable, as they break the beam up into many small beams and a great loss of light occurs.

The beam splitter.

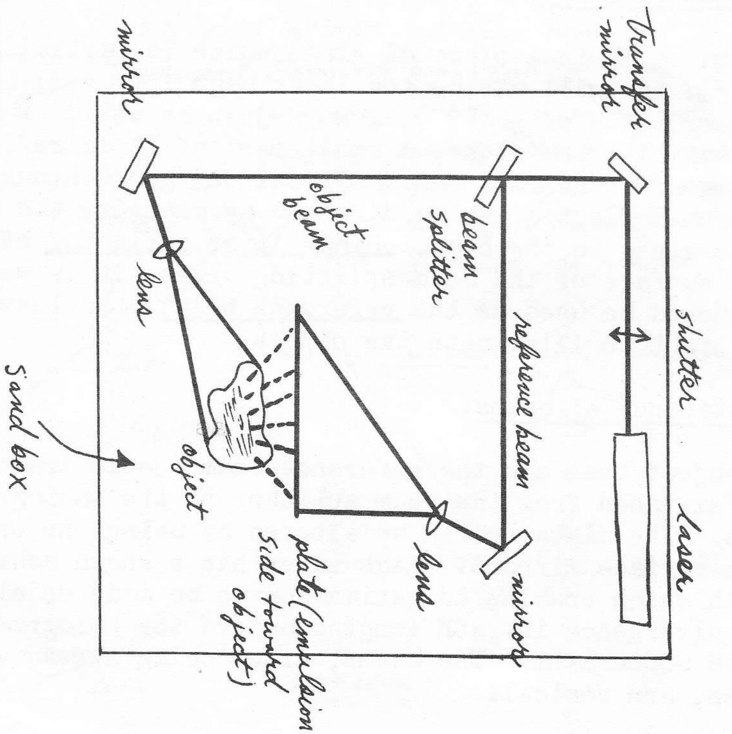
This is an optical piece of glass which is partially silvered and will divide the laser beam into two; but an ordinary piece of glass will work just as well. When the beam hits the glass, a small part of it is reflected off the front surface and the remainder goes through it. The part reflected can be directed by changing the angle of the glass to the beam. Since it is reflected off the front surface of the beam-splitting glass, it is weaker and should be used as the reference beam; this leaves more light to illuminate the object.

Equidistance of beams.

The object beam and the reference beam should travel the same distance from the beam splitter to the photographic plate. The distance can be altered by using one or more front surface mirrors. Each laser has a known coherence length which enables an estimation to be made on allowable divergence in path lengths before the hologram will not be successful. The beams, after being spread with lenses, are conical.




Set-up for transmission hologram




Set-up for reflection hologram

Exposure.

This must be made in total darkness, the only light being that coming from the laser. The two beams are generally referred to as the object beam (the beam that illuminates the object or scene) and the reference beam (the beam that is directed to the light-sensitive emulsion on the photographic film or plate). The reference beam is usually much stronger than the object beam because a great deal of light is lost illuminating the object; none of the reference beam is lost as it only passes through a lens that expands it to cover the entire plate as evenly as possible. A pin-hole is used to keep the reference beam evenly intense and free from dust and marks on the optics which would otherwise show on the plate. (This is not essential, but helpful.)

The object beam, after being scattered off the object, and the reference beam both hit the plate and make an interference pattern which is recorded on the emulsion. The ratio of intensity at the plate of one beam to the other varies; as a general rule, the reference beam is 1 or 2, and the object beam is 1. This ratio, 1:1 or 2:1, serves most situations and can be judged by eye or meter. If the reference beam is too strong, it can be reduced to the required amount by using a holographic plate with varied exposure across it. A spatial filter, although expensive, is helpful; used as a beam splitter, its gradiated mirrored surface allows exact beam ratio adjustment by selecting the place on its surface that allows the right light transmission.

For transmission holograms, the emulsion side of the plate or film is placed facing the reference beam and the object beam. With this kind of hologram, it is much harder to brightly illuminate transparent or very light-absorbing dark objects.

The exposure time increases as the area to be illuminated increases.

* It is important that no light from the object beam should hit the plate directly, and no light from the reference beam should hit the object.

## Developing.

Holographic plates are developed in the same way as ordinary black and white photographic film. The plate should be taken, still in total darkness to ensure against further exposure, and developed for five minutes in ordinary photographic developer (or more specialized developers are available). It should then be placed in a stop bath for thirty seconds and fixed for about five minutes in standard fix (but reflection holograms should not be fixed). The plate should be rinsed between each stage and finally washed for a few minutes, rinsed in photoflo, and then allowed to dry.

An indication of the brightness and sharpness of the hologram can be obtained by simply holding it up to an ordinary light bulb and assessing the brightness of the spectral smear. The side with the emulsion is determined by wetting fingers or lips and feeling both sides of the plate at a corner for a few seconds - the emulsion side is stickier.

## Manufacturers of plates.

(Holographic emulsions have an A.S.A. of less than 1.)

Agfa-Gevaert - Plate sizes: 3 1/4" x 4 1/2", 4" x 5", 8" x 10", 11" x 14", 18" x 24".

- Plate numbers: 8E70, 8E75, 10E70, 10E75 (4 times faster than 8E70 and 8E75).

- Processing: Agfa fine developer. Stop. Fix. (Other emulsion speeds are available, also film in 35mm rolls, 5" and 10" wide.)

Agfa-Gevaert will take special orders for 3" x 4" plates and 42" wide rolls of film.

Kodak - Plate sizes: 3 1/4" x 4 1/2", 4" x 5", 8" x 10".

- Plate numbers: 649F.

- Processing: D19 developer. Stop. Fix.



## Bleaching.

After developing and fixing, some plates are bleached (taking out the silver nitrate) so that the plate loses all its blackness and becomes almost transparent. There are numerous bleaching processes to improve the light transmission of the plate or film. This tends to brighten the hologram.

A simple and efficient process for bleaching in one step (as opposed to more complicated processes) is as follows: Add 7 gm. potassium ferric cyanide and 8 gm. cupric bromide to 10 millilitres of water in some container like a developing tray. Stir until all the powder is dissolved. It should be agitated gently while the plate is completely submerged in it, until the black in the emulsion disappears. Bleaching an over-exposed plate might result in graininess or fuzziness of the image. When the black disappears, the plate must be removed immediately and washed carefully for ten or fifteen minutes, to make sure the bleaching action is stopped.

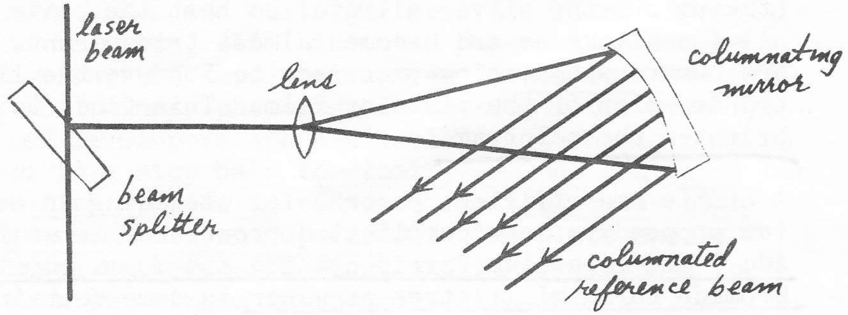
Photoflo can be used to even the drying process, or the plate can be squeegied off and allowed to dry at room temperature. The wet emulsion swells so that the clarity of the image cannot be assessed until the emulsion is dry and in the same state as when it was taken.

## Coatings.

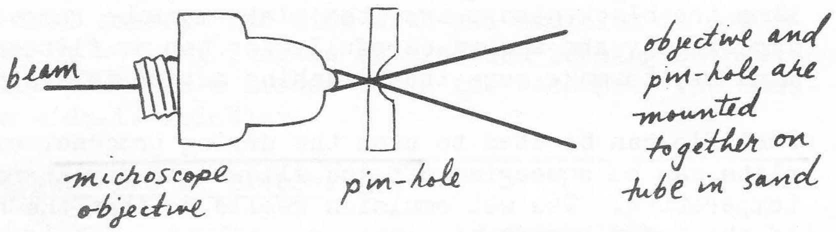
The emulsion containing the interference pattern (the visual information seen as a hologram) is very sensitive. It can be protected against wear and handling, etc., by covering (i.e. backing) the emulsion side of the plate with a piece of glass or clear plastic, the edges taped or put in a frame to keep it clean and free from dust. There are also some liquid coatings that can be sprayed or brushed on quite safely; two such coatings, which are very tough, are Polyurea varnish, and liquid acrylic thinner with Xylene. These are put on thinly so that no chipping or cracking occurs, and may even be used on film. Xylene has the advantage of having the same index of refraction as glass and can therefore be used between glass and the emulsion. This seems to increase the brightness of the hologram, but a good seal around the edges is necessary or it will evaporate.

## Projected image hologram

(transmission hologram made with columnating mirror for the reference beam)

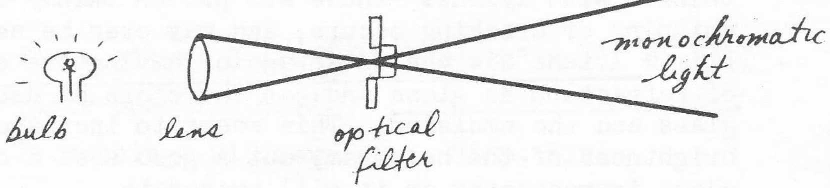



## Microscope objective and pin-hole assembly




The pin-hole must be adjustable on all 3 axes. Once light passes through a pin-hole, it is clean, even and dust-free. The pin-hole should be the last thing the reference beam contacts before it hits the plate. (This is not essential, but it gives a more even exposure of the plate, and therefore some control over the light intensity ratio.)

## White light source assembly



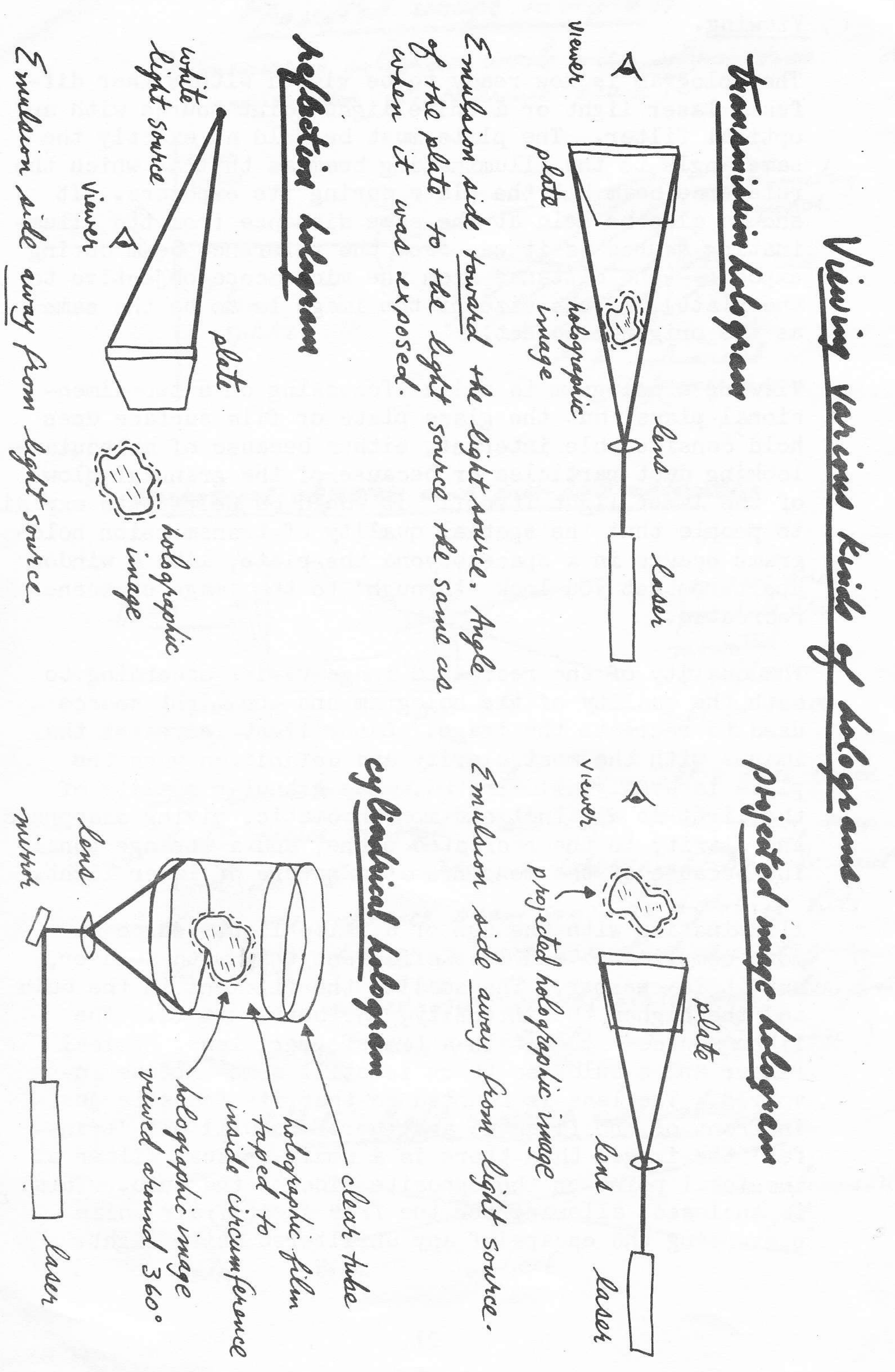

Viewing.

The hologram is now ready to be viewed with either diffused laser light or a white light point source with an optical filter. The plate must be held at exactly the same angle to the illuminating beam as that at which the reference beam hit the plate during its exposure. It should also be held at the same distance from the illuminating source as it was from the reference beam during exposure (the distance from the microscope objective to the plate), if the size of the image is to be the same as the original object.

Viewing a hologram is unlike focussing on a two-dimensional plane, but the glass plate or film surface does hold considerable interest, either because of molecular-looking dust particles or because of the granular glow of the laser light itself. It would be helpful to explain to people that the spatial quality of transmission holograms occurs in a space beyond the plate, like a window aperture that you look 'through' to the image or scene recreated.

The quality of the recreated image varies according to both the quality of the hologram and the light source used to recreate the image. Laser light recreates the images with the most clarity and definition when the plate is evenly illuminated. The granular quality of the light is distinct and monochromatic, giving sharpness and clarity to the recreated scene, and a strange tonality because of the monochromatic nature of laser light.

Illuminating with the sun or a white light source is more complicated and less efficient than with a laser, but it is cheaper. The smaller the filament in the bulb and the higher the intensity, the better it is. The light source may contain a transformer, lens, optical filter and a bulb, so there is still some expense involved. The lens is mounted so that its focus is just in front of the filament and therefore will not 'transfer' the image; then there is a small optical filter at the focal point on the opposite side of the bulb. This is enclosed, allowing for the free flow of air while preventing the escape of any unfiltered white light.




Less bright, but a simpler and cheaper source, is a tensor high intensity lamp with lens and filter. However, because of the less efficient filtering, the light is not as monochromatic as with a laser source and consequently the sharpness and clarity suffer.

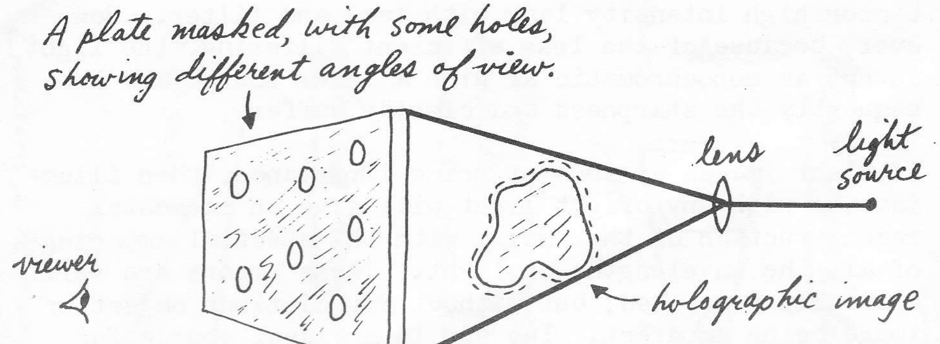
If clear images are not of prime importance, then illuminating with any bright light will give an elemental reconstruction of the image, with the spectral smearing of all the wavelengths of light. These smears are still spatially recreated, but without any distinct object or image being apparent. The sun is an ideal source for such elemental reconstruction.

The basic advantage of reflection holograms is that there is no light source problem; any white light source will recreate the image clearly, because in the making of the hologram the emulsion itself acts as a light filter. * Reflection holograms, unlike transmission holograms, are illuminated from the same side as the viewer, but they still require an exact reference angle reconstruction. They are generally angle sensitive, with a narrower angle of viewing, but they have an interesting color - less 'rarified' than laser illuminated holograms.

Projected image holograms can be made exactly like transmission holograms. Instead of using a flat mirror to reflect the reference beam, a columnating mirror is ? used to keep the light from expanding. After exposure and development, the image is reconstructed between the observer and the plate (or in the observer's own space). The size of the image and the size of the plate (background) determine the angle of view, as the image gets cut off beyond the edge of the plate.

Full color holograms have been made. They are more complicated because each plate contains three or four separate holograms, each one made separately with a different primary color of laser light. Color registration is also a problem, and additional equipment and expensive lasers are needed. Cylindrical holograms have also been made: a strip of holographic film is placed on the inside of an acrylic tube, exposed around the 360°, with the object in the middle. An object and reference beam are still used, but the viewing apparatus is more complex than other holographic viewing techniques.

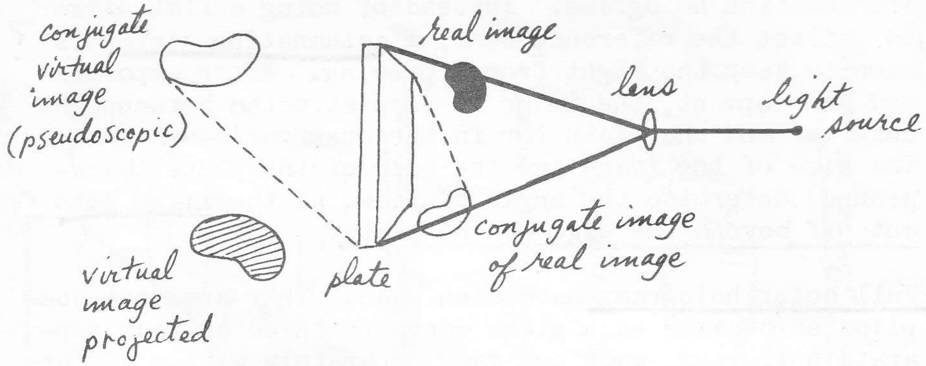
## Some properties of holograms




The eye from each location on the plate sees the complete image, but each time from a different angle.

If the plate is broken, the image can still be recreated using each individual piece.

## Conjugate and pseudoscopic images




The pseudoscopic image is the image being reconstructed back to front. Movement gives evidence of parallax reversed. Although not readily visible, these images exist in most holograms.

Additional.

Libraries are a good source of information. Optical and mathematical explanations of the holographic process can be found in almost any book on holography. A greater depth of information can be obtained from many published articles in LASER FOCUS, OPTICS TODAY, and SCIENTIFIC AMERICAN. Some articles have also been printed in photographic magazines. Much of the information in these articles is difficult for the layman to understand, but the diagrams are usually very good and informative.

Front surface mirrors can be obtained from surplus stores or mirror glass companies. Optical filters and beam splitters can be bought through EDMUND'S SCIENTIFIC. Spatial filters and pin-hole assemblies will probably have to be obtained from one of the companies actively involved with holography or lasers.

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Communications to the author relating to material in this book may be addressed to the Publisher.

## Notes

## Biographical Note

Jerry Pethick is a sculptor working in plastics, holography and other three-dimensional illusionary processes. He is an Associate of the Royal College of Art, London, whose work has been exhibited in five group shows in England, including one at the Whitechapel Gallery in London. He has been awarded two grants by the Canada Council. His holograms, including the world's first animated holographic film, have been shown at the Finch College Museum of Art (New York), Cranbrook Academy, Rochester, Syracuse, Albany, Ann Arbor, Los Angeles and San Francisco. He was born in London, Ontario in 1935, and currently lives in San Francisco and London, England.

ON HOLOGRAPHY AND A WAY TO MAKE HOLOGRAMS

by J. Pethick

Cover drawing by Peg Bennett, based on a sculpture by J. Pethick

A BELLTOWER BOOK





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