SET UPS

How to Record Holograms

SEVEN SINGLE BEAM PROJECTS

ED WESLY

Fermi National Accelerator Laboratory, P.O. Box 500. Batavia, IL 60510
Columbia College, 600 S. Michigan Avenue, Chicago, IL 60605
Lake Forest College Holography Workshops, Lake Forest. IL 60045

Abstract

A curriculum for low budget holography classes is presented consisting of seven different types of holograms, requiring no more equipment than a laser, beamspreader, and a mirror. Of these seven holograms, three are white light viewable, and two of these are image plane types. In addition to the software, hardware in the form of a novel isolation device dubbed "The Big Beam" is described.

Introduction

As the demand for holograms increases, so does the demand for well-trained holographers. Just as poets must learn their ABC's to be in control of their craft, so should holographers know the medium inside out- so well that the technical aspect is second nature to them. There are certain programs for the elementary teaching of reading and writing, and there should be some guidelines for the teaching of holography.

This paper outlines such a curriculum, entitled "Seven Single Beam Projects", which illustrates almost all the concepts of wavefront reconstruction through hands-on experience. These projects show the student what is possible with the medium by finding out its shortcomings, limitations and impossibilities. On the other hand, the students will also see what is so wonderfully possible that is unique to this medium that no one could ever imagine it without having been initiated into the field at the grass roots level. The students should begin to think holographically, from recording to reconstruction.

Single Beam Philosophy

No one should pooh-pooh these projects as not being "true holography" for not splitting the beam. They are not just Mickey Mouse science fair projects but do have real life applications. Many of the world's more impressive holograms have been made using these techniques. See the references with each project.

This curriculum has been designed to be catholic in its approach, by training students to make good holograms regardless of whether they are technically or aesthetically oriented. Learning is by doing, and working within the framework of restrictions. Knowledge gained in this program, on this type of equipment, gives students an understanding of what to do once they get out in the real world and want to set up their own systems.

It is best to start out small, so mistakes are less costly and time consuming. For the learning process includes discovering not only what to do but also what not to do. There is no need to back student time up waiting to use more expensive equipment to learn the rudiments. All that can be learned earlier in preparation. By making the projects single beam simple, troubleshooting becomes easier as less variables are involved.

These seven single beam projects, three of which are white light viewable and two are image-plane types, require nothing more in the way of equipment than a laser, beamspreader, hologram holder, objects, glue gun and for one project, a large front surface mirror. This software can be applied to any type of table: steel, concrete, or sand. But a solution to the problem of cheap, portable, yet effective isolation has been found in a novel piece of hardware which I have dubbed "The Big Beam".

The Big Beam

The beam itself should be 2 to 3 meters long - the major considerations being the desired reference source to holographic plate distance and/or whether the unit will fit in the holographer's car. There is one practitioner who has a home beam and one for the road for demonstrations. The tee crosspiece should be long enough to straddle two inner tubes. See Figure 1.

Wood is the preferred material of construction, as it is strong and rigid in sizes 4" by 4" and larger in cross-section, and it can be glued and screwed into. Good polyurethane varnish and nice flat black enamel paint are necessary to seal the beam from the effects of humidity. Carriage bolts and wingnuts fasten all the pieces together for easy assembly and disassembly. All the tools the holographer need have access to are a saw and a drill with an alignment device to drill holes into the wood nice and straight.

These units with their three point suspensions and only one axis of symmetry are very hard to couple into a resonant mode. They have been successful in environments as hostile as third floor lofts and fifth floor classrooms. The trick is to have the whole unit move together by bolting and clamping everything so that there is no relative movement between the object, reference source, and holo-plate. Of course, single beam set ups have an advantage here, using only the minimal amount of components.

Exact sizes are not given in the blueprint of the Big Beam, as this should be an exercise in ingenuity and improvisation with materials on hand, especially for the fabrication of mirror mounts, beamspreaders, object stages and laser holders. There is room for growth, as split beam type set ups like rainbow transfers can be done on the beam in a double decker fashion.

The Curriculum

The descriptions of the projects are presented in a formto either be Xeroxed and passed out to students in a basic holography class or to be used by the instructor as a crib sheet. It is hoped that these modest outlines can be helpful in organizing a class and that the instruc tors can flesh out these rough sketches with their own personal examples and explanations. It is recommended that instructors work the bugs out of the systems by preparing their own classroom set of all the projects using an object common to all the holograms.

These exercises work on any scale, certainly lasers with power > 5mW are preferred, but we have been successful at reflection holography with 800 microwatts of power exposing 60 by 60 mm plates for 20 to 40 seconds at Columbia College in Chicago's Loop on these units. But at the other

These exercises work on any scale, certainly lasers with power >5mW are to be preferred, but we have been successful at reflection holography with 800 microwatts of power exposing 60 by 60mm plates for 20 to 40 seconds at Columbia College in Chicago's Loop on these units. But at the other extreme,when we had a chance to have fun with a 25 Joule Ruby laser at Fermilab, the first thing that we did was to spray paint our hand silver and make large Denisyuks of them. These Seven Single Beam Projects provide a firm foundation which will pay off in the students' future adventures in holography, whatever type of laser or recording material may be available to them at that time.

Photographs of Successful Big Beams would be a welcome addition to my collection, please send them to my in care of the Lake Forest Holography Workshops, as well as any questions or comments.

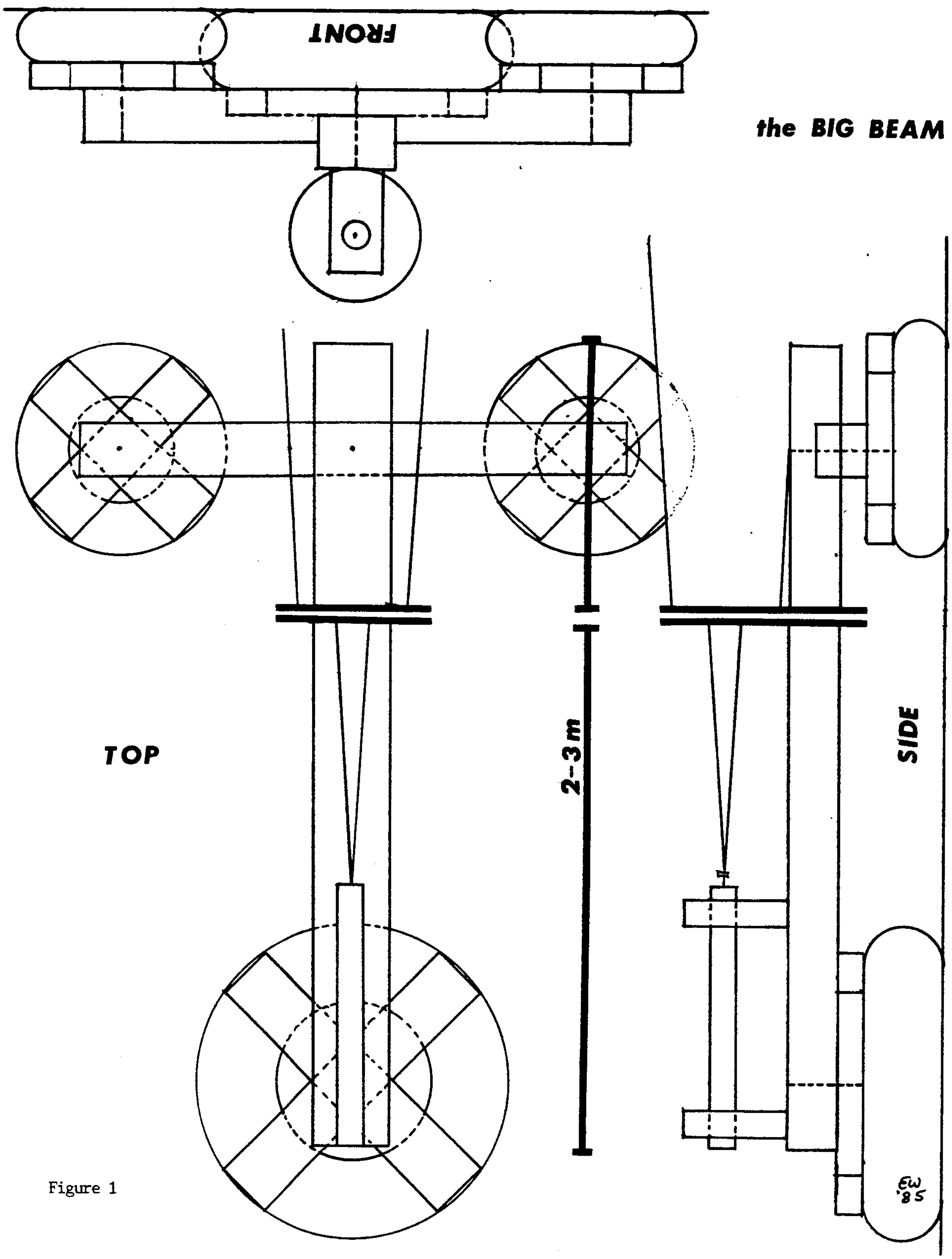
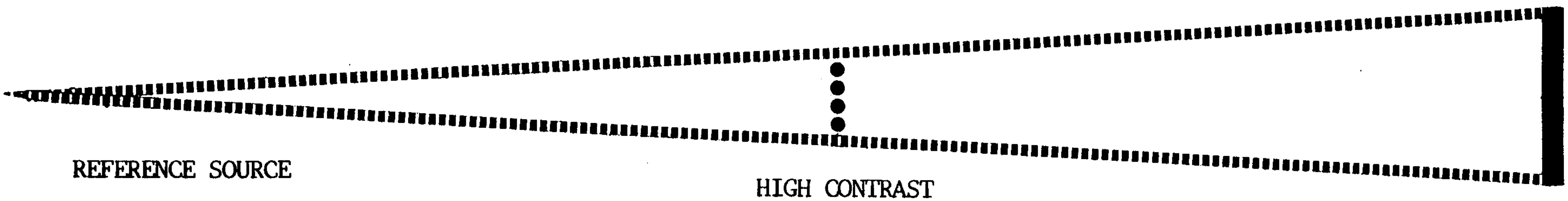


Figure 1

PROJECT 1a: *In-line Holograms*



SET UP STEPS: 1) Spread Beam. 2) Position object somewhere between reference source and plate holder. 3) Settle and shoot hologram. 4) Process and reconstruct it.

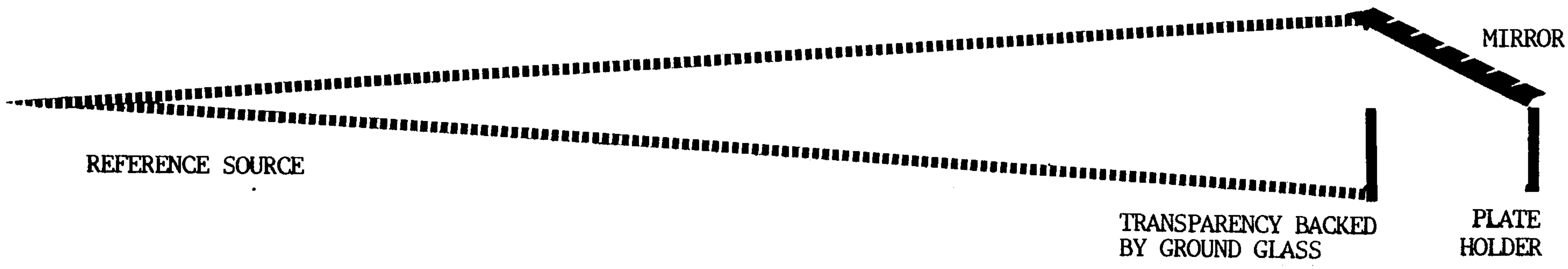
OBSERVATIONS/ DEMONSTRATIONS: Simultaneously reconstructed real and virtual images along with the zero-order, lack of redundancy, evidence of wavelike nature of light in the patterns on the hologram.

OBJECT POSSIBILITIES: High contrast black and white transparencies, aerosol sprays, bubble chamber bubbles

REFERENCES and EXAMPLES:

D. Gabor, "A New Microscopic Principle", Nature 161, p.77 (1948)
D. Gabor, "Microscopy by Reconstructed Wavefronts", Proc. Roy. Soc. (A), CXCVII, p.454, (1948)
G. L. Rogers, "Experiments in Diffraction Microscopy", Proc. Roy. Soc. (Edinburgh), A63, p.193, (1952)
B. J. Thompson, P. Dunn, "Advances in Far-Field Holography", SPIE Vol. 215, p. 102, (1980)
H. Akbari, H.Bjelkhagen, "Big Bubble Chamber Holography", this proceedings

PROJECT 1b: Off-axis Holograms



SET UP STEPS: 1) Spread beam. 2) Position groundglass and transparency. 3) Direct reference beam with overhead mirror onto holographic plate. 4) Settle and shoot hologram. 5) Process and reconstruct it.

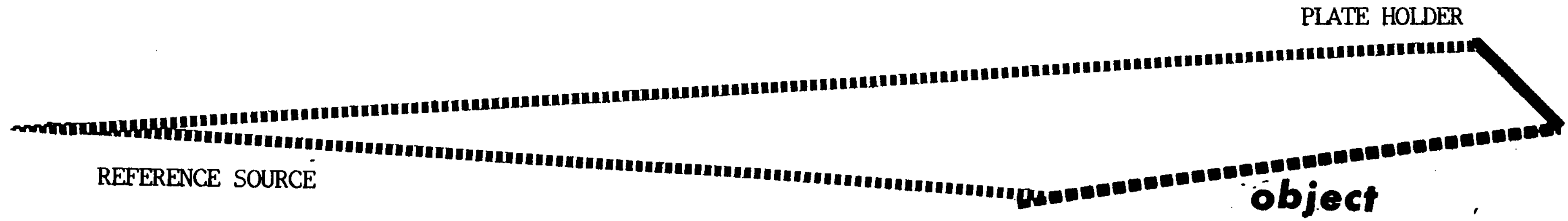
OBSERVATIONS/ DEMONSTRATIONS: Separate real and virtual images; zero-order removed from field of view of the object; redundancy; relationship of this set up to holographic stereograms

OBJECT POSSIBILITIES: Black and white transparencies, or phase objects like cut glass could be put in between the groundglass and holographic plate holder.

REFERENCES:

E. N. Leith, J. Upatnieks, "Wavefront Reconstruction with Diffused Illumination and Three-Dimensional Objects", Journ. OSA 54, 11, p.1295, (1964)

PROJECT 2: Deep Scene

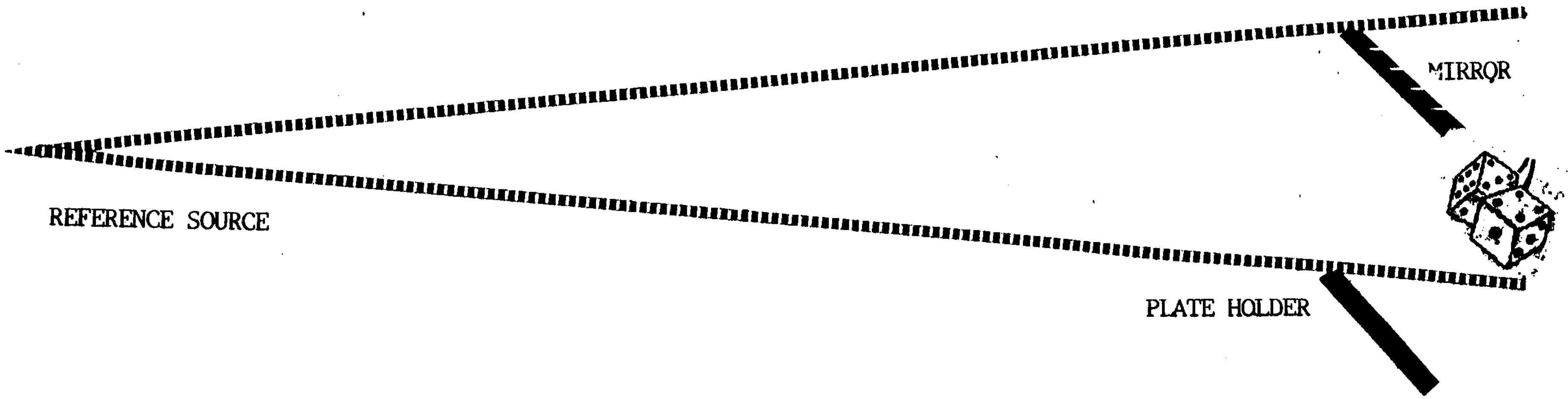


SET UP STEPS:	1) Spread beam. 2) Arrange object so that light skips off it. 3) Position plateholder so that object can be seen from its position but also get hit with direct light from the laser. 4) Settle system and shoot hologram. 5) Process and reconstruct it.
OBSERVATIONS/ DEMONSTRATIONS:	Virtual image reconstruction; real image projection with undiverged beam; redundancy; white light reconstruction: holographic processing techniques.
OBJECT POSSIBILITIES:	Limited mainly to flat ones, but may be extremely long.
DISCUSSION TOPIC:	Why object may be longer than the coherence length of the laser.

REFERENCES

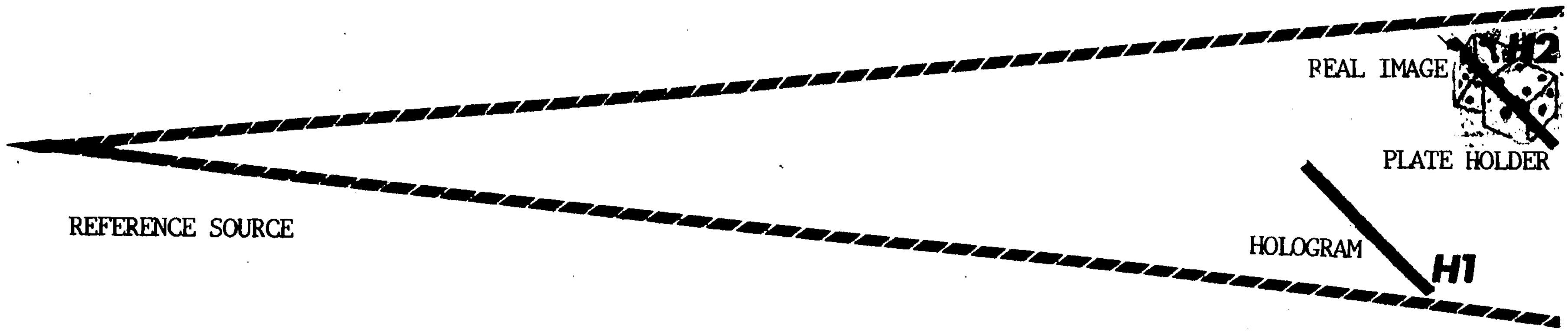
T. H. Jeong, "The One-Beam Transmission Hologram", The Physics Teacher, p.129, Feb. 1980.
A. Pepper, "Doug Tyler's Art of Simplicity", holosphere, p.4 September 1982
F. Unterseher, J. Hansen, B. Schlesinger, HOLOGRAPHY HANDBOOK, Ross Books, 1982, p. 161

PROJECT 3: Division of Amplitude



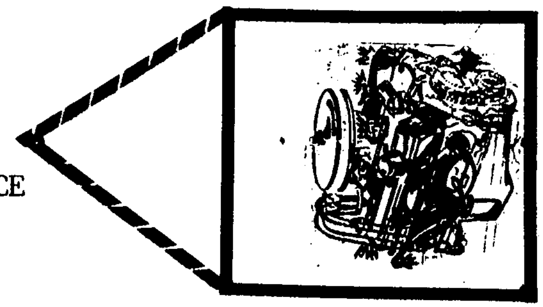
SET UP STEPS:	1) Spread beam enough to cover object and reference mirror. 2) Position plate holder. 3) Direct reference beam to plateholder using mirror . Equalize beam path lenghts lengths at this point. 4) Settle system and shoot hologram. 5) Process and reconstruct the hologram. NOTE: Reference mirror may be above, below, or to the side of the object. TIP: Ratio can be controlled by locating reference mirror in secondary ring of the Gaussia Gaussian beam profile, or with a semi-reflecting mirror or a "Black Mirror".
OBSERVATIONS/ DEMONSTRATIONS:	Same as for Project 2.
OBJECT POSSIBILITIES:	Just about anything that is rigid enough to not move during exposure. May even be larger than the holographic plate.
PROJECTS for EXPLORATION:	Variety of interferometric experiments, multi-channeling, contact copying, coherence length holograms, tests of processing schemes and materials.
MASTERING CONSIDERATIONS:	FOR PROJECT 4: Make refernce beam path as long as possible. Place object as close to plate as possible, without shadowing reference beam. Find best exposure and development times for good brightness and low noise. Hologram must be larger than object.
REFERENCES	E. N. Leith, J. Upatnieks, "Wavefront Reconstruction Photography", Physics Today, p. 26, August 1965. N. Abramson, THE MAKING AND EVALUATION OF HOLOGRAMS, Academic Press, 1981, p. 225-238. Unterseher, et al., p.140-150 H. Bjelkhagen, "Experiences with Large Scale Reflection and Transmission", SPIE Vol. 120, p.122 (1977).

PROJECT 4: Pseudo-Achromat Transfer



SET UP STEPS:	1) Spread beam so that it is big enough to cover both master and copy plate. 2) Reconstruct real image from master made in Project 3. 3)Focus image onto second hologram plate holder while blocking H²'s reference beam. 4) Settle system and shoot hologram. 5) a. Reconstruct under laser light. b. Reconstruct with white light.
OBSERVATIONS DEMONSTRATIONS:	Images straddling the film plane; Achromatic effect; Aperture effect; Spherical Aberation; Dispersion.
TIPS:	Success here depends on master. Longitudinal Chromatic Aberation is controlled by depth of object. Keep object shallow and lashed to the plate. Spherical Aberation is controlled by pinhole to plate distance. Use exact conjugate beams if possible, otherwise the longest possible beam path.
DISCUSSION TOPICS:	How the full-blown Benton achromat and rainbow set ups work.
REFERENCES	G. B. Brandt, "Image Plane Holography", App. Opt. 8, 1421-1429 (1969) H. Bjelkhagen, op.cit. S. A. Benton, "The Mathematical Optics of White Light Holograms", Proceedings of the Int'l Symposium on Display Holography, Vol. 1 p.5 (1982) Unterseher, et al., p.277-281.

PROJECT 5: Cylindrical Holograms



"If you're going to go 3-D, why not go 360°?"

SET UP STEPS: 1) Spread beam as wide as possible to bring reference source close to cylinder. 2) Position cylinder and object. 3) Settle and shoot. 4) Process and reconstruct hologram.
TIPS: Beam spread must be extremely fast. Use circularly polarized light. Making film stable is a chore.

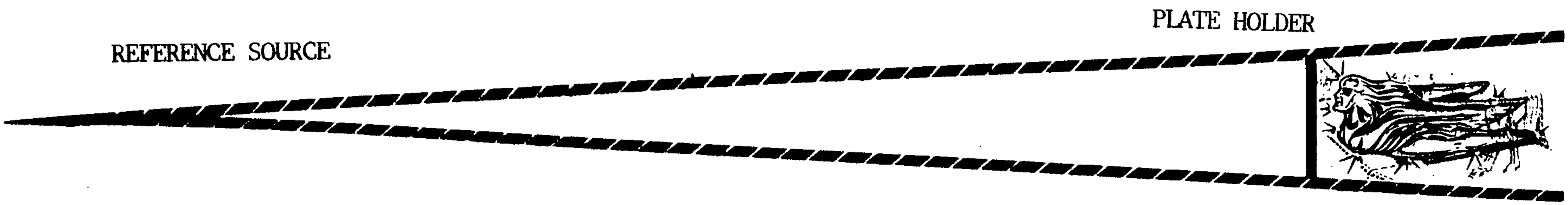
OBSERVATIONS/ DEMONSTRATIONS: Reconstruct the virtual image. For kicks, reconstruct the image flattened out.

PROJECTS for EXPLORATION: Try covering the object with a cone shaped piece of film for 360° reflection holograms.

REFERENCES

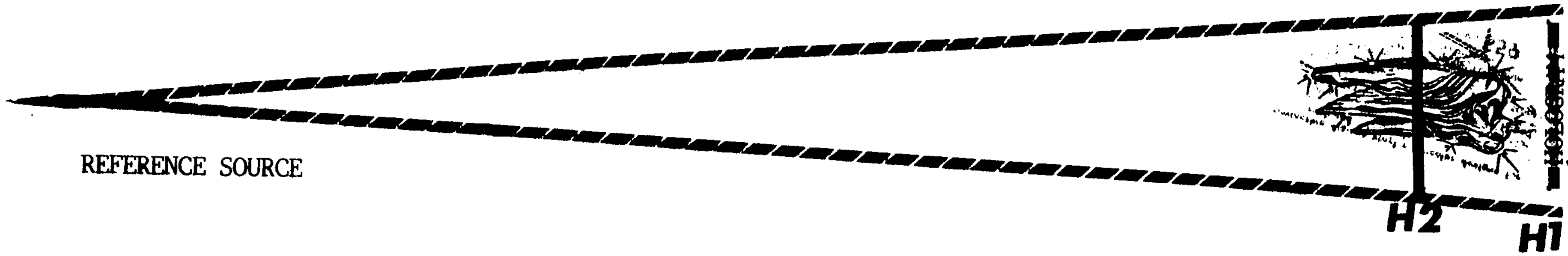
T. H. Jeong, "Cylindrical Holography and Some Proposed Applications", Journ. OSA 57, 1396-1398, (1967).
J. Upatnieks, C. D. Leonard, E. J. Martilla, "Archival Storage of Three- Dimensional Images", International Optical Computing Conference Digest of Papers, p. 108, (1975).
B. A. Stirn, "Recording 360° Holograms in the Undergraduate Laboratory", American Journal of Physics 43, April 1975, p. 297.
S. T. Hsue, et al., "360° Reflection Holography", American Journal of Physics 44, October 1976, p. 297.
E. A. Bush, "Hologram Cylinders, 4 Meters Long, Display Rare Objects Without Risk", holosphere 7. October 1978, p. 1.

PROJECT 6: Denisyuk Holograms



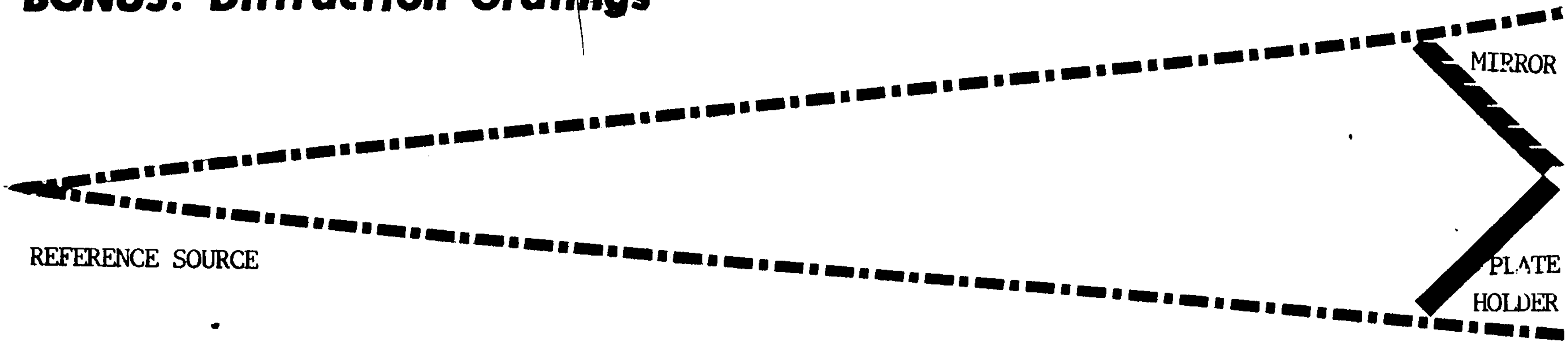
SET UP STEPS:	1) Spread beam so that primary Gaussian center is larger than the holographic plate. 2) Position object and plate holder. 3) Settle system and then shoot hologram. 4) Process hologram then reconstruct under white light.
OBSERVATIONS/ DEMONSTRATIONS:	Real and virtual images; color changes as a result of processing and exposure; the need for good isolation.
PROJECTS for EXPLORATION:	Pseudoscopic imagery; color control with triethanolamine; exact laser color reconstruction; testing processing variables.
OBJECT POSSIBILITIES:	Must be highly reflective without being too specular. Krylon #1401 Bright Silver Spray Paint works swell. Must be about the same size as the plate without being too deep.
TIPS:	Don't bother with film at first, go with plates. Make sure polarization is in proper plane to minimize woodgrain. Mounting object upside down or on its side will make it easier to attain top reference angle in some configurations.
MASTERING CONSIDERATIONS	For PROJECT 7: Use a process which reconstructs brightly under laser light. Make master hologram larger than object.
REFERENCES and EXAMPLES:	Yu. N. Denisyuk, "On the Reproduction of the Optical Properties of an Object by the Wave Field of Its Scattered Radiation", Optics and Spectroscopy 15. p.279, (1963) Unterseher, et al., p.279.
PROCESSING:	W. Spierings, "Pyrochrome Processing Yields Color-Controlled Results with Silver Halide Materials", holosphere 10, July/Aug. 1981, p.1. G. Saxby, "Jottings From the UK", holosphere, Fall 1983, p.9. D. J. Cooke, A. A. Ward, "Reflection Hologram Processing for HIgh-Efficiency in Silver Halide Emulsions," App. Opt. 23, p.934, (1984).
COLOR CONTROL:	L. Moore, "Pseudo-Color Reflection Holography", Proc. of the Int'l Symp. on Display Holography, Vol. 1 p.163, (1982). J. Kaufman, "Previsualization and Pseudo-Color Image Plane Reflection Holograms", ibid., p.195.
PSEUDOSCOPY:	J. Blyth, "Pseudoscopic Moldmaking Handy Trick for Denisyuk Holographers", holosphere, Nov. 1979, p.5.

PROJECT 7: Image-Plane Denisyuk Holograms



SET UP STEPS:	1)Spread beam wide enough to cover master and copy plates. 2) Reconstruct real image from master made in PROJECT 6. 3) Position copy plate. 4) Settle system and then shoot hologram. 5) Process and reconstruct the hologram in white light.
OBSERVATIONS/ DEMONSTRATIONS:	Sharp image straddling the film plane; the lack of redundancy; the aperture effect.
REFERENCE:	H. Bjelkhagen, "Denisyuk Reflection Holography; Recording and Copying Technique", Proc. of the Int'l Symp. on Display Holography. p.45, (1982).
EXAMPLES:	Millions of Dichromate Pendants.

BONUS! Diffraction Gratings



SET UP STEPS: 1) Spread beam twice as big as the hologaphic plate. 2) Tilt plate holder and mirror for desired interbeam angles. 4) Settle system and shoot hologram. 5) Process and reconstruct.

BONUS 2!! Holoroids

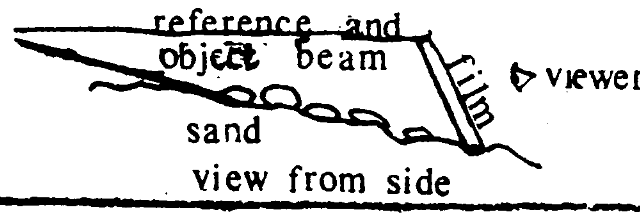
SET UP STEPS: 1) Undiverged laser beam project real image onto SX-70 type film pack. 2) Settle system and expose. 3) replace film pack into camera. Finished holoroid will eject.

OBJECTS FOR HOLOGRAMS

At the beginning, some objects will be more successful than others in the different set-ups for holograms. Here are some suggestions:

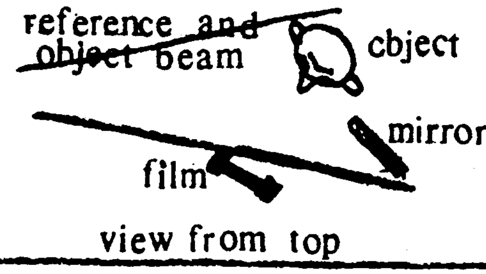
SINGLE BEAM TRANSMISSION
(DEEP SCENE)

Long, low objects are necessary because they are backlit, but depth of almost two feet is possible. Things like necklaces, springs, and sea shells work fine.



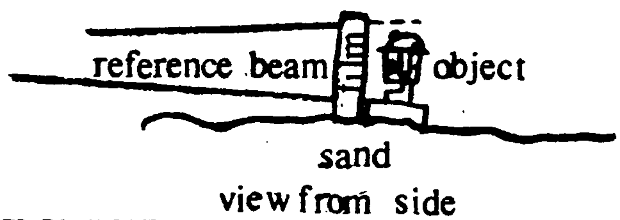
SINGLE BEAM TRANSMISSION
(DIVISION OF AMPLITUDE)

Depth is shallow, but object is more front lit than set-up above. Busts, small statues, skulls are good, the lighter colored the better.



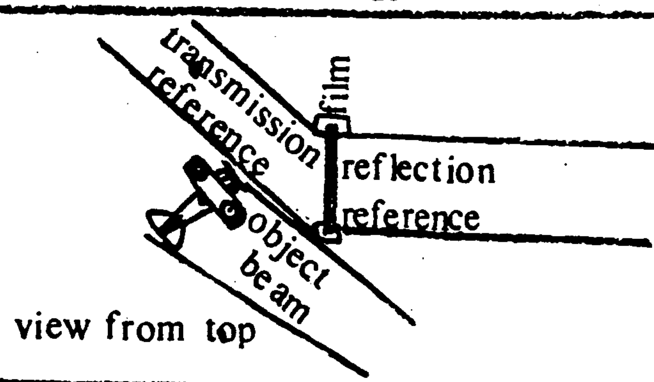
SINGLE BEAM REFLECTION

Object must be very shiny, preferably metallic, and will be pressed up against the film holder. Keys, coins, and hood ornaments work well since the depth is only a couple of inches.



MULTIPLE BEAM TRANSMISSION
AND REFLECTION

Because there is more control of the object's lighting, almost anything works in the transmission mode; however, very shiny objects are easier to work with in the reflection mode.



SIZE CONSIDERATION - A hologram is like a window, and the size of the hologram-window in this class is three inches square. Whatever you can view through a three inch square frame will be included in the finished hologram. Also, be aware aesthetically of what you are filling the space with. BRING AS MANY OBJECTS AS POSSIBLE. Remember, they will be used in a sand box.

FINE ARTS RESEARCH & HOLOGRAPHIC CTR.
1134 W. WASHINGTON BLVD.
CHICAGO, ILLINOIS 60607

SINGLE BEAM REFLECTION HOLOGRAM
(for 4 by 5 and 8 by 10 inch Holograms on the EXPERIMENTAL TABLE)

SKETCH THE SET UP IN THE BOX ABOVE

PARTS LIST

1. LASER
2. SHUTTER
3. SPATIAL FILTER
4. 8 by 10" MIRROR in GOALPOST CONFIGURATION with TWO MAGNETIC BASES and RIGHT ANGLE CLAMPS
8. WELL-FIXTURED DIFFUSELY REFLECTING OBJECT
6. 4 by 5" PLATEHOLDER ASSEMBLY (if necessary)
7. 10 by 12" MIRROR in GOALPOST CONFIGURATION with TWO MAGNETIC BASES and RIGHT ANGLE CLAMPS (optional)
8. BAFFLES

ALIGNMENT AIDS:

9. CLEAN GLASS PLATE
10. GNOMON
11. OFFITIAL RULER

APPROPRIATE OBJECTS

The objects themselves must be stable and reflective. Paper, most food, and thin-walled hollow plastic things are constantly moving. Paper could be dry-mounted to something thicker; hollow things could be filled with sand or something similar. Plaster or clay could be used, but should be well-cured.

Solid metal objects are stable but may sometims be too reflective, and only specular highlights may come out due to the harsh point source lighting of the **SPATIAL FILTER**. A <u>dulling spray</u> may be necessary.

Green, blue and black objects will not come out due to poor reflectivity of the red beam. When in doubt, look at the **Object** under **Laser Light**. Yellow, orange, red, white, silver and gold work quite well. The favorite permanent spray paint for peak holographic performance is **Krylon #1401 Bright Silver**, as its pigment is small particles of aluminum, which not only is highly reflective, but preserves the polarization of the incoming beam to a certain degree.

Objects may be temporarily colored by hair sprays that will reflect well but may not stick to everything. They are usually carried at venues that cater to alternative culture*.

SET UP STEPS

1. Send the Beam from the **LASER** held in its usual position at the end of the **ISOLATION TABLE** to the center of an **8 by 10" MIRROR** held between two **MAGNETIC BASES** in the GOALPOST manner. Check for the **OFFICIAL BEAM HEIGHT** with the **OFFITIAL RULER** at the **MIRROR**.

2. Direct the Beam from **MIRROR (4)** diagonally across the Table to the opposite corner. Check for the **OFFICIAL BEAM HEIGHT** with the **OFFITIAL RULER** at the last **MIRROR** and tilt **MIRROR (4)** if necessary.

3. If the **OBJECT** is to be mounted on its back on the **Tabletop** or stood upright (See the **Handout, SBR Variations**) another **LARGE MIRROR** on a GOALPOST needs to send the beam downwards. One edge of a **GLASS PLATE** is laid on the **Tabletop** to reflect the undiverged beam back to the **Laser** to verify that the beam is incident in the <u>vertical plane</u> only. The **Magnetic Bases** of the GOALPOSTS are manipulated like shuffling feet to rectify the illumination.

3a. If the object is like the **Waffle Iron** or is mounted on a **KINEMATIC PLATEHOLDER**** it can be placed on the GOALPOST Arrangement instead of the **MIRROR**. Use a **Glass Plate** as

---

*. For instance, **The Alley**, at 858 West Belmont Avenue, Chicago, 312-525-3180.

. See the **Handout, KINEMATIC PLATEHOLDER, in press.

described above on the **Object Holder** to make the **Reference Beam** purely vertically incident. Note that the top of the **Object** is at the bottom of the arrangement for Top-lit reconstruction.

4. Insert the **SPATIAL FILTER (3)** with a **10X Microscope Objective** after the **SHUTTER (2)**. Leave about two inches clearance further downbeam from the shutter for more components to be added in later setups. Center the Spread Beam on a **TARGET CARD** after the **MIRRORS** at the far end of the **TABLE**. Clean the beam with the **Pinhole***.

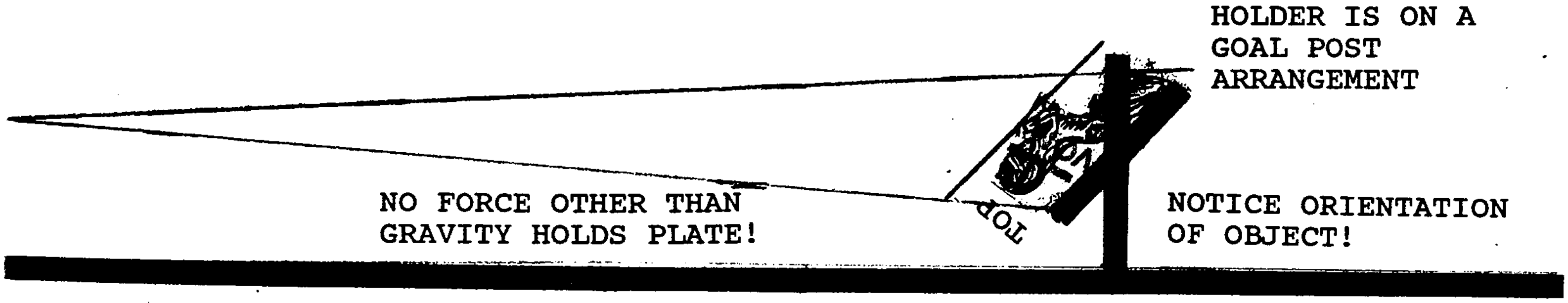
5. Block STRAY LIGHT, especially any that might come from behind the **PLATEHOLDER** that could act as a second REFERENCE BEAM! Usually a piece of cardboard or the cover from a **MIRROR** leaning up against the **Laser** will shade the **Holographic Plate** from the laser spot on the **SHUTTER**.

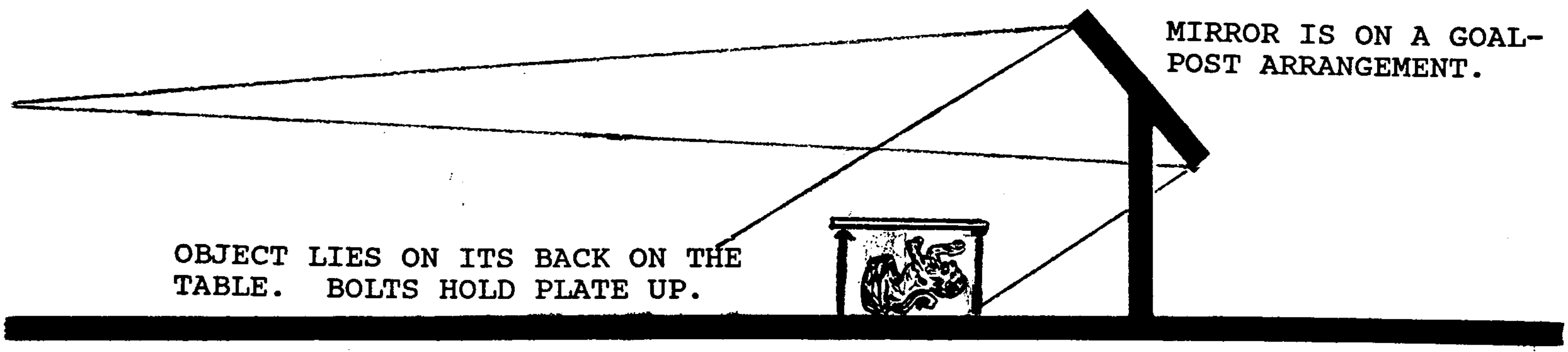
6. Expose, process and evaluate the hologram. Use the **DEMONSTRATION HOLOGRAMS** as exposure guides for color control and brightness.

---

*. See the **Handout, SPATIAL FILTERS**.

sbt VARIATIONS





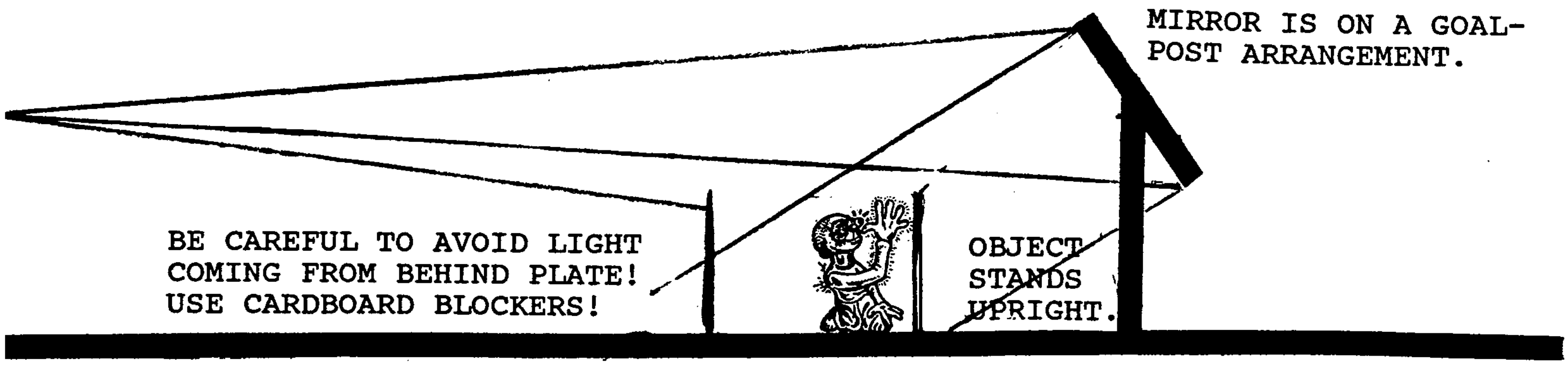
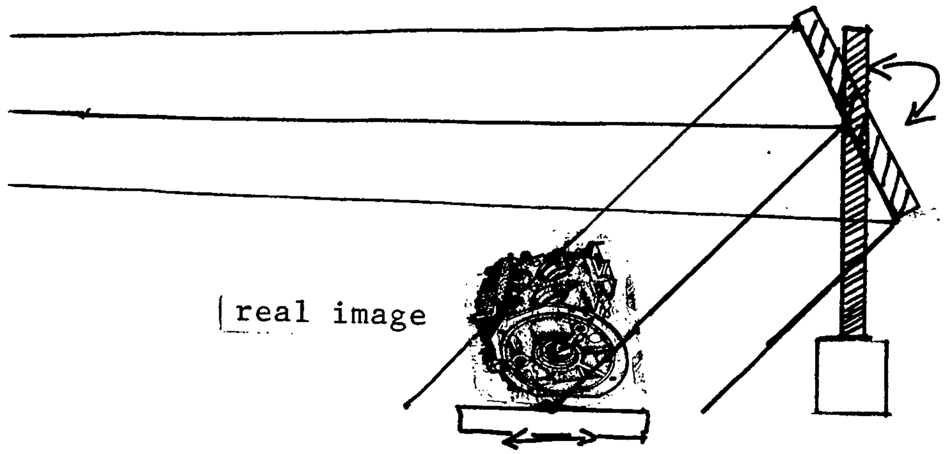


PLATE HELD AT BOTTOM. DANGER! THE TOP OF THE PLATE MAY END UP FLAPPING IN THE BREEZE! THE BOTTOM OF THE HOLOGRAM MAY COME OUT, BUT NOT THE TOP!

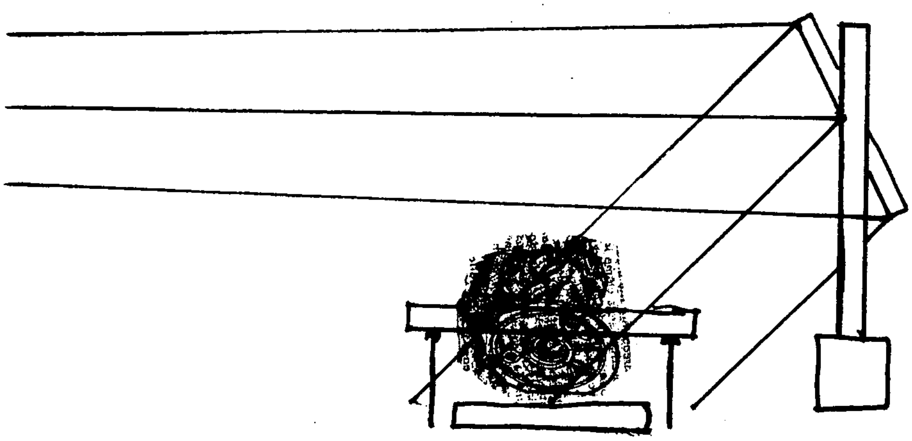
OBJECT MAY BE FIXTURED SIDEWAYS, SO THAT A HORIZONTAL BEAM ACTS AS A VERTICAL ONE! JUST THINK ABOUT LOOKING AT THE FIRST FIGURE AS A TOP VIEW INSTEAD OF A SIDE ONE!

image plane SBR

A bright, low noise reflection hologram that reconstructs well under laser illumination is a must! The non-image side may need to be painted black or the hologram should be placed on something black.



STEP I: May need to chase hologram back and forth to find the best replay of the real image.



STEP II: Find appropriate level for copy hologram by screwing bolts into table with line up plate on them.

BEWARE of shadows cast by edge of plate or tape on the edge.

PLAN AHEAD! Master may need to be trimmed to fit!

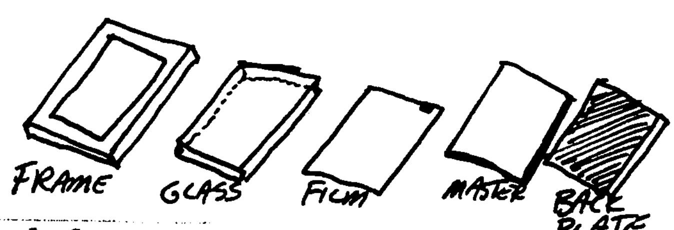
STEP III: Expose and develop just like you would for hologram of regular object.

CONTACT COPYING OF REFLECTION HOLOGRAMS

As long as the master (H1 or H2 as made above) is bright under laser illumination, the copies will be successful!

STEP I: Find reference angle for master lying on table in contact print frame on table.

STEP II: Assemble glass-film-master sandwich in the contact print frame.



STEP III: Expose and process as usual for reflection holograms.

CAUTION! MAKE SURE THAT YOUR POLARIZATION VECTORS ARE PROPERLY ALIGNED!

EW 2/13/89

"Pseudoscopic" Moldmaking Handy Trick for Denisyuk Holographers

by
Jeff Blyth
Holographic Developments Ltd.
Number Ten, Marshallsea Road
London SE1 1HL, ENGLAND

On 17 May this year, I gave an impromptu talk to a gathering of holographers in the evening at the Museum of Holography. No one at the time appeared to know how I managed to make a two-color reflexion hologram showing a red real-image hand in front of a dark green virtual image statuette, using only a HeNe laser and one sheet of Agfa 8E75HD film (it did in fact take many preparatory experiments before I made the hologram). The hologram created quite a degree of interest when on exhibition in Eindhoven, Holland and later in the "Laser '79" exhibition in West Germany. There were of course two tricks involved, and I will explain them separately. Firstly, how did I manage to make a real image hologram of my hand without using a pulse laser? A further interesting point about the way I did it is that it was much easier to make a real image than a virtual one, which is of course quite the reverse of general experience.

This was how I did it: I made a "pseudoscopic mold" out of plaster of Paris. I added 420 cubic centimeters of ice-cold water to one kg of "dental grade" plaster of Paris and mixed it well while wearing rubber gloves. After precisely one minute I removed the gloves and quickly poured the mix into a square polythene container. At this moment the mix had a putty-like nature and was stiffening rapidly. I pushed my left hand in so that the fingers were half immersed at the back of the hand and held it steady while with my other hand I removed any bits of plaster which overlapped and formed what industrial molders would term a "re-entrant angle." A "re-entrant" angle prevents a solidified object being removable from a rigid mold and for holographic purposes prevents light from reaching the inner areas of the mold behind the re-entrant angle (it also imprisons the hand. My first experiment was to put both hands in plaster at the same time. I had so many re-entrant angles that I could pull neither hand out and was effectively handcuffed in a plaster of Paris block. It created some considerable laughter when my wife watched me having to smash the block on the pavement outside in the street to free myself).

I found that 10 minutes was enough for the block to set hard enough to be able to remove my hand without deforming the mold. It was slightly painful because the mold trapped small hairs from the skin, but these hairs did add to the final realism of the hologram (I have tried using more modern molding material but its inherent surface reflectivity was very inferior and reacted badly when I tried to improve it with a light coat of white spray paint).

A peculiar problem I found with plaster of Paris was connected with the need to dry out the excess water. I could either obtain holograms from the mold when it was freshly made and full of water or when it was well dried, but not obtain good holograms during the many days it took to dry out. I put this down to an irregular contraction process occuring of the order of ½ a wavelength of red light during the 20 or so seconds of time needed with my HeNe laser. One can judge if the drying process is complete by weighing. One kg of the original powder should finish up weighing 1.2 kg. when dry.

When my mold was dry I squeezed my hand back into it tightly and sprayed black paint all over it and the mold. After a few minutes I removed my hand and left the mold looking like a white shadow on a black background (see picture). To actually use this pseudoscopic object, I placed it close up to the film upside down and exposed it to a single beam in a simple Denisyuk arrangement. The resultant hologram is then viewed on the same side as that which faced the pseudoscopic object.

Now to deal with the trick of obtaining two colors using only a HeNe laser. Firstly I had to use a processing system which would roughly reproduce the original red illumination in white-light viewing (such as Steve Benton's system in *holosphere*, July 1978, p.4).

The procedure I contrived was as follows. Firstly, to expose the hologram to the pseudoscopic hand for an exposure time three times longer than would usually be sufficient. Without further treatment to develop the latent image, I then soaked it in a solution of 12 per cent triethanolamine and blotted the film on a fresh and new piece of unfolded or uncreased blotting paper, pressing evenly over the back of the hologram. The much-increased exposure time was needed because I found the latent image was apparently much weakened by this triethanolamine swelling treatment. The blotted film was left in a dark room at 25°C for an hour before making a second exposure. Since I required an ordinary virtual image on the second exposure, the emulsion side was positioned the opposite way round and upside down with respect to the first exposure. The object was then placed in a predetermined position with respect to the film. The exposure time was then in the second case only 2/5 of what it would normally have been, because the emulsion had been sensitized both by the triethanolamine and probably also by the first exposure.

After developing and bleaching as usual, the triethanolamine was completely removed and therefore the gelatin contracted to its usual thickness, decreasing the wavelength of the viewing light for the second exposure but leaving the viewing light of the first exposure in the red. The result was an interesting superposition of a real-image red hand in front of a virtual green figurine. In my experiments I did not find that reversing the order of exposing by first leaving the emulsion swollen and later unswollen gave as good a result.

(Continued from previous page)

who wants to work in integral holography directly must be willing to acquire their own printer. BUT when you do,BUILD TWO, one for the commercial jobs that will pay the rent and meet the rising cost of living, and one you can rearrange to suit your own vision as an artist.

Sharon McCormack is a holographic stereographer and is a member of the San Francisco School of Holography.

Answer:
Integral holograms do not yet have the elegant finished look of a well-executed plate hologram. The integral system, making use of movie film, has great possibilities for innovative imagery.

I enjoy the integral process and have worked consistently for myself and clients. "For My Father" and "Self-Portrait as a Smearing Carpenter" are two 360° integrals that regardless of all drawbacks I feel are finished pieces and am proud of.

I am still very interested in integral holograms. Recently I changed format to the "minigram." This system improves image quality, cleans up the packaging and makes holograms more accessible.

Abe Rezny is an independent commercial/ artistic holographer.

Answer:
Everything is a viable art form – the problem, as with holography, is expressing one's identity and concerns successfully.

Integral holography is a tenuous art form because its difficult technology limits access and often results in an overemphasis of technology.

You can say it in 3D and with mystery.

"Inches" from serigraph laser scan calligraphy. c1979 by Peter Van Riper.

Peter Van Riper is an artist who has worked extensively with lasers and holography, among other media.

"In fact, **telephone systems** will become so **intelligent** that phones will function like **computers**. And perhaps, by 2029, what science writer Isaac Asimov calls the **ultimate communications system – holographic projections** with two way-sensory circuits – will be unveiled." *Business Week*, Sept. 3, 1979.

Holographic techniques were used in the design of a new **Hi-Fi speaker system** being marketed by Rank Hi-Fi, Inc., *20 Bushes La., Elmwood Park, NJ 07407.*

SINGLE BEAM TRANSMISSION WITH MIRROR MASTER HOLOGRAM (for 4 by 5 inch Holograms on the EXPERIMENTAL TABLE)

SKETCH THE SET UP IN THE BOX ABOVE

PARTS LIST

1. LASER
2. SHUTTER
3. SPATIAL FILTER
4. 8 by 10" MIRROR in GOALPOST CONFIGURATION with TWO MAGNETIC BASES and RIGHT ANGLE CLAMPS
5. 10 by 12" MIRROR in GOALPOST CONFIGURATION with TWO MAGNETIC BASES and RIGHT ANGLE CLAMPS
6. 4 by 5" PLATEHOLDER ASSEMBLY
7. LITTLE JOKER ASSEMBLY
8. WELL-FIXTURED DIFFUSELY REFLECTING OBJECT
9. HALF-WAVE PLATE ASSEMBLY
10. BAFFLES

SET UP STEPS

1. Send the Beam from the **LASER** held in its usual position at the end of the **ISOLATION TABLE** to the center of an 8 **by 10" MIRROR** held between two **MAGNETIC BASES** in the GOALPOST manner. Check for the **OFFICIAL BEAM HEIGHT** with the **OFFITIAL RULER** at the **MIRROR**.

2. Direct the Beam from **MIRROR (4)** diagonally across the Table to the center of the **10 by 12" MIRROR (5)** held between two more **MAGNETIC BASES** in the usual GOALPOST

manner. Check for the **OFFICIAL BEAM HEIGHT** with the **OFFITIAL RULER** at the last **MIRROR** and tilt **MIRROR (4)** if necessary.

3. Direct the Beam from **MIRROR (5)** across the Table more or less parallelto the Table's edge. Check for the **OFFICIAL BEAM HEIGHT** with the **OFFITIAL RULER** at the edge of the Table and tilt **MIRROR (4)** if necessary.

4. Insert the **SPATIAL FILTER (3)** with a **10X Microscope Objective** after the **SHUTTER (2)**. Center the Spread Beam on a **TARGET CARD** after the **MIRRORS** at the far end of the **TABLE**.

Steps 1-4 are not necessary if the **SINGLE BEAM TRANSMISSION WITH MIRROR MASTER HOLOGRAM SET UP** evolves out of the **SINGLE BEAM REFLECTION HOLOGRAM SET UP**, as there will be a Spread Beam at the Official Height headed for **MIRROR (5)**. To find the proper tilt angle for **MIRROR (5)** follow Step 4a.

4a. Trim a piece of Paper to the Official Height. Hold it in front of **MIRROR (5)** to ascertain that the center of the Spread Beam is at this Height. Manipulate **MIRROR (4)** if necessary. Then check that the Spread Beam reflected from **MIRROR (5)** to the opposite end continues along parallel to the Table's top and edge.

5. Mount the **OBJECT** in the bright central portion of the Beam. Object on its **MOUNTING BLOCK** is tipped toward the light in order to be top lit. Notice the orientation of the **OBJECT** in its **HOLDER**! Although the **REFERENCE BEAM** approaches from the side, this will be the **TOP** of the final **HOLOGRAM**, and therefore the **OBJECT'S TOP** should be pointing toward the **REFERENCE BEAM**!

6. The **PLATEHOLDER on MAGNETIC BASE ASSEMBLY** loaded with a **4 by 5" PIECE OF GLASS** should be positioned as close as possible to the **OBJECT** without the **GLASS** casting a shadow onto the **OBJECT**. It should be tilted so that the **PLATEHOLDER** is parallel to the **OBJECT'S** Plane. Composition of the scene can be viewed by looking through the **PLATEHOLDER**.

7. With the **GNOMON** in the **PLATEHOLDER**, aim a REFERENCE BEAM at it with one of the **LITTLE JOKERS** planted so that it is as far back as the plane of the center of the **OBJECT** and off to its "top" side close enough to reflect some prime beam but not so close to be directly visible from the viewpoint of the **PLATEHOLDER**. Rotate and tilt the **LITTLE JOKER** with the knobs on the **Daedal 5700** until the REFERENCE ANGLE is 45 degrees as

indicated by the **GNOMON**.

8. Block STRAY LIGHT, especially any that might come from behind the **PLATEHOLDER** that could act as a second REFERENCE BEAM!

9. Insert the **HALF-WAVE PLATE ASSEMBLY (9)** after the **LASER (1)** but before the **SHUTTER (2)**. Align the POLARIZATION VECTOR for minimum reflection and maximum penetration per the Handout, **ALIGNING POLARIZATION VECTORS**. Now is the time to check the tune of the **Pinhole** of the **SPATIAL FILTER (3)**.

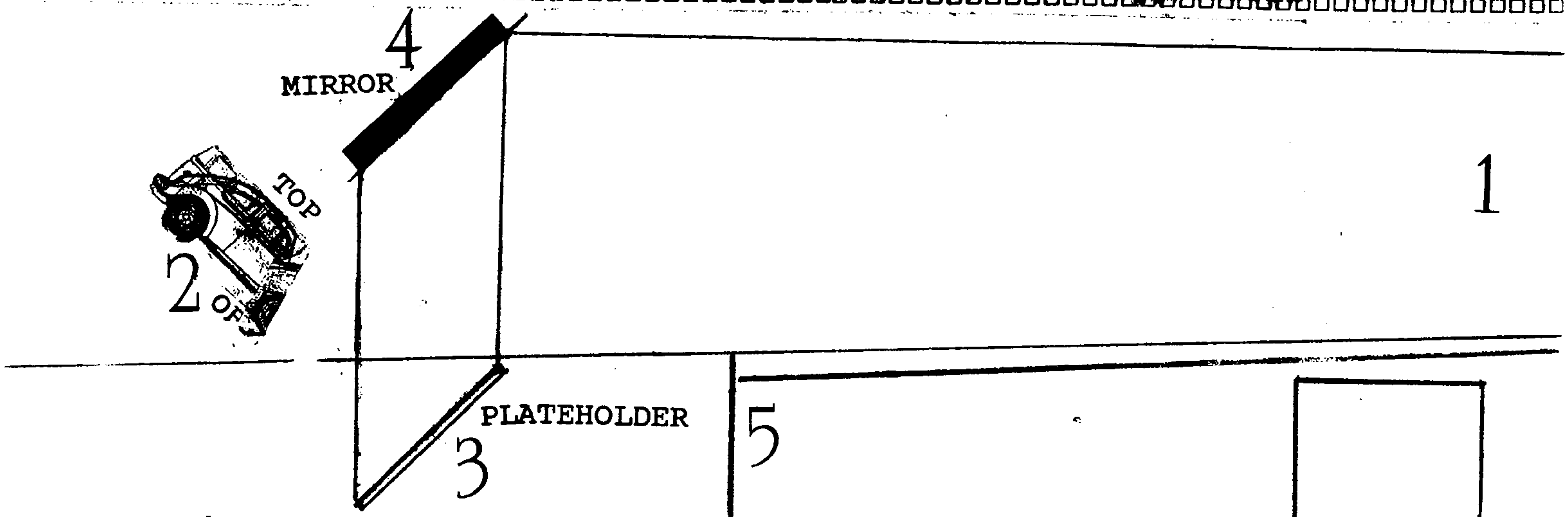
10. Check the INCIDENT FLUX at the **PLATEHOLDER** with the **Probe** of the **S & M MODEL A-3 PHOTOMETER** placed where the center of the **HOLOGRAPHIC PLATE** will be. See the HANDOUT, **S & M MODEL A-3 PHOTOMETER**, for the **EXPOSURE TABLE**.

11. Expose, process and evaluate the hologram.

SINGLE BEAM TRANSMISSION with mirror

HORIZONTAL SET UP

1 ESTABLISH THE BEAM HEIGHT __________ ABOVE THE TABLE. FOR HOLOGRAMS TO BE USED AS MASTERS, START THE BEAM SPREADING NEARBY THE LASER WITH A SPATIAL FILTER, (ALLOWING ROOM FOR THE SHUTTER AND A POWER METER IF NECESSARY!) LET IT BOUNCE OFF A MIRROR AT THE END OF THE TABLE, AND THEN TRAVEL THE LENGTH OF THE TABLE. A 20X OBJECTIVE WITH MATCHING PINHOLE MAY BE NECESSARY.



2 MOUNT THE OBJECT IN THE BRIGHT CENTRAL PORTION OF THE BEAM. OBJECT ON ITS MOUNTING BLOCK IS TIPPED TOWARD THE LIGHT IN ORDER TO BE TOP LIT. NOTICE THE ORIENTATION OF THE OBJECT IN ITS HOLDER! ALTHOUGH THE REFERENCE BEAM APPROACHES FROM THE SIDE, THIS WILL BE THE TOP OF THE FINAL HOLOGRAM, AND THEREFORE THE OBJECT'S TOP SHOULD BE POINTING TOWARD THE REFERENCE BEAM!

3 PLATE HOLDER ON MAGNETIC BASES SHOULD BE POSITIONED AS CLOSE AS POSSIBLE TO THE OBJECT WITHOUT CASTING A SHADOW ONTO THE OBJECT. IT SHOULD BE TILTED SO THAT THE PLATE HOLDER IS PARALLEL TO THE OBJECT'S PLANE. COMPOSITION OF THE SCENE CAN BE AIDED WITH THE NAIL\NORMAL ON A CLEAR PLATE.

4 INSTALL THE REFERENCE MIRROR ON ITS OWN MAGNETIC BASE. FIND A POSITION WHERE THE REFLECTED LIGHT EVENLY ILLUMINATES A WHITE CARD WITH A NAIL PLACED IN THE PLATE HOLDER, WITH A REFERENCE ANGLE OF 45 DEGREES.
CAUTION: REFERENCE BEAM PATH SHOULD EQUAL OBJECT BEAM PATH LENGTH. MEASURE SPATIAL FILTER TO OBJECT TO PLATEHOLDER PATH WITH A PIECE OF STRING, THEN COMPARE IT TO THE DISTANCE FROM SPATIAL FILTER TO MIRROR TO HOLOPLATE. REPOSITION MIRROR IF NECESSARY. (PATH LENGTH DIFFERENCE TOLERANCE WITH OUR LASERS = 4 INCHES.)

5 BLOCK STRAY LIGHT, ESPECIALLY ANY THAT MIGHT COME FROM BEHIND THE HOLOPLATE THAT COULD ACT AS A SECOND REFERENCE BEAM!

CHECK POLARIZATION VECTORS.

READ BEAM INTENSITIES AND THEIR RATIO.

EXPOSE AND DEVELOP.

10/13/90 Eu

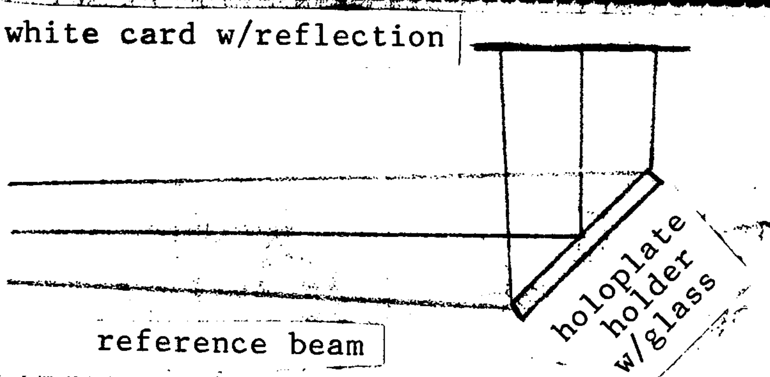
ALIGNING POLARIZATION VECTORS

Most lasers are polarized. Proper alignment of the plane of polarization will increase throughput of light through glass plates and minimize the dreaded woodgrain!

Cylindrical laser heads can simply be rotated to find the proper plane of polarization. Lasers which have a permanent orientation require the magic of half-wave retardation plates to spin their vectors.

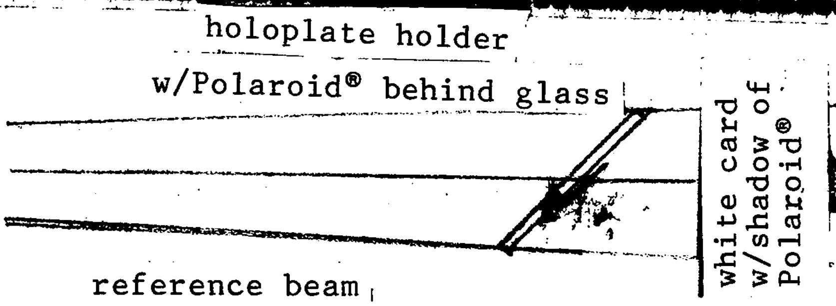
For single beam work, a half-wave plate positioned before the spatial filter is all that's necessary. When splitting the beams with a rotary or mirror type beamsplitter a half-wave plate positioned before the beamsplitter is all that's necessary again; but rotating the half-wave plate may change the beam balance ratio because the reflected beam may get stronger or weaker depending on the orientation of the beam going into the splitter.

But since the beams coming out of polarizing beamsplitting cubes are polarized at right angles to each other a half-wave plate may be necessary in one beam or the other or both! Check both beams!

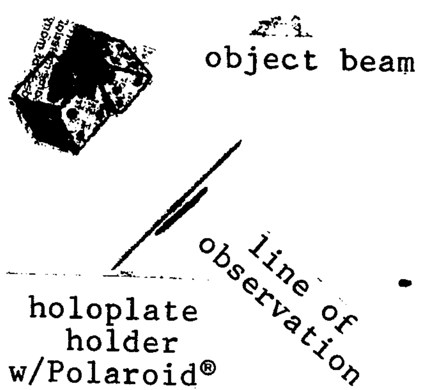


STEP I: Observe the reflection of the reference beamfrom a piece of glass in the plateholder on a white card. Rotate the polarization until this reflection is minimized.

STOP!! DONE FOR SINGLE BEAM WORK!



STEP II: Determine orientation of plane of polarization by minimizing the shadow of a Polaroid filter (rotate the filter) placed in contact with the glass plate placed in the plate holder.



STEP III: Rotate the polarization of the object beam to match the reference beam. Look through the Polaroid at the object and rotate the polarization of its beam so that the throughput is minimized. PROBLEM - Some objects do such a good job of randomizing the polarization that there is no best orientation of the half-wave plate.

BOTH BEAMS MUST HAVE THE SAME POLARIZATION VECTOR ALIGNMENT TO INTERFERE!!!

SINGLE BEAM TRANSMISSION PSEUDO-ACHROMAT* HOLOGRAM
(for 4 by 5 inch Holograms on the EXPERIMENTAL TABLE)

SKETCH THE SET UP IN THE BOX ABOVE

PARTS LIST

1. LASER
2. SHUTTER
3. SPATIAL FILTER
4. 8 by 10" MIRROR in GOALPOST CONFIGURATION with TWO MAGNETIC BASES and RIGHT ANGLE CLAMPS
5. 10 by 12" MIRROR in GOALPOST CONFIGURATION with TWO MAGNETIC BASES and RIGHT ANGLE CLAMPS

6& 7. 4 by 5" PLATEHOLDER ASSEMBLIES

8. HALF-WAVE PLATE ASSEMBLY
9. BAFFLES

SET UP STEPS

Usually this set up is used almost immediately after making the **MASTER HOLOGRAM**, so there should be no need to reconfigure the mirrors and **SPATIAL FILTER**. (See the **HANDOUT**, **SINGLE BEAM**

---

*. Achromatic means without color; this image is black & white near the image plane. Pseudo distinguishes this hologram from the "true achromat" of Dr. Stephen Benton of MIT who produces the same result through a long and complicated process involving tilted masters and Holographic Optical Elements.

TRANSMISSION WITH MIRROR MASTER HOLOGRAM (for 4 by 5 inch Holograms on the EXPERIMENTAL TABLE), Steps 1 through 4 if starting from scratch.)

1. Remove from the **TABLE** and put away the **OBJECT** and **LITTLE JOKER** where they belong.

2. Roughly orient the **PLATEHOLDER ASSEMBLY** in the hot center of the spread beam at the farthest reaches of the table. For top-lit "landscape" format masters, which will be side-illuminated in this set up, angle the plateholder so that the side with the screws is facing toawrd the obsever and the top of the U shape it angled toward the reference beam.

3. Find the <u>Virtual Image</u> in the **MASTER HOLOGRAM**. Put the master plate in the plateholder, and spin and flip the hologram through the four permutations until you find the image. Rotate the **PLATEHOLDER** until you get the brightest image, making sure that this plate is centered in the Bright Stuff.

4. Once the <u>Virtual Image</u> is found, then rotate the **MASTER HOLOGRAM** along the current vertical axis which puts the replay light into the hologram exactly backwards, so that the <u>Real Image</u> pops out.

5. Assemble the **5 by 7" CONTACT FRAME PLATEHOLDER ASSEMBLY** between a couple of **MAGNETIC BASES** in the usual Goalpost Configuration. (This **HOLDER** can hold plates or film for <u>Transmission Holograms</u>.) Put a piece of **4 by 5" GROUNDGLASS** in the **FILMHOLDER** and observe the focus of the <u>Real Image</u> while translating the **FILMHOLDER ASSEMBLY** toward and away from the **MASTER PLATEHOLDER ASSEMBLY**. It helps to block the light that misses the master that could hit the **GROUNDGLASS** as it clouds the <u>Real Image</u>. The height of the **COPY FILMHOLDER** should be adjusted to frame the image properly.

6. The stray light mentioned above is the **REFERENCE BEAM** for the Hologram. Make sure that the light missing the **MASTER PLATEHOLDER** covers the place where the **Copy Hologram** will be exposed. A well-exposed **Master's Image** will be visible under the <u>Coherent Background</u>.

7. Block STRAY LIGHT, especially any that might come from behind the **PLATEHOLDER** that could act as a second REFERENCE BEAM!

8. Insert the **HALF-WAVE PLATE ASSEMBLY (9)** after the **LASER (1)** but before the **SHUTTER (2)**. Align the POLARIZATION

VECTOR for minimum reflection and maximum penetration per the Handout, **ALIGNING POLARIZATION VECTORS**. Now is the time to check the tune of the **Pinhole** of the **SPATIAL FILTER (3)**. (This could be still set up from the **MASTER SET UP**.)

9. Check the INCIDENT FLUX at the **PLATEHOLDER** with the **Probe** of the **S & M MODEL A-3 PHOTOMETER** placed where the center of the **HOLOGRAPHIC PLATE** will be. See the HANDOUT, **S & M MODEL A-3 PHOTOMETER**, for the **EXPOSURE TABLE**.

10. Expose, process and evaluate the hologram. The sharpest image will be visible under laser light, although a black & white image is visible under white light. Applying a color filter to the hologram will result in any hue of image.

SINGLE BEAM TRANSMISSION HOLOGRAPHIC DIFFRACTION GRATING #1: LOW FREQUENCY GRATING

For 8 by 10 inch or Smaller HOE's on the Beginning Table

SKETCH THE SETUP IN THE BOX ABOVE.

PARTS LIST

1. LASER
2. SHUTTER
3. SPATIAL FILTER
4. 8 by 10" MIRROR in GOALPOST CONFIGURATION with TWO MAGNETIC BASES and RIGHT ANGLE CLAMPS
5. 10 by 12" MIRROR in GOALPOST CONFIGURATIONwith TWO MAGNETIC BASES and RIGHT ANGLE CLAMPS
6. 4 by 5" PLATEHOLDER ASSEMBLY
7. LITTLE JOKER ASSEMBLIES (2)
9. HALF-WAVE PLATE ASSEMBLY
10. BAFFLES
11. GNOMON
12. PIECE OF GLASS
13. S & M LIGHT METER

A pair of medium-sized mirrors in this set up each direct half of the divergent beam to the **Holographic Plate**. The intra-beam angle for this interference field is very small, about ten degrees, and generates fringes of low spatial frequency, sometimes big enough to see! This type of grating works great in conjunction with point sources, neon tubes, fluorescent lamps, LED's, or as an image multiplier.

SET UP STEPS

1. This setup is an add-on to the basic **SINGLE BEAM TRANSMISSION WITH MIRROR MASTER HOLOGRAM** layout. Refer to steps 1 through 4 of the **HANDOUT**, **"Single Beam Transmission with Mirror Master Setup"** to send a diverging beam zig-zagging across the table if the equipment is still not on the **TABLE**.

2. Cover the **SECOND LARGE CORNER**, ((5) in the above-mentioned Handout), with its black wood cover. Place the two **LITTLE JOKER ASSEMBLIES** in front of it, with their edges butting each other.

3. At the opposite end of the table, position the **HOLOGRAPHIC PLATEHOLDER (6)** so that its center is at the juncture of the two **LITTLE JOKERS**.

4. With the **TARGET CARD** in the **PLATEHOLDER**, move one of the **LITTLE JOKER MIRROR ASSEMBLIES** so that its reflected light is incident on the **PLATEHOLDER**. Manipulate the other **LITTLE JOKER** so that its reflection also lights up the **TARGET CARD**.

5. If the beam is spread wide enough, the **PLATE** should be evenly illuminated from side to side.

6. Place a **PIECE OF GLASS** in the **PLATEHOLDER** and make sure that the light of each **LITTLE JOKER'S MIRRORS** reflects off the **GLASS** back towards the other one. This makes an <u>Unslanted Grating</u>, which has its fringes oriented perpendicular to the **HOLOGRAPHIC FILM BASE**, which is not so biased to any particular direction of light.

7. Align the **Polarization Vector of the Laser** for minimum reflectivity (maximum penetration) according to the directions given in the handout, **"ALIGNING POLARIZATION VECTORS"** if necessary.

8. Measure the intensity of both beams, singly and together, with the **S & M LIGHT METER** aiming for as close to a 1 to 1 **BEAM BALANCE RATIO** as possible, and plan your exposure according to their combined total.

9. Expose and process. **CAUTION!** This is one of the few times when it is <u>mandatory</u> to use the **'Chrome, Silver Solvent, Reversal, or Yellow Bleach** in processing the **HOE**. (See the **Handout, CWC2**.) Also use exposure number 250 instead of 450 when calculating the exposure time.

10. Look through the grating at a variety of light sources to amuse and amaze yourself.

SINGLE BEAM TRANSMISSION
HOLOGRAPHIC DIFFRACTION GRATING #2:
90 DEGREE DISPERSING GRATING
For 8 by 10 inch or Smaller HOE's on the Beginning Table

SKETCH THE SETUP IN THE BOX ABOVE.

PARTS LIST

1. LASER
2. SHUTTER
3. SPATIAL FILTER
4. 8 by 10" MIRROR in GOALPOST CONFIGURATION with TWO MAGNETIC BASES and RIGHT ANGLE CLAMPS
5. 10 by 12" MIRROR in GOALPOST CONFIGURATION with TWO MAGNETIC BASES and RIGHT ANGLE CLAMPS
6. 4 by 5" PLATEHOLDER ASSEMBLY
7. LITTLE JOKER ASSEMBLY
9. HALF-WAVE PLATE ASSEMBLY
10. BAFFLES
12. GNOMON
13. S & M LIGHT METER

A large mirror in this set up directs half of the divergent beam to the Holographic Plate while the other half is directly incident. The intra-beam angle for this interference field is 90 degrees for maximum dispersion. This type of grating works great in conjunction with a slide projector.

SET UP STEPS

1. This setup is an add-on to the basic **SINGLE BEAM TRANSMISSION WITH MIRROR MASTER HOLOGRAM** layout. Refer to steps 1 through 4 of the **HANDOUT, "Single Beam Transmission with Mirror Master Setup"** to send a diverging beam zig-zagging across the table if the equipment is still not on the **TABLE**.

2. After the **SECOND LARGE CORNER**, ((5) in the above-mentioned Handout), at the end of the table opposite to it, position the **HOLOGRAPHIC PLATEHOLDER (6)** so that one of its edges is at the center of the spread circle.

3. Verify that the spread beam is incident upon the **HOLOGRAPHIC PLATEHOLDER** at 45 degrees from the normal using the **HOLOGRAPHIC ANGLE FINDING TARGET CARD (GNOMON)**.

4. With the **TARGET CARD** still in the **PLATEHOLDER**, move one of the **LITTLE JOKER MIRROR ASSEMBLIES** up to the **PLATEHOLDER** so that one of its edges butts up against the **HOLOGRAPHIC PLATE** and that it directs the spread beam so that it too, is incident upon the **TARGET CARD** at 45 degrees. The **PLATEHOLDER** and **MIRROR** should then be perpendicular to each other.

5. If the beam is spread wide enough, the **PLATE** should be evenly illuminated from side to side.

6. Align the **Polarization Vector of the Laser** for minimum reflectivity (maximum penetration) according to the directions given in the handout, **"ALIGNING POLARIZATION VECTORS"** if necessary.

7. Measure the intensity of both beams, singly and together, with the **S & M LIGHT METER** aiming for as close to a 1 to 1 **BEAM BALANCE RATIO** as possible, and plan your exposure according to their combined total.

8. Expose and process. Place the freshly-made **GRATING** in the path of a **SLIDE PROJECTOR** and tilt it at 45 degrees to the light. A rainbow should be diffracted at right angles out of the **HOE**. Also try the trick with a point source.

SINGLE BEAM TRANSMISSION DEEP SCENE HOLOGRAM
(for 8 by 10 inch or Smaller Holograms on the EXPERIMENTAL TABLE)

SKETCH THE SET UP IN THE BOX ABOVE

PARTS LIST

1. LASER
2. SHUTTER
3. SPATIAL FILTER
4. 8 by 10" MIRROR in GOALPOST CONFIGURATION with TWO MAGNETIC BASES and RIGHT ANGLE CLAMPS
5. 10 by 12" MIRROR in GOALPOST CONFIGURATION with TWO MAGNETIC BASES and RIGHT ANGLE CLAMPS
6. 4 by 5" PLATEHOLDER ASSEMBLY
7. WELL-FIXTURED, LOW-LYING, DIFFUSELY REFLECTING OBJECT
8. HALF-WAVE PLATE ASSEMBLY
9. BAFFLES
10. CLEAN GLASS PLATE
11. GNOMON
12. S & M LIGHT METER
13. OFFITIAL RULER

SET UP STEPS

Follow Steps 1-4 of the **SINGLE BEAM TRANSMISSION WITH MIRROR MASTER HOLOGRAM SET UP** if this setup evolves out of it or the **SINGLE BEAM REFLECTION HOLOGRAM SET UP**, as then there will be a Spread Beam at the Official Height headed for **MIRROR** (5).

5. Lay the object down on the tabletop at the end of the table opposite **MIRROR** (5). Then try to light the object at close to grazing incidence by tilting the mirror and translating the **Magnetic Bases**.

6. Arrange the Holographic Plateholder or Filmholder at the foot of the object, tilting it so that the light that misses the object hits the Holographic Plate directly as a reference beam. It is actually recommended to use the outer, weaker secondary ring of the beam to have a lower beam ratio for higher brightness!

7. From the viewpoint of the Holographic Plateholder, check the object lighting. You may have to move the object and Plateholder nearer to **MIRROR** (5) for a steeper angle of illumination, or tilt the object by propping one end up. (Keep the goddess of stability in mind!)

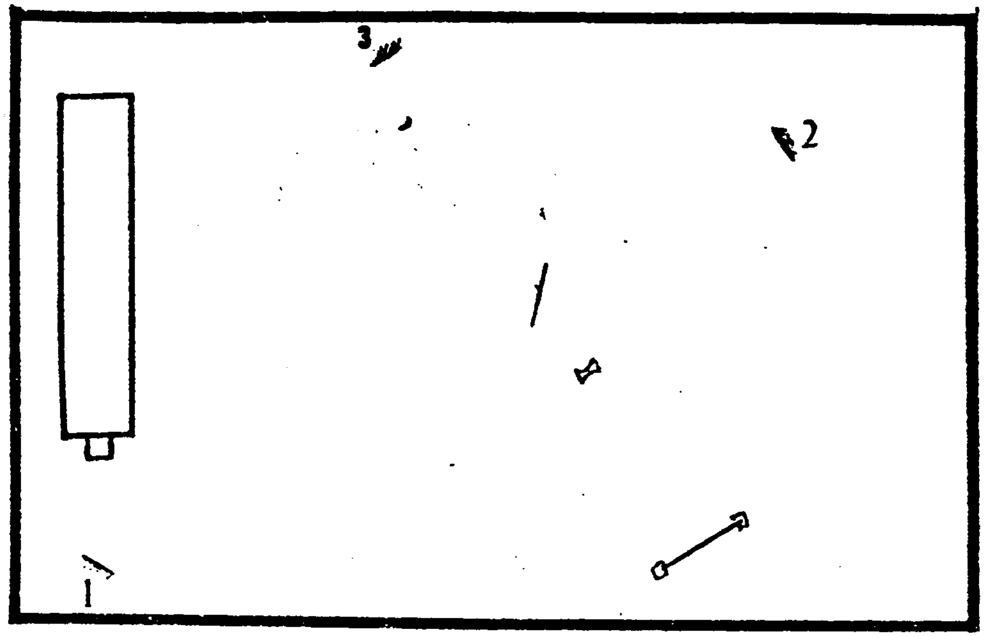
8. Block STRAY LIGHT, especially any that might come from behind the **PLATEHOLDER** that could act as a second REFERENCE BEAM!

9. Insert the **HALF-WAVE PLATE ASSEMBLY** (9) after the **LASER** (1) but before the **SHUTTER** (2) if it isn't already in there. Align the POLARIZATION VECTOR for minimum reflection and maximum penetration per the Handout, **ALIGNING POLARIZATION VECTORS**. Now is the time to check the tune of the **Pinhole** of the **SPATIAL FILTER** (3).

10. Check the INCIDENT FLUX at the **PLATEHOLDER** with the **Probe** of the **S & M MODEL A-3 PHOTOMETER** placed where the center of the **HOLOGRAPHIC PLATE** will be. See the HANDOUT, **S & M MODEL A-3 PHOTOMETER**, for the **EXPOSURE TABLE**. (The secret film number is 450.)

11. Expose, process and evaluate the hologram.

MICHELSON'S INTERFEROMETER



NOTES

This set up is used to measure the relaxation time of the isolation table in its environment. It can be used also to measure the coherence length of a laser.

Interference fringes of low spatial frequency are formed and viewed on a white card. When the table is totally stabilized, the fringes will remain in place. If there is any motion introduced into the system, such as vibration coming from the floor or component drift, the fringes will jiggle around.

SET UP STEPS

1. Direct beam diagonally down the table with the first mirror in the corner by the laser.

2. Position a second mirror kitty-corner down the table and direct the beam back onto itself.

3. Place a beamsplitter in the beam about halfway down the table, so that the two reflections are perpendicular to the first beam's path.

4. A third mirror sends one of the beamsplitter's reflections back onto itself and onto the reflection from the opposite side of the beamsplitter. The distance from the beamsplitter to the second mirror must equal the distance from the beamsplitter to the third mirror.

5. Block out extraneous beams.

6. Spread out the two overlapping beams with a lens onto the white card.

7. Observe the fringes. Tap the table and see how long it takes them to come to rest. This is the table relaxation time.

8. **TO MEASURE COHERENCE LENGTH:** Move the third mirror in closer to the beamsplitter about an inch at a time, observing the fringes. When the end of coherence length is reached, the fringes will grow dim and lose contrast. The coherence length then is the difference in the beam path lengths from the beamsplitter to the second mirror minus the distance from the beamsplitter to the third mirror.

ONE STEP RAINBOW SHADOWGRAM
For 8 by 10 inch or Smaller Holograms on the Beginning Table

SKETCH THE SET UP IN THE BOX ABOVE

PARTS LIST

1. LASER
2. SHUTTER
3. SPATIAL FILTER
4. 8 by 10" MIRROR in GOALPOST CONFIGURATION with TWO MAGNETIC BASES and RIGHT ANGLE CLAMPS
5. 10 by 12" MIRROR in GOALPOST CONFIGURATION with TWO MAGNETIC BASES and RIGHT ANGLE CLAMPS
6. 8 by 10" FILMHOLDER ASSEMBLY in GOALPOST CONFIGURATION with TWO MAGNETIC BASES and RIGHT ANGLE CLAMPS
7. HALF-WAVE PLATE ASSEMBLY
8. POLARIZING BEAMSPLITTING CUBE ON MAG BASE AND TILT PLATFORM ASSEMBLY
9. HALF-WAVE PLATE ASSEMBLY
10. FIRST OBJECT BEAM STEERING MIRROR ASSEMBLY
11. SECOND OBJECT BEAM STEERING MIRROR ASSEMBLY
12. CYLINDRICAL LENS ASSEMBLY
13. THIRD OBJECT BEAM STEERING MIRROR ASSEMBLY
14. DIFFUSELY REFLECTING SLIT ASSEMBLY
15. SLIT BAFFLES
16. DRILL PRESS VICE TO HOLD OBJECT
17. CLEAN GLASS PLATE
18. GNOMON
19. S & M LIGHT METER
20. OFFITIAL RULER
21. MIRROR COVER WITH VELCRO

NOTE

Notice that this set up grows out of the **SINGLE BEAM TRANSMISSION WITH MIRROR MASTER SET UP**, and that parts 1-5 and 7 may already be on the table, with only slight tweaking to get the beam where you need it.

SET UP STEPS

1. Send the Beam from the **LASER** held in its usual position at the end of the **ISOLATION TABLE** to the center of an **8 by 10" MIRROR** held between two **MAGNETIC BASES** in the GOALPOST manner. Check for the **OFFICIAL BEAM HEIGHT** with the **OFFITIAL RULER** at the **MIRROR**.

2. Direct the Beam from **MIRROR (4)** diagonally across the Table to the center of the **10 by 12" MIRROR (5)** held between two more **MAGNETIC BASES** in the usual GOALPOST manner. Check for the **OFFICIAL BEAM HEIGHT** with the **OFFITIAL RULER** at the last **MIRROR** and tilt **MIRROR (4)** if necessary.

3. Direct the Beam from **MIRROR (5)** across the Table more or less parallelto the Table's edge. Check for the **OFFICIAL BEAM HEIGHT** with the **OFFITIAL RULER** at the edge of the Table and tilt **MIRROR (4)** if necessary.

4. Direct beam from **MIRROR (5)** more or less parallel to the table edge to center of **8 by 10" FILM HOLDER (3)** also held between two **Large Magnetic Bases** in the goalpost manner. Check the angle of incidence of the raw undiverged beam with a **PROTRACTOR** and adjust it to 45 degrees from the normal (or whatever you need). Use the **Gold Painted Lines** on the **Tabletop** as positioning guides. The center of the **FILMHOLDER** should be lined up with the right bar of the **SLIT ASSEMBLY**.

5. Insert the **FIRST HALF-WAVE PLATE ASSEMBLY (7)** into beam after **LASER**, before the **SHUTTER (2)**. This **HALF-WAVE PLATE** will be used to control the **BEAM BALANCE RATIO**.

6. Insert **POLARIZING BEAMSPLITTING CUBE ASSEMBLY (8)** into the beampath, oriented so that the reflected beam (the one that makes the 90 degree turn) heads away from the center of the table, toward the edge.

7. Measure the **REFERENCE BEAM PATH Length** with string, from **POLARIZING BEAMSPLITTING CUBE ASSEMBLY (8)** to **LARGE CORNER MIRROR (4)**, to other **LARGE CORNER MIRROR (5)**, to **8 by 10"**

FILM HOLDER (6). Tie one end of the string to the **BEAMSPLITTING CUBE SUPPORT ROD**, and mark the other end of the string with a piece of tape.

8. The **OBJECT BEAM PATH** starts at the **POLARIZING BEAMSPLITTING CUBE ASSEMBLY (8)** and is defined by a trio of **SMALL MIRROR ASSEMBLIES (10), (11) and (13)** (consisting of a **Newport MM-2** or equivalent on **Magnetic Bases**) reflecting light to the **DIFFUSELY REFLECTING SLIT ASSEMBLY (14)** and then to the **8 by 10" FILM HOLDER**. Since **(8)** and **(14)'s** positions are defined, and the **OBJECT BEAM PATH Length** must match the already-measured **REFERENCE BEAM PATH Length**, use the string to find the proper locations of **(10), (11)** and **(13)**. Attach one end of the string to the **POLARIZING BEAMSPLITTING CUBE ASSEMBLY** and follow the **REFERENCE BEAM PATH** with it and attach the other end to the **FILM HOLDER** with tape. Keep the string attached to the **FILM HOLDER** and draw it taut over to the **DIFFUSELY REFLECTING MIRROR ASSEMBLY**. The slack will then be taken up by the trio of **SMALL MIRROR ASSEMBLIES**. Usually the first one, **(10)** will be placed almost immediately after the **POLARIZING BEAMSPLITTING CUBE ASSEMBLY** and direct the undiverged beam along the table edge to locate the second **Mirror, (11)**, next to the **8 BY 10" MIRROR** which then sends the beam to the center of the table. With the **BEAM PATH STRING** wrapped around the first two mirrors, the remaining slack, from **Mirror (11)** to the **SLIT ASSEMBLY** must be taken up by the third **Mirror**. This **Mirror** may be placed anywhere the string allows, but the best location is where the knobs are convenient for tuning the color.

9. Another **HALF-WAVE PLATE ASSEMBLY (9)** needs to be placed in the **OBJECT BEAM PATH** to rectify the **POLARIZATION VECTOR** of the beam reflected out of the **POLARIZING BEAMSPLITTING CUBE** to match that of the transmitted **REFERENCE BEAM**. Verify that the transmitted beam is indeed <u>horizontally polarized</u> with a sheet of **POLARIZING FILTER**. Put the **POLARIZING FILTER** in the **OBJECT BEAM PATH** and rotate this **HALF-WAVE PLATE (9)** in its mount until the two polarizations match. (See the handout, **ALIGNING POLARIZATION VECTORS**, for additional hints.)

10. A **CYLINDRICAL LENS (12)** is placed before the **THIRD SMALL MIRROR ASSEMBLY (13)** to vertically expand the laser beam. Adjust the **SMALL MIRROR ASSEMBLY** so that its <u>horizontal adjustment</u> is racked out to the maximum right position. Adjust the **SMALL MIRROR ASSEMBLY'S Magnetic Base** so that the undiverged laser beam impinges on the **DIFFUSELY REFLECTING SLIT ASSEMBLY** on its right edge, (the one lined up with the center of the **FILMHOLDER**), at the height

of the center of the **FILMHOLDER**, and then the diverged stripe should have its bright center at that spot. The stripe should be completely vertical. Simply turning the horizontal control on the **SMALL MIRROR ASSEMBLY (13)** should sweep the stripe across the **DIFFUSE REFLECTOR**.

11. With the **Light Stripe** at the right edge, tilt the **DIFFUSELY REFLECTING MIRROR ASSEMBLY** so that the maximum amount of light is reflected onto the **FILMHOLDER** from the right **MIRROR STRIP**. Try not to move the right edge of the **REFLECTOR** away from the center of the **FILMHOLDER**.

12. With the **THIRD MIRROR** move the stripe beam to the **SECOND REFLECTOR** on the **SLIT ASSEMBLY**. Loosen the knobs on the top and bottom of the **REFLECTOR** and aim it so that the maximum amount of light is reflected onto a white card in the **FILMHOLDER**.

13. Tune the rest of the **SLIT ASSEMBLY'S REFLECTORS** to direct the maximum amount of light onto the **FILMHOLDER**.

14. **REFERENCE BEAM PATH:** (The beam straight through the **Beamsplitter**) Add the **SPATIAL FILTER (3)** after the **POLARIZING BEAMSPLITTING CUBE ASSEMBLY**. Align it so that the diverged beam is centered on a white card in the **8 by 10" FILM HOLDER**. Verify that the **angle of incidence** of the diverged beam is **45 degrees** with a **gnomon**. For **8 by 10" holograms**, use the **10X MICROSCOPE OBJECTIVE** with the **25 micron PINHOLE**. Put off installing the **PINHOLE** until the end.

15. Balance the **BEAM RATIO** by rotating the first **HALF-WAVE PLATE (7)** for a **REFERENCE TO OBJECT BEAM RATIO** between 2:1 and 4:1. Find the appropriate exposure time from the handout, **S & M's SUPERSENSITIVE PHOTO METER DARKROOM MODEL A-3**.

16. Insert the **SHUTTER ASSEMBLY (2)**. Add the **CARDBOARD SLIT BAFFLE ASSEMBLY (15)** (consisting of two closely spaced tall pieces of cardboard in a grooved holder) to eliminate the scatter on the **DIFFUSE REFLECTOR** from the **CYLINDRICAL LENS**. Add other baffles as necessary, especially one near the **LASER**, which should also be posItioned to prevent the **HOLOGRAPHIC FILM** from seeing the spot of light reflected from the **SHUTTER**. Don't forget to put the **PINHOLE** in the **SPATIAL FILTER**.

17. Expose, process, and evaluate.

CALIBRATION OF THE ONE-STEP RAINBOW SHADOWGRAM SET UP

I. EXPOSURE

Usually the recommended exposure time determined by the **SCIENCE & MECHANICS A-3 PHOTO METER** is good enough for a decently bright hologram. But if you are going to mix images and colors with this set up, it is essential to make a good exposure test series hologram for reference, as the response of the eye to brightness and different colors and that of the holographic film don't necessarily match. Our eyes are most sensitive to green colors, less to the red, and even less to the blue. To compound the problem even further, the typical incandescent source used for reconstruction is strongest in the red, and weakest in the blue. To make a **RAINBOW HOLOGRAM** in which the three primaries are apparently matched in luminosity would require that the blue image be the brightest, the red a little weaker, and the green weakest. By examining the dynamic range available in the hologram through a test strip, good results can come quicker.

A good starting point is to make a series of four exposures on a single sheet, one-fourth of, one-half of, the recommended time and twice the recommended time. You might not be able to see much difference between the first three, so you might like to expose even shorter, (keeping the development time the same!) to find the threshold of exposure for the set up, as subtle colorings are essential for mixing. The extra overexposure is necessary to find the saturation point of the process, as you may want to expose three or even four times, and may need to use up all the available information storage capacity.

II. COLOR CALIBRATION

Control of color in any **RAINBOW HOLOGRAM** (using a single color of laser light) is determined by the position of the slit during the exposure. With the **ONE-STEP RAINBOW SHADOWGRAM SET UP** on the **Experimental Table**, color tuning is made as simple as turning a knob on a **Newport MM-2 Mirror Mount**. The stripe of laser light on the **SLIT ASSEMBLY** determines the location of the dispersed spectra in the final holographic replay. (For the Theory, see the diagrams later on in this handout.)

MAKING A COLOR CALIBRATION HOLOGRAM

1. Make sure that the stripe of laser light is directly in front of the normal to the **FILHOLDER**. This will become the red exposure.

2. Cover all but one-fourth of the **FILMHOLDER** with a **CARDBOARD BAFFLE**. Expose for the Normal Time.

3. Take the **CARDBOARD BAFFLE** off the **FILMHOLDER**, and uncover the next quarter strip of film, covering the rest. Cover

the **FILMHOLDER** with a **VELCROED MIRROR MOUNT COVER**. Open the **SHUTTER**. Move the **SLIT BAFFLE** out of the way. Translate the **STRIPE OF LASER LIGHT** to the next **REFLECTOR** on the **SLIT ASSEMBLY**. Replace **SLIT BAFFLE**. Close **SHUTTER**. Remove **VELCROED MIRROR MOUNT COVER**. Expose again for the Normal Time. (Now it may become apparent why the **CYLINDRICAL LENS** is placed before the **MIRROR MOUNT**.)

4. Repeat **STEP 3** twice, moving the slit to the left each time and uncovering a fresh quarter of film, keeping the other ones covered.

5. Process the film and let it dry for the evaluation.

EVALUATING THE COLOR TEST

The colors in a **RAINBOW HOLOGRAM** are <u>iridescent</u>; they change with position of the hologram with respect to the viewer or to the reference beam. To properly evaluate this tester, flatten the hologram between two pieces of glass, hold the sandwich at arm's length, your eyes located in the center of the vertical dimension, and look along the NORMAL. Walk toward or from the replay light with the hologram until the first quarter is red, and observe what colors the other quarters replay in. If lucky, the last one will be blue or violet. If the last quarter is green while the first is red, then the slit was not moved enough; if the last is vacant (barring recording difficulties) and the third is blue, then the slit was moved too much.

OTHER OBSERVATIONS: Try tilting the hologram; in one direction the red part will become green, the green blue, the blue disappearing, (actually turning ultraviolet). The other way will make the red disappear, (turning infrared), with the green becoming red, and the blue turning green.

Have someone else hold the hologram, and position yourself so that the first quadrant is red again. As you squat down, the red will become green, the green blue, and the blue UV. Standing on tippy-toes will make the red IR, the green red, and the blue green. When creating **RAINBOW HOLOGRAM ARTWORK**, you should keep in mind these effects, and program your colors for a certain viewing height.

OBJECT PLACEMENT

Usually the object is placed far enough back from the **FILMHOLDER** so as to not intrude into the reference beam, which would create a dead space on the surface of the hologram. But if the object is too far back, its edges start to blur out and may become too vague and greatly enlarged.

Sometimes in the case of generating abstract patterns it may be more interesting to let the object cast its shadow into the reference beam. A moire pattern could be generated by the object generating a beat frequency with the light transmitted through it from the slit and the reference beam.

If <u>text</u> is to be used, its orientation is important so that it will become readable in the final replay. Since the real, pseudoscopic, or "flipped" image is used, the letters need to be "pre-flipped" in the recording stage, <u>but not written backwards</u>! As an example, consider the simple message, **SAIC HOLO**, to be used in a top lit hologram. It should read thus from the viewpoint of the **HOLOGAPHIC FILMHOLDER**:

It is best to rehearse the placement of the object, by holding it in front of the plateholder as it would float in the final reconstruction, and then rotate it along the flipping axis of the **FILMHOLDER** back into the recording zone. Sometimes if you make a mistake, you can display the hologram with a bottom reference beam. However, this type of hologram will not work with side references, at least not for three-dimensional effects. With a side reference an object would have a rainbow wash across it from side to side.

FUN WITH OBJECTS IN THE ONE-STEP RAINBOW SHADOWGRAM

THREE-DIMENSIONAL OBJECTS: The most obvious thing to do is to make black three-dimensional silhouettes of things, surrounded by a colored ground. The objects used could be less than stable, since their surface is not holographed, only their shadows cast by the backlighting strip. This means that parts of the body, like finger language, or facial profiles can be made without pulsed lasers or stereographic techniques.

Transparent or translucent objects can also be used to great advantage. One of the best things made in this lab were spider webs of hot glue on glass sheets.

2-D GRAPHICS (Holographic Silkscreening): This is the basis of the holographic sticker industry. Color separated graphics are typically used, but continuous tone photographic imagery could also be utilized. The underlying design principles are similar to the thinking required for <u>silkscreening</u>. If a certain color is desired in an area, clear areas will let light through, like ink, and then to color in the other areas, a negative of the above is used when the slit is changed.

The transparencies could be sandwiched with the film itself, on the cover glass of the **FILMHOLDER**, or separated completely, leaving the imagery floating in space. Watch out so that the object isn't located in the **Reference Beam**.

HOLOGRAPHIC NEON: Cutting thin outlines out of cardboard will result in colored lines floating in a black space, like a neon sign. Hold a couple of razor blades together side by side, maybe with a piece of cardboard between them to vary their width, and the design will be cut as a pair of parallel lines. Carefully poke out the cardboard inside, and use in the setup.

Another source of materials to use are recycled dud holographic film or plates. Develop the non-hologram with the room lights on until it gets as dark as it possibly can. Wash and Photo-Flo and dry. Then scribe away the black emulsion with a pointy object for your design.

MOIRE PATTERNS: Using chunky grids, with visible moire patterns, like the white plastic racks in the **AGFA PLATE BOXES**, will give cool patterns that can be collaged into new designs. But Moire can also be generated by two objects that were were not exposed simultaneously, by first holographing one grid, then moving the slit and grid for a second exposure.

CAUTION: Serious consideration must be given to the choice of transparency material used in the above configurations. Some plastics are birefringent; they twist polarizations. Light may pass through them, but its exiting polarization may become oriented 90 degrees to the way that it came in, when it was aligned in the same plane as the reference beam. It may not interfere with the **Reference Beam**. Black bars may appear on the artwork. Polyester, especially Kodak **Estar**, used in **Kodaliths**, is the worst. Acetate, which is what **Holographic Film** is made of, does not have this problem, and neither does glass. Since our eyes do not detect alignment of polarization vectors, the material must be interrogated.

TEST FOR BIREFRINGENCE, WHITE LIGHT: Place a sample of the material between a pair of crossed polarizers. (No light passes through the two crossed "picket fences" for polarization vectors.) If colors are seen through the sandwich, then the material is birefringent.

TEST FOR BIREFRINGENCE, LASER LIGHT: Put the material in the **ONE-STEP RAINBOW SHADOWGRAM SET UP** and look at the light of the slit through it with a polarizing filter. If black bands appear on the artwork, it is unacceptable. Watch the black bands change positions as you rotate the polarizing filter.

As contradictory as it sounds, a birefringent piece of transparency can be used if it is in contact with the **HOLOGRAPHIC FILM**. This is because both the **Reference** and **Object** beams will have their polarizations twisted the same amount, and therefore will still be able to interfere.

However there is a different danger when film is in contact with the **Holographic Film**. Some overhead transparency films have a toothy texture to their surface to accept the toner and will destroy the spatial coherence of the **reference beam**. This results in **ONE-STEP RAINBOW SHADOWGRAM HOLOGRAMS** that reconstruct with weak pastelly results.

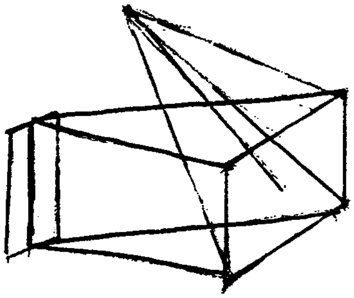
THE TEST FOR FUZZINESS: Look through the overhead material (and even some photographic film bases exhibit this defect) at a point source, like a holographic replay light, an LED, or the pinhole of a **Spatial Filter**. If there is a hazy cloud around the source of light, then the material is unacceptable for placing in contact with the **Holographic Film**. It is OK to use in the **Object Beam Path** only.

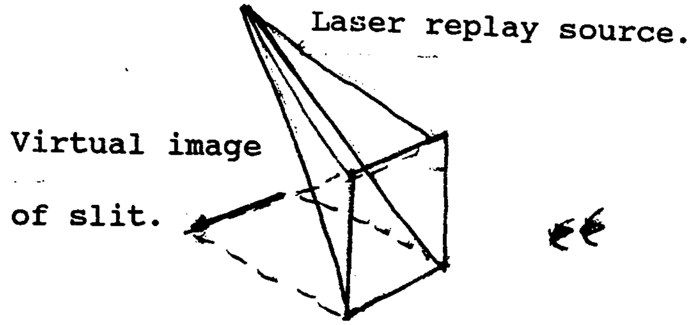
PERCEPTION OF THE ONE STEP RAINBOW SHADOWGRAM

This is perhaps one of the most difficult holograms to perceive; sometimes it takes moments of study to establish spatial relationships in the reconstruction. The reason is that the observer is looking at the holographic plate in the same relationship as a pair of eyes positioned along the diffusing slit views the holographic plateholder during the recording. Because the latter pair of eyes are linked to the slit, allowing lateral movement the perception of the vertical aspects of the object cannot be made by vertical repositioning of the observer but rather by tilting the eyes up and down, which takes longer to process. It is like looking at the entirety of a construction site through a gap in horizontal fence boards. Since the non-image plane objects (those generated by masks not placed directly on the filmholder but separated) are silhouettes (pure black shadows) or are filled in with different colored shapes, spatial relationships cannot be deduced until their edges are established, using temporal paralactic movements by seeing which things occlude what, but complicating this is the fact that some objects are transparent.

Another problem is that the hologram's image is typically pseudoscopic, and more than likely severely aberrated because of mismatching of the recording and replay reference beams. Motion of the viewer's head will cause the objects to move unnaturally fast and contrary to the expected result. Of course, this is the fun of this type of hologram.

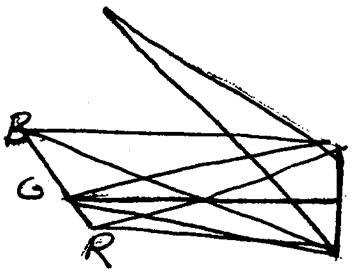
Because of aberrations, the size of the holographic image is much larger than the object, and the danger is that the objects may be so much enlarged that they do not fit in the frame of the plate. When an object is occluded by the edge of the hologram, the perception of it floating in front of the film plane immediately changes to that of an object at the film's surface or behind it. (In actual, non-holographic space the only reason why an object would disappear at the edge of a frame is because it is behind the window.) Keep the object placed pretty much in the center of the frame. This is also the reason that fields of pure color, with no objects in the way, seem to lie on the surface of the plate and not off the surface.

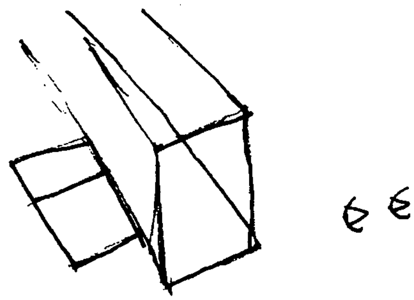




Although the reference beam enters the holographic plate from the side and the stripe of laser light on the ground glass is oriented vertically,

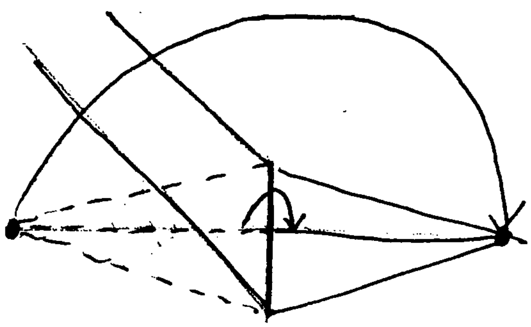
the hologram is designed to be reconstructed with an overhead reference beam with the slit horizontal.

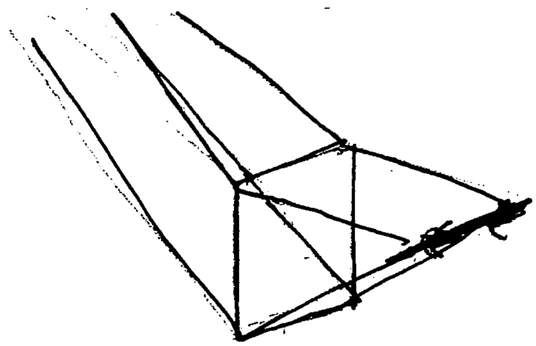




When the hologram is illuminated with white light, each color reconstructs its own image of the slit at a different position.

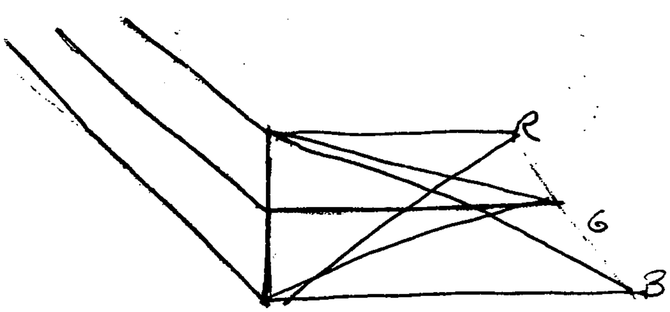
The viewer sees a rainbow virtual image of the slit.

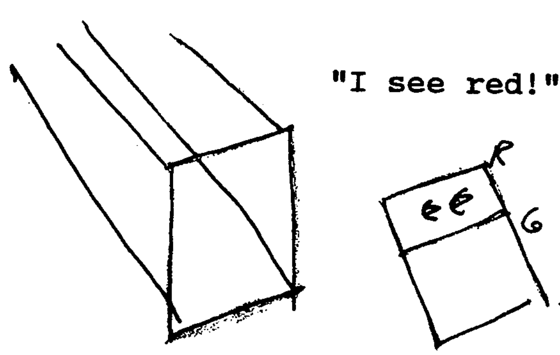




If the laser lit hologram is "flipped" a real image of the slit is focussed in space.

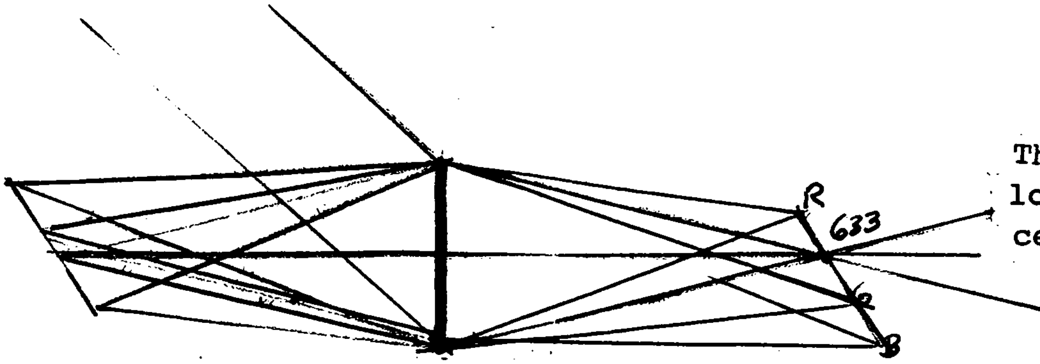
When the viewer's eyes are positioned at the slit the whole hologram glows red.





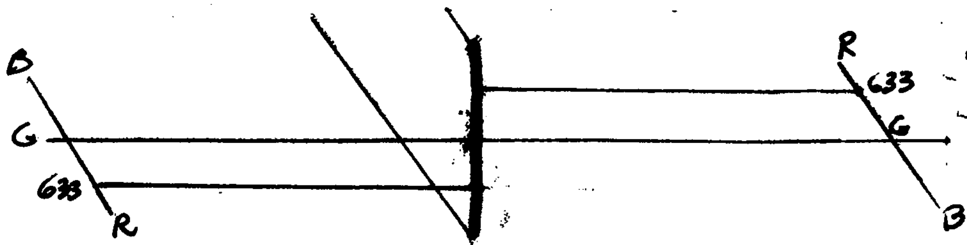
White light replay of the flipped hologram produces a separate real image of the slit for every wavelength.

The image changes color with the vertical position of the viewer.

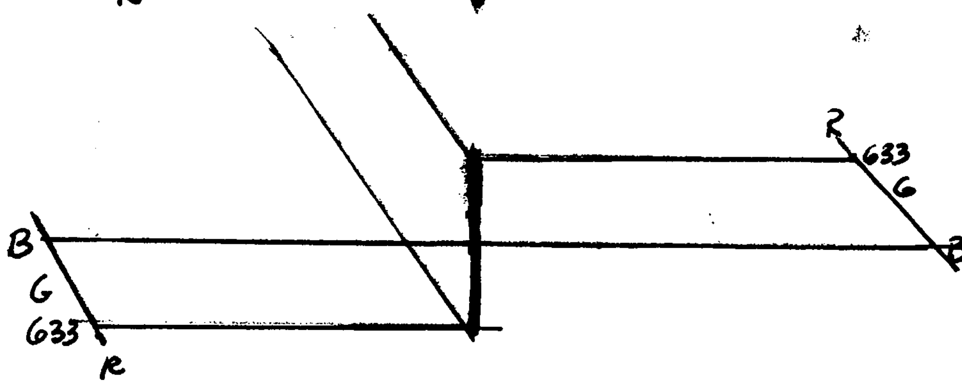


The viewer sees red looking at the center of the plate.

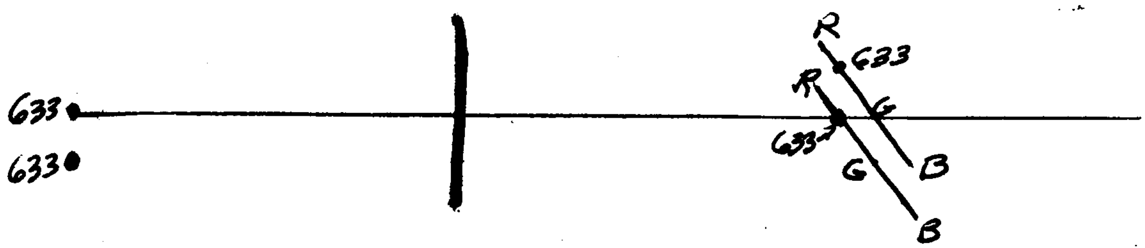
The position of the slit during the recording determines where the 633 nm component of white light will appear in replay. The rest of the rainbow spreads out proportional to wavelength.



The viewer sees green along the center of the plate.



The viewer sees blue along the center of the plate.



A pair of slits can blend colors according to the additive primary rules.

Where the colors fall can be calculated, but making a color pallette is more fun.

PARAMETERS WE USED:

_______SLIT DISTANCE

_______REFERENCE ANGLE

DISTANCE FROM NORMAL CENTERLINE

_______RED

_______GREEN

_______BLUE

Designing for Embossing

Dorothy James

This is the second article written for people with a graphic arts background who want to work with embossed holography. In the Winter 1984 article, general design considerations were discussed. Here I will go into more detail about the design process and expense for embossing.

Your design process should start with some homework: get a small selection of embossed holograms and study them carefully. With really dimensional images, how deep does the volume of the image appear compared with the frontal dimensions of the hologram? If part of the image projects, how far does it appear to project out of the image plane? Does part of the image appear pseudoscopic (inside out and backwards)? Are you satisfied with the clarity of the image? What is the content of the image, and what market would it appeal to? Looking at dimensional images which have been embossed, you will find that most are images of objects which have a "generic" quality to them – seashells, rocks, bones, dice, etc. Occasionally a hologram with narrative content will be embossed, such as Dan Schweitzer's *Stargate*. Too little work has been done with 3D "sets" for there to be much reference available in this aspect of holographic design. Generally it seems that someone has said: "Here's a neat object to make into a hologram. It's small and dense and probably will appeal to a lot of people." Not much imaginative use of space inside the image volume is in evidence in most of the 3D embossed holograms. This is a good area to show your stuff as a creative person: how can you use the volume effectively? What can you offer to the viewer besides just an object? Can you evoke emotion or tell a story?

More creative work is being done in the 2D/3D design area, although the general idea seems to be to produce cute, innocuous images. The "generic" idea in these graphic holograms tends towards hearts, stars, rainbows, mythical beasties, city scenes and the like – common symbols with proven mass market appeal. Many of the 2D/3D's have a "star field" background, which does not always seem congruous with the graphic content of the image.

Looking at the 2D/3D stickers analytically, count the numbers of separate layers which constitute the total graphic image. Manipulate the hologram under a good point light source and count the different colors visible at any given angle of view. Each separate color area in a layer represents an exposure at a different diffraction angle when the master hologram was made.

The following illustrations may help you to analyze the 2D/3D images you have seen. Fig. 1 shows the black and white graphic elements as they may appear in the design for the hologram.

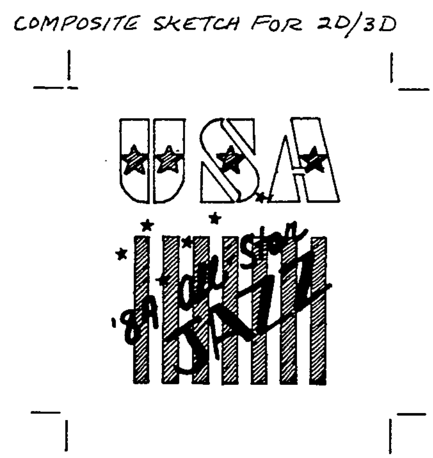


fig. 1

In Fig. 2 you can see how these elements may be separated for color and spatial arrangements. Note the use of crop marks and center marks for registration. This is critical in 2D/3D's and diffraction grating artwork, where a slight misregistration may produce a line of light or an opaque gap where edges adjoin.

Dimensional images and graphic elements can be combined in a design. Be sure that you have indicated clearly how they are to be placed in the image volume relative to one another; provide detailed sketches for the embosser to go by. For registration of a 3D object to your 2D graphics, some leeway should be planned into the design. Try not to make the position of the object and graphics critical to within 1/8 in., for example, in a 2 in. x 2 in. image. If you have 2D graphics at the surface of the image, plan on anything directly behind that to be obscured by the 2D – you cannot see through the diffraction grating to look at something behind it.

Mount your 3D object so that it is as stable as possible, supported from behind and in a manner which will provide that stable support whether your object is upright or turned 90° on its side. This will allow the embosser maximum flexibility in lighting for proper reconstruction. If you are not sure of how to mount the object, wrap it securely and send it with detailed sketches (fig. 3, 4) for the embosser to use as guidelines in placement. (An alternative: mount the object on nondistorting optical glass, with registration marks on the glass.) Make sure you indicate clearly what part(s), if any, of the object will project in the finished piece. Ron Erickson recommends that depth for embossed holograms be under ½ in. for small images like 3in. x 3in., and only a few inches for larger images such as 8in. x 10in. Projection should be about half the depth behind the image plane (¼ in. for 3 in. x 3 in., 1 in. for 8 in. x 10 in).

No one said it would be easy! Now that you have an idea of how to produce your design in concrete terms, what about cost?

Start with the embossing master. It will cost you from $1000 up, with $3500 being a good round figure to start your budget for an image of any complexity. The first 1000 images may be included in the cost, if the image is 3 in. x 3 in. or smaller. The embossing masters are very ticklish to make (which is why there are so few companies in embossing to date). The more angles of diffraction, layers of depth, or numbers of elements to be combined in the image, the more the embossing master will cost. The square inches of the design area are also a cost factor – the bigger the hologram, the higher the cost.

Embossers like to break down the expense into pennies per square inch to make it more palatable. They combine the cost of the master with the size of the hologram and the number to be embossed, then divide by the number of square inches in the total production. The process really is priced on the basis of the total square footage of material being embossed, including the mastering cost. The cost of the master "disappears" in very large quantities of images. Typically, you will be looking at a cost of 5 cents to 1 cent per square inch. For a 3 in. x 3 in., you could pay 45 cents to 9 cents per unit, depending on the total quantity ordered for a single production run. Once the master has been made, additional production runs will be significantly cheaper – probably about half as expensive or less, again depending on the size of the order.

If you have a wonderful design, but cannot afford to make the first run yourself, consider making a devil's bargain. See if the embosser is willing to manufacture the image in return for a lion's share of the profits on the first go. Or sell the design outright – but you forfeit any rights to the image (this is called "work for hire" and is not recommended by the Artist's Guild. Your design could make millions for the embosser, and you would not get a cent – although to be fair, if it's a dog in the marketplace, the embosser loses too).

Be aware that the copyright office does not yet recognize holographic designs as being in their realm of protection. I suggest that you attempt to protect your rights by placing the copyright symbol, your name, and the date on all artwork you supply to the embosser, and plan to have it included on the edge of your embossed image for which you wish to retain rights. I am confident that the copyright people will recognize the obvious soon, and you are better off protected to start with than wishing that you were when it is too late. The copyright information must be visible on the front of the image itself, not on the back or on the packaging material.

An idea for getting your first design done more cheaply is to work cooperatively with other artists. Create a "ganged" image, with common design parameters, and split the expense. For example, three artists each design a 2 in. x 2 in. image with the same numbers of diffraction angles and layers of depth. Each design is made as a part of a total mechanical for the embossing master. They will be separated by cutting at the end of the embossing process.

If this works the way I think it does, you should each wind up paying 1/3 of the total cost for a 3 in. x 6 in. master and the initial production run, rather than each paying the full shot for a 2 in. x 2 in. master and run. Consult with the embosser for details on costs.

It may have occurred to you by now that the ideal way to get your first embossed holograms is to get someone else to pay for it – namely, a client or two among your graphic arts contacts. If you are clever, you may be able to design an image for someone else that you will be proud to have in your portfolio. Or you may know just the retail outlet to talk to about handling a line of embossed holograms in your area – in which case you might want the embosser to let you act as his agent.

Holograms will be popping up in your local stores soon – especially 2D/3D stickers for kids and greeting cards for the jaded consumer. You may not be able to compete with these mass distribution pieces on price. Currently a 3 in. x 3 in. 3D sticker may go for $2.50, a 1 in. diffraction grating for 15 cents, a greeting card for $3.00. But that may change abruptly when the big mass market items hit the stores, especially if they can be retailed for about 50 cents to appeal to the juvenile consumer. Make sure you are not left holding the bag – your design must be unique enough to be distinct in the marketplace, and worth its price tag.

For further information, or abstract of thesis "Holographic Illustration", write to: *The HOLO/GRAPHIC Design Studio, 37 Werner Park, Rochester NY 14620, attn. Dorothy James.* Please enclose SASE.

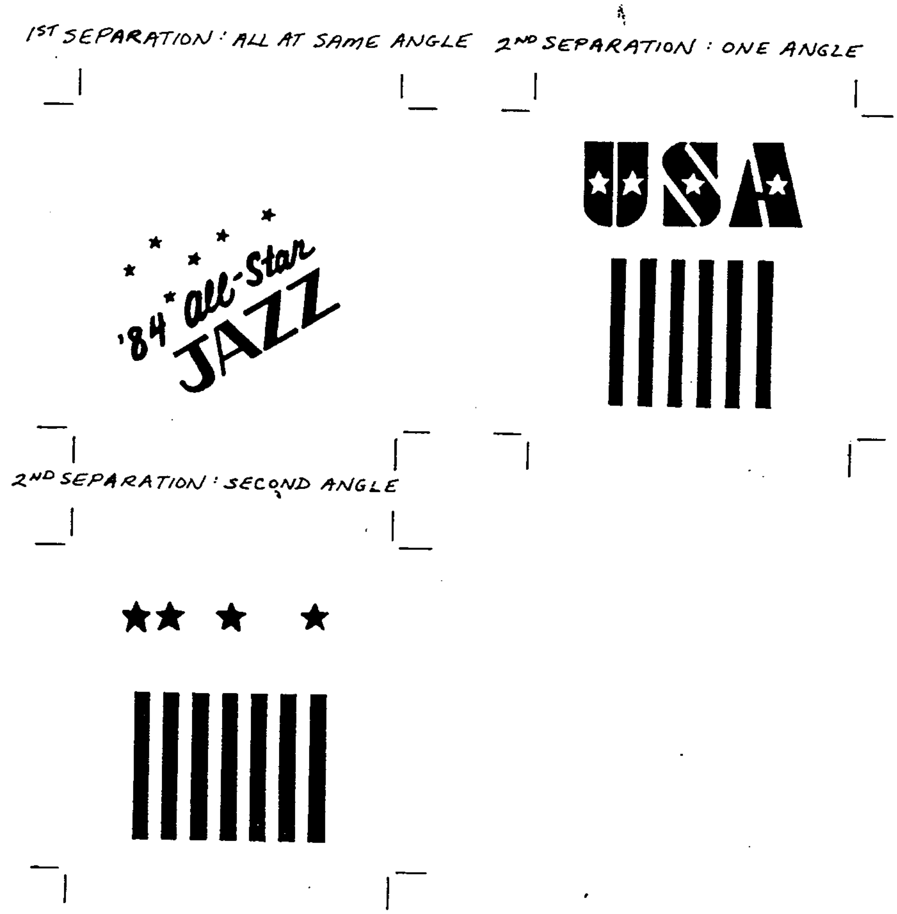


fig. 2

STAGE	SYMPTOMS	CAUSE	CORRECTION
Set-up	Dark bands appear on object or reference beam	The two reflected beams from the beamsplitter are interfering with each other.	Block one of the reflected beams close to the beamsplitter. It may be necessary to use a thicker beamsplitter to separate the beams more.
	Very grainy pattern around laser beam	Dirt on the exit window of the laser.	Clean the laser exit window gently with a cotton swab covered with lens tissue with a small amount of spectrum grade acetone. Wipe dry.
	Bull's eye like patterns of dark bands on object or in reference beam.	Optical components are dirty.	Clean lenses with lens tissue and lens cleaner. It is never advisable to clean mirrors in manner other than simply blowing dust off them with canned air or nitrogen.
Film Processing	Exposed film does not darken in developer or takes an extremely long time to reach the desired density.	1. Insufficient exposure 2. Laser or component shifted from initial alignment. 3. One or both beams are still blocked. 4. Developer contaminated or formula mixed incorrectly. 5. Developer too cold.	1. Increase exposure time. 2. Reposition components and recheck that they have stabilized. 3. Unblock both beams. 4. Replace developer. 5. Stabilize developer at higher temperature.
	Uneven development	1. Reference beam not centered on the film area. 2. Poor agitation.	1. Check reference beam ~~and re-position if needed.~~ 2. If developing time is found to be short, agitate very quickly in all directions for the first five seconds and then use smooth, continuous agitation for the remaining developing time.
	Film becomes dark excessively fast.	1. Over-exposure. 2. Fogged film. 3. Safelight too bright 4. Developer temperature too warm. 5. Developer contaminated or mixed incorrectly.	1. Reduce exposure time. 2. Test film for fogging by developing an unexposed piece. 3. Test film for fogging due to bright safelight by developing unexposed film with and without safelight. 4. Reduce temperature. 5. Replace developer.
	Hologram develops very dark in one area, but poorly in others.	1. Reference beam not centered on film plane. 2. Object is reflecting strongly to one area of the film plane.	1. Check reference beam and re-position. 2. Block reference beam to check for this; paint object for a more even reflection if necessary.
	Random, very dark areas	Highlights from object reflecting directly to film.	Tilt object or spray with matted finish.

STAGE	SYMPTOMS	CAUSE	CORRECTION
Viewing	No image apparent	1. Transmission hologram being viewed at wrong angle to beam. 2. Reflection hologram not dry.	1. Make sure you are recreating the original reference beam. Rotate, flip or tilt film while viewing. 2. Dry film thoroughly.
	Blank viewing areas or bands of visibility	Film movement	Adjust film holder to insure a snug fit. Changes that reduce exposure time may help.
	Dark bands on object	Object movement	Secure object (glue to a platform), stiffen moving parts (spray paint may help). Changes which reduce exposure time may help.
	Section of object is dim	1. Part of object is loose. 2. Object beam does not evenly illuminate object.	1. Secure loose part. 2. Adjust centering or object beam spread. Moving lenses or adding lenses may be required.
	Entire object dim.	1. Entire object moved. 2. Reference beam to object beam ratio too high.	1. Secure object or shorten exposure. 2. Adjust ratio for greater object beam.
	Object appears dim and incorrectly oriented to film plane	Film is being viewed at incorrect angle.	Find correct orientation by flipping, rotating or tilting film while viewing.
	Image appears brighter from one section of the film.	Reference beam was not centered on the film plane; the object usually appears brighter where the reference beam was brighter.	Readjust the reference beam so that it is centered.
	Very grainy appearance, grainy area around image, or ghost image.	1. Beam ratio too low 2. Developed to too high of density.	1. Adjust beam ratio for less object beam. 2. Develop for less time or reduce exposure.
	Image fuzzy or appears to be out of focus	1. Object was too far from the film plane. 2. Poor viewing light.	1. Reposition object closer to film. 2. Use a light without a frosted bulb (reflection hologram) or one with an internal reflector.
	Milky appearance across film surface.	1. Developed to too high density. 2. Incompatible developer and bleach. 3. Chemicals contaminated or used out of proper sequence.	1. Reduce exposure or development time. 2. Use suggested sets or try different combination. 3. Retry processing per instructions; if problem persists, discard chemicals.
	Different colored blotches across film.	Water spots refracting different color to viewing positions.	Rewash and dry.
	Speckled pattern on film surface.	Scattered laser light has hit the film.	Block reference and object beams from close to film. Then, check for scattered light and trace back to origin. Block scattered light from origin.
	Secondary image from certain viewing positions or from slightly different reference angle.	Stray light from around components has struck film and caused a secondary reference beam.	Locate and block any stray laser light.

SETTING UP THE LIGHTS AND BOLEX FOR SHOOTING MOVIE FILM FOR INTEGRATION INTO HOLOGRAPHIC STEREOGRAMS

SKETCH THE SET UP IN THE BOX ABOVE

PARTS LIST

1. SUBJECT ON TURNTABLE
2. BOLEX H16 CAMERA ON TRIPOD
3& LARGE LIGHT BOXES ON BOGEN
4. LIGHT STANDS
5. SMALL LIGHT ON VERY TALL STAND TO ILLUMINATE TOP OF SUBJECT'S HEAD
6. EXTENSION CORDS AND PLUG BOXES
7. BACKGROUND
8. BACKGROUND LIGHT (OPTIONAL)
9. SEKONIC LIGHT METER
10. FRESH AND EMPTY 16mm FILM BOXES
11. PLUMB BOB
12. TAPE MEASURE

SET UP STEPS

1. GET THE **HOLOGRAPHY DEPARTMENT'S BOLEX H-16 CAMERA** FROM THE BACK LAB, STORED ON THE BIG SHELF AT THE FAR LEFT END, IN A **BEAT UP WHITE SUITCASE** (for camouflage purposes).* READ THE INSTRUCTION BOOKLET AND/OR THE **Handout, "BOLEX 16mm CAMERA"** BEFORE PROCEEDING.

---

*. ALTERNATIVELY, YOU COULD GET AUTHORIZED ON THE BOLEX AT THE MEDIA CENTER, ZOOM AND/OR FIXED FOCAL LENGTH LENSES, ALTHOUGH WE USUALLY USE THE 25 mm FOCAL LENGTH LENS, THE SEKONIC LIGHT METER, THE HEAVY DUTY TRIPOD, LOWELL LIGHT KIT, AND THE 16 mm KODAK PAGEANT PROJECTOR, BECAUSE IT'S GENTLER ON THE FILM!

2. GET A 100 FOOT ROLL OF **16MM KODAK PLUS-X REVERSAL FILM**, (AVAILABLE AT THE **FILM CAGE***) OR EQUIVALENT. (50 ASA/ISO, BETTER QUALITY BECAUSE IT'S LESS GRAINY AND HIGHER MAXIMUM DENSITY.) **KODAK TRI-X REVERSAL** (OR EQUIVALENT) IS OK, ESPECIALLY IN LOW LIGHT LEVEL CONDITIONS OR FOR MORE DEPTH OF FIELD.

3. SET UP **LIGHTS** AROUND THE **TURNTABLE**. SKETCH THE SET UP IN THE BOX AT THE TOP OF THIS HANDOUT. IT HELPS TO USE A **BLACK SHEET** BEHIND THE SUBJECT OR A **WELL LIT WHITE ONE** TO AVOID THE PROBLEM OF DISTRACTING SHADOWS.

4. SET CAMERA WITH THE **25mm LENS** AT ITS CLOSEST DISTANCE, ABOUT 1.25 METERS, FROM THE CENTER OF THE TURNTABLE. ALTERNATIVELY A **ZOOM LENS** COULD BE USED, SET TO **25mm**. GET SUBJECT TO SIT RIGHT ON THE CENTER IF POSSIBLE. A **PLUMB BOB** HUNG FROM THE CEILING CAN HELP DEFINE BOTH THE SUBJECT'S AND TURNTABLES CENTERS OF ROTATION. FINE TUNE THE FOCUS OF THE CAMERA.

5. SET **CAMERA's RUNNING SPEED KNOB** TO 12 **FRAMES PER SECOND**. USE **SEKONIC STUDIO DELUXE METER** IN INCIDENT LIGHT MODE AND FIND THE RIGHT F/STOP**. SHOOT SOME FOOTAGE AT THE RECOMMENDED F/STOP, PLUS ONE AND TWO STOPS SMALLER F/#'s, WHICH LET MORE LIGHT INTO THE CAMERA***, AS WE HAVE FOUND THAT THE PRINTER LIKES A SLIGHTLY LIGHTER THAN NORMAL DENSITY POSITIVE. (YOU MAY BE INTERESTED TO TRY SHOOTING AT OTHER FRAMING RATES, HOWEVER THE SIZE OF THE SLIT AND NUMBER OF STEPS ON **EVET** MAY NEED TO BE CHANGED.)

6. IF YOU DON'T FINISH THE ROLL, IT CAN BE REWOUND AND REUSED LATER IF YOU REMEMBER TO MARK DOWN HOW MUCH FOOTAGE HAD BEEN USED. (REMEMBER TO RUN OFF THE FIRST BIT OF THE ROLL WITH THE LENS CAP ON!) OR YOU CAN CUT THE ROLL WHERE YOU LEFT OFF (IN THE DARK!) AND TURN IN A PARTIAL ROLL. (YOU MUST CALCULATE HOW MUCH FOOTAGE YOU ARE TURNING IN AND PRORATE THE PAYMENT.) WHEN YOU ARE FINISHED WITH THE ROLL, YOU CAN DROP OFF THE FILM AT THE FILM CAGE, BUT REMEMBER YOU MUST ENCLOSE A CHECK WITH YOUR ORDER! YOU

---

*. Be prepared to go through the **SAIC Resale Account Rigamarole**.

. See the **Handout, SEKONIC STUDIO DELUXE II MODEL L-398M OPERATING INSTRUCTIONS.

***. Don't forget that in the f/numbering system, a smaller numbered opening allows more light into the camera.

CAN TAKE THE FILM TO ASTRO* YOURSELF FOR POSSIBLY QUICKER TURNAROUND. FOR THE TRULY DARKROOM-ADVENTUROUS, THE **HOLOGRAPHY DEPARTMENT** DOES OWN A SET OF **TANKS AND REELS** FOR DEVELOPING 16mm 100' ROLLS OF FILM[1].

---

*. 61 West Erie Street, Chicago, IL 60610, 312-280-5500. Just down the strret from the very cool **International Cinema Museum**, 319 West Erie Street, Chicago, IL 60610, 312-587-7035

REFERENCES

1. See the Kodak Publication.

HOLOGRAPHIC STEREOGRAM PRINTER

This unit is the most advanced technology available in the **Holography Department** at **SAIC**, and the quality of the final holograms rival that of commercial businesses. The only other accredited college in the country that has something similar is MIT. Although a fairly involved and time consuming process, the student can make holograms of outdoor scenes, living objects that would not have the slightest chance of coming out in continuous wave laser recorded holograms, and even of objects that never even existed! **Intermediate/Advanced Holography** students have lab time access to the **SAIC holographic Stereogram Printer**, even overnight.

HISTORY

The optical layout of this device was assembled by graduate student Dean Randazzo, while Eduardo Kac took notes of the operation. Over the Summer of 1989, on a budget of less than $100 for a flea market 16 mm projector and an electric typewriter chassis to move the slit (the laser and hardware were already in the lab), they made a system rivalling those at commercial holographic labs in quality to produce their own imagery taken from life or computer generated. The prototype electronic controller was built by the SAIC's very capable electronic technician, Ed Bennett, from bits and pieces of recyclable material that had accumulated at the School over the years. It resembled the guts of a pinball machine, having plenty of 'clunk and thunk' with its washing machine-like circuitry; but, just like the washers at the laundromat, this thing worked day-in/day-out for over a year without malfunction. An improved, slicker control box with thumbwheel controllers for the TTL logic and LED readouts was built by another graduate student, Matt Deschner, under Mr. Bennett's tutelage.

The original format size was an 8 by 10 inch master with slits for 48 motion picture frames to be transferred to an 8 by 10 inch copy film. Expansion to 30 by 40 centimeter-sized masters and copy was accomplished in the Spring of 1991 at the Columbus Drive Building with the addition of a new **Slit Translating Plateholder** based on a dot-matrix computer printer chassis.

Rainbow and achromatic white light transmission copies and reflection copies have been made from the stereogram masters, with the equipment for making them spread out over two unconnected Newport tables that were not floating! & !! The laser and beamsplitter were on one table; the master and copy plate holders were on the other one. Long beam throws were used in this set-up to "flatten out" the wavefronts. Microscope objectives of 5X power with 50-micron pinholes are used to provide a slowly expanding beam that is thrifty with the light.

The success rate of this set-up was surprisingly nearly 100%, barring film movement problems.

Since the move to the "Charlie Club" building, (112 South Michigan), the mastering is now done on the **Printer Table**, with the transferring done on the other Newport table, totally dedicated to that task.

A variety of improvements have been implemented to the system, mainly through the efforts of Jesus Lopez. These include the installation of a more modern projection optic on the old film projector, the expansion of the reference beam path by a half a table length, with attendant cleaning up of the mirrors and added stability, plus convenience features like reversing slit directions, opening of the shutter electrically during alignment, and remote controls for the **Beam Balance Ratio** and **Projection Objective Focussing**. Virtually all components are screwed into the tabletop, for added stability and tamper resistance.

BASIC PRINCIPLES

A variety of 16 mm motion picture film views of an object are recorded. For the rotation rate dictated by the SAIC Holography Department Turntable, we shoot the subject located at its center of rotation with the **Holography Department's 16 mm Bolex Camera** (also available from the Media Center) at 12 frames per second, with the 25 mm focal length normal lens on the camera, which is positioned 1.25 meters away from the subject.

For filming off computer screens, a rotation rate of about 1/2 degrees per frame of motion picture footage is about right. In either case, bracket the exposure of the movie film, usually one stop on the overexposed side, because we are rear projecting the image and need it to be less dense than the image that would normally be enjoyed on a front-lit screen.

By making a hologram of each of those motion picture frames that is about the width of the entrance pupil of you eye, and having them spatially multiplexed so that each eye sees two different viewpoints of the object, (although the two views are recorded at slightly different moments in time of a rotating object rather than from two different camera viewpoints), stereoscopic fusion of the two flat images into three-dimensional space occurs. Since there are many combinations of stereo pairs across the horizon of the hologram, some time related actions may also be included, making this a truly four-dimensional media.

DESIGN CONCEPTS

The **SAIC HOLOGRAPHIC STEREOGRAM PRINTER'S** primary function is to produce the first step, the **LASER TRANSMISSION MASTER HOLOGRAM** of the **TWO-STEP IMAGE PLANE HOLOGRAM** process, which is then transferred to a **WHITE LIGHT RECONSTRUCTING HOLOGRAM** on the **Transfer Table**. The relationship between the two tables is similar to that of a photographic camera and enlarger, and they are tuned in to each other so that the maximum amount of production may be done with the minimum amount of resetting up.

The production of a **Laser Transmission Holographic Stereogram Master** requires6 87 frames of **16 mm Movie Film** with different views of the object. (See the handout, **HOLOGRAPHIC STEREOGRAM MASTERS**.) The **Printer** projects a single frame of the **Film** onto a **Groundglass Screen** with **Laser Light**. A slice of **Holographic Film** looks at this screen while simultaneously being exposed to a **Reference Beam**, recording a 30 centimeter tall by 6 centimeter wide hologram of that frame through a **Translating Slit**. The process of expose by opening a shutter for the appropriate amount of time, closing the shutter and then advancing the movie film and translating the slit one frame at time, and then waiting to make the next exposure until all 87 frames have been shot is serviced by a variety of subsystems whose design and function are detailed below.

One of the **Printer's** outstanding features is its versatility to produce other types of holograms, thanks to an extremely stable **Reference Beam Path** that is designed to cover a 30 by 40 centimeter film at 45 degrees incidence on its short side. With **Beam Stealers** and **Accessory Packages** the **Object Beam Path** can be converted to produce **ONE STEP RAINBOW SHADOWGRAMS** and **LASER TRANSMISSION MASTERS OF DIFFUSELY REFLECTING OBJECTS** in conjunction with the locked into position **Reference Beam Path**. This same **Reference Beam Angle** is the one used on the **Transfer Table**, also.

The length of the **Reference Beam Path** is made as long as possible to flatten out the wavefront to approximate a collimated beam, useful for lowering aberrations in the **Real Image To Be Transferred**. The expanding beam traverses the **Printer Table** 2 1/2 times, the half table length being picked up from starting the **Reference Beam** expanding from its **Spatial Filter** immediately after the **Beamsplitter**. This pathlength is approximately 5 meters long, 10X the length of the diagonal of the **Film Format**.

A TOUR OF THE TABLE

The foundation for the SAIC **HOLOGRAPHIC STEREOGRAM PRINTER** is a **Newport Research Series Table Top Model No. RS-410-12**. It is supported on four **Newport Modle XL-A Pneumatic Vibration Isolating Legs**, which are filled with pressurized air from a **Sanborn 3 1/2 Horsepower Air Compressor**. Three of the **Legs** have **Regulators** on them, so they are **Slaves** to the **Master**, which is the one without. The **Regulators** have **Level-Sensing Valves** on them, and will prevent the table from resting on the **Restraint**

Stops at the upper and lower positions. The pressure on the legs is approximately 50 psi. These legs are so effective that **Stereogram Frames** have been exposed while the **Compressor** is running, filling its tank, and have been no different than those made with the noise off!

The **Compressor** has a large capacity tank, and when its pressure is below a certain factory set level, the motor is triggered. This could happen at almost any time, although if the tables are not messed with, the tank holds its load for four to six hours. Setting up the tables, shifting weight around on them, pressing film, or using the **Air Nozzles** to clean things will deplete the tank sooner than its usual entropic leaks and fire it off more often. We have been promised a separate storage space for it, eventually.

The system has been optimized to float the table well, **PLEASE DO NOT TOUCH ANY ADJUSTMENTS ON EITHER THE COMPRESSOR OR THE TABLE LEGS!!!** The only thing that needs to be done by the holographer is to turn on the **Compressor** at the beginning of their **Lab Time**, and off if there is no one working after them. The switch is on the side of the **Compressor** that faces North, and can be found easily using a flashlight. Over a period of inactivity, all the air will leak out of the legs, but the **Compressor** will fill them upon being turned on. It is fun to observe how the almost one ton **Table** pops up after the critical amount of air fills the table legs.

Surrounding the table, Velcro'ed to their **Support Structure**, are the **Acoustical Vibration Isolating Panels**. They are composed of a Sintra - Styrofoam -Sintra sandwich, with a inch by inch and a half patch of the **Fuzzy Part of the Velcro** screwed to their corners. Note that the bottom corners have the Velcro at the edge, the top has them slightly lower than the edge. They should be implemented during the **Holographic Recording**.

EQUIPMENT DETAILS

LASER

The source of photons for this set up is the SAIC Holography Department's trusty **Spectra-Physics Model 127-35 helium Neon Laser**. To turn it on, make sure that the **In-Line Electrical Switch**, (found at the foot of the SouthEast leg of the **Acoustical Isolating Structure** surrounding the **Printer Table**), feeding power to the table is <u>On</u>. The Laser should fire up after the BRH approved time delay, otherwise check out the Safety Key at the back of the laser. This key has been flakey ever since the laser arrived at the School in 1987, and it sometimes will not turn the laser <u>off</u>. (The beam stays on even if the key is in the off position.) If the laser tube glows, but there is no output beam, check the **Shutter** in the front bezel of the **Laser**. If it is open, then it is time to panic and call a **Departmental Assistant**.

The **Laser** is a light source also generating large quantities of heat. It is mounted up off the **Table** so that air can flow all around it with a pair of **ThorLabs 6" Stainless Steel Posts** capped with **Custom-made Aluminum Baseplates**, at roughly the height of the **Center of the Holographic Plateholder**. Since the laser has slots which emit large amounts of collateral radiation, venting is provided to eliminate the heat, while shielding the set up from the garbage light.

BEAMSPLITTER

Beamsplitting chores are handled by a **Newport Model No. 930-63 Variable Attenuator/Beamsplitter**, which has been modified by having the second **Half-Wave Plate** removed, its **Polarizing Beamsplitting Cube** rotated for mounting simplicity, and the **Rotating Half-Wave Plate's** mounting rotated so that the adjustment knob is on the bottom and the **Beam Balance Ratio** can be changed without fingers getting in the way of the laser beams. The Model 930 is screwed onto a **Newport Model 340-C Clamp** which holds the **Beamsplitter** at the right height above the table on a **Newport Model 45 Damped Rod** screwed into the **Tabletop**.

REFERENCE BEAM PATH

After the Reference Beam exits the Beamsplitter vertically, it is headed on its horizontal path by a **Newport Model 670-TC**, mounted atop a **Newport Model 45 Damped Rod** above the **Beamsplitter**. A **Front-Surface Mirror** is mounted on a cylinder cut at 45 degrees, which is controlled by a pair of **Micrometers**. The horizontally mounted one rotates the mirror about the vertical axis, while the other one mounted vertically controls the tilt. Coarse adjustment of the mirror can be accomplished by turning the black knurled ring on the top of the unit. It should be screwed down tight, but brushing against it in the dark could cause the **Reference Beam** to stray. It is the first control to twist if after tuning in the **Reference Beam Path Spatial Filter** the beam does not appear to pass through the center of its **Iris Diaphragm**.

HALF-WAVE PLATE

A **Melles Griot 02 WRM 023 Mica Half-Wave Retardation Plate** sits in a **M3 Visual Research Laboratories Rotating Mount**, bolted to the **Table** via a **Newport Model PH-6 Post Holder** and **Steel Rod** and **Right Angle Clamp**, so that it can be tilted so that the **Laser Beam** is incident along the **Wave-Plate's normal**. This unit is used to vertically orient the **Reference Beam's Polarization Vector** for minimum woodgrain. There is a locking knob on top of the device, release it before rotating the **Wave Plate**.

SPATIAL FILTER
Beam cleaning is accomplished by a **Newport Model 900 Spatial Filter**, equipped with a **5X Objective and 50 micron Pinhole**. This choice of beamspread was predicated on keeping exposure times down, so that there is about one stop of drop of intensity (a halving) from the center to the edge of the **Reference Beam** at the **Holographic Plateholder**. If that bothers you, feel free to change to a **10 X Objective**, promising to return the **5X**.

IRIS DIAPHRAGM
This simple device found in the used bins at **Darkroom Aids** limits garbage light from polluting the **Reference Beam**. Its aperture is centered on a properly aligned **Spatial Filter**, and should not be tampered with, because its usefulness as a guide would be compromised. It can be used to quickly check the tune of the **Spatial Filter**.

SPREAD REFERENCE BEAM MIRRORS
There are three of them, starting after the **Spatial Filter** with a **Newport Model 625A-6C** on the **Mirror Stack**. The latter is a **ThorLabs 14" plus 6" Stainless Steel Posts** screwed directly into the table, accomodating a mirror for the **OBJECT BEAM PATH** as well as the formerly-mentioned **6" Diameter Reference Mirror Mount**. This **Mirror Mount** piece of equipment is an excellent example of surplussing. Having taken the latest MWK Industries* catalog with me to my favorite place for perusing such items, I noticed that they offered a package which included:

Newport Item	Price (1993 Catalog)
Model 625A-6C	$386
Model 45 Damped Rod	199
60D10 Round Pyrex Mirror with Enhanced Aluminum Coating ER.1	588
Pair of Model 850B-5 Closed-Loop Micrometer Replacement Actuators, @ $1030 Each	2060
Total	$3173

for only $300! I got a Purchase Order and snagged the item immediately. The **Motorized Actuators** had to be replaced by the traditional **Micrometers**, but still such a deal! Although the required **Newport Model PMC200 Controller** costs $2645 to run the **Motorized Positioners**.

The decision was made to enlarge the **REFERENCE BEAM** before bouncing off this mirror at the edge of the table to to flatten out the wavefront a bit more, so a large mirror was necessary at this post. This deal came at a fortuitous time.

---

*. MWK Industries, 198 Lewis Court, Corona, CA 91720, 1-800-356-7714, Fall-Winter '93 Catalog, p.25.

The **Bargain Mirror** sends the spreading beam slightly upwards to the opposite end of the table to a **Daedal Model X5700 Mirror Mount** on top of three **ThorLabs 14" stainless Steel Posts** screwed into the **Table** as far back as possible. The mounting screws of the **Mirror Mount** have been reversed so that the angle bracket faces behind the mirror plate, and an **Edmund Scientific Front Surface Mirror 204 X 254 mm G40,067** is hot glued onto it, without a wooden frame. The unfortunate thing about wooden frame borders is that they always come out well in the holgram around the reference beam. Mounting without a frame cleans that up. Notice the overspill onto the **Acoustical Vibration Isolation Panel** behind it. This light is reflected off to the side so that it doesn't wind up traveling with the rest of the **Reference Beam**.

The trio of solid steel posts hold the **Mirror Mount** up high extremely stably, with the **Mirror's** center along the optical axis determined by the centers of the **Holographic Plateholder**, the **Groundglass Projection Screen**, and the **Movie Projector**. This mirror's adjustment screws are locked in position and should not be adjusted during **Reference Beam Alignment**; move the undiverged beam using only the **Newport Model 625A-6C** on the **Mirror Stack** in cooperation with the **Newport Model 670-TC** above the **Beamsplitter**. And never, ever, move the **Jumbo Reference Beam Mirror** (next paragraph. The undiverged beam is attacking the **Plateholder** at the proper <u>altazimuthal angle</u> when it hits the center of a **Target Card** in the **Plateholder** and its reflection from the **Front Clear Glass** lands on the **Line Drawn on the Table to Denote the Optical Axis of the Object Beam**.

The **Jumbo Reference Beam Mirror** is just before the **Plateholder**. It consists of an **Edmund Scientific No. G85,206 406 X 406 mm Mirror** in a **Wooden Frame**, supported by sand filled pipes assembled together with **Kee Klamps**. The mounting framework is critically postiioned on the table so that the **Mirror's** whole surface is used to deliver a 45 degree incident **Reference Beam** along the short side of a 30 by 40 cm hologram. Don't try to change the **Reference Angle** as there will be vignetting of the beam at the film plane. Motice that there is some beam overspill above and below the **Jumbo Mirror**. Luckily this overspray never gets to the **Plateholder**, but you can use it to view test holograms.

By the time the **Reference Beam** finally makes it to the **Plateholder** it has had the opportunity to pick up bullseyes from dust at every step of the way. The **Mirrors** should periodically be blown clean with the **Air Nozzle** from the **Compressed Air Supply**. Although there may be this "cosmetic noise", the **Reference Beam** is free from spurious reflections thanks to effective baffling and irissing, as evidenced by the observation (through a piece of Polaroid) of nothing more than a small spot issuing from the Spatial Filter looking back through all the **Mirrors** from the **Plateholder's** position.

OBJECT BEAM PATH

BEAMSPLITTER

The **Polarizing Cube** inside the **Newport Model 930-63** was reoriented to reflect the horizontal polarization upwards out of the unit, which becomes the **Reference Beam**, while the vertically polarized vector is transmitted straight through the box. No **Half-Wave Plate** is necessary in this beam as it travels parallel to the tabletop and preserves its vertical polarization orientation to interfere with the like-polarized reference beam.

STEERING AND PATH LENGTH MATCHING MIRRORS

This **Object Beam** arrives at a **Newport Model 625A-2C** with an **A-2-1 Adapter** for a **10D10 Pyrex mirror with ER.1 Enhanced Aluminum Coating** on a **Model 45 Damped Rod** screwed into the Table. From here it is bounced to the **Lower Mirror** on the **Mirror Stack**, again a **Newport Model 625A-2C** with an **A-2-1 Adapter** for a **10D10 Pyrex Mirror with ER.1 Enhanced Aluminum Coating**. Yet a third **Newport Model 625A-2C** with an **A-2-1 Adapter for a 10D10 Pyrex mirror with ER.1 Enhanced Aluminum Coating** catches the beam and turns it about 90 degrees to aim it into the **Spatial Filter Before the Movie Projector.**

All these mirrors are necessary to path length match the **Object Beam** to the long throw of the **Reference Beam**. With both these beams traveling a combined path length of about a dozen meters, air currents become a crucial issue. Keeping the **Acoustical Isolation Panels** on during exposures is essential to keep the refractive index eddies under control.

OBJECT BEAM SPATIAL FILTER

The light illuminating the **Movie Frame** should be nice and clean, so a **Newport Model 900 Spatial Filter with a 5X Micxroscope Objective with 50 micron Pinhole** is employed before the laser light goes into the **Movie Projector**. It is a tight fit here, so the **Spatial Filter** is attached to a **Newport Model 360-90 Angle Bracket** to squeeze it into place. Fine lateral tuning is accomplished by sliding the **Spatial Filter** on the **Angle Bracket**. The **Angle Bracket** is screwed onto a **Newport Model 340-C Rod Clamp** clamped onto a **Newport Model 45 Damped Rod** screwed directly into the **Tabletop**. It would be rude to slide this **Spatial Filter** down its **Mounting Post** to run undiverged laser light into the **Movie Projector**; leave its chassis in place, but remove the **Microscope Objective** and **Pinhole** instead. Leave them on the **Newport Model 360-90 Angle Bracket** so that you can find them when you replace them.

MOVIE PROJECTOR
There is no documentation for this Burke & James 16 mm Home Movie Projector, so its date of manufacture and anything else about its industrial heritage would be a greatly appreciated trivia answer. It dates from an era when photographic consumer items were cast out of iron, rather than molded by injection in plastic. In its original incarnation light from a **Projection Lamp** entered a hole on the left side of the casting, and a mirror pointed it forward to the **Film Gate**. The **Mirror in the Projector** was simply glued into the casting, but the thick **Brown Crackle Finish** was too lumpy, and the casting roughly unfinished, for this mounting method to work with the higher precision required for working with laser light. (Since **Projection Bulbs** are multi-filamented, irregularities would be smoothed out.) A **Daedal Miniature Straight Mount Model 2100** (although purchased from **Edmund Scientific** as their **Stock No. 33,502 with Mirror.**) replaces that fixturing, for perfect alignment of the bright center of the **16 mm Film** along the **Plateholder's Optical Axis** in cooperation with the **Newport Model 625A-2C** before the **Object Beam Spatial Filter.** Observe that when this beam is properly aligned, it doesn't necessarily pass through sensible landmarks like the center of the **Light Entrance Hole on the Side of the Projector**, nor the center of the **Daedal Miniature Straight Mount Model 2100.** The latter is the only **Mirror** that needs to be moved when changing the **Slit Position** when using the **Printer** to make **ONE-STEP RAINBOW SHADOWGRAMS.**

The **Film Gate** is a simple stamped guide, heavily plated for low friction on the **Film.** Notice that as you look at the **Projector** from the front, the **Film Gate** is not in line with the **Take-Up and Supply Reels.** It is in line with the center of the **Holographic Plateholder.** Holes are punched in it for the light to pass through and for the **Film Advance Claw** to latch onto a sprocket in the **Film.** In ordinary motion-picture work, the **Film** is standing still during the projection time, then the **Motor** drives a mechanism that passes a **Shutter** between the **Light Source** and **Film**, pokes a **Mechanical Finger** through the slot in the **Film Gate**, which gets stuck in a **Sprocket-Hole**, yanks the **Film** downward quickly one frame, retracts, and the **Shutter** allows the Projection Light to pass through again. This jerky method of moving the **Film** through the **Gate** requires that there is a path with **Loops** in it to take up the tension; follow the markings cast into the **Projector Body** when loading the **Film.**

A continuously running **Motor** serviced the **Projector** in its original incarnation to run the film through at 16 frames per second, but nowadays the holographic application demands about one frame every minute. The modification by Ed Bennett to perform this rate included fixturing a new slower motor to drive the old film advance mechanism, with a cam and Micro-Switch equipped follower timing one full revolution or cycle of advance. Mark Bain (BFA 1991) supplied the **Jog Switch** in a **Spray Paint Can Top.**

GROUNDGLASS SCREEN

A piece of double-strength window glass lightly sand-blasted is used as a back-projections screen. It is placed 60 centimeters from the **Plateholder** and is held in position by two **Newport PH-6 Postholders** with **1/2" Steel Rods** in them to clamp to two **1/2" Steel Rods** screwed into the sides of the **Wooden Frame of the Groundglass** with **M-3 Visual Research Laboratories Right Angle Clamps.** **Collars** on the **1/2" Steel Rods** ensure that the **Groundglass Screen** remains at the proper height to keep its center in line with the **Optical Axis of the Holographic Plateholder** in case it is ever removed. A third post holder, **Newport Model PH-2,** grabs a **Short 1/2" Steel Rod** screwed into the bottom of the **Groundglass Screen.** The ground side of the **Screen** is toward the **Holographic Plateholder** to avoid ghost images with back reflections from the flat side.

HOLOGRAPHIC PLATEHOLDER

A wooden frame based on photographic Cntact Print Frame technology (clear glass in front, spring-loaded pressure plate in back) is coupled to the chassi of a dot-matrix computer printer. The printing engine was geared to move a thousandthe of an inch per pulse, and teh current state is to move 19 steps for each Holographic Sterogram Frame.

BAFFLES

are strategically placed all over the printer to make sure that the **Holographic Film** only sees a tiny spot in the **Reference Direction** and nothing other than the **Projected Movie Frame** in the **Object Direction.** No longer is there noise from spurious reflections off of optics thanks to 3 millimeter thick sheets of **Sintra Material** fastened to the table with **Angle Irons** and screws. Don't try taking them down unless you plan to spend a couple of hours replacing them; their shadow casting positions' tolerances are really close to 100's of microns! (Half a millimeter, really!)

There is a **Baffle** around the **Laser** to channel off heat and **Garbage Light (Collateral Radiation).** It insulates the **Reference Beam Path** from heat convection currents that mess with the **Refractive Index of the Air.**

There is a **Great Wall of China Baffle** that follows a curve that circumvents the **Spurious Reflections** from every other optic on the table ending up at the **Plateholder,** which terminates at the **Movie Projector,** where another **Baffle** squarely in front of it lets nothing but the **Image Light** through a square hole. A pair of **Sintra Chunks** describe a right angle in front of the **Newport Model 625A-6C** to to prevent illumination of the trio of **ThorLabs P14 Mounting Posts** which supports the **Daedal X5700 Mirror Mount** of the **Reference Beam**.

OPERATING THE SYSTEM

Before doing anything, make sure that the **Laser** is turned on, using the key in its back panel. To open the **Shutter**, **Herman and Evet** must be on, and the **Shutter Toggle Selector Switch**, located at the bottom right of the **Filmholder**, should be in the **"OPEN"** position.

I. LOADING THE PROJECTOR

Before loading the film, use a **Q-Tip** and some solvent (acetone, film cleaner) to clean out the film gate. Open it up by pushing the film gate lever, and rub the cotton swab through.

Find the center frame of the sequence using the **Movie Editor** and **Take-up Reels** bolted onto the **Printer Table**. (Typically it is the frame where the subject is looking straight ahead in portraits.) Count off 43 frames above it. This will be the first frame of the hologram. There should be a taped guide on the table itself for counting convenience. Marking the frame before the first, on the image area, with a **Sharpie** or **Grease Pencil**, will help in finding the starting spot of the sequence once the film is in the projector.

Put a few frames before the first frame into the film gate of the projector. There is a lever that opens up the film gate hidden under the projector lens. Place the film under the pressure plate. The image on the film will be upside down; the top of the head of a person will be at the bottom. Usually the emulsion side of the film goes toward the lens, when the film is to be projected on a reflecting screen, which is the usual mode of cinematography. (Think: light comes through the camera lens in recording the scene, exposing the light sensitive emulsion placed towards it. To reconstruct the scene, light passes through the base of the film, then the emulsion, then into the lens, and out onto a screen, diffusely scattering the image into the audience.)

But in our case, the holographic master is looking at a <u>back-projected image</u>, and if the film is placed in the usual mode in the projector, left and right will be reversed on the screen. Therefore the film in our set up, (as well as in all other back projected slide or movie schemes, unless mirrors or prisms are part of the optical chain), should be placed with the emulsion away from the lens.

MOVIE FILM IS LOADED INTO THE PROJECTOR WITH THE TOP OF THE IMAGE DOWN, WITH THE EMULSION AWAY FROM THE LENS!!!

To tell which face of the film is the emulsion side, examine the film with reflected light. The plastic base looks smooth and glossy, while the emulsion coated on it has a grainy, speckly, matte finish to it. Usually on a roll straight from the processor the emulsion is rolled inside, but on rolls that have been around the block a few times this may not be the case.

Advance the frame with the pushbutton switch mounted in the paint can cap so that the engagement claw in the projector latches onto the film and centers it on the groundglass screen. Sometimes you will see parts of two frames on the screen, so if the frame is not centered left to right, re-open the film gate and slide the film around so that it finds the guides in the film gate groove. You can find the beginning frame of your shot at this point to focus on.

II. SELECTING AND MOUNTING THE PROJECTION LENS

There are two lenses* for the **Projector**, both made by the **Canon Camera Company** for their line of 35mm SLRs. For **Landscape** or **Horizontal** format, use the **50mm f/1.4**, as it blows up the horizontal side of the 16mm frame to approximately 15 inches.

The other lens, **35mm f/2.8**, is for **Portrait** mode, as it blows up the short vertical side to the full 15 inches height-wise. The

---

*. **HISTORY OF THE PROJECTION LENS:** The lens that came origianlly with the projector was a 2" focal length f/2.8, of the same vintage as the projector. Internal reflections from non-anti-reflection coated elemnets gave ghost images that were annoying to say the least. Then we were loaned a **2" f/1.4 Bell & Howell Projector Lens**, and it had a better design and had no ghost images but there were now a seies of concentric interferometric bands across the screen, visible with no film in the projector and subtly so in the highlights of the film.

A gift of $400 was made to the **Holography Department** from Absolute Graphics courtesy of the largesse of Mel Theobald (MFA 1960). It was thought that a brand-new **zoom lens** would answer the need for a clean image and would be able to vary the size of the projected image, for horizontal and vertical formats, from wallet-sized to 30 by 40 cm. Zoom lenses of various focal lengths ranges, f/stops and manufacturers were shuttled back and forth from **Central Camera**, all exhibiting the fringes caused by internal reflections from their many lens elements and AR-coatings not tuned in for the 633nm He-Ne Laser wavelength.

Finally a **Canon 50mm f/1.4** was brought back to fill the need quickly for a normal optic, and it had fewer elements and better AR coatings for a blemish-free image. Later the **35mm slightly wide-angle lens** was bought to serve as the full 30 by 40 portrait format lens.

horizontal dimension is about 20", so things in the periphery of the scene will be cropped when the transfer is made onto a 30 by 40 cm film oriented vertically, but the image of a face in this mode is as big as life!

The lenses are complete with front and rear caps, and reside behind the **Projector** on the **Printer Table**. Try to keep them as clean as possible, by replacing the **Caps**, and blast them with air before mounting to clean off dirt. Fingerprints should be removed from the lens in accordance with the **Handout, "CLEANING OPTICS"**.

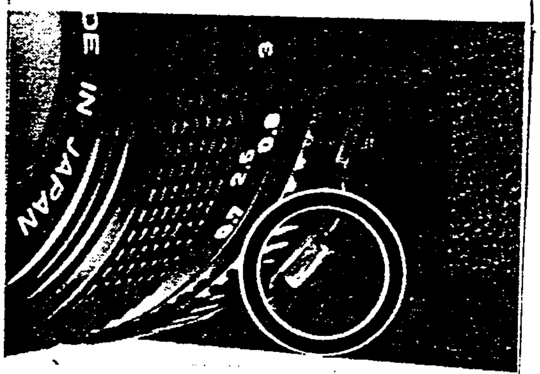
The **Canon Camera Company** of Japan and the **Newport Corporation** of America must draw from the same pool of engineers as some of the products from either company have some basic concepts wrong and follow their own wacky paths of illogic. (See the Handout, **BOGUS NEWPORT PRODUCTS**.) Removing the Canon lenses is easy: simply push the release button, (which is low on the side of the lens away from the holographer when standing by the Printer,) and turn the lens counterclockwise when viewed from the front until it is free of its mount. See the figures, following page.

Because the **SAIC HOLOGRAPHIC STEREOGRAM PRINTER** uses a **Canon Camera Macro Extension Tube** as the lens mount, there is a little extra trick involved in getting the lens into the optical system. The **Macro Tube** disconnects the lens from the metering system and the automatic diaphragm feature of the camera body. There is a long tab extending from the rear of the lens, and it needs to be manuevered to the side to clear a tab inside the **Macro Tube** when mounting.

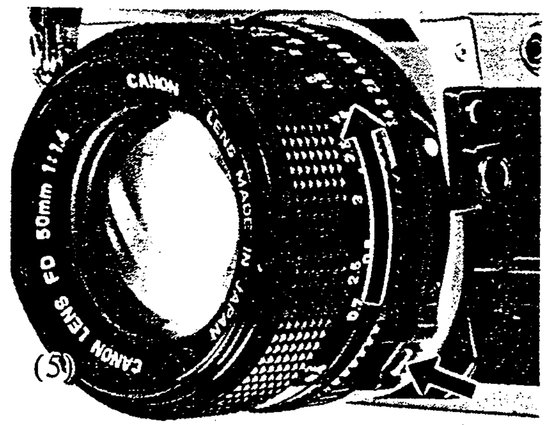
Follow the directions from the camera instructions on the next page below, but before lining up the red dot on the lens with the groove in the lens mount, rotate the lens so that the red dot is at the one o'clock postion (as viewed from the front of the lens) and slide the lens toward the mount until contact is made. Then rotate the mount counterclockwise so that the red dot lines up with the groove, press the lens back into the mount, then rotate the ring clockwise until it clicks. Make sure that the lens is at its largest opening (smallest number) before projecting for the brightest image.

Although conventional photographic wisdom preaches that a lens produces its sharpest images one or two stops down from the largest opening, it is best in our application to leave the lens wide open for the maximum brightness. There is no need to fear about lack of sharpness as the problems that arise from aberrations are usually found in the corners of the field of view. When comparing the sizes of the 16 mm versus 35 mm formats, the latter of which the canon is designed to be used on, shows that the 16mm film is definitely in the sweet spot of the field of view.

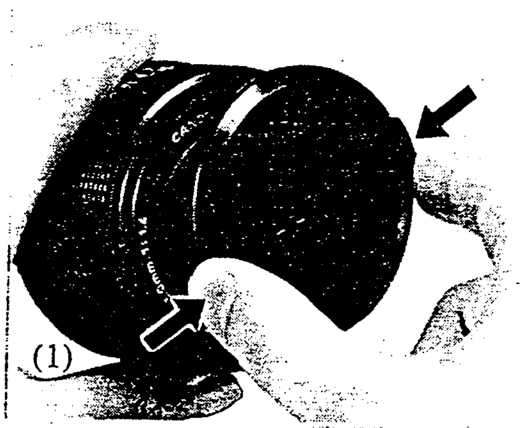
REMOVING THE PROJECTION LENS



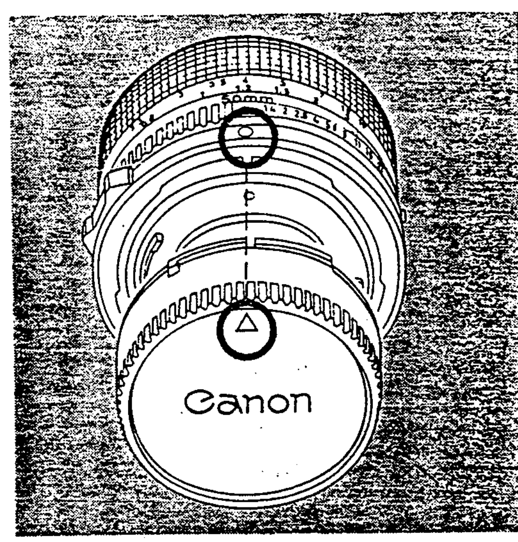
Location of **Lens Release Button.**



Press **Lens Release Button** and rotate lens **CCW** to remove from mount.



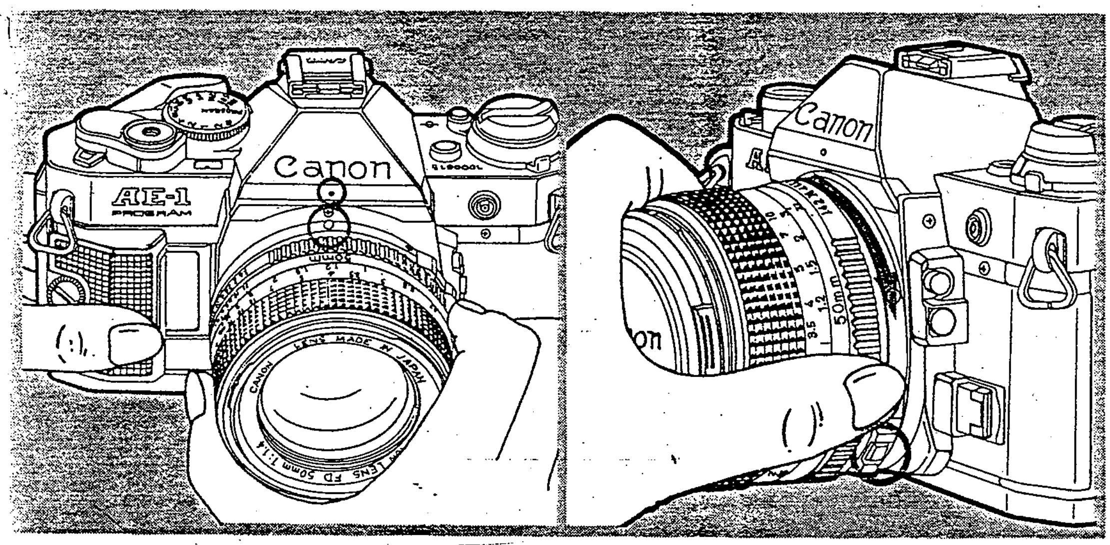
Don't forget to reattach the **Front Lens Cap** and the **Rear Dust Cap.**



To reattach the rear lens cap, align it with the lens as illustrated. Then lightly push it in and turn it clockwise until it stops.

Illustrations courtesy **Canon Camera Company.**

ATTACHING THE LENS



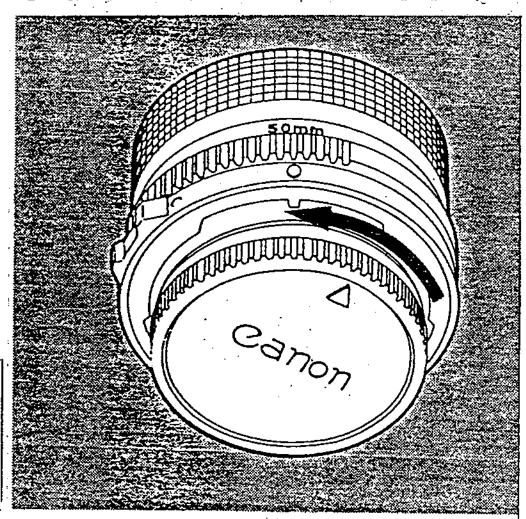
Since we don't have a **Canon Body**, approach the mount with the red dot at <u>1 o'clock</u>. When contact is made with the **Mounting Ring**, turn lens **CCW** to align **Red Dot** at top.

To mount the lens, first align the red positioning point on the lens with the red dot above the camera mount as illustrated.

Then turn the lens in the direction of the arrow until it stops and the lens release button pops out with a click.

Make sure the lens release button has popped out. Otherwise, the lens will not work properly. DO NOT press the lens release button while mounting or it may not pop out.

Turn the rear lens cap in the direction of the arrow until it stops and pull it off the lens.



Illustrations courtesy **Canon Camera Company.**

III. FOCUSSING THE IMAGE

Run the **Beam Balance Control** to place all of the light into the **Projector**. Look at the the image projected onto the groundglass from the vantage point of the holographic plate. Move the projector lens back and forth by remote control by pushing the button on the top of the **Newport Model No. 846HP High Power Shutter Box** on the right side of the **Holographic Filmholder**. This powers the **Oriel Motor Mike** which drives the **Newport Model 430 Translation Stage**. The motor runs very slowly, so be patient when watching the image go in and out of focus.

Sometimes you may even have to stick your head through the **Filmholder** aperture to get a close enough look. It is rewarding, as you can see distinctly when the image is in focus, as the dark interference bands around each edge disappear.

Be careful when focussing as the stage may have reached the limits of its travel. There is a **Reversing Switch** on the **Focus Control Box**, and this should be flipped to help hunt for the best lens focus position. There really isn't any reason to move the lens from its infinity focus position.

IV. CENTERING THE IMAGE

Thanks to a **Newport Model No. 460XZ Translating Stage** the **Canon Lens** can be moved horizontally or vertically to center the projected image on the **Groundglass**. This can take care of small misaligments in the shooting stage. The micrometer knobs are under and to the side of the lens mount, and are awkward to get to, but are smooth-running once they are found.

V. CHECKING THE REFERENCE BEAM

Look at the intensity distribution of the reference beam where it falls on the wall at the end of the table. It should be nicely centered in the shadow of the **Filmholder** frame without its back. If the reference beam looks funky, check to see that the **Reference Beam Path Spatial Filter** is properly tuned in. It can quickly be judged by looking at the **Reference Beam Path Iris Diaphragm** located immediately after the **RBPSF**. The diverging beam should go directly through the enter of the **Iris**. Trying anything more than small corrections with the mirrors on the **Newport Model 670-TC** above the **Beamsplitter**, or on the **Newport Model 625A-6C**, the top one on the **Stack of Mirrors**, might lead to anger and frustration, with a major readjustment procedure to cure the ills. Take heart, the procedure outlined in **HOW TO ALIGN THE STEREOGRAM PRINTER** IS NOT ALL THAT DIFFICULT!

VI. POLARIZATION

A good thing to check before shooting, or if the holograms develop nicely but don't come out at all and/or if there is lots of woodgrain on the surface of the hologram is the state of the polarization of the reference beam. Place a white card on the tabletop in front of the filmholder and look at the reflection from a piece of glass held in the **Stereogram Printer Filmholder** with a nail, awl, Allen key, etc. placed in the hole on top for that purpose. The reflection should be at a minimum, and is adjusted with the **half-wave plate** in its mount before the **Reference Beam Spatial Filter**. When the reflection is at its minimum, it means the beam is vertically polarized with respect to the **Isolation Table**, and this orientation penetrates the glass so there is minimal reflections from all the surfaces, minimizing woodgrain, plus that is the way that the object light is oriented, thanks to the **Polarizing Beamsplitting Cube**. The polarizations must be the same to interfere!

VII. EXPOSURE AND BEAM BALANCE RATIO READINGS

Place the probe of the **S & M Exposure Meter** in the center of the Filmholder thanks to screwing the 5/8" pole that the Meter Probe is stored on into the bottom of the unit and read only the reference beam's power. The target is to read 15 on the **Three Scale** in the reference beam. This gives an **Exposure Time** of 30 seconds.

To divide the power between the **Reference** and **Object Beams** a **Newport Model 930 Beamsplitter/Attenuator** is utilized. Jesus Lopez added a gear to the Newport's control knob, positioned a small DC motor with pinion gear next to it, and hooked it up to a DPDT switch mounted in a **Newport Model No. 846HP High Power Shutter Box** like the **Focussing Remote Control**. By depressing the **Beam Balance Ratio Control** just to the left of the **Filmholder**, the complete range of ratios may be accessed. If the proper setting is overshot, then the motor can be reversed with the **Sliding Switch** on the side of the **Box**.

The action is cyclical, which means the run button may be depressed and the ratio will vary but end up back where it was started from. The focussing mechanism on the other hand has a definite beginning and end, and it must be monitored at the extremes of its travel to prevent catastrophic failure of the **Motor Mike**. If there seems to be no action on the focus, inspect the **Motor Mike's Position Indicator** to see if it parked at a dead end.

There really is no need to measure the light from the movie frame. With this reference setting, a 15 on the 3 scale, a properly exposed film will appear very bright on the screen to the eye, almost to the point of "blooming". Because the subject matter has a photographic tonal scale, with ofttimes darkness prepondering, an accurate object beam reading is impossible.

With our testing procedures, on a variety of footage we have found that simply setting the reference beam to 15 gives sharp, low-noise and bright masters, with brightness of each object point dependent on its photographic density. This tonal scale will be preserved during the transfer step also.

It appears that the optimum exposure of the movie footage for our applcation seems to occur at one stop more than the film manufacturer's recommendation. Set your light meter to one half the ISO Speed number listed on the film box. **Kodak Plus-X Reversal Film** stock exposed at 25 ISO is the primary recommendation for **Holographic Stereogram Portraits** because of its good density, tonal range, and graininess.

An alternative **Beam Balancing Routine** that is necessary to use in the case of over- or under-exposed footage is too look at the image on the **Groundglass** and run the **Beam Balance Ratio** through its range. When there is too much light coming through the film, the image will "bloom" and have a halo around the objects. Back the light down until the bloom disappears, read what's in the **Reference Beam**, and calculate the exposure time based on the information in the **Handout, S & M Model A-3 Supersensitive Photo Meter**.

For salvaging really dark footage, try exposing for a full minute with the **Reference Beam** reading only a 5 on the **3 Scale** and developing 3-4 minutes. Try first with a tiny test strip as there is no guarantee that anything bright enough to be tranferred would be recorded.

After replacing the **Light Meter Probe** in its home, (and turning the **Meter** off), don't forget to reattach the **Slit Curtains** on the **Filmholder**. They simply Velcro on and off, and should be put on neatly, with their top edges underneath the **Cardboard Flap** on the top of the **Filmholder**.

VIII. FILMHOLDER AND SLIT PREPARATION

Ascertain which direction the slit will move by examing your first frame. If the left side of the subject is showing (the right side of the person as they think of it themselves) then the slit moves from left to right (from the outside towards the laser side of the table), and set the **Slit Direction Reversing Switch** (located on the lower left side of the **Filmholder**,) with the toggle tip pointing toward the laser. Otherwise do the opposite. With our **typical turntable rotation footage**, the **Slit** translates from left to right.

Check the size of the slit against the standard hologram. Its size is determined by a piece of tape on the left side (away from the laser) of the metal carriage. Once the piece of spring steel on the right side (toward the laser) fell off, triply exposing each position on the hologram to three frames of footage. But that was not discovered until after the hologram was shot. If this ever happens again, reglue (re-epoxy really) the piece of spring steel onto the right side of the slit mount, aligning its right side to the right side of the milled out piece of steel.

The specially adapted window shades were a stroke of genius on Dean's part. You may un-Velcro them to get a clear view of the groundglass screen. But don't forget to replace them, both sides, before starting the printing. Tuck the window shade under the cardboard light trap at the top of the wooden frame, otherwise streaks may be found along the top of the finished hologram.

Slide the slit carriage all the way to the right, the side by the laser. It will make a noise that sounds awful, but it is only a spring loaded clutch that is meant to take that punishment, as the unit has its roots in an industrial strength computer printer.

You may find once in a while that the **Slit** is not on the **Filmholder**. It may have been taken off to expose as much of a 30 by 40 cm film as possible. Hopefully the slit is easily found, and it can be quickly replaced by screwing the **Shear-Loc Cap Screws** onto the **Transport Carriage**.

IX. FINAL DETAILS

At this time it is good to check that your intitial frame is in the **Film Gate**. If not, the **Film** can be advanced using the centrally-located pushbutton on the **Filmholder**, which is another **Frame Advance Control Button** for the **Projector**.

Or it might better to let the whole unit run through a couple of cycles so that you can verify that both beams are arriving at the **Holographic Filmholder** (in case you forgot to remove any blocking cards while checking the beam balance ratio); that the **Projector** is plugged in and running without chewing up film; that the **Slit** is being translated (make sure its **Control Box, Yvette**, is plugged in)(and don't forget to reset the **Slit** after verifying that it does indeed work!); and that the **Shutter** is in place and functioning with its **Mode Selector Control Toggle** set to the Automatic position. And don't forget about the **Curtains** on either side of the **Slit Carriage** on the **Filmholder**!

X. LOADING THE HOLOGRAPHIC FILM

Clean the **Front Clear** and **Black Backing Glasses** for the **Filmholder** and let them dry and thermally equilize after the spraying and polishing. Place a clean **Photo-Wipe** on top of a

Squishy Pad on the **Printer Table** behind the **Groundglass Screen** and place the **Clear Glass** on it. **WITH THE ROOMLIGHTS OFF, and THE SHUTTER SWITCH IN THE AUTOMATIC POSITION**, the emulsion of the Holographic Film should be placed down, and then the **Black Backing Glass** followed by the Wooden Plateholder Pressure Plate. Push down on the wood with all your weight to squeeze all the air OUT of the sandwich. You will feel the **Newport Table**, if it's on, push back up against your force, and then when you release, the **Table** will PSSSSSSSS out all the air it accumulated. Be aware that this might trigger the **Compressor**.

Slide the sandwich off the **Table** and place it in the **Filmholder**. **CAUTION!!! THERE ARE TWO IRON ANGLE PLATES AT THE BOTTOM CORNERS OF THE FRAME WHICH MAY "TRIP YOU UP" DURING ASSEMBLY!** You should rehearse this operation in the light once or twice. Yes, the **Sheet Steel Springs** on the back of the **Wooden Plateholder Pressure Plate** are made to be that strong to guarantee film stablity during exposure.

XI. PROGRAMMING THE CONTROLLER

After optimizing the recording parameters, step into the **Beginning Holography Studio** and set the controls on **Herman** to the following. A changed thumbwheel setting will not appear on the **Digital Readouts** of the **Settling and Exposure Timers** until the **Reset Button** is pressed. Run for a single cycle to see that all systems are go, or until your marked frame shows up. Reset the **Controller** and **Slit Transport** back to the beginning.

HOLOGRAPHIC STEREOGRAM PRINTER SETTINGS

Reference Beam = 15 on the 3 Scale
Object (Movie Frame) = Not Important
Exposure Time = 30 seconds
Settling Time = 30 seconds
Number of Exposures = 87

Before hitting the **Print Button** on **Herman**, turn on the **Compressor** with a **Toggle Switch** that is on its **Control Panel***. This will fill the legs up with air and hopefully won't top off the tank of the compressor during an exposure, plus it's a good settling time for the recently loaded **Holographic Film**. Check that the machine is running before leaving to run errands, otherwise you may find that no **Stereogram** had been printed while you were gone!

X. PROCESSING

Develop for 4 minutes in **CWC2 Developer** at 75 degrees Fahrenheit (24 degrees Centigrade) and bleach in **Copper Sulfate**. **Wash** and **Photo-Flo** as usual.

---

*. See the **Handout, THE MIGHTY AIR COMPRESSOR.**

RECAP OF THINGS TO CHECK BEFORE STARTING THE PRINTER

BOTH BEAMS UNBLOCKED.

SHUTTER IN POSTION; TOGGLE SWITCH IN AUTO POSITION.

PROJECTOR PLUGGED IN, FOCUSSED, AND PROPER FRAME IN PLACE.

LENS CAP OFF!

SLIT ADJUSTED TO PROPER SIZE, PROPER DIRECTION ASCERTAINED, AND MOVED TO ITS STARTING POINT.

WINDOW SHADES ATTACHED, BOTH SIDES.

SPRAY A LITTLE 3-in-1 ON THE SLIT CARRIAGE RAILS.

DON'T FORGET ABOUT THE COMPRESSOR!

PRINTER HOLOGRAPHIC PARAMETERS

DISTANCE FROM REFERENCE BEAM POINT SOURCE TO PLATEHOLDER: 8.28 meters

DISTANCE FROM GROUNDGLASS SCREEN TO FRONT SURFACE OF GLASS IN PLATEHOLDER: 60 centimeters

"OFFITIAL" OBJECT BEAM HEIGHT: 28.5cm or 11 1/4"

NUMBER OF FRAMES: 87

SLIT WIDTH: .190 inch

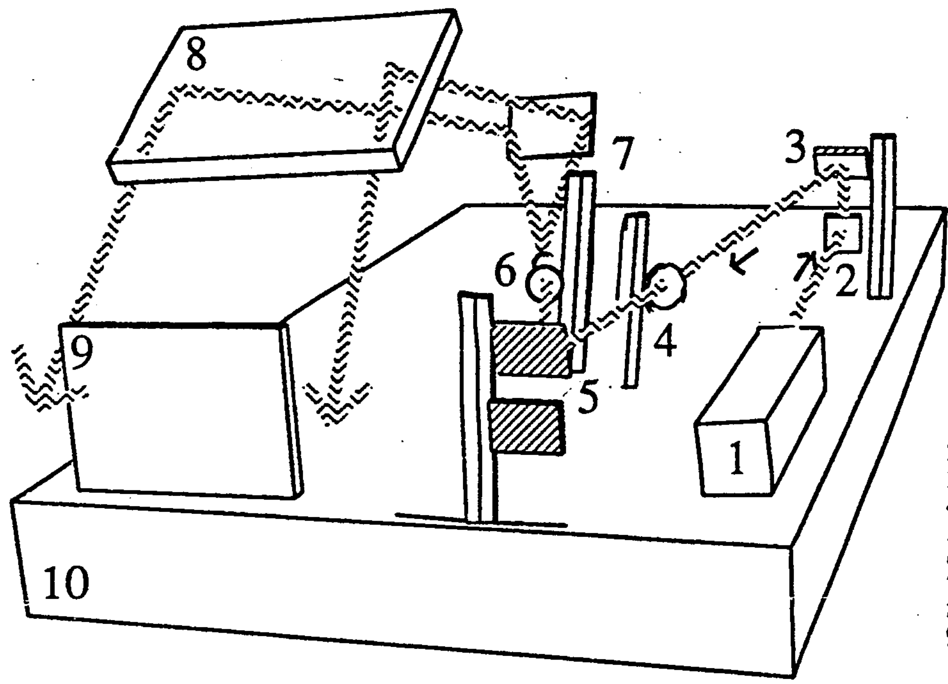
SIZE OF STEPS SET ON YVETTE: 19

REFERENCE BEAM READING: 15 on the 3 Scale (Typical)

OBJECT BEAM READING: We try to standardize on a particular reference beam reading, with attendant exposure time, developer and its time, and not worry about the object beam. A properly exposed movie film (actually for our purposes it is usually a stop overexposed from the manufacturer's recommended film speed for white light reflected projection!) will give a nice, bright, low noise easily transferable laser transmission hologram. The reason we do it this way is that it is very hard to read the object beam light, since in the case of portraits and computer graphics the background is usually black. Sometimes grossly overexposed movie footage will show a "blooming" effect around itself, and then you should decrease the object beam, and compensate for the shorter exposure time by consulting the light meter chart.

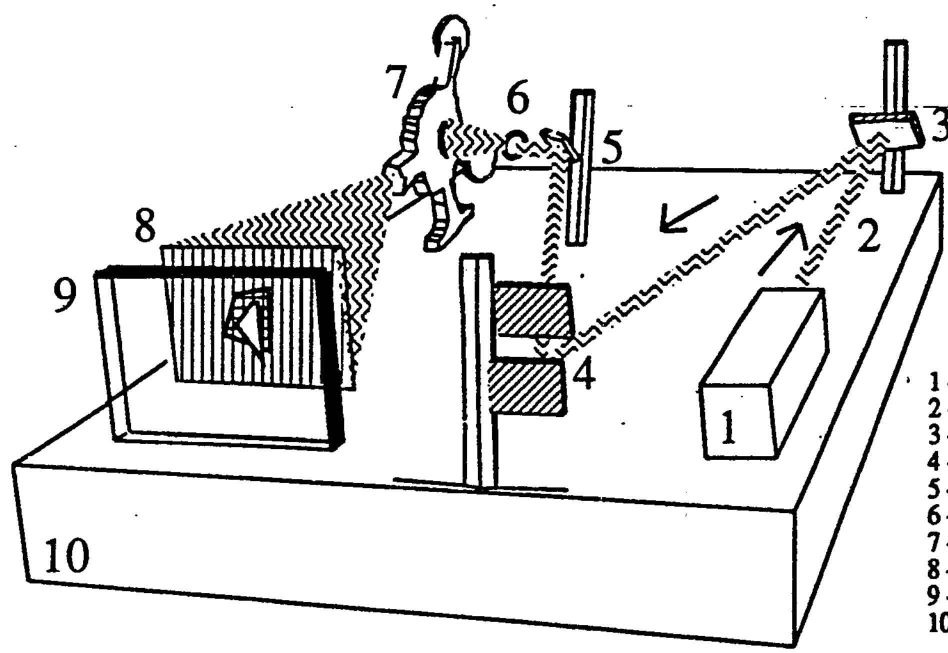
LASER TRANSMISSION MASTER DIAGRAM OF SET UP

REFERENCE BEAM



1 - Laser
2 - beam splitter
3 - mirror
4 - half-wave plate (for polarization)
5 - mirror
6 - spatial filter (lens and pinhole)
7 - mirror
8 - overhead mirror
9 - plate holder and slit mechanism
10 - optical table

OBJECT BEAM



1 - Laser
2 - beam splitter (not shown)
3 - mirror
4 - mirror
5 - mirror
6 - spatial filter (lens and pinhole)
7 - projector and film
8 - ground glass
9 - plate holder and slit mechanism
10 - optical table

HOW TO ALIGN THE STEREOGRAM PRINTER

If for some reason it is immediately obvious that there is something wrong with the STEREOGRAM PRINTER, look for a Departmental Assistant or Graduate Student to help you set it straight. There should be no need to realign anything, as that table and all that equipment is dedicated to that experiment, and **SHOULD NEVER BE MOVED OR REMOVED!** There is plenty of other equipment to make any set up that you can imagine. There should never be any need to borrow anything from the printer. All essential printer pieces are marked **"DO NOT TOUCH"**.

In case there is catastrophic chuckleheadedness or malicious behaviour (WHICH I WILL NOT TOLERATE!) these are the steps to follow to right any wrongs in the system.

REFERENCE BEAM PATH: This path is as long as possible to flatten out the wavefront, using the fewest mirrors after the spatial filter to keep the beam as free from dirty artifacts as possible. Place the Official Stereogram Filmholder Target Card in the Filmholder under glass. If the intensity distribution at the film plane is slightly off-center, first check the tune of the Spatial Filter. The weak magnets of the **Newport Model 900 Spatial Filter** have been bolstered with **Radio Shack Magnets**, so the **Pinhole** shouldn't wander.

If the Spatial Filter is in tune and the spreading beam does pass through the **Iris Diaphragm**, then try adjusting the beams's position on the **Filmholder** by manipulating the position with the control on the **Newport Model 625A-C**, the upper one on the **Mirror Stack** directly to the right of the **Filmholder**,

If there is gross misalignment, unscrew the **5X MICROSCOPE OBJECTIVE** out of the **NEWPORT SPATIAL FILTER** and remove the Pinhole. Check to see if the undiverged beam is arriving at the **Filmholder** centered, from directly above, and not from the side. To check for any sideways deflection, inspect the reflection of the undiverged Reference Beam from a piece of glass in the **Filmholder**. It should hit the **Golden Center Line** directly in front of the **Filmholder**. If it does not, manipulate the **Newport Model 670-TC Mirror**, the one directly above the **NEWPORT 930 BEAMSPLITTER** and the **Newport Model 625A-C** on the **Mirror Stack**. on the **DOUBLE MIRROR POLE**. The **8 BY 10 INCH FRONT SURFACE MIRROR** on the far end of the table, as well as the **JUMBO OVERHEAD REFERENCE MIRROR**, are permanently mounted in position and should not have to be touched.

After the raw reference beam is aligned, then replace the **MICROSCOPE OBJECTIVE**. The mount of the **Spatial Filter** may have to be moved, left, right, up and down but hopefully the most difficult adjustment, the angle of the tilt of the chassis of the **Spatial Filter** will not have to be done.

CHECKING THE POLARIZATION VECTOR:
Reference Beam: Put a piece of glass in the filmholder, and a white piece of paper on the tabletop between the filmholder and the groundglass rear projection screen. If the reflected woodgrain of the reference is very weak, then the polarization is right. If the reflection is strong, rotate the half-wave plate before the Reference Beam Spatial Filter in its mount until the reflection disappears.

Object Beam: The polarization of the projected image is set to be vertical by the POLARIZING BEAMSPLITTING CUBE in the NEWPORT 930 BEAMSPLITTER, and need never to be messed with.

ALIGNING THE OBJECT BEAM PATH:
The two guide posts in the alignment of the object beam path are 1.) that the undiverged beam is centered in the **Film Gate**, and hits the center of the **Holographic Plateholder**. A special **target card** for the **Filmholder** shows that the center of the film is not the center of the image area, because of the **Slit Carriage** and the overhang of the **Filmholder**.

Great pains were taken to align the center of the **Film Gate** in the **Projector** to the center in the **Filmholder**, at the **Offitial Beam Height**. With the **Microscope Objective** of the **Spatial Filter** before the **Projector** removed, and the **Projector Lens** out of the way, a piece of **Kodak Lens Cleaning Tissue** in the film gate will show the position of the beam there, and allow enough light to pass through unimpeded so that a laser spot can be observed at the **Filmholder**.

The bottom **Newport Model No. 625A Mirror Mount** on the **Mirror Stack** delivers the beam to the **Newport Model No. 625A Mirror Mount** before the **Projector Spatial Filter** and doesn't have too much leeway as to where to place the beam. Because of the skewed nature of never having the screws on the bottom flange of the **Newport Model No. 45 Damped Rods** line up exactly where you want them to, the correct place for the beam sent from the **Mirror Stack** is off the center of the **Mirror**, toward the **Projector**.

The major part of the alignment task is undertaken by the **Newport Model No. 625A Mirror Mount** before the **Projector** and the **Daedal Model No. 5100** bolted to the **Projector**. Since this is the **Mirror** that gets moved when the **Printer** is used in its **One Step Rainbow Configuration**, it is best to begin adjustment here.

But the pre-projector **Mirror Mount** needs to be moved in concert with this one. The philosophy of tuning is to move the beam with one of the mirrors in the direction opposite to the way you wish it positioned on the **target card** in the **Filmholder**, then work the knob on the other mirror to move the beam to the center, and check to see if the beam is centered at the **Film Gate**. If it's worse, then go the other direction.

When the **target card** is under glass in the **Filmholder**, the reflection off the glass will head back to the projector but not necessarily go right back into the **Film Gate**. It usually is above the hole in the baffle and toward the table edge. The **Filmholder** has a slight back lean and twist to it, but that doesn't alter the holographic image any.

Part of the **Zen of holography** is to make a conscious effort to remember what you are doing, like putting in the forefront of your short-term memory something like "I am starting by turning this knob <u>clockwise</u>" and correlating the results at the beam destination with the starting point. And to have the patience to start over again if you get lost. Don't forget, somebody did tune it at one time, so it can be done again.

THE TRANSFER TABLE

The **TRANSFER TABLE** is to the **HOLOGRAPHIC STEREOGRAM PRINTER** as a photographic enlarger is to a photographic camera; they work as a team to produce the final image. A camera produces a photographic negative which has its tones reversed, and it needs to have them re-reversed to make the final, legible print. Although the **HOLOGRAPHIC STEREOGRAM PRINTER'S** output is laser-viewable, the final holographic print from the **TRANSFER TABLE** is white-light viewable. This is accomplished by projecting the real image of the **MASTER HOLOGRAM** from the **HOLOGRAPHIC STEREOGRAM PRINTER**, which is pseudoscopic, or space inverted, a spatial negative, onto a second holographic film, and irradiating it with its own reference beam to record a new hologram, using the image from the first as the object for the second.

In the old lab this process was accomplished by stealing the beam from the **Spectra-Physics Model No. 127-35 Helium-Neon Laser** before it went into the **HOLOGRAPHIC STEREOGRAM PRINTER Apparatus**, passing it through the requisite beamspreading optics on the one table and zig-zagging the spreading beams across the two non-floating **Newport Model Isolation Tables**. However in the more vibration-hostile space at 112 South Michigan Avenue this could no longer be accomplished, so the decision was made to dedicate each of the **Newport Tables** to specific tasks.

DESIGN CONCEPTS

The **SAIC HOLOGRAPHIC TRANSFER TABLE'S** primary function is to convert the first step, the **LASER TRANSMISSION MASTER HOLOGRAM** of the **TWO-STEP IMAGE PLANE HOLOGRAM** process, into a **WHITE LIGHT RECONSTRUCTING HOLOGRAM**. The two tables are tuned in to each other so that the maximum amount of production may be done with the minimum amount of resetting up.

The length of the **Reference Beam Path** is made as long as possible to flatten out the wavefront to approximate a collimated beam, useful for lowering aberrations in the **Real Image To Be Transferred**. The expanding beam traverses the **Transfer Table** 2 1/2 times, with the pathlength approximately 8 meters long*, >16X the length of the diagonal of the **Film Format**.

A TOUR OF THE TABLE

The foundation for the SAIC **HOLOGRAPHIC TRANSFER TABLE**, like its cohort, the **HOLOGRAPHIC STEREOGRAM PRINTER** is a **Newport Research Series Table Top Model No. RS-410-12**. It is supported on four **Newport Model XL-A Pneumatic Vibration Isolating Legs**, which are

---

*. This explains the digits in the WL-828 logo you may see floating around the table.

filled with pressurized air from a **Sanborn 3 1/2 Horsepower Air Compressor**. Three of the **Legs** have **Regulators** on them, so they are **Slaves** to the **Master**, which is the one without. The **Regulators** have **Level-Sensing Valves** on them, and will prevent the table from resting on the **Restraint Stops** at the upper and lower positions. The pressure on the legs is approximately 50 psi. These legs are so effective that **Transfer Holograms** have been exposed while the **Compressor** is running, filling its tank, and have been no different than those made with the noise off!

The **Compressor** has a large capacity tank, and when its pressure is below a certain factory set level, the motor is triggered. This could happen at almost any time, although if the tables are not messed with, the tank holds its load for four to six hours. Setting up the tables, shifting weight around on them, pressing film, or using the **Air Nozzles** to clean things will deplete the tank sooner than its usual entropic leaks and fire it off more often. We have been promised a separate storage space for it, eventually.

The system has been optimized to float the table well, **PLEASE DO NOT TOUCH ANY ADJUSTMENTS ON EITHER THE COMPRESSOR OR THE TABLE LEGS!!! AND DON'T EVER SIT ON IT, ESPECIALLY WHILE IT IS FLOATING!!!** The only thing that needs to be done by the holographer is to turn on the **Compressor** at the beginning of their **Lab Time**, and off if there is no one working after them. The switch is on the side of the **Compressor** that faces North, and can be found easily using a flashlight. Over a period of inactivity, all the air will leak out of the legs, but the **Compressor** will fill them upon being turned on. It is fun to observe how the almost one ton **Table** pops up after the critical amount of air fills the table legs.

Surrounding the table, Velcro'ed to their **Support Structure**, are the **Acoustical Vibration Isolating Panels**. They are composed of a Sintra - Styrofoam -Sintra sandwich, with a inch by inch and a half patch of the **Fuzzy Part of the Velcro** screwed to their corners. Note that the bottom corners have the Velcro at the edge, the top has them slightly lower than the edge. They should be implemented during the **Holographic Recording**.

EQUIPMENT DETAILS

LASER

The source of photons for this set up is the SAIC Holography Department's trusty **Spectra-Physics Model 124 Helium Neon Laser**. To turn it on, simply switch on the **Plug Box** suspended from the **Acoustical Vibration Isolating Panels' Support Structure** at its West end. It's up high. Be careful of the **Wall Socket** on the

West Wall as a bump on the **Plug** will momentarily shut down the **Laser** and lights.

The **Spectra-Physics Model No. 264 Laser Exciter** for this **Model 124 Laser** is plugged directly into this **Plug Box**, with its **On-Off Switch** set to the On position, as the **Power Supply** is located in a rather inaccessible location. The Laser should fire up after the BRH approved time delay; however, since this is the oldest laser in the **Holography Department** it may take a few minutes before emission is observed. If the laser tube glows, but there is no output beam, check the **Shutter** in the front bezel of the **Laser**. If it is open, then it is time to panic and call a **Departmental Assistant**.

The **Laser** is a light source also generating large quantities of heat. It is mounted up off the **Isolation Table** so that air can flow all around it with a pair of **Newport Support Posts SP-4** capped with **Newport Sliding Base B-2s**, slid into **Newport VPH-6 Post Holders** at roughly the height of the **Center of the Holographic Plateholder**, which is 11 1/4 inches. **Sintra Shielding** is provided to block the heat and the light thwarted by the **Shutter**.

SHUTTER

Timing chores are handled by an **EPOI Enlarging Timer**, graciously donated to the **Holography Department** by the **SAIC Kinetics Department**. It is attached to the **Acoustical Vibration Isolating Panels' Support Structure** near to the **Plug Box**, and can be set for exposure times form .1 second to 110 seconds. When its **Rocker Switch** is set to Focus, the **Shutter** will open and stay that way for alignment purposes. The Expose position turns on the **Safelight**, (a **Premier 5 by 7 inch Safelight** equipped with a bunch of **Green LED's** and readies the Resistor-Capacitor Timing Network so that a press of the **Expose Button** on the lower right of the unit will flip the **Shutter** out of the way of the **Laser Beam**. The Middle Position of the **Rocker Switch** turns both the **Safelight** and the **Shutter** Off.

Just outside the **Door that Separates the Beginning and Advanced Studios** is a **Push-Button Switch** which activates the **Shutter Timer** just like the **Expose Button** on the **Timer**. This is the preferred mode of operation, as the Holographer can be outside of the **Room with the Transfer Table**. There is a **Light** above the **Push-Button Switch**, which appears to be green but will glow yellow when the **Shutter's Power Supply** is energized. This Special Touch (engineered by Jesus Lopez) assures the **Holographer** that the proper amount of push was administered to the **Button Switch** and alerts anyone who may be milling about that an **Exposure** is in progress, and when it is terminated. Since the **Light** is wired in parallel to the **Shutter Power Supply** it should assure everyone that an exposure was successful, barring mechanical failure of the **Shutter**.

BEAMSPLITTER
Beamsplitting chores are handled by an **MWK Industries Item 39AU2 Polarized Beamsplitter**, mounted on a **Newport Model MM-2 Mirror Mount** lying on its back, supported by a **Newport Model SP-4 Support Post** slid into a **Newport Model VPH-6 Post Holder** on a **Newport Sliding Base B-2** screwed into the **Isolation Table**.

To vary the ratio between the reference and object beams, a **Melles Griot 02 WRM 023 Mica Half-Wave Retardation Plate** sits in a **M3 Visual Research Laboratories Rotating Mount**, bolted to the **Isolation Table** via a **Newport Model VPH-6 Post Holder** and **Steel Rod**. Jesus Lopez added a geared ring to the **Rotating Mount** and mounted its matching **Pinion Gear and DC Motor** on the stationary part of the **Mount**. These components came from a junked **Super-8 Movie Camera Zoom Lens**. It is controlled by a **Mouse** at the **West End** of the **Table**, and will allow the holographer to vary the **Beam Balance Ratio** by Remote Control.

Both buttons on the **Mouse** need to be pushed simultaneously; a switch on the side controls the direction. Unfortunately the action is not cyclical like on the **Printer's Beamsplitter**; there is a rough spot where the motor binds. So if no change in the relative intensities of the **Reference and Object Beams** is observed, flip the **Reversing Switch** to avoid burning out the motor.

Another **Melles Griot 02 WRM 023 Mica Half-Wave Retardation Plate** sits in a **M3 Visual Research Laboratories Rotating Mount**, bolted to the **Table** via a **Newport Model VPH-6 Post Holder** and **Steel Rod** to orient the Polarization Vector of the beam reflected from the cleave inside the **Polarizing Beamsplitting Cube** to match that of the transmitted beam. (For details on this configuration, refer to the handout, **BEAMSPLITTING WITH POLARIZING BEAMSPLITTING CUBES**.)

MASTER REPLAY BEAM PATH

The beam that projects the real image onto the **Copy Hologram** is the one reflected by the cleave in the **Polarizing Beamsplitting Cube**. It is aligned to be parallel to the **Tabletop** by the knobs on the underside of its platform, a **Newport Model MM-2 Mirror Mount**, and its alignment to the **Isolation Table's** edge is controlled by twisting the **Support Post** in its **Post Holder**. This alignment should never need to be tinkered with, but brushing against it in the dark could cause the **Reference Beam** to stray.

HALF-WAVE PLATE
A **Melles Griot 02 WRM 023 Mica Half-Wave Retardation Plate** sits in a **M3 Visual Research Laboratories Rotating Mount**, bolted to the **Table** via a **Newport Model PH-6 Post Holder, Steel Rod** and **Newport Model B-2 Sliding Base**. This unit is used to horizontally orient the **Master Replay Beam's Polarization Vector** for minimum woodgrain. There is a locking knob on top of the device, release it before rotating the **Wave Plate**. There shouldn't ever be any reason to tinker with this, but aligning the polarization vector properly is accomplished by minimizing the reflection off the Glass by observing the garbage light on the wall.

SPATIAL FILTER
Beam cleaning is accomplished by a **Newport Model 900 Spatial Filter**, equipped with a **5X Objective and 50 micron Pinhole**. This choice of beamspread was predicated on keeping exposure times down, so that there is about one stop of drop of intensity (a halving) from the center to the edge of the **Replay Beam** at the **Holographic Master Plateholder**. If that bothers you, feel free to change to a **10 X Objective**, promising to return the **5X**.

This **Spatial Filter** is attached to a **Newport Model 360-90 Angle Bracket** which is screwed into a **Newport Model 370-C Rod Clamp** whose pinion gear rides in the rack of a **Newport Model 75 Damped Rod**. This way all four holes in the base of the **Model 70** can be screwed into the **Tabletop** for the ultimate in stability, and the **Spatial Filter** can be slid tranversely to and fro on the **Angle Bracket** to be precisely situated in the center of the beam.

The power of the magnetic micrometers on the **Spatial Filters** has been restored with **Radio Shack Magnets**. Now the **Pinholes** don't have the nasty habit of drooping out of alignment.

SWITCHING TO THE CYLINDRICAL LENS FOR RAINBOW TRANSFERS is accomplished simply by removing the **Pinhole** and **Microscope Objective** from this **Spatial Filter***, letting the undiverged beam pass through the chassis, and moving into position a **Melles Griot 25 mm Focal Length Cylindrical Lens** in a modified **Newport Model MM-2 Mirror Mount**. The rotating Part allows the stripe of laser light to be perfectly vertical; the tilting knobs let the stripe stay centered on the Master.

IRIS DIAPHRAGM
An **MWK Industries 66BNS2 Iris Assembly** limits garbage light from polluting the **Replay Beam**. Its aperture is centered on a

---

*. and storing them on the **Angle Bracket** where everyone else can find them.

properly aligned **Spatial Filter**, and should not be tampered with, because its usefulness as a guide would be compromised. It can be used to quickly check the tune of the **Spatial Filter**. It is attached to the **Isolation Table** with a **Newport Model PH-6 Post Holder, Steel Rod** and **Newport Model B-2 Sliding Base**.

SPREAD REPLAY BEAM MIRRORS
There are two of them, starting after the **Spatial Filter**, on the opposite side of the **Table** with a **Newport Model 625A-2C** on a **Newport Model 45 Damped Rod** screwed directly into the **Table**. Instead of the usual one or two inch mirror screwed into the recess in the **625**, an **Edmund Scientific Stock # 40,043 First Surface Mirror** (127 x 178 x 6 mm or 5 by 7 by 1/4 inches) is hot-glued to the **Mount**.

There is a special **Target Card** for aligning the undiverged and spread beams on this **Mirror** and its twin in the **Copy Reference Beam Path**. It is stored with other **Alignment Tools**, and is simply used by placing in front of the **5 x 7 Mirrors**.

Then the spreading beam is directed back toward the **Laser End of the Table** where it is incident upon an **Edmund Scientific Stock # 32,248 First Surface Mirror** (254 x 313 x 6 mm or 10 by 12 by 1/4 inches) hot-glued to a **Newport Model 625A-2C** on a **Newport Model 45 Damped Rod** screwed directly into the **Table**. This throws the beam back toward the other end of the **Isolation Table**, where it is intercepted about 2/3 of the way down by the

MASTER PLATEHOLDER
which supports the **Master Hologram to be Transferred**. This piece of equipment was designed and built here at SAIC by Steve Wolf (BFA 1988). The **Offitial Beam Height** for this table is determined by the center of a 30 by 40cm piece of film in this **Holder**.

COPY PLATE REFERENCE BEAM PATH

BEAMSPLITTER
The **Polarizing Cube** is oriented to transmit the horizontal polarization vector, which becomes the **Reference Beam Path for the Copy Hologram**. No **Half-Wave Plate** is necessary in this beam as it travels parallel to the tabletop and preserves its horizontal polarization orientation to interfere with the like-polarized light coming from the real image of the master hologram.

STEERING AND PATH LENGTH MATCHING MIRRORS
This **Beam** then arrives at a **Newport Model 625A-2C** tucked in the corner of the **Transfer Table** with the **"Electric Mirror"** of the

DikroTek Fringe Stabilizer mounted in it to send the beam to the opposite end of the **Table**.

This **Mirror** is a half-inch square mounted on a speaker cone, which will compensate for component drift, table bowing, and slowly moving air currents when it is plugged into the **Fringe Stabilizer Control Box**. (For more details, see the handout, **FRINGE STABILIZERS**.) It does not seem to be necessary for the **Transmission-Type of Transfer**, either **Achromatic** or **Rainbow**, but may be essential for **Reflection Copies**. (As of this publication, **Reflection Copies** are still unexplored turf.) Without being plugged into its **Controller**, the **Mirror** is just as stable as the regular, non-electric type.

Before the **Beam** bounces off the rest of the **Copy Reference Beam Path Mirrors**, it must first be diverged by the

COPY REFERENCE BEAM SPATIAL FILTER

The light acting as the **Copy Reference Beam** should be nice and clean, so a **Newport Model 900 Spatial Filter with a 5X Microscope Objective with 50 micron Pinhole** is employed after the "**Electric Mirror**". The **Spatial Filter** is attached to a **Newport Model 360-90 Angle Bracket** screwed onto a **Newport Model 340-C Rod Clamp** clamped onto a **Newport Model 45 Damped Rod** screwed directly into the **Tabletop**.

The two **Spatial Filters** and all the components before them are permanently atached to the table, and should be left in those positions; adjustments to the **Transfer Set-up** are made by the components downbeam, except when changing the **Microscope Objectives**, and then some finagling of the **Spatial Filters** themselves may be in order.

COPY REFERENCE BEAM MIRRORS CONTINUED

The diverging light from the **Spatial Filter** travels to the opposite end of the **Table** to meet up with another **Newport Model 625A-2C** on a **Newport Model 45 Damped Rod** screwed directly into the **Table**, with an **Edmund Scientific Stock # 40,043 First Surface Mirror** (127 x 178 x 6 mm or 5 by 7 by 1/4 inches) hot-glued to the **Mount**, a twin to the one on the **Master Replay Beam Path**. From here it is bounced back to the **Laser End of the Table** where it is caught by **Edmund Scientific Stock # 32,248 First Surface Mirror** (254 x 313 x 6 mm or 10 by 12 by 1/4 inches) hot-glued to a **Newport Model 625A-2C** on a **Newport Model 45 Damped Rod** which is not screwed directly into the **Table**, but screwed onto a **Newport Model 200 Low-Profile, Heavy Duty Magnetic Base**. This is one of the few components on this **Table** which is not fastened directly, and that's because this piece needs to be flexible as its position is determined by the position of the **Copy Plate Holder**, the **Reference Angle** for it, and the attendant path-length-matching.

All these mirrors are necessary to path length match the **Object Beam** to the long throw of the **Reference Beam**. With both these beams traveling a combined path length of over a dozen meters, air currents become a crucial issue. Keeping the **Acoustical Isolation Panels** on during exposures is essential to keep the refractive index eddies under control.

COPY PLATE HOLDER

There are either **8" by 10" or 30 by 40 cm Wooden Plateholders** available to hold the **Holographic Film** rigidly during the exposure. They are supported by a pair of **Enco On-Off Magnetic Base Indicator Holders King Size Model 625-0360** in the usual Goal Post style, with the **30 by 40 cm Filmholder** resting on the **Isolation Tabletop**, and the **8" by 10" One** being aided by a **Short Rod** at its bottom clamped by a **Swivel Clamp** to a **Magnetic base with a Short 1/2" Diameter Rod** to prevent the **Filmholder** from swiveling around during the loading of the film operation and as an added measure of stability during the exposure. To fully stabilize the bigger **Plateholder** place a couple of **Magnetic Bases** on either side of the **Frame**.

The **Magnetic Bases** are stationed at the appropriate position so that the **Real Image of the Projection Screen in the Master** is focussed right at the plane of the **Holographic Film** under the glass in the **Filmholder**. This position is marked in **Sharpie** on the table. There is no guarantee that the equipment may be in these spots when you start to work, but if everyone is doing the same types of things then there should be no need to move the **Magnetic Bases**. To preserve the semi-permanent positions of the **Magnetic Goalposts** when switching from the larger to smaller format, use long **1/2" or 5/8" Diameter Rods** on the sides of the **8" by 10" Filmholder** to attach it to the **Enco On-Off Magnetic Base Indicator Holders King Size Model 625-0360**.

The **Projection Groundglass to Holographic Filmholder Distance** in the **HOLOGRAPHIC STEREOGRAM PRINTER** is 60 centimeters. Throwing the real image out of **Master Holograms** in our system increases that distance a few centimeters, and that distance depends on whether the real image is flushed out by either a **Spatial Filter** or a **Cylindrical Lens**. When switching from **Open-Aperture or Achromatic Copies** to **Rainbow Copies** an adjustment in focus distance is necessary. Follow the directions given in the **FOCUSSING THE REAL IMAGE** section below if required, but usually the marks on the table will suffice for a usable focus. Note that **Rainbow** and **Achromat Transfers** focus at different distances.

BAFFLES

are strategically placed all over the **Transfer Table** to make sure that the **Holographic Film** only sees a tiny spot in the **Reference Direction** and nothing other than the **Projected Real Image of the Master** in the **Object Direction**. No longer is there noise from spurious reflections off of optics thanks to 3 millimeter thick sheets of **Sintra Material** fastened to the table with **Angle Irons** and screws. Don't try taking them down unless you plan to spend a couple of hours replacing them; their shadow casting positions' tolerances are really close to 100's of microns! (Half a millimeter, really!)

There is a **Baffle** around the **Laser** to channel off its heat, comprised of a big sheet of **Black Sintra Material** with a piece of **Styrofoam Insulation** glued behind it. This sandwich insulates the **Beam Paths** from heat convection currents that mess with the **Refractive Index of the Air**. If it ever becomes necessary to access the **Laser** for service, this cover can be unscrewed from the **Table**.

There is a **Large Baffle** containing all the spurious reflections from the **Beamsplitters** and **Spatial Filters** and that is all there needs to be to prevent those funny little rainbows from appearing at odd spots in the **Holographic Reconstruction**. There is a **Baffle** to the side of the **Plateholder** to eliminate stray light from the **Twin Mirrors**. Looking from the vantage point of the **Copy Plateholder**, there are no little dots of laser light visible which can be recorded as noise.

OPERATING THE SYSTEM

I.MASTER PREPARATION

First open the **Shutter** using the **Rocker Switch** on the **EPOI Printrol Electronic Enlarging Timer**. Using one of the spread beams, find the virtual image of your **Master Hologram** and note the orientation of it with respect to the reconstructing beam. The left side of the **Master** when viewing the virtual image will be at the top in the **Master Plateholder**, and the top of the **Master** when it is normally viewed will be at the North end of the **Table**, which is the end away from the **Laser**.

If you put a mark on the Upper Right of your **Master**, then it will be positioned on the bottom of the **Master Holder**, with the mark on the side toward the wall. The **Master Plateholder** is marked where the mark should go, but you must move to the side of the table by the wall to see it.

Clean the **Glass** that holds the **Master** in the **Master Plateholder** with **Glass Cleaner** and **Paper Towels**, and while they are drying and cooling off, clean the **Holographic Master** with a **Photo-Wipe** and **Edwal** (or **Kodak**) **Anti-Stat Film Cleaner**. Assemble the **Sandwich** for the **Master Plateholder** by first laying a **Photo-Wipe** on top of a **Squishy Pad**, or if using a smaller than **30 by 40 cm Master**, a **White Target Alignment Card** (with the diagonal lines on it to center the **Master** in the **Glass**) on the **Isolation Table**, to keep the freshly-cleaned **Glass** clean, and to make sure that there are no chunks of dirt under it, so that there is no stress on the **Glass** during the <u>Squeezing Step</u>. On top of the cushion, place one of the **Master Holding Glasses**, then the **Master**, noting the its orientation so that there is no confusion when placing it in the **Master Holder**, then the other piece of glass, and then using the **Wooden Backing Pressure Plate** from a **Holographic Filmholder** press down on the **Sandwich** with all your weight to squeeze out all the air inbetween the **Glass-Film Interfaces**. Then slide the **Sandwich** off thew **Table** and slide it into the **Master Plateholder**, and clamp it into position with the bolts on it.

FOCUSSING THE REAL IMAGE
The **Copy Plate Holder** should be in the appropriate position if everyone cooperates for maximum production, but if there is a need for focussing, it is accomplished by placing a piece of **Groundglass** in the **Copy Plateholder**, and loosening the **Magnetic Bases** which hold the **Plateholder** to the **Table**, slide the **Assembly** back and forth until the image is at its clearest.

The focus of a **Holographic Stereogram Master** can be very hard to judge, so to make it easier to focus, there is a **Standard Focussing Hologram**, simply a whole piece of **Holographic Film** exposed in the **HOLOGRAPHIC STEROGRAM PRINTER** to a single frame of a **SMPTE*** **Test Chart**. This **Master** is kept in the **Film Cabinet** for classroom use. If you need this aid, it should be used before loading the **Master** to be transferred. Of course this trick works only if the **Groundglass** in the **HOLOGRAPHIC STEREOGRAM PRINTER** is left in the 60 cm from the **Master Plateholder** position.

Once the **Copy Plateholder** is at the proper position, then the **Copy Plate Reference Beam Path** needs to be attended to. Place a **Holographic Angle Finder** in the **Copy Plateholder**, and observe the **Reference Beam** incident on the **Plateholder**, looking for beam centering and uniformity on the **Copy** at the desired **Reference Angle**. The two **Mirrors**, one attached to the table and the other, on the **Newport Model 200 Low-Profile Magnetic Base**, may need to be slightly adjusted to give the desired **Reference**. Use the **Micrometers** on the **Newport Model 625-A2 Kinematic Mirror Mount with the 5" by 7" Front-Surface Mirror** to move the beam onto the other. This second **Mirror Mount's** position determines the **Reference Beam Angle**.

---

*. Society of Motion Picture and Television Engineers.

After adjusting these positions, then the **Beam Balance Ratio** needs to be adjusted. Thanks to Jesus Lopez this operation becomes a cinch with his convenience invention. Place the **Probe** ov the **S & M Photometer Model A-2** in a **Swivel Clamp** attached to a rod on a **Magnetic Base** at the appropriate place in the **Copy Plateholder** behind a piece of glass, and plug the probe into the **Meter** located handily near. Alternately block the **Reference** and **Object Beams** to get a reading from the **Reference Beam** that is twice as bright as the **Object Beam**, which is the **Real Image** from the **Holographic Master**. Use the **Mouse** to vary the power distribution. Then read both beams simultaneously, and calculate the exposure. Remember that 15 on the <u>3</u> Scale on the **Photometer** means a 30" exposure with a 3 minute development at 75F, then a 30 reading means a 15" exposure, etc.

After all these readings are done, set the exposure time on the **EPOI Printrol Electronic Enlarging Timer**, flip the rocker switch to <u>expose</u>, turn out the roomlights, and load the **Holographic Film** into the **Copy Plateholder** under safelight illumination, as outlined in the handout, **HOLOGRAPHIC STEREOGRAM PRINTER**. Sneak out of the room, wait a few minutes for the film to settle, and press the **Remote Exposure Button**. Process and evaluate the results.

HOLOGRAPHIC STEREOGRAM PRINTER
Configured for the
ONE STEP RAINBOW SHADOWGRAM
(Quick and Dirty Set Up)

1. Remove the 50 micron pinhole and the 5X Microscope Objective from the Newport Model 900 Spatial Filter befroe the Movie Projector on the **HOLOGRAPHIC STEREOGRAM PRINTER**. DO NOT slide the whole Spatial Filter Assembly from the Thorlabs 6" Stainless Steel Posts by loosening the gnurled nuts on the Newport Model 340-C Rod Clamp, otherwise you'll live to regret it when you replace the Microscope Objective and Pinhole when you return the **HOLOGRAPHIC STEREOGRAM PRINTER** back to its Stereogram Prining Configuration. Lay the removed parts on the Newport Model 360-90 Angle Bracket so that they are easy to find.

2. Check where the beam hits the **Groundglass Screen** with a **White Cardboard Target Card**. It should be centered, if not do so with the two Mirrors on either side of the **Projector**. Perfection is attained when the back reflection off the **Groundglass** re-enters the **Projector**.

3. Insert a **Glass Rod** functioning as a **Cylindrical Lens** in the undiverged **OBJECT BEAM PATH** of the **PRINTER** after the **Projector** to diverge the beam to a stripe on the **Groundglass**. Hold the **Glass Rod** in one end of a **Double-Swivel Clamp** so that it can be tilted to make the fanning beam parallel to the **Tabletop** and the other end can be attached to a 1/2" Diameter Rod firmly ensconced in a **Post Holder** screwed into the **Magnetic Base** of your choice. Position the **Beam-Fanning Assembly** far enough from the **Groundglass** so that a smooth, even slit appears on it.

4. The 633 nm red calibration position is when the slit is in the exact middle of the **Groundglass**. Moving the slit downward using the **Daedal Miniature Straight Mount Model 2450** on the **Projector** changes the final image's hue to a green or blue. The problem with this set up is that as the replay color is shifted, the undiverged beam is heading downward, and then so to is the scatteer off the **Groundglass**, and the good filet of the Gaussian distribution misses the **Plateholder**.

5. Screw the **Probeholding 5/8" Steel Rod** into the hole on the bottom center of the **Plateholder** and snap the **Probe** of the **Science & Mechanics Super-Sensitive Photo Meter Model A-3** into it. Make sure that the **Probe's** male RCA plug is in the female receptacle of the extension box. Using the button on the modified **Newport Model 846HP High Power**

Shutter on the left of the **Printer's Filmholder** check the **Meter** while alternately blocking the **Reference and Object Beams** to find a ratio between 4:1 to 2:1, in favor of the **Reference Beam**.

6. Shoot an exposure based on what you measured in both beams, process and evaluate the hologram.

7. Different colors can be obtained by moving the slit up and down on the **Groundglass**. Blends of colors from the extremes of the spectrum are not that successful, owing to the mis-aim of the light scattered from the **Groundglass**, but reds on top of greens are fine. For better color rendering, see the **Handout, USING THE HOLOGRAPHIC STEREOGRAM PRINTER IN THE FULL-BLOWN ONE-STEP RAINBOW SHADOWGRAM CONFIGURATION.**

USING THE HOLOGRAPHIC STEREOGRAM PRINTER IN THE FULL-BLOWN ONE-STEP RAINBOW SHADOWGRAM CONFIGURATION

RESEARCH IN PROGRESS

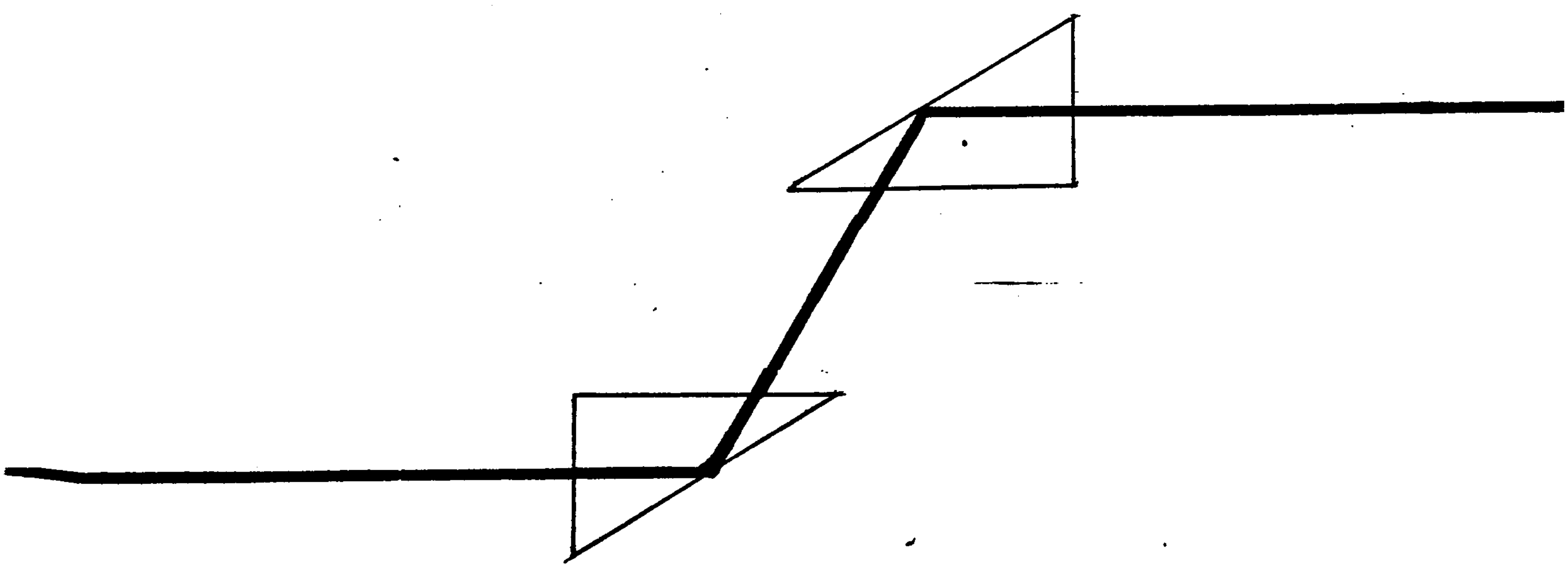
USING THE HOLOGRAPHIC STEREOGRAM PRINTER TO RECORD MASTERS OF DIFFUSELY-REFLECTING OBJECTS

NOTE

Since the **Overhead Reference Beam Mirror Assembly** is incredibly stable, it would be a shame not to use it for other types of holograms on the **Printer Table**. By removing the **Groundglass**, **Diffusely Reflecting Holographic Objects** can be positioned the same distance away from the **Master** as the **Projected Image**, so that the same basic **Transfer Set Up** can be used for both **Stereograms** and **Object Holograms**. The **Object Holograms** can be either achromatic or rainbow, with the possibility of multi-coloring (i.e., a red this, a blue that) in the latter.

The beam headed for the **Projector** is diverted by a **BeamStealer** that sends light down to a **Beamsplitting Assembly**. The beam can be divided in any ratio to two **Spatial Filters** that send divergent light to two **Small Round Mirrors** that aim the spreading beam up at two **Large Mirrors** flanking the **Holographic Filmholder**. These **Large Mirrors** send the light down to the **Object**.

The **BeamStealer** is a **Newport MM-1 Mirror Mount** that is attached to a device that was found in the **Electronics/Kinetics Studio** across the hall that came out of who knows what and is mounted on a **Thorlabs 8" Stainless Steel Post**. It is retracted and out of the way for the **Stereogram Printing Mode**, but the thingamajig does a fairly good job of snapping back to the same spot time after time so that only small corrections of the **Mirror Mount** are necessary to send the laser beam into an **Edmund Stock #43,649 Technical Spec 30, 60, 90 degree Littrow Dispersion Prism**, mounted in a **Custom-Designed Rotator** on a modified **Newport Model MM-2 Mirror Mount**.



The **Prism** is used interestingly enough in a **TIR*** configuration, which directs the light down to its twin which levels the light off at the height where the **Beamsplitter** and **Spatial Filters** do not block the **Projector's Beam**. Fine-tuning of the beam height and inclination can be achieved by tilting the **Prism** with the **Mirror Mount Knobs** or rotating it.

The beam is introduced into a **HALF-WAVE PLATE** in an **M-3 Visual Research Laboratories Rotating Mount** which rotates the vertical polarization vector of the beam to vary the ratio of the transmitted and reflected rays through the **Polarizing Beamsplitting Cube Assembly**.

Although the two beams out of the **Beamsplitter** are polarized orthogonal to each other, there is no **Half-Wave Plate** after the **Cube** to rectify the vectors. It would be to no avail, as diffusely reflecting objects depolarize polarized light. Look at an object through a polarizing filter and rotate it and notice that there is no change in intensity.

The two beams are spread by a pair of **Jodon Spatial Filters**. Their **Rods** are slid into **Newport VPH-2's** screwed onto **Newport Model B-2's**. The **Pinholes** and **Microscope Objectives** should be out of the **Spatial Filters** during preliminary alignment, positioning the **Small and Large Mirrors** to center the undiverged beam on the **Object**.

When the **Objectives** are reintroduced into the set up, the spread beams may not be going where the undiverged ones were. The fault is in the **Microscope Objectives**, not in your handiwork. The whole **Spatial Filter** needs to be repositioned, so loosen the screws on the **B-2's** to move the **Spatial Filter** across its beam, and loosen the knob on the **VPH-2** to raise or lower the **Spatial Filter** to bathe the object in the prime fillet of the beam.

The **Microscope Objectives** normally implemented in this set up are **4X power**. This is usually good enough to illuminate an object that will fit in an **8" by 10" Copy Hologram**. Larger objects may require a switch to **5X** or **6.3X** **Objectives** which spread the beam more. Really the limiting factor to the size of the object are the **Large Mirrors**.

The **Small Round Mirrors** are **Daedal 3250's** on **Newport Post Holders**. A **Custom-Fabricated Angle Bracket** gives the mirrors more upward angle than stock. The **Mirror Control Knobs** can center the undiverged beam on the **Large Mirrors**.

---

*. **Total Internal Reflection.**

These **Large Mirrors** are mounted on **Enco Model Number Angle Drill Press Vise**, cut up to handle the mirrors and drilled to screw onto a **Newport Model 370 Clamp**. These **Mirror Mounts** are not so easy to adjust; they require an <u>open end wrench</u>, (found in the **Tool Area** to the right, wrapped up in a plastic storage bag.) Improvements are forthcoming. They are at a position that seems to serve for most objects, with small revisions of the spread beams made possible by the easy to turn adjustment knobs on the **Small Round Mirrors**.

The Improved Newport Model 370 Clamp grasps a stack of **Thorlabs Stainless Steel Posts**, tall enough to hold the **Large Mirrors** above the **Printer's Filmholder** yet under the **Jumbo Reference Mirror**. A <u>flagpole</u> like this would "flap in the breeze" if it were not for the added stability of a **Bogen Super Clamp** connecting the **Stainless Steel Posts** to the **Jumbo Reference Beam Mirror Support Structure**.

The distance from the **Newport Model No. 930-63 Variable Attenuator/Beamsplitter** to the **Newport Model 625A-2C** with an **A-2-1 Adapter** for a **10D10 Pyrex mirror with ER.1 Enhanced Aluminum Coating** on a **Model 45 Damped Rod** screwed into the far end of the Table back to the **Lower Mirror** on the **Mirror Stack**, again a **Newport Model 625A-2C** with an **A-2-1 Adapter** for a **10D10 Pyrex Mirror with ER.1 Enhanced Aluminum Coating** and over to the **BeamStealer** through the **Edmund Stock #43,649 Technical Spec 30, 60, 90 degree Littrow Dispersion Prisms**, mounted in **Custom-Designed Rotators** on modified **Newport Model MM-2 Mirror Mounts** through the **Polarizing Beamsplitting Cube** and off the **Small Round Mirrors** up to the **Large Mirrors on Modified Drill Press Vices** then down to the **Object** (exactly at the center of where the **Groundglass** goes) and to finally arrive at the **Printer's Filmholder** has been path-length-matched to that of the **Reference Beam**, no mean feat for pathlengths >8m. The <u>coherence length tolerance</u> is about 4 inches.

When used in conjunction with the **Groundglass** as a back-illumination device, combinations of front- and back-lit objects can appear in the same hologram. For more details see the **Handout, USING THE HOLOGRAPHIC STEREOGRAM PRINTER TO RECORD MASTERS OF BACKLIT OBJECTS.**

If due respect is paid to the equipment, **Set Up Steps 3 through 6** shouldn't normally be necessary. Only the **Beamstealer** should need to be adjusted, as it is subject to being thrown out of alignment as it is flipped in and out of position. And fine-tuning of the light on the object need only be done with the **Small Round Mirrors**.

SET UP STEPS

1. Flip the **BEAMSTEALER** up into position to divert the **Object Beam** headed for the **Movie Projector** into the **Object-Illuminating Optics**. It resides behind the **Great Baffle Wall**, and a chair of stool may be necessary to locate it.

2. If you're lucky, the **Beam** will go into the **Spatial Filters** with just a little bit of tweaking with the control knobs on the **MM-1** of the **BeamStealer**. If not, unscrew the **Microscope Objectives** and remove the **Pinholes** from the **Spatial Filters**.

3. The beam should go through the center of the **Half-Wave Plate** and the **Polarizing Beamsplitting Cube**. If not, adjust with the controls on the **Modified MM-2 Prism Holders**.

4. The straight-through or transmitted beam from the **Beamsplitter** should head for the **Small Round Mirror's** center. It may be off center slightly, because of the **Small Mirror Mount's** location due to the **Tabletop's Hole Pattern**.

5. The Reflected Beam from the **Beamsplitter** can be centered to some degree by tilting the **Beamsplitting Cube** on its **MM-2 Mount**. Again, it may arrive slightly off-center. This **Small Mirror Mount** is behind the **Great Wall Baffle** and you may need to stand on a stool or chair to access it.

6. Use the knobs on the **Small Round Mirror Mounts** to center the undiverged Beam on the **Large Mirrors Flanking the Filmholder**. Be aware of the criss-crossing that the beams make on their way up to the **Large Mirrors**. Remember that one of the **Small Round Mirror Mounts** is hidden behind the **Great Wall Baffle**.

7. Remove the **Groundglass** and stow in a safe place. Position the **Object** where the center of the Groundglass had been, using the **Newport Model 410 Vertical Height Mounting Assembly** as a Heavy-Duty Object Holder, or any other devices using your ingenuity.

8. Aim the undiverged beam at the Object using the Large Mirrors. The tilt of the beam is controlled by the hinge of the Modified Drill Press Vice. You will need an open-end wrench to loosen all 4 bolts on the ex-Drill Press Vise. Loosen the bolts just enough so that you can move the mirror Mount, but not so loose that they swing open forward.

9. To rotate the beam into position, loosen the knob of the Newport Model 370 Improved Clamps to twist the whole Mirror Mount to point the beam on the Objects's Center. The knobs are unfortunately located under the Brace of the Modified Angle Drill Press Vice. Fortunately we have installed Custom-Made Collars under the Newport Model 370's to prevent the Large Mirror Mounts from slipping to the floor.

10. Reinstall the Microscope Objectives in the Spatial Filters. If the Spread Beam doesn't go to the center of the Object, slide the Spatial Filter transverse to the beam by loosening the screws holding the Newport B-2 to the table. Vertical adjustment is accomplished by loosening the knob on the Post Holder and bringing the Spatial Filter up or down. If the beam is slightly off, small adjustments can be made by adjusting the Small Round MIrrors.

11. Now is the time to vary the ratio between the left side and right side object beams. Rotate the **Half-Wave Plate before the Polarizing Beamsplitting Cube** in its mount to redistribute the light to either side.

12. With the object properly lit insert the **Pinholes** in the **Spatial Filters**. Looking into the **Small Round Mirror** behind the **Great Baffle Wall** will let you watch the output of that **Spatial Filter**.

13. Time to set the **Overall Beam Balance Ratio**. Since objects' reflectivities vary, we set the **Reference Beam** to 7 1/2 on the **3 Scale** of the **S & M Super-Sensitive Photo Meter Model A-3** and shoot a small test strip for one minute and develop for **2 minutes** at 75F in **CWC2**. Bleach in **Copper Sulfate**. If this is good, shoot a full piece.

14. The **Slit** can be removed from the **Stereogram Printer's Filmholder** with the two **Shear-Loc Knobs** holding the **Slit Assembly** on the **Translating Carriage**. Roll the **Curtains** to the side.

15. **PROGRAMMING HERMAN:** (**Evet** need not be turned on.) Set the Settling Time on Herman to a fairly long time, like 5 to 10 minutes. (300 to 600 seconds.) **Exposure Time** 60 seconds at first. Set **Frame Counter** to 001, especially if you leave the room, as the equipment will cycle through many exposures if the count is other than 001. If you leave the room while the machine is settling and exposing, make sure you start it before exiting. Also write a note

on the **Marker Board** on the door to the **Printer Room** if other holographers are coming and going so that they don't give your hologram a surprise dose of light and vibration.

16. **TROUBLESHOOTING:** If the test strip is not bright, or there is no image at all, check the object and all the mirrors for stability. If there are dark bands on the object, then it is unstable and moved during exposure. If there are dark spots on the object's surface, then it's skin is locally moving, and may need reinforcing braces or to be filled up with sand.

For uncooperative objects, the exposure time may be shortened and the hologram developed longer, like up to six minutes. But try longer settling times before pushing the film.

Another type of banding comes from lack of coherence. A large object may fall out of the coherence volume of the **S-P Model 127 Laser**. The coherence band will move as you look at the hologram from side to side. Tilt the object so that it is oriented more cross-wise to the beam, rather than length-wise.

If all equipment seems to be stable, and the hologram develops up nicely, and the object still needs to be brighter, add more **Object Light**. This will be at the expense of the Reference Beam, and you may end up with only a 3 1/2 on the **3 Scale**, and exposing two minutes.

USING THE HOLOGRAPHIC STEREOGRAM PRINTER TO RECORD MASTERS OF BACKLIT OBJECTS

NOTE

Since the **Overhead Reference Beam Mirror Assembly** is incredibly stable, it would be a shame not to use it for other types of holograms on the **Printer Table**. **Transmissive or Translucent Holographic Objects** can be positioned in front of the illuminated **Groundglass**, so that they glow, just as they would be if they were to photographed. The Object will be positioned roughly the same distance away from the **Master** as the **Projected Image**, so that the same basic **Transfer Set Up** can be used for both **Stereograms** and **Object Holograms**. The Groundglass can be focussed at the Copy Hologram's Plane, or the Copy Filmholder can be moved toward the **Master** so that the object straddles the Copy Film Plane. The **Object Holograms** can be either achromatic or rainbow, with the possibility of multi-coloring (i.e., a red this, a blue that) in the latter.

SET UP STEPS

1. Illuminate the **Groundglass** with light from the **Projector**, using the **Canon 35mm f/2.8 Lens** wide open to light up the whole thing.

2. Now is the time to set the **Beam Balance Ratio**. Place the **Probeholder** of the **Light Meter** in the center of the **Filmholder**; aim for a four times brighter **Reference** than **Object Beam**. Notice that exposure time will be much shorter than for a **Stereogram**, as almost all the light available through the **Groundglass** will interfere with the **Reference Beam**.

2. Fixture the **Object** in front of the **Groundglass**. Shim it up to the required height with solid objects, not empty film boxes.

3. Expose, process as usual and evaluate a small test strip. If it's good, go for it!

Instead of using glassware or the like as three-dimensional objects, layers of two-dimensional graphics can be recorded in this configuration. They can be cardboard cut outs, scratched recycled holographic film, painted glass, overhead transparencies, etc. Just remember the **caveats** about plastics in the **Handout, THE ONE-STEP RAINBOW SHADOWGRAM.**

The 2-D graphics can then be transferred, in a variety of colors, or mixed with object or computer imagery, on the **Transfer Table**.

A METHOD OF COMBINING BACK-LIT AND FRONT-LIT OBJECTS

Using a back-lit background, like a star pattern behind a front-lit object like a Robot, can give a great effect of depth. The stars are simply pinholes pricked in black cardboard or paper, like the stuff that comes in the Film Boxes and that we store in the Baffling Materials Bin. The star background can be exposed behind the object, so that natural parallax interpositioning can occur.

Because the **Spreading Front-illuminating Beams** are clipped by the **Groundglass**, it cannot be in place during the **Front-Lit Exposure**. First set up the **Back-Lighting** of the scene. Tune it into perfection, so that it is ready to expose film. Add **Cheapo Magnetic Bases** around the **Groundglass** so that it can be repositioned accurately and easily. Then remove the **Groundglass**.

Next <u>steal the beam</u> by popping up the **BeamStealer**, and tune up the **Front-Lighting of the Object**. This set up will be shot first, then the **BeamThief** gets snapped out of position, the **Groundglass** replaced, and the **Back-Lighting** exposed.

If the same piece of film is to be exposed to both styles of lighting, then a black cloth can be draped over the **Filmholder** during the switchover. Then the **Shutter Controller** can be switched to **<u>OPEN</u>** from **<u>AUTOMATIC</u>**, so that you can see if the Beam is following the intended path.

There is a **Portable Safelight** on the **Lighting Shelf** of the **West Wall Storage Shelves**. A beat-up but reliable Kodak Round Safelight with a dim Wratten Number 3 Safelight Filter can throw some light safely on the table in a jam. Don't forget to settle extra long after using a <u>hot light source</u> on the **Tabletop**.

If the two scenes are to be recorded on separate pieces of film for multi-coloring, then the film can be removed from the **Filmholder** and returned to the box between shots and the room lights put on.

The use of multiple masters in the transfer raises the issue of registration in both mastering and copying steps. If full sheets of **30 by 40 cm Holographic Film** were used, then all exposures could be indexed to the **Laser Side** of the **Filmholder**, as that is the edge that is down in the **Filmholder on the Transfer Table**.

If the <u>Rainbow Colors</u> were planned out ahead of time, then a big piece of film could be placed in the **Filmholder**, and the different scenes would be exposed to different parts of the same piece of film. For example, a red front-lit robot is backed by a blue-green star pattern. The bottom of the film would be exposed to the robot, with the top covered by a horizontal piece of cardboard, and then this bottom strip is covered and the top uncovered for the second exposure, the back-lit screen with stars.

A piece of glass that replaces the regular one in the **Filmholder** with windows for just this purpose was fabricated by Greg Fister (BFA 1992, MFA 1997?). It is stored in an clearly-marked **Express Mail Envelope** and should either be on the **Transfer Table** or in the **Alignment Tool Slot** in the **West Wall Storage Shelves**.

In the case when the **Front-Lit Object** is positioned where the **Groundglass** had been, and a **Back-Lit Background** is to be added to this object, the **Groundglass** needs to be located to a position further back than its normal home. A pair of **Magnetic Bases** used in the **Goalpost Configuration** can support the Groundglass.

There is a limit on just how far back the **Groundglass** can be positioned due to the **Great Wall of Baffle**. Dismantling the **Baffle** is a very risky undertaking, as it is cut to **exactly** conform to the **Beam Paths**. Rotating the **Groundglass Screen** so that it is taller than wider may help the fit, or substitute a smaller one from the **Top Shelf of the West Wall** in the **Printer Room**.

To eliminate another variable when changing from front to back light, the **Reference Beam** for this set up should be set to 7 1/2 on the **3 Scale** just like the front-lit object. Usually the background is predominately black, so there will be no overwhelming of the reference beam with object light, which could happen if the full screen's light is interfered with this low of a **reference reading**.