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CONTENTS

CONTENTS

TABLE OF CONTENTS

SEVEN SINGLE BEAM PROJECTS

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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 instructors 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.

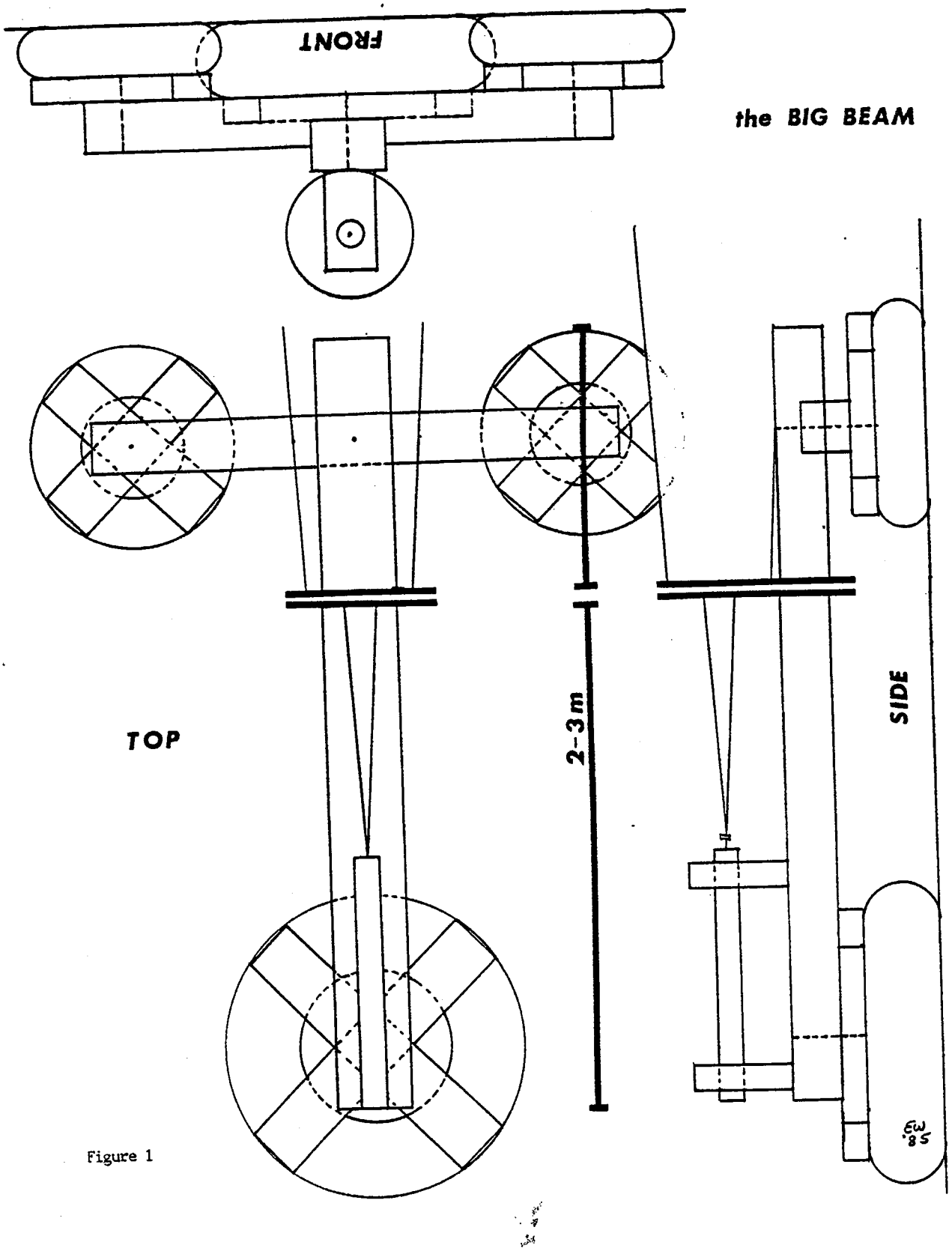
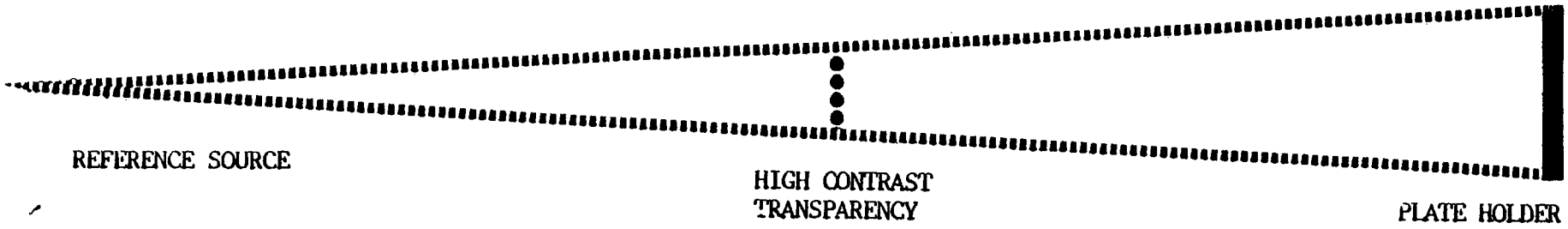


Figure 1

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.

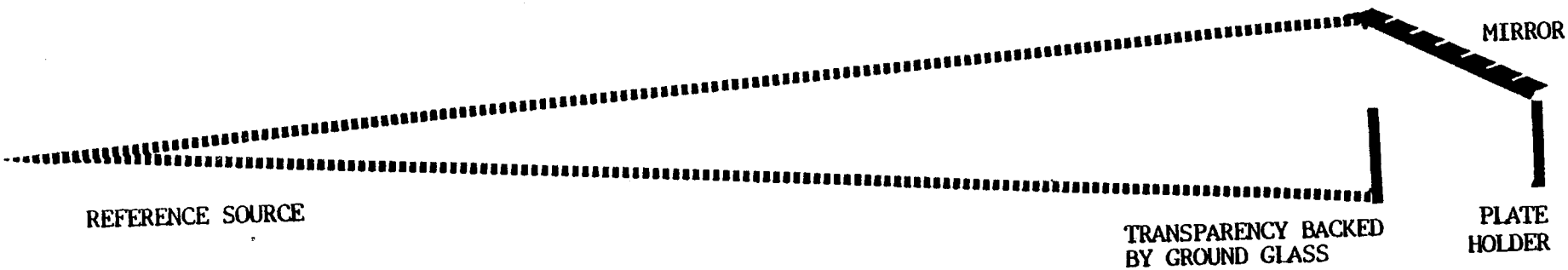
OBSERVATIONS/ DEMONSTRATIONS: Simultaneously reconstructed real and virtual images along with the zero-order, lack of redundancy, evidence of wavelike nature of light in the patterns on the hologram.

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



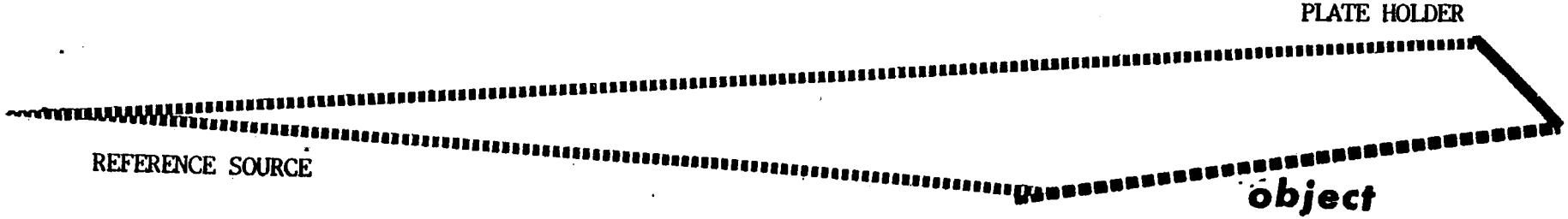
SET UP STEPS: 1) Spread beam. 2) Position groundglass and transparency. 3) Direct reference beam with overhead mirror onto holographic plate. 4) Settle and shoot hologram. 5) Process and reconstruct it.

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.

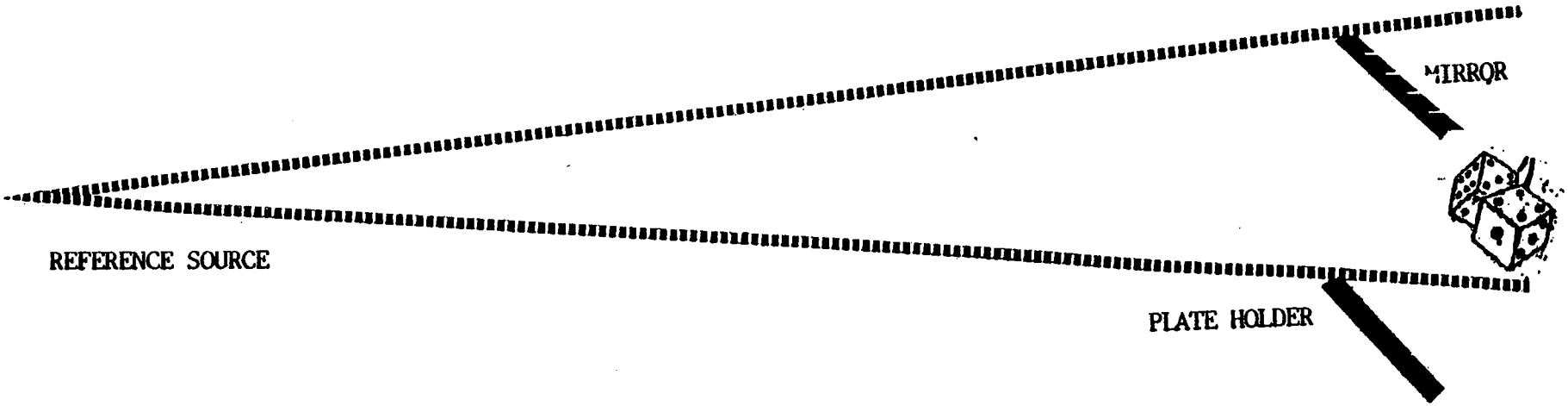
REFERENCES: E. N. Leith, J. Upatnieks, "Wavefront Reconstruction with Diffused Illumination and Three-Dimensional Objects", Journ. OSA 54, 11, p.1295, (1964)

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.

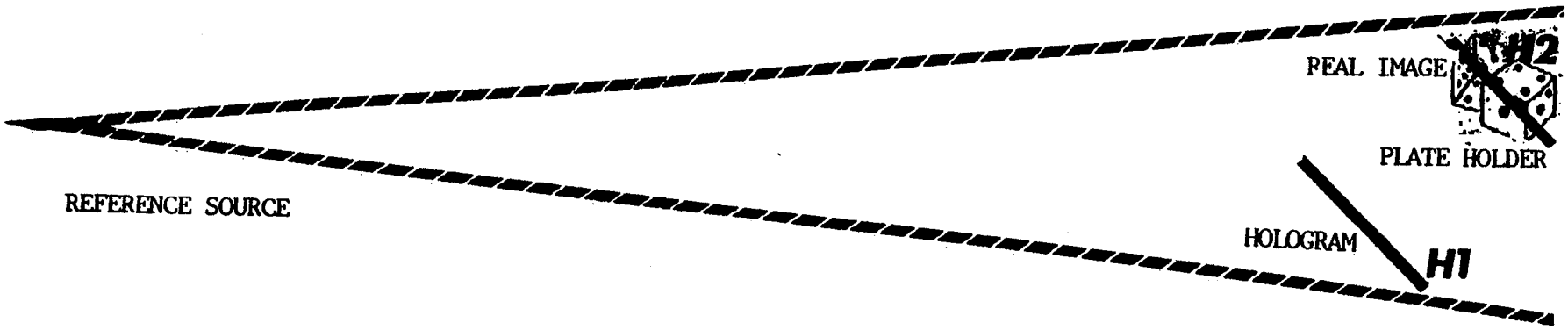
OBJECT POSSIBILITIES: Just about anything that is rigid enough to not move during exposure. May even be larger than the holographic plate.

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.

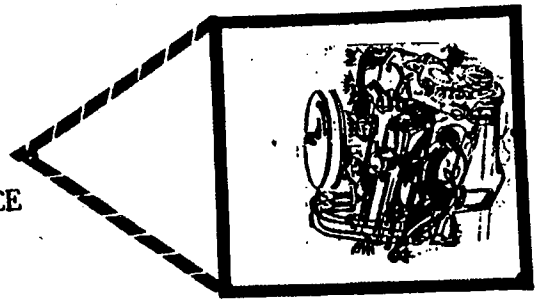
TIPS: Success here depends on master. Longitudinal Chromatic Aberation is controlled by depth of object. Keep object shallow and lashed to the plate. Spherical Aberation is controlled by pinhole to plate distance. Use exact conjugate beams if possible, otherwise the longest possible beam path.

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.

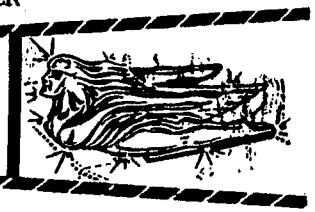
S. T. Hsue, et al., "360° Reflection Holography", American Journal of Physics 44, October 1976, p. 297.

E. A. Bush, "Hologram Cylinders, 4 Meters Long, Display Rare Objects Without Risk", holosphere 7. October 1978, p. 1.

PROJECT 6: Denisyuk Holograms

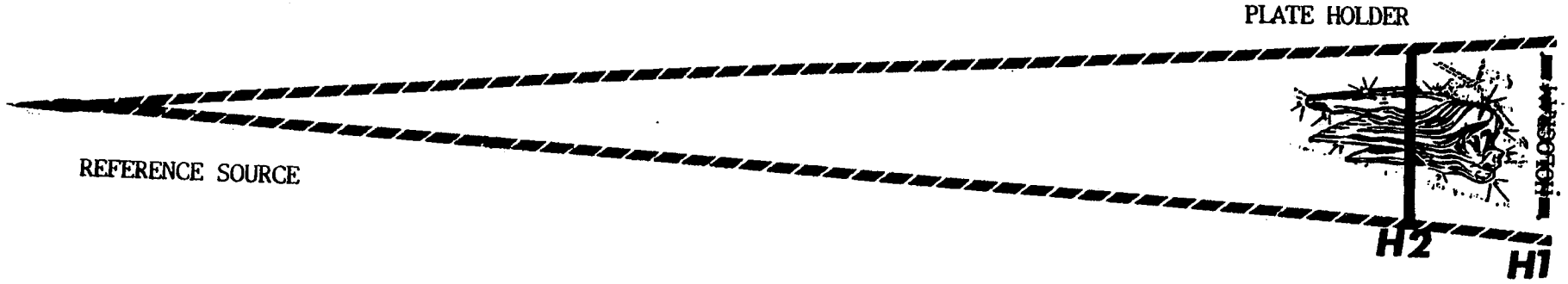
REFERENCE SOURCE

PLATE HOLDER



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



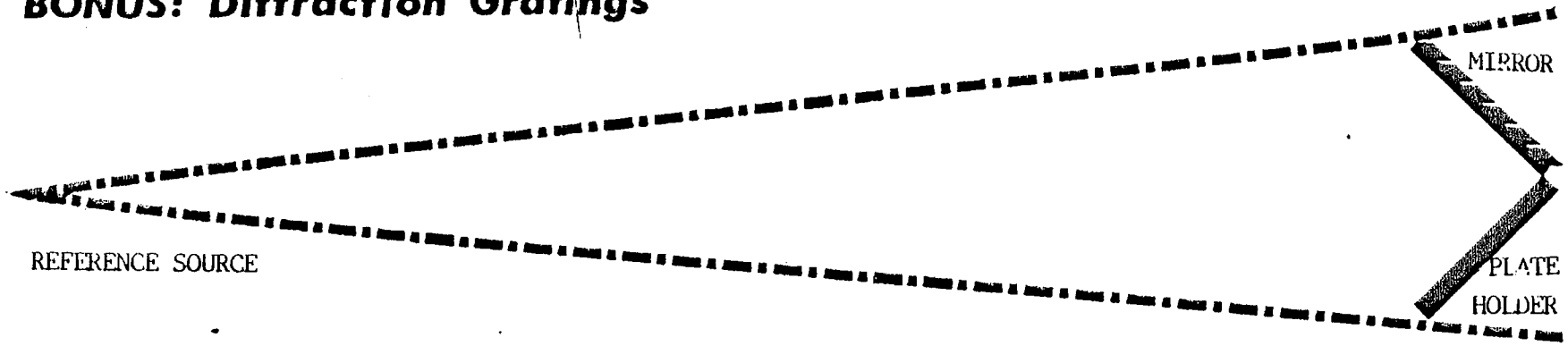
SET UP STEPS: 1)Spread beam wide enough to cover master and copy plates. 2) Reconstruct real image from master made in PROJECT 6. 3) Position copy plate. 4) Settle system and then shoot hologram. 5) Process and reconstruct the hologram in white light.

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).

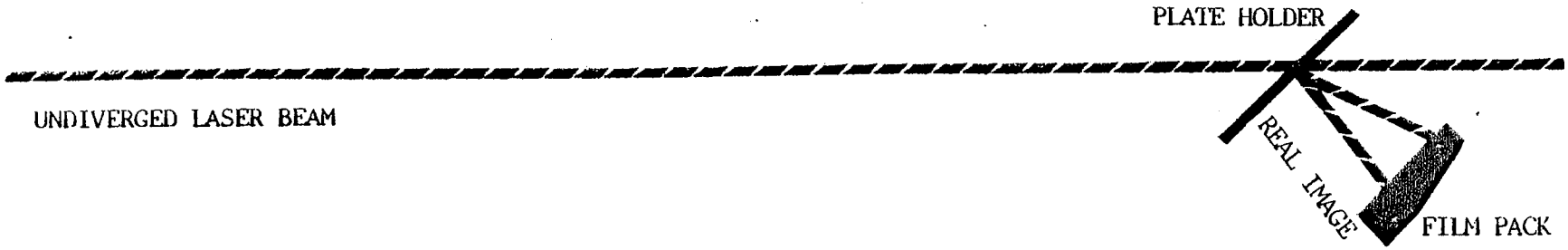
EXAMPLES: Millions of Dichromate Pendants.

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.