HOLOGRAPHY II

Holography II is a class designed to improve techniques acquired in Holography I. The first half of the quarter will stress control over the process in the battle of brightness versus noise. Students will concentrate on various aspects of the holographic process in order to troubleshoot and analyze their own set ups.

The second half of the class will be devoted to the introduction of new concepts such as conjugate and collimated beams, real image and cylindrical holograms and color alteration of reflection holograms. Or during lab periods students may experiment toward aesthetic ends on their own using multiple object beams, top lighting, multi-channeling or designing new methods of recording holograms. The main objective of this class is to encourage students to think holographically.

There will be some homework assignments as well as a final exam, consisting of a written test and a laboratory exercise. There is a lab fee of $25.00 and a film fee of $15.00 for all the film you can shoot in the quarter.

Here are the lesson plans for the ten week session:

I Introduction

II Single beam reflection hologram development tests

III, IV & V Ratio and development test with multiple beam transmission holograms

VI Slide show and discussion of aesthetics and techniques unique to holography

VII, VIII, & IX Complete any unfinished tests or may try new techniques

X Written test and laboratory practical

Please report your absences by telephone so that arrangements can be made to make up the missed work. Be on time, as classes will start promptly at 6:30 p.m. Be prepared for the week's lesson by bringing your notebook, pencils and pens, with one of them being a red one, completed assignments, objects for the night's holograms, and plenty of enthusiasm. You will only get out of this class what you put in. Here's to a successful quarter of Holography II!

CETA HOLO II

1. INTRO DUCTION
2. SBR EXPOSURE + DEVELOPMENT TESTS
3. WORK ON YOUR OWN SBR PRO JECT
4. CONE HOLOGRAMS
5. MBR HOLOGRAMS
6. MOVIES ETC.
7. DIFFRACTION GRATINGS FOR YOUR LASER SCANNER
8. MULTIBLE BEAM TRANSMISSION TESTS
9. MORE OF THE SAME
10. ONE STEP IMAGE PLANE

WH4

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HOLO II - FIRST NIGHT

REVIEW EVERYTHING ABOUT THE PROCESS

- TALK ABOUT THE MATERIALS AND PROCESSING

- NEXT WEEK'S EXPERIMENT

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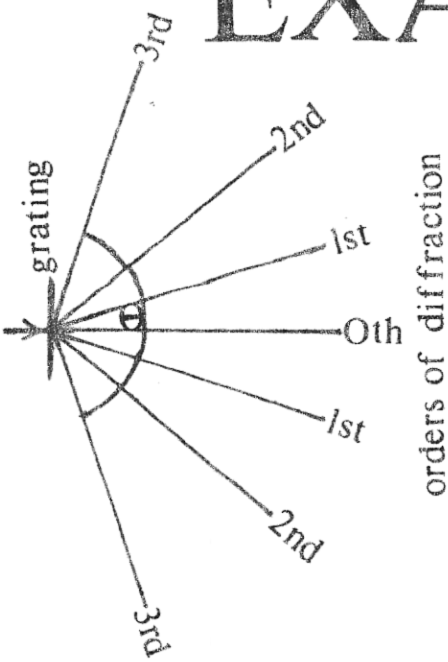
DIFFRACTION EXAMPLES



Light from a He-Ne laser with wavelength of 633 nm encounters a diffraction grating with a spatial frequency of 500 lines/mm. To what angles does the light get diffracted? Spatial frequency of 500 lines/mm = fringe spacing of 1/500 mm = .002 mm = 2 μm = 2000 nm. The diffraction equation is $m\lambda = d \sin\theta$, which changes to $m\lambda/d = \sin\theta$.

For the first order, m = 1, λ= 633 nm, d = 2000 nm

$\sin\theta = 1 \times 633$ nm / 2000 nm = .3165

$\sin\theta = .3165$, $\theta = 18.5°$.

For the second order of diffraction everything is the same except that now m = 2, so

$\sin\theta = 2 \times 633$ nm / 2000 nm = .633

$\sin\theta = .633$, $\theta = 39.3°$.

For the third order, m = 3, so

$\sin\theta = 3 \times 633$ nm / 2000 nm = .9495

$\sin\theta = .9495$, $\theta = 71.7°$.

Fourth order, m = 4,

$\sin\theta = 4 \times 633$ nm / 2000 nm = 1.266. There is no angle with sine greater than 1, so there is no fourth order of diffraction for this grating at this wavelength.

If the fringe spacing, d, were smaller, like 1000 nm, then first order diffraction would have an angle of 39.3°. Second order of diffraction ends up with a sine greater than one, so there is no second order in this instance. Generally for a given wavelength the higher the spatial frequency, which means a smaller fringe spacing, the larger the angle of diffraction.

One method of separating the colors from a multi-line laser is to pass the undifferentiated beam through a diffraction grating. For a Krypton ion laser tuned to these four colors, the dispersion can be predicted by solving the grating equation four times.

Let d = 1000 nm

First order diffraction m = 1

BLUE: λ= 457 nm

$\sin\theta = 1 \times 457$ nm / 1000 nm = .457

$\sin\theta = .457$, $\theta = 27.2°$.

GREEN: λ = 514 nm

$\sin\theta = 1 \times 514$ nm / 1000 nm = .514

$\sin\theta = .514$, $\theta = 30.9°$.

YELLOW: λ = 568 nm

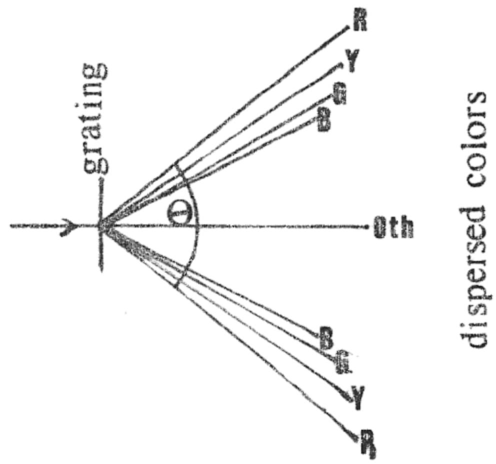
$\sin\theta = 1 \times 568$ nm / 1000 nm = .568

$\sin\theta = .568$, $\theta = 34.6°$.

RED: λ = 647 nm

$\sin\theta = 1 \times 647$ nm / 1000 nm = .647

$\sin\theta = .647$, $\theta = 40.3°$.



The angle of diffraction is dependent not only on the grating spacing, but on the color or wavelength of the light incident on the grating. Short wavelengths, the blues, are bent less than the longer wavelengths, from green to yellow to red. This is called dispersion through a diffraction grating. White light can be broken up into all its components through a grating producing a continuous spectrum.

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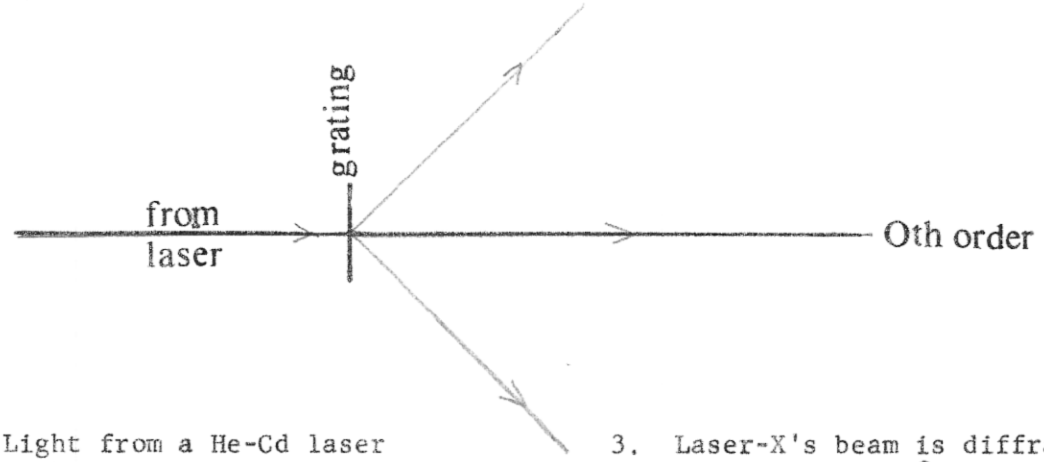
DIFFRACTION PROBLEMS

Use your pocket calculator, protractor, colored pencils and the diffraction grating equation to solve these problems. ($m\lambda = d \sin \Theta$, where m = the number of the order of diffraction, λ = the wavelength of the light, d = the grating spacing, and Θ = the angle between the diffracted light and the normal to the grating.)

1. A pulse of Ruby laser light (694 nm wavelength) falls perpendicularly on a grating with spacing of 1 μm. (Don't forget to change all lengths to the same units!) Find Θ for all the possible orders and draw them.



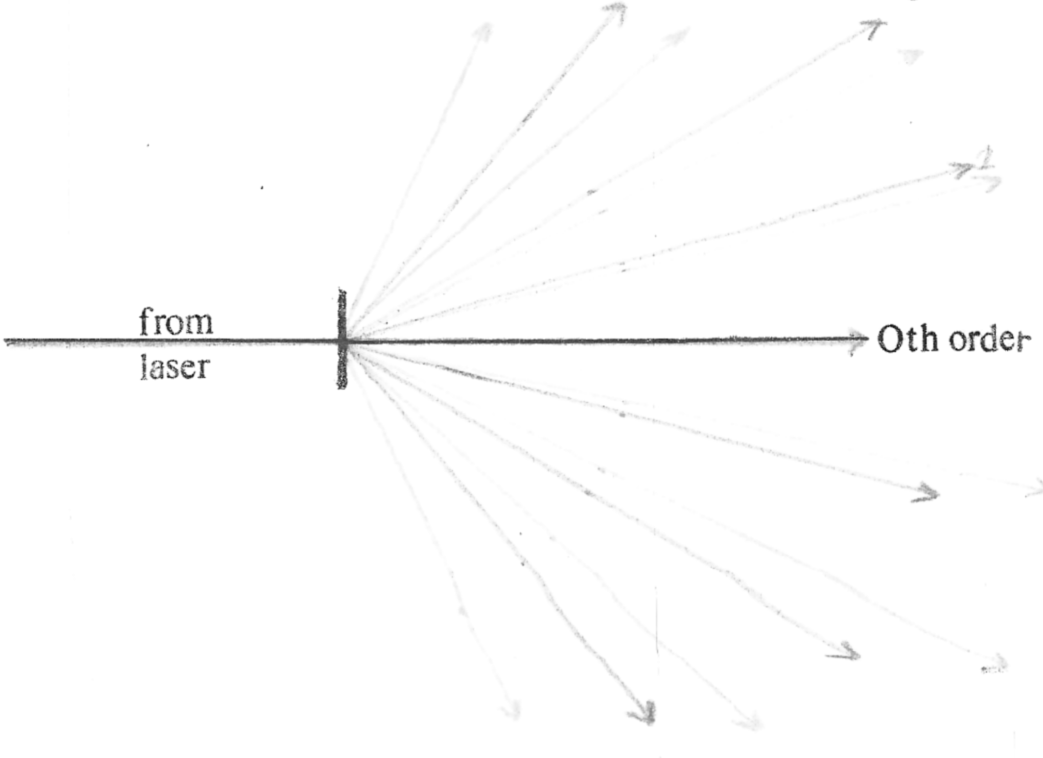
2. Light from a He-Cd laser (λ = 441 nm) is diffracted by an angle of 25° for the first order. What is the grating spacing d?

1043.5 nm

3. Laser-X's beam is diffracted through an angle of 45.7° through the grating in problem 1 for its second order. What is its wavelength?

357.8 nm

4. A light show wishes to separate the blue 458 nm line and the green 514 nm line from their Argon ion laser. For a grating whose spacing is 2000 nm, draw all the orders of diffraction for these two wavelengths.



CALCULATIONS FOR D. PROBLEMS


$$m\lambda = d \sin\theta$$

$$1 \times 694 = 1000 \times \sin\theta$$

$$.694 = \sin\theta$$

$$\theta = 43.94 \approx 44^\circ$$

$$m\lambda = d \sin\theta$$

$$1 \times 441 = d \times \sin 25^\circ$$

$$m\lambda = d \sin\theta$$

$$2 \times \lambda = 1000 \times \sin 45.7^\circ$$

$$m\lambda = d \sin\theta$$

$$1 \times 458 = 2000 \times \sin\theta$$

$$1 \times 514 = 2000 \times \sin\theta$$

13.23
27.26
43.39
66.35

GREEN

14.89
30.93
50.44

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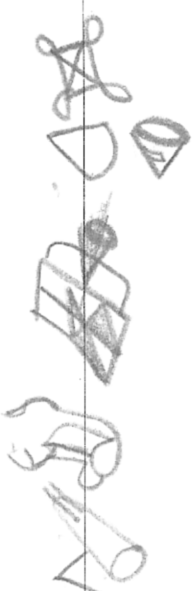
HOLO II #2

COVER ANY QUESTIONS
EXPLAIN NEXT WEEK'S EXPERIMENTS
BRIEFLY

SEND THEM UP

LAY OUT TWO LINES FOR PROCESSING
TO PREVENT CROWDING



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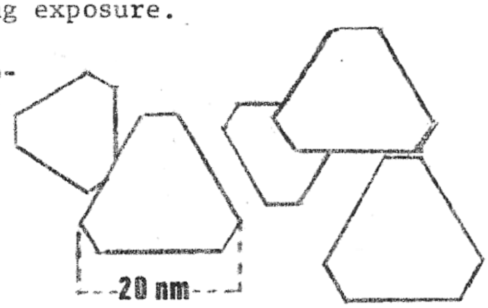
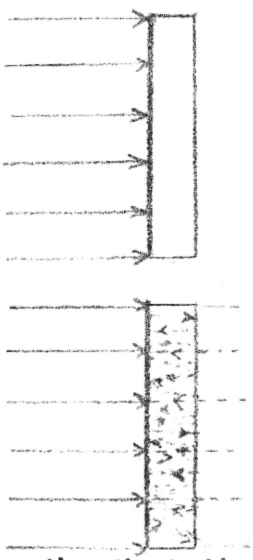
PHYSICAL STRUCTURE

The light sensitive particles are suspended in a gelatin environment, hence the term emulsion. For holography films, this emulsion is between 5 and 15 microns thick, coated ither on an acetate film support or on a glass plate. The film support is less than half a millimeter thick while glass plates are about one to two millimeters thick. The emulsion accounts for only one hundredth of the total thickness of the glass plate. The glass is dimensionally stable, but the film must be sandwiched between plates of glass to hold it in place and to prevent it from curling during exposure.



Inside the emulsion are the tiny, light sensitive silver halide crystals. They range in size from 20 nanometers to 50 nanometers and this classifies them as having a micro-fine grain structure. The crystals are composed of many millions of positive silver ions and negative ions of either bromine or chlorine in a hexagonal lattice. When light hits these crystals, a few (like one in 10 or 100 million) of the silver ions are changed into metallic silver. These crystals are now ready to be developed and they carry the latent image. A problem with these micro-fine grained materials is that they "forget" their latent image with time. For instance, Kodak Holographic Plate SO-120 loses 20% of its latent image to decay if developing is postponed for an hour. This is typical of all present day holographic materials.

Other junk inside the emulsion are sensitizing dyes. Some of these dyes increase the sensitivity of the silverhalides to light in general, while others increase the sensitivity to specific colors of light. Kodak High Speed Holographic Film SO-253 has a nasty blue dye dispersed throughout its emulsion that must be removed during processing in a methanol bath but gives the film its unusually high sensitivity.



notice the inside scatter

Another type of dye put into the emulsion or more precisely, behind it, is the antihalation backing. This backing prevents light from scattering off the support material or the film holder back into the emulsion, fogging and ruining the interference pattern. For reflection holograms, the film cannot have the antihalation backing because the reference and object beams are coming from opposite sides of the film. So there is usually a choice between backed materials, (antihalation or AH for short), or unbacked (non-antihalation or NAH).

All these elements of the film or plate are very fragile. High humidity or temperature can ruin the light sensitive particles and can cause overall fog on the film. The crystals lose their sensitivity to light over time; that is why there is an expiration date on the package to ensure that the materials are used while they are still fresh and active. The gelatin emulsion can soften and fall off the support in hot water. The film support is either acetate or Estar, a propetary polyester from Kodak, which is rather durable. But glass can easily break, and even though the holographic information is all over the plate, it is better to keep it all in one piece. Holograms should be stored in a cool dry place, preferably covered and framed or just overmatted. Silver, being a precious metal is often subject to major fluctuations in market value and the films and plates then follow suit. Possible replacements for this technology are being investigated right now; perhaps in the future silver halide plates will be to holography as the daguerreotype is to photography.

FILM SPEED

Some light-sensitive materials need more light to hit them than others to do their job. An emulsion that requires very little light to darken it has a high speed or is called fast, while the ones that need more light are described as slow or having low speed. Generally there is a trade-off between resolving power and film speed. Higher speed means larger clumps of silver halide crystals in the emulsion which are more readily activated by the light, but because of their size there is a loss of fine details, as evidenced in grainy photographs. Smaller silver halide crystals give finer detail but need more exposure to light. The micro-fine grained materials necessary for holography are notoriously slow; they require a lot of energy to make the tiny silver halide crystals developable.

Photographic film is assigned a number on a relative scale of sensitivity designed by the International Standards Organization (ISO). In this system, higher numbers denote greater sensitivity, lower numbers mean less sensitivity to light. A film with an ISO speed number of 100 is twice as fast as a 50 speed film, and would require half the amount of exposure of the latter since it's twice as sensitive. Light meters are calibrated with this scale and make exposure calculations easy and convenient.

But holographers don't have it so easy -- their emulsions are so slow compared to camera film that ISO numbers do not apply. Instead their exposure requirements are given in ergs/cm^2. An erg is a measure of energy, and the cm^2 in the denominator refers to the area in square centimeters upon which the energy is distributed. A lower number means the film requires less energy to produce the reqired change in density and therefore less exposure. A lower number denotes a faster material; higher numbers mean low speed.

By knowing the energy required to produce a certain density on a material, relative sensitivities of emulsions can be deduced as well as calculating exposures. Here is a chart of the relative speeds and resolving powers of some products used in holography. Note the trend as speed increases, resolving power diminishes.

FILM DATA

EMULSION (↑ higher speed)	SENSITIVITY to He-Ne Laser (ergs/mm^2)	RESOLVING POWER (lines/mm) (finer resolution ↓)
Kodak SO-253/131	5	1250
Agfa 10E75	20	1500
Agfa 8E75	75	2000+[1]
Kodak SO-173/120	400	2000+[1]
Kodak 649-F	900	2000+[1]
Russian Plates	?	10000 (claimed)

This data was compiled from the Newport Research Catalog, 1978-1979 and Kodak Pamphlet P-110. Processing can change speed and resolving power. [1]Classical means of determining resolving power fail at these levels. Reflection holograms can be made on these materials.

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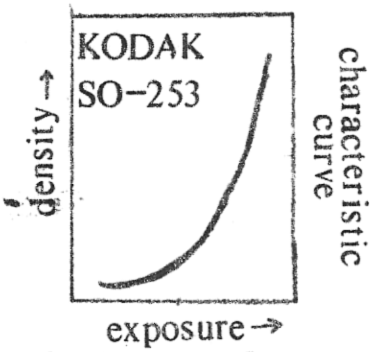
DENSITY

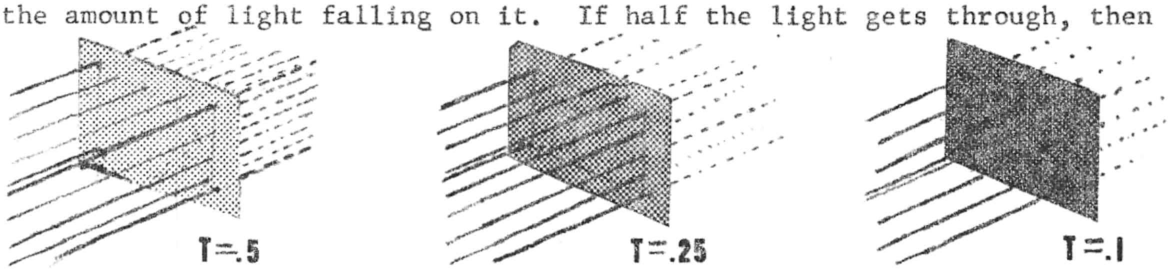
Density is a term used to measure how dark a transparent object is. The lower the number, the lighter and more transmissive the object is, and the higher the number the darker it is. The system is logarithmic; density of 2.0 is not twice as dark as 1.0 but ten times as dark. This scale is used because it is convenient in graphing the relationship of exposure to developed darkness in the characteristic curve of a silver halide based photosensitive material.



The most important idea to know about density is when to use it. Holograms are developed to match different densities for different applications, like usually .8 density for transmission, 1.0 or 2.0 for reflection holograms. Using a standardized calibrated step wedge for comparison will help when developing holograms by inspection.

Density is defined as the logarithm of opacity which is the inverse of transmission. Don't panic -- here are the terms one step at a time.

TRANSMISSION is the ratio of light that passes through an object to the to the amount of light falling on it. If half the light gets through, then the



transmission is ½ or .5 or 50%. If one fourth the incident light gets through, then transmission = ¼ = .25 = 25%; one tenth of the light passing through gives transmission of 1/10 = .1 = 10%.

OPACITY is the inverse or reciprocal of the transmission. Transmission of 50% or ½ means opacity of 2, while transmission of 10% or 1/10 would equal an opacity of 10.

DENSITY takes the opacity number and changes it to a logarithm of base 10. An opacity of 10, (which was a transmission of 1/10), changed to density is $\log_{10}10 = 1.0$. A transmission of only 1% or 1/100 is opacity of 100 which then becomes density of 2.0 because $\log_{10}100 = 2.0$.

To change a transmission of 25% to a density on a pocket calculator you would first enter .25, push the inverse button, 1/x, to get the opacity, (display will show 4), then punch the log x key. You should get the density of .60205999 which rounds to .6. Try completing this table.

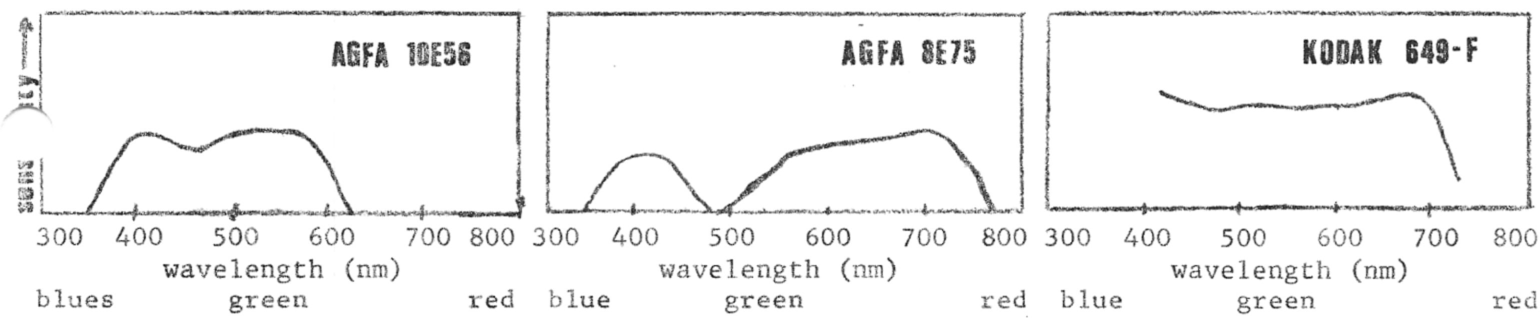
TRANSMISSION	OPACITY	DENSITY
.1	10	1
.3	3.$\overline{3}$	.52
.5	2	.3
.125	8	.9
100%	1	0

SPECTRAL SENSITIVITY

A problem with silver-based technology since the days of early photography has been that the materials are inherently more sensitive to the higher frequencies of light (the short wavelengths in the blue end of the spectrum) because they carry the most energy. Blues and whites would photograph fine, but the greens and reds would come out relatively darker because the material was not responding to those colors. In the latter part of the nineteenth century, the discovery of introducing dyes into the emulsion which made the halides sensitive to green and red paved the way not only for black and white photographs with the colors in their natural tonal relationships, but also color photography as well as holography by Helium-Neon Laser.

Choosing a material for holography depends on its sensitivity to the color of the laser that is being used. Consulting a spectral sensitivity curve for the material in question will help make this decision as this is a graph of the relative sensitivity of the material to the different wavelengths. The vertical axis represents

SPECTRAL SENSITIVITY CURVES



relative sensitivity, the horizontal axis depicts the colors of the spectrum by wavelength. From looking at the above curves, the 10E56 emulsion is sensitive to blue and green light only, and is not suitable for making holograms with red lasers, but it can be handled under red safelights. 8E75 lacks green sensitivity, so a green safelight is used. This film was designed for holography with Helium-Neon and Ruby lasers. The Kodak Spectroscopic Plate 649-F is panchromatic -- it is sensitive to light of all colors. This material is extremely fine grained and was used in recording the earliest holograms of Leith and Upatnieks. Its slow speed makes its use prohibitive with small lasers but with its panchromatic sensitivity it can be used for recording full-color holograms.

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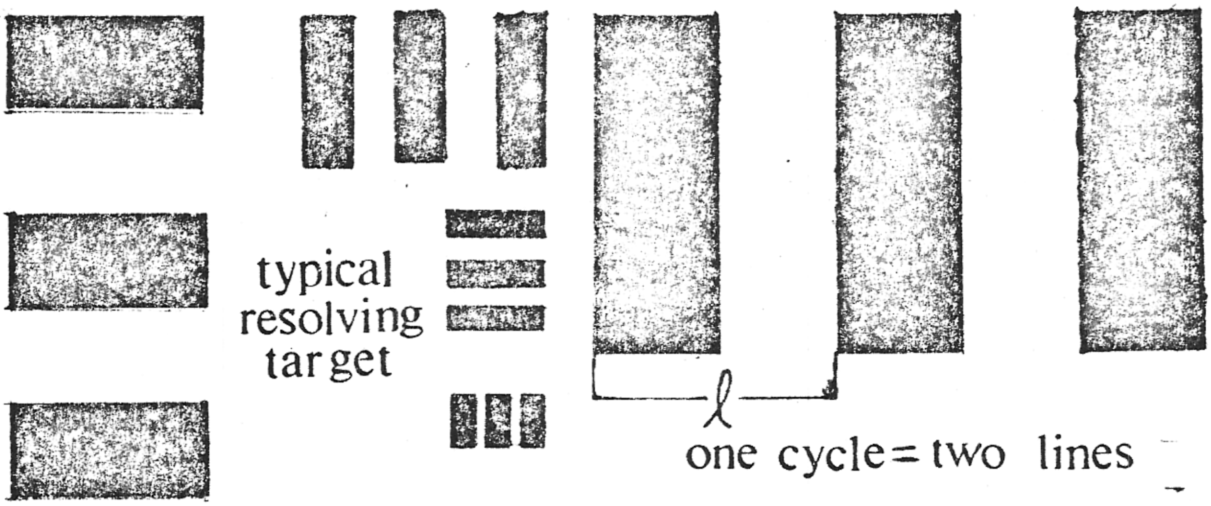
RESOLVING POWER



How fine a detail a photosensitive emulsion can discern is quantified in its resolving power. A test target is photographed through a lens of known resolving power, and the emulsion is developed under stringently controlled conditions. This target is composed of cycles of alternating light and dark bands. When a film reaches the limit of its resolution, then the light and dark bands are not differentiated but blend into a blob. If ℓ is the smallest distance between a cycle of a light and a dark band, then the resolving power, r is given by:

$$r = 1/\ell \text{ lines per mm}$$

For instance, if the smallest spacing observed in the emulsion under a microscope was .02 mm, its resolving power is 1 / .02 = 50 cycles per mm. Since one cycle = 2 lines if the dark and light spaces are equal in size, then the resolving power would be 100 in the more familiar lines per mm. Notice that resolving power is an application of spatial frequency.

What we are capturing on the holographic film are patterns of bright and dark fringes. The range of resolving powers necessary to make holograms start at less than 100 line/mm for diffraction made with red laser light with a small angular separation to over 4000 lines/mm for a reflection hologram made with blue light. Typical camera films resolve at best 200 lines/mm for a fine grain emulsion like Kodak Panatomic-X. Holography films belong to the family of micro-fine grained emulsions.

The classical test for resolving power fails at the high spatial frequencies necessary for holographic recording. Manufacturers of these films will publish statements of estimated resolving powers or will say the film is capable of making reflection holograms with certain colors of laser light.

See the FILM SPEED sheet for a listing of comparative resolving powers for typical holographic emulsions.

9/20/88
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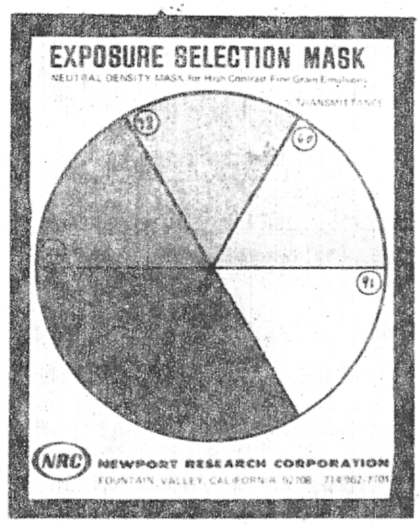
EXPOSURE AND DEVELOPMENT TESTS

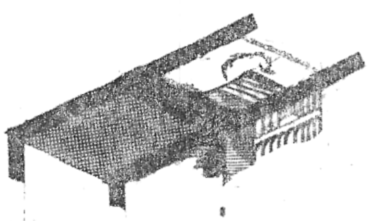
The density of a hologram is controlled by the development and exposure of the film. More exposure and less development can produce the same density as less exposure and prolonged development. But the quality of the hologram will not necessarily be the same in both cases. This test is designed to find the right combination to produce the brightest and least noisy hologram. It can be used with any silver halide material or applied to many other recording materials.

Make the set up and adjust the reference beam to a smooth, even spot. Put the film in the center of the holder and expose four different quadrants. Use the attenuator card and expose each quadrant twice as long as the previous. If you have an exposure mask like the one illustrated on the right, you may do this in one shot. Sandwich the mask in with the film between the pieces of glass in the holder.

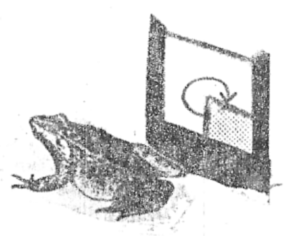


For single beam reflection and transmission holograms or a multiple-beam transmission hologram, all that is necessary is a single attenuator or mask on the reference side of the film. For multiple-beam reflection holograms, two paired attenuators or masks are required, one on the reference side, the other on the object side, as shown in the illustrations below.

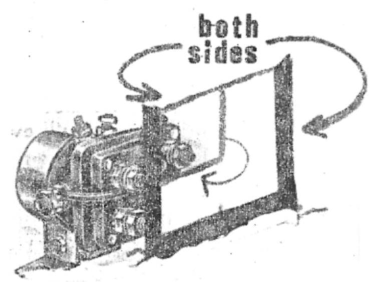
Single Beam Reflection



Multiple Beam Transmission



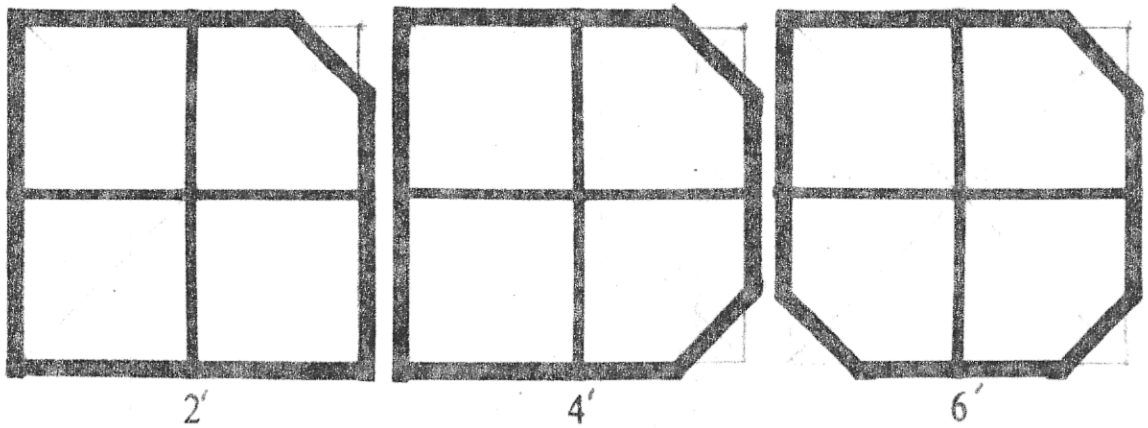
Multiple Beam Reflection



Shoot as many holograms as there will be different development times. Make sure you mark the hologram to distinguish the different processing times.. See the top of the next page for an example.

7/25/80

EACH QUADRANT IS A DIFFERENT EXPOSURE TIME



CUT CORNERS DENOTE THE DIFFERENT DEVELOPMENT TIMES

When the processing is done, compare the holograms side by side. Choose the best test results and expose a complete hologram based on them.

The choice of initial trial exposure and development times may sometimes be a matter of best guess. The manufacturers will recommend certain developing times. You may start there and hold the development constant, and try to zero in on the exposure time. Expose a hologram, using the test method previously described. If the first test strip doesn't darken much at this particular development time, make another test strip at longer times. Or if the film gets too dense, then try another series at shorter times. If there is no manufacturer's recommended developing time, or if the developer is home made, you'll have to rely on intuition. But systematically fine tune to the best development time. No piece of film is wasted if you learn something! Making clear records and notes is a necessity!

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2-M

Which exposure produced the brightest image on each test strip?___

____

Is it the same exposure on each strip?________________________

Which exposure produced the noisiest image on each test strip?

____________________How does the noise level relate to the brightness?____

Which developing time produced the brightest hologram for a given exposure time? ______________________________________

Which developing time produced the noisiest hologram for a given exposure time?____

Which combination of exposure and development times gave the brightest hologram of all?____________________the Noisiest hologram of them all?_______________________________________

Out of all those combinations, which one gave the best compromise between brightness and noise?____________________________

Describe the effect that development has on both brightness and noise.____

Describe the effect of exposure on both brightness and noise._____

____

On the back of this page, explain why you think this happens.

(If different bleaches are used) Compare the brightness and noise levels of the bleaches.______________________________________

____________________Is there a significant difference?____________

(If unbleached holograms are made) Compare the exposure time of the best bleached hologram to that of the best unbleached hologram.____

Is the noise level the same for bleached and unbleached holograms?

____________________How do you account for this?__________________

____

10/2/80
(ω)

SBR exposure and development tests

Label some glassine envelopes with the following information: (One hologram per envelope.)

FOR THIS CLASS:

THE DEVELOPER(S) WILL BE: ____________

THE DEVELOPMENT TIMES WILL BE: ________

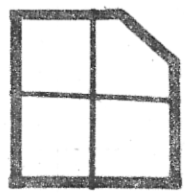
____

THE BLEACH(ES) WILL BE: ______________

____

DEVELOPER D. TIME

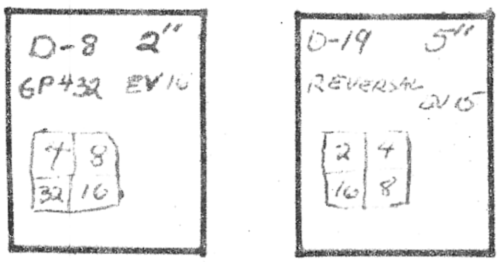
BLEACH EV #



PLACE EXPOSURE TIME IN EACH QUADRANT

DENOTE HOW MANY CORNERS ARE CUT OFF

EXAMPLES



Make a typical Single Beam Reflection hologram set up, either overhead or head on. Use an object that is fairly homogenous over the area of the film plane. Record the light intensity at the film plane.

Expose as many test strips as there will be different development times. Process and compare. Then answer the questions on the following page.

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Which exposure produced the brightest image on each test strip?

____

Is it the same exposure on each strip?____________________________

Which developing time produced the brightest hologram for a given exposure time?____

Which combination of exposure and development times gave the brightest hologram of all?____

What do you think is the trend?____________________________________

(If different bleaches are used) Which bleach gave the brightest image?____

Does the same exposure and development give the same result with the different bleaches?____

(If unbleached holograms are also made) Compare the exposure time of the best bleached hologram to that of the best unbleached hologram.____

What color is the unbleached hologram?____________________________

How do you account for this?______________________________________

____

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cw

BLEACHING

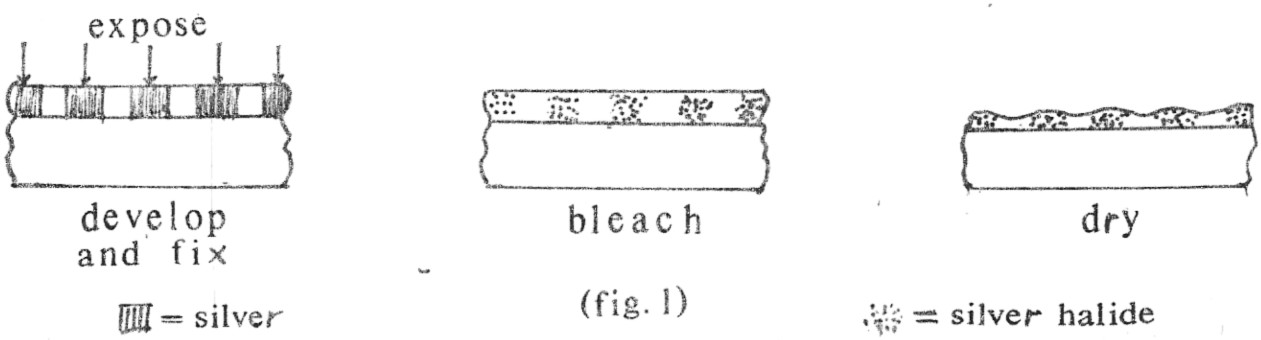
Photography uses the light and dark silver deposits on black and white prints or slides to tell us information about the amplitude of the light reflected from the subject. When holographers use silver halide materials they are not interested in recreating the amplitude variations (lightness and darkness) of the subject but in recreating the phase differences in the wavefront that came from it. Tonal variations in the hologram are a by-product of the phase information.

Silver halide materials are negative-acting; where more light hits them more silver is developed and the area is darker. Where less light reaches the material less silver is formed. Therefore an <u>absorption</u> hologram's fringes are dark where there was constructive interference and lighter where there was destructive interference in the recording process. In reconstruction the reference beam's light is diffracted through the gaps between the dark fringes into a zeroeth order and the object wavefront bearing first order. Much of the light incident on the hologram is absorbed by the dark silver deposits. This attenuation wastes light that could otherwise be used for a brighter image.

A method of increasing holographic image brightness is to change an absorption hologram into a phase hologram by bleaching. The bleach makes the hologram transparent so that more light will pass through, gaining diffraction efficiency and brightness. It retains its ability to modulate the phase differences into the beam by passing the light through areas with different indices of refraction which bend the light into the reconstructed wavefront by alternately slowing it down and speeding it up. Typically the substances that introduce these changes are the gelatin of the emulsion with a low index of refraction and a silver halide, either silver bromide (AgBr), or silver iodide (AgI) with their relatively higher indices of refraction. Bleached holograms must be exposed more to deposit the maximum amount of silver for the maximum index change.

REHALOGENATION

This type of bleach typically takes an absorption hologram that has been fixed and washed and changes the developed out silver crystals back into silver halides. It may take the form of a bath that contains potassium bromide or iodide which donates its halide to the silver crystal making it once again transparent silver halide. Some form of activating agent like potassium ferricyanide or ferric nitrate is added to start the reaction. Bromine, either as a vapor or dissolved in a liquid like water or methanol does a fine job of rehalogenating with the added bonus of added stability from printout.

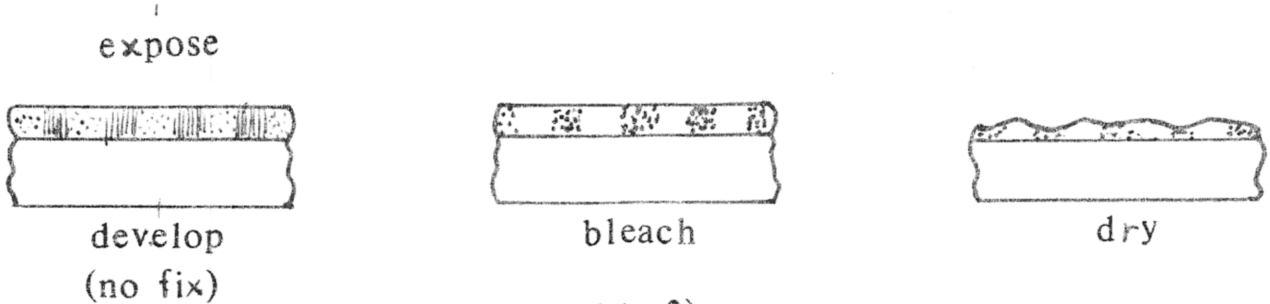


(fig. 1)

REVERSAL

These types of bleaches were originally designed for producing positive images on black and white photographic film. They also work well in producing low-noise phase holograms.

A developed and stoped but unfixed hologram is placed in the bleach which eats away the developed silver, leaving a residue of the unexposed and undeveloped silver halide. The areas of constructive interference are then represented by the gelatin, and the destructive interference by the left over silver halide. This is the reverse of the previous type of bleach, where the constructive interference is represented by the rehalogenated silver and the unexposed silver halides of the destructive interference where washed away in the fixer. The reconstruction mechanism is the same for both these types of bleaches, as the light passes through varying indices of refraction dispersed throughout the hologram. The reversal bleaches may be used either for transmission or reflection holograms.



(fig.2)

These bleaches either contain potassium dichromate or p-Benzoquinone (PBQ) to remove the silver. The PBQ bleaches also effect changes in the hardness of the gelatin to improve diffraction efficiency.

INTENSIFIERS

These bleaches do not produce phase holograms but are typically used in reflection holography. The mercuric chloride bleach rehalogenates the developed and fixed silver emulsion, and then it is "redeveloped" to plate out silver with mercury attached to it for high reflectivity. This bleach usually shrinks the emulsion, reducing the size of the fringe spacing and changing the color of reflection holograms recorded with red light to green. It's losing its popularity because the mercuric chloride is very poisonous and expensive, and the image is not very stable.

NOISE

Development brings surface relief to the emulsion by its tanning action. As the exposed silver halide is developed, the grain expands and so does the gelatin surrounding it. The gelatin gets hardened in these areas. The fixer takes out the remaining undeveloped silver halides, causing the gelatin to collapse in the undeveloped areas. This surface relief causes Optical Path Variations (OPV) and where light travels through a longer path through the gelatin, it can get refracted from the signal, causing noise.

In the rehalogenating bleaches, the areas of high index of refraction are also the areas of high surface relief, augmenting the low spatial frequency noise. (See fig. 1.) On the other hand, the reversal bleach takes out the silver in the high relief areas, leaving the gelatin in its hardened shape. The undeveloped silver halide is left in the low relief areas. (See fig. 2.) This tends to balance the index changes with the OPVs, minimizing the noise.

The choice of bleach depends on the intended use of the hologram, whether reflection or transmission, and the material being used. Kodak films don't respond well to Potassium Ferricyanide, but they recommend reversal bleaches. GP 432 bleach was designed for Agfa HD plates, and works well with others. Some bleaches are brighter but noisier than others. Personal preference comes into play here.

For successful bleaching, follow the recommended procedures and then fine-tune the process by trial and error to optimize the quality of the holograms. Bleaching technology is changing all the time; communication with other holographers will keep you abreast of the latest improvements.

8/26/

BLEACHES

rehalogenating

FERRICYANIDE BLEACH (FCN)
1 liter Water
30 g Potassium Bromide
30 g Potassium Ferricyanide

FERRIC NITRATE BLEACH (GP 431)
600 cc Water
30 g Potassium Bromide
300 mg Phenosafranine in 200 cc of Methanol (optional)
Water to make one liter.
Dilute 1 part bleach with 4 parts water to make working solution.

BROMINE WATER (VERY DANGEROUS!!!)
Dissolve several drops of Bromine in a liter of water. Let stand overnight to disperse. Immerse hologram in liquid until clear. Keep container covered to contain fumes.

reversal

1 liter Water
2 g Potassium Dichromate
30 g Potassium Bromide
2 cc Sulphuric Acid

KODAK R-9 BLEACH
1 liter Water
9.5 g Potassium Dichromate
12 cc Sulphuric Acid

GP 432 BLEACH
700 cc Water
50 g Potassium Bromide
1.5 g Boric Acid
Water to make 1 liter
2 g of p-benzoquinone should be added just before use.

intensifier

MERCURIC CHLORIDE BLEACH (EXTREMELY TOXIC!!!)
20 g Mercuric Chloride
20 g Potassium Bromide
1 liter Water
Bleach until clear, then "redevelop" in Kodak Rapid-Fix.

Distilled or de-ionized water is recommended for all these bleaches, although not essential. Bleach the hologram until clear, then wash it 5 - 10 minutes in running water, Photo-Flo and dry.

10/14/80
EW