DEPARTMENT OF PHYSICS

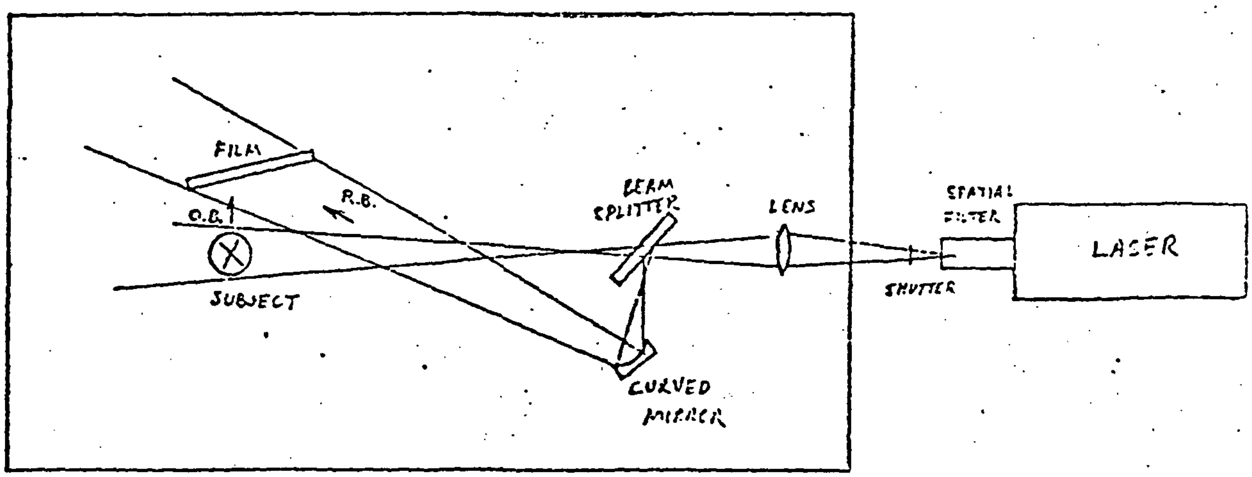
PHYSICS 131A - WINTER 1983
HOLOGRAPHY MANUAL

INTRODUCTION

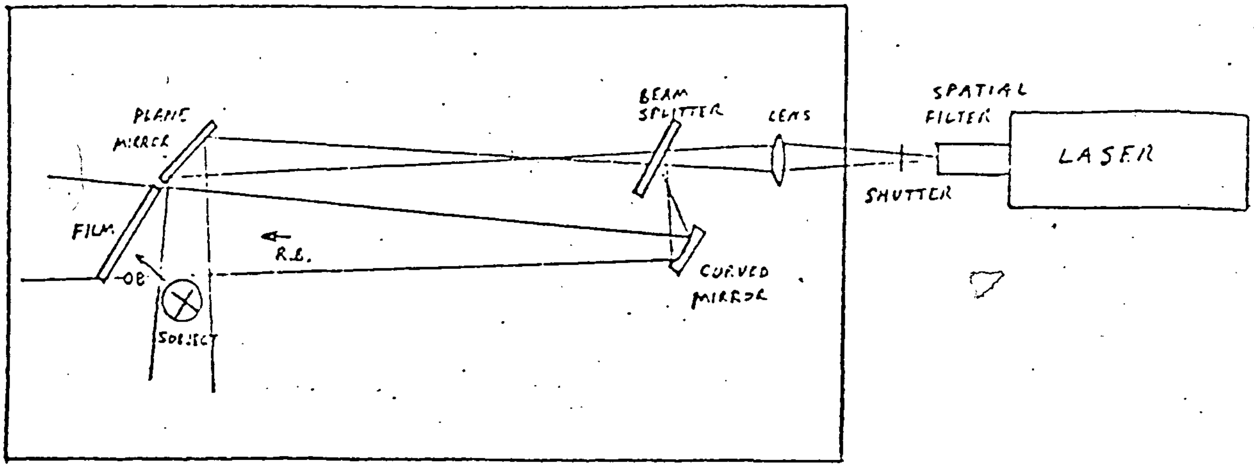
This manual is designed to serve as a basic guide in the holography laboratory. It is by no means complete, nor is it intended to be. Much room is left for individual experimentation, and a bit of imagination is necessary for interesting holograms. Please read this entire manual before starting, and adhere carefully to the remarks concerning the care of the equipment.

SETUP

Refer to the first two drawings. Light from the laser is first spatially filtered (mounted on the laser) and then split into two beams. One beam illuminates the subject, the other is diverged and uniformly illuminates the film plane (reference beam). Light reflected from the subject (object beam) interferes with the reference beam and turns the film into a highly complex diffraction grating - a hologram.



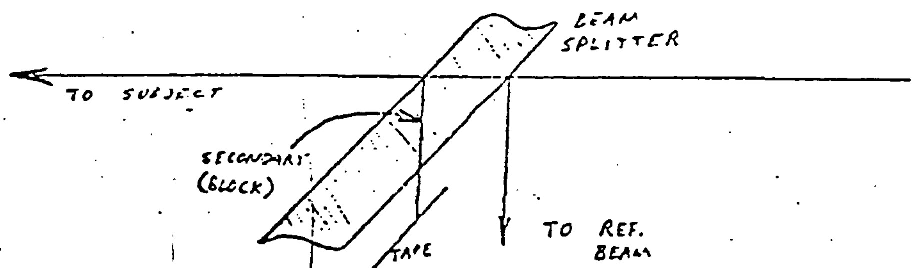
Setup #1



Setup #2

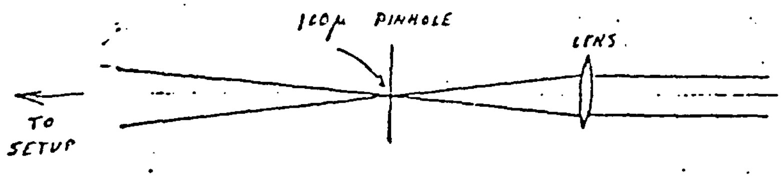
While the second setup requires one more mirror, it has the advantage that the subject is illuminated from nearly behind the film plane.

Two beam splitters are available, a wedge type (uncoated), and a plane-parallel 50-50 splitter. Since the 50-50 splitter has parallel surfaces, it produces a secondary beam off the back surface which, when combined with the primary reflection, sets up a troublesome interference pattern in the reference beam. The lens and masking tape serve to spatially separate and block the secondary reflection:



The wedge splitter does not have this problem.

The spatial filter is a device which cleans up the laser beam. It consists of a lens which focuses the beam down to a 100 micron hole; NOISE in the beam will focus at a different point, thereby being blocked out:



Should the emerging beam be anything but round, play with the micrometer positioning screws. These provide X-Y adjustment for the pinhole. Do not attempt to adjust the lens.

STABILITY

Movements of the optics by $\frac{1}{4}$ wavelength (about 1500 Å) will destroy a hologram, so stability is critical. The massive, foam mounted concrete table provides a vibrationless, hard surface to work on. All optics, the subject, and film must be reliably mounted. Don't use masking tape, rubber cement, wood, gum, etc. These tend to creep during exposure. Even conventional adjustable lens holders are marginal. Also, stay away from plastics and plexiglass.

The subject must be equally stable. Where a cubic arrangement of resistors will reliably stand still resting on three resistor leads, a chesspiece with a felt bottom will not.

Try setting up a Michelson interferometer and observing the interference pattern. There should be no appreciable fringe shift over a 30 second interval. Stamp on the floor, shout, touch the table, wave your arms over it. Get an idea how sensitive it is to vibrations, air currents, etc.

The laser need not be mounted on the table, as long as it's reasonably stable. (Why?)

TAKING AN EXPOSURE

Arrange a setup, either as already suggested, or come up with something yourself. The reference beam should uniformly cover the film plane. The back side of the film holder has a white screen on it for this purpose. For best 3-D effect, position the subject as close to the film as possible without casting a shadow in the reference beam. (usually 3" to 5"). Make sure the subject is fully illuminated. Now, carefully remove the film holder from its stand and slide the photometer into the film plane.

There are two quantities to find, the beam ratio and total intensity. The beam ratio is the ratio of reference to object beam intensities (expressed as RB:OB) which is obtained by alternately blocking each beam. Anything from 1:1 to 10:1 will work; optimum seems to be around 2:1 to 5:1. The total intensity determines the length of exposure. This film requires about ~~600~~ 4 ergs/cm^2 for a normal exposure, or equivalently, ~~60~~ .4 μW/cm^2 - sec. The meter is calibrated in μW/cm^2. To find the exposure time, divide ~~60~~ .4 by the intensity in μW/cm^2. Ex.: If I= 0.5 μW/cm^2, then $T = \frac{\cancel{60}\ .4}{.5} = \cancel{120}\ .8$ sec. The exposure value is not too critical; anything from ~~200~~ 2 to ~~1000~~ 8 ergs/cm^2 will work to varying degrees, but ~~600~~ 4 seems optimum.

Kodak High Speed Holographic Film

An exposure can now be taken. Shutter the laser, set the exposure time, and turn out the lights. Remove one sheet of film from the box, close up the box, and load the film holder. With the notch in the upper left-hand corner, the emulsion is towards you. Carefully put the holder back in its stand. Sit back a minute to let vibrations and air currents die down, then expose the film.

DEVELOPING

Developing is done in total darkness. Load the film into a developing holder, and using the timer, develope as follows:

1. 7 min. @ 20°C in D-19 developer, agitate continuously
2. 30 sec. stop bath
3. 3 min. rapid fixer (agitate)

4. Wash in running water 5 min.

5. Photo-flo 30 sec.

6. air dry

Drying can be speeded by using a hair dryer, but let the film drain for at least 60 sec. before application of warm air.

The developed sheet should be rather light, uniform, perhaps with a few spots and swirls here and there. The lines which form the hologram are of course invisible. If the sheet is totally clear (bluish actually), then you've probably loaded the film backwards.

Developing times are not too critical. The temperature of the D-19 will normally sit at 20 - 21°C, so don't worry about it.

Take care not to contaminate the chemicals. If you do, don't panic, and don't blow it for others. Tell the T.A., and he'll mix some more. Also, keep the lid on the D-19 tank when not in use. The developer oxidizes.

VIEWING

Diverge the laser beam, and let it fall on the film at the same angle as the origional reference beam. Make sure the emulsion is away from you, and that the film is not upside down. With any luck, you've got a hologram.

CARE FOR OPTICS

It's essential to keep all optical surfaces clean and dust free. Nothing is more frustrating than seeing someone's grimy pawprint on a lens or mirror. It not only introduces noise, but skin oils are very corrosive to optical surfaces.

Take care not to touch the film surface either. The heat from your fingers causes the film to warp, and as it regains thermal equilibrium, it moves.

TROUBLESHOOTING

1. No app\arent exposure

    Film loaded backwards

    Incorrect photometer reading

    Incorrect developing

2. Exposure fine, no hologram

    Something's moved - tighten all stands, check subject stability

    Beam ratio way off

3. Good hologram in spots, blank in others

    Film moved - allow more time for film to stabilize, don't touch film

4. Hologram very dim

    Beam ratio off (generally too large)

    Exposure time incorrect

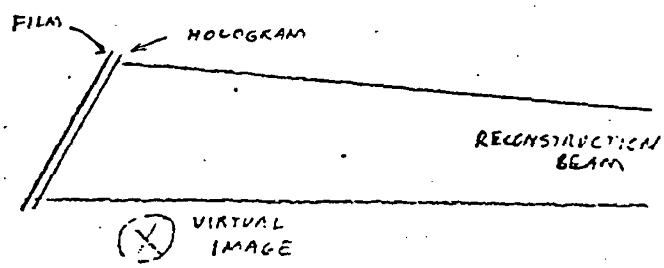
A FEW IDEAS

It's possible to produce more than one hologram on a single piece of film by varying the angle of the reference beam. Suppose two subjects are to be holographed. Go through the usual procedure for subject A, but expose it for only half as long as usual. Then rotate the film about any axis at least 30° and holograph subject B, again for only half the normal time. Keep beam ratios low, about 1:1 to 2:1. Upon viewing, either subject A or B will appear, depending upon the orientation of the reconstructing beam.

Even more interesting is the technique of holographic interferometry. This is basicly a double hologram as described above, but of the same subject in two slightly different forms, i.e. a C-clamp stressed and unstressed, a light bulb cold and warm, etc. Use your imagination.

As an example, set up a frosted light bulb as a subject, with provision that the filament can be heated to just below luminescence(~10VAC). Take half an exposure with the bulb cold, turn on the filament for a minute to let the bulb heat, then finish the exposure. The resultant interference pattern on the reconstructed image clearly shows where thermal expansion has moved the surface.

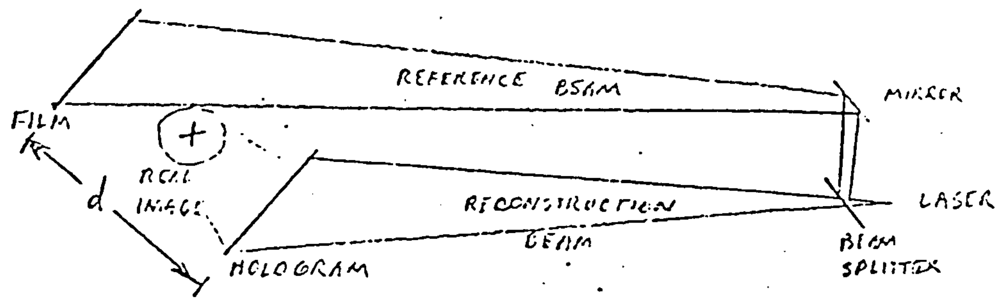
Holograms can be easily duplicated in a sophisticated contact printing process. Set up the hologram to be duplicated in the normal viewing position and take a light reading just behind it (viewer side). Shutter the laser and slip a piece of film into the holder behind the hologram, emulsion forward:



Upon exposure, the reference and object beams are both automatically produced. With some loss in intensity, you should get a good duplicate.

Until now, the virtual image has appeared behind the film plane, as seen by the viewer. A variation on the foregoing duplication process can effect a translation in space, projecting the image out in front of the film. The effect is quite startling and well worth the effort.

Start by setting up a good hologram to view the <u>real</u> image. Next, set up the film plane a distance d from the hologram, and provide a reference beam:



Be sure the real image can be seen by the entire film plane. Expose the film as usual, and set up the developed hologram to again view the real image. The resultant image is the real image of the real image of the original subject; this double inversion process restores the normal appearance. During the process, the image has been moved a distance d toward the viewer. If the subject were originally 5" behind the film, and d = 10", then the final image would appear to float 5" out in front of the film.

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1-10-73