Chapter **7**

Single-beam holography

The preceding chapters have prepared you to shoot holograms. Let's begin now with a single-beam holography setup on the isolation table. It is a good idea to keep records concerning all of your setups along with the results to help you gain experience and learn from your mistakes faster. Your records show you what works and what doesn't work, and more importantly, what you need to do to get it to work. Whether you need to change an exposure time, optical component, or beam ratio, your records will be there for you to refer to when planning new setups. Figure 7-1 is an example of such a record that you can photocopy for your setups.

SINGLE-BEAM REFLECTION HOLOGRAM

Start with 2.5 × 2.5-inch plates. The exposure times given are calculated for this plate size. These times should put you in the ballpark, but you will probably have to adjust the exposure time a little to produce the brightest images for your environment. The easiest way is to check the density of the hologram while developing. Or if you are familiar with the procedure for making test strips, commonly used in photography for determining exposures, this method can be adapted to holography by masking and uncovering the plate for different exposure times.

A single-beam white light reflection hologram is viewable with white light and is quite impressive. Figure 7-2 illustrates the setup on the table. If you have the 12 × 12-inch metal plate (recommended in chapter 2) on the end of the table, it will be much easier to set up various configurations on the table because you can eliminate the bottom horizontal metal plate of the holographic film plate holder. The magnetic holders secure to the 12-inch-square metal plate itself. When using optical components on this end of the table, you only need the vertical metal plate of the inverted T. Place it alongside a magnet secured to the 12-inch-square metal plate.

Holographic Information Record

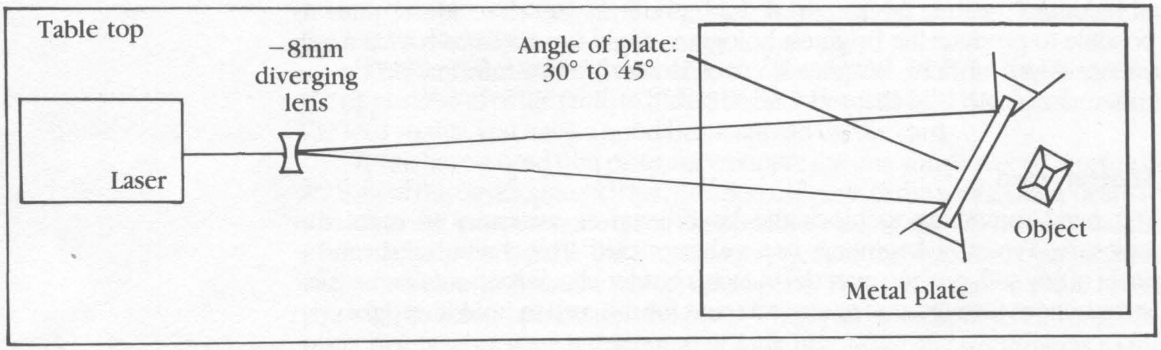
Hologram ID / Name			
Date		Temperature	
Film Size & Type		Exposure Time	
Developer		Development Time	
Bleach		Bleach Time	
Laser			
Beam Strength Ratio	Ref	Obj.1	Obj.2

Sketch

Results:

Put Additional Information On Reverse Side

7-1 Holographic information record.



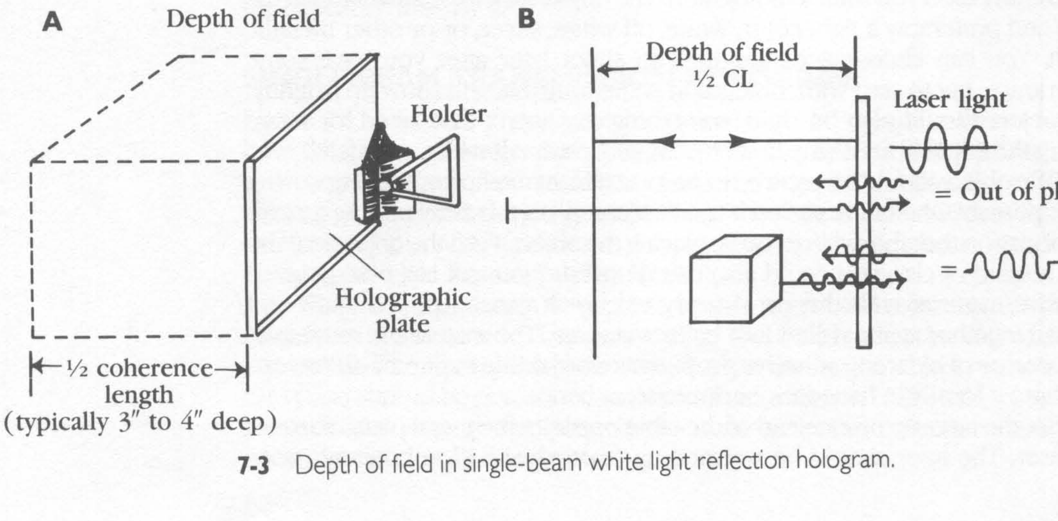
7-2 Setup for single-beam white light reflection hologram.

Depth of field

Single-beam reflection holograms have a restriction on the depth of field behind the plate that can realistically be holographed. This restriction is approximately one-half the coherence length of the laser. For the low-power (0.5 mW to 5.0 mW) HeNe lasers we are using, the coherence length is usually around 6 to 10 inches, which means you have a depth of field of 3 to 5 inches behind the plate. Figure 7-3 illustrates the depth of field that you can holograph in a single-beam setup.

The coherence length of the laser is a measurement of the distance the light will remain coherent with itself when it is split. To see this more clearly, examine FIG. 7-3B. The laser light is incident on the plate and passes through the emulsion (recall the emulsion material is transparent). The reason the depth of field is one-half the coherence length is that the light must travel twice the distance of the depth: first through the plate, to the object, then reflected back to the plate to meet the incoming light. So the round-trip distance the light travels is actually two times the depth.

The interference pattern is produced by the reflected light off of the object and the incident light on the plate. You should place whatever object you want

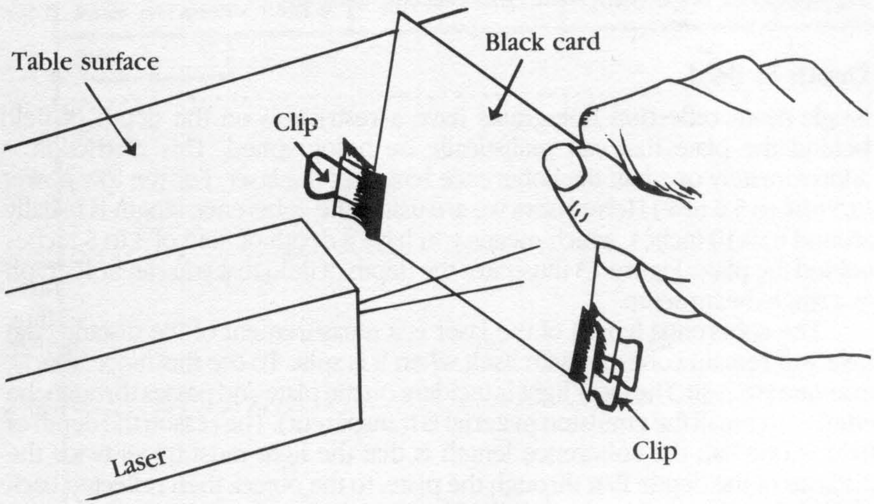


7-3 Depth of field in single-beam white light reflection hologram.

to holograph within this depth of field, preferably as close to the plate as possible to produce the brightest hologram. (Split-beam setups have a much greater depth of field, but that is covered later.) More information on the coherence length is in chapters 2 and 12.

Shutter card

You need something to block the laser beam as necessary to make the exposure. Typically, beginners use a shutter card. The shutter card can be made of any stiff, opaque material. Attach a binder clip to each side of the card at the bottom (see FIG. 7-4) to act as a stand for the card to hold it upright.



7-4 Using a shutter card.

Procedure

Choose an object you want to holograph. The object should be smaller than the plate and preferably a light color, white, off white, silver, or or other metallic finish. You can choose a darker item to shoot later after you have some experience, but to start with, holograph something that will show up brightly. The object should also be rigid, something that won't flex, bend, or move during the exposure. For my first object I chose a small white sea shell.

The object should be secured to prevent it from moving or rocking during the exposure. One of the easiest ways to accomplish this is by putting a small ball of clay on the table where you're placing the object. Push the object into the clay. Instead of clay, you could also use "Fun-Tak." Fun-tak is a blue-colored adhesive material with the consistency of clay. It can be pulled apart and pushed together again, rolled into balls, whatever. The material is reuseable, and because of its strong adhesive property is worthwhile to purchase. You can purchase it locally in hardware or dime stores.

Set the laser up on one end of the table opposite the metal plate. Turn on the laser. The laser should be warmed up (turned on) 30 minutes or more before you start shooting any holograms. This warm-up period is necessary for the laser to stabilize.

Position the −8mm lens close to the laser aperture. Hold a white card at the opposite end of the table to make the laser beam visible. Position and adjust the lens so that you have a good beam spread on the card.

If you have a used film plate, for example the one you practiced moving in and out of the development trays, position the plate in the spread laser beam so that it has the most even illumination possible. Placing a white card behind the plate can help determine the illumination. Secure the magnetic plate holders in that position to hold the holographic plate. Position and secure the object you want to holograph behind the plate. When you view the object through the plate, that is what your hologram will look like. Make any adjustments to the object to holograph it in the best position possible. Remember to keep the object as close to the plate as possible.

Remove the used plate, keeping the plate holders in position. Position the shutter card in front of the laser to block the beam. Turn on the safelight and shut off all other lights. Wait a minute to allow your eyes to adjust to the lower light level. Remove a fresh holographic plate from the box. Check for the emulsion side. Place the plate in the plate holders with the emulsion side facing the object.

Lift the shutter card off of the table, but not high enough to let the beam pass. Keep the card in this position for the relaxation time (about 30 seconds). To make the exposure, raise the card above the beam for the exposure time (about 1 second; see following list), and return the card to the table. The plate is ready to be developed (see chapter 6).

The exposure time for reflection and transmission holograms using 2.5-inch-square holographic plates with Agfa 8E75:

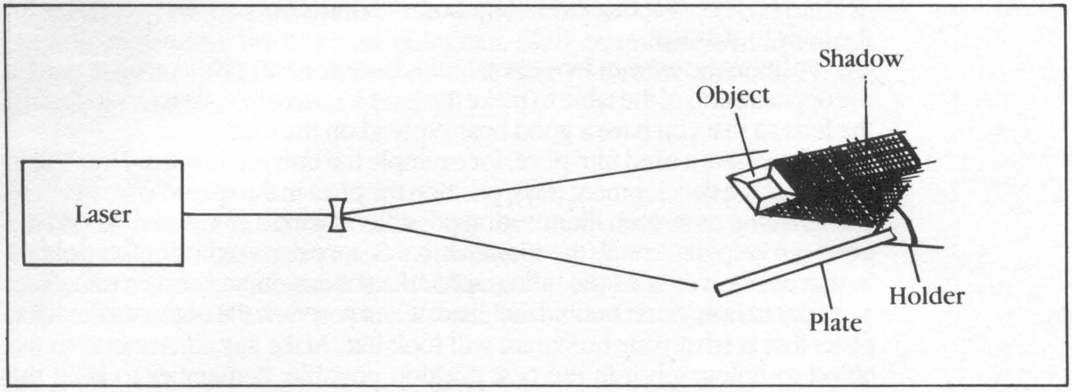
5.0 mW laser—1 to 1.5 seconds
2.5 mW laser—2 to 3 seconds
1.0 mW laser—5 to 7 seconds

For 4×5-inch holographic plates with a 6-inch-diameter beam spread, multiply the exposure time by 4.

SINGLE-BEAM TRANSMISSION HOLOGRAM

Figure 7-5 illustrates a single-beam transmission holographic setup. Notice how the beam geometry has changed from the reflection setup. With the reflection hologram, the interference pattern was generated from the reflected light off of the object (object beam) behind the plate and the incident light on the front of the plate (reference beam). Essentially, each beam struck the holographic plate from opposite sides.

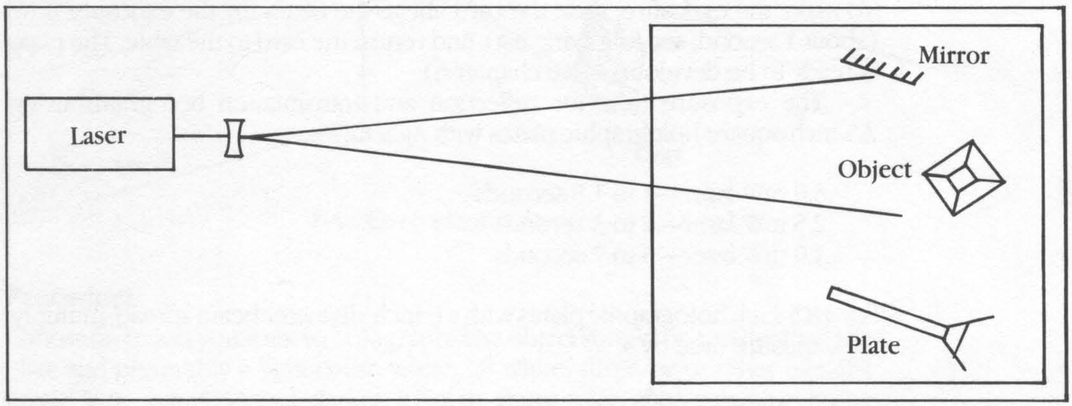
With the transmission setup, both beams, object and reference, strike the plate from the same side. The geometry of this simple setup isn't ideal, but it does work. The illustration shows the shadow cast by the object to show that the object should be positioned so that its shadow doesn't fall on the plate. The procedure to expose the plate is the same as in the reflection hologram (described earlier in this chapter).



7-5 Setup for single-beam transmission hologram.

IMPROVED SINGLE-BEAM TRANSMISSION

The addition of a front-surface mirror as depicted in FIG. 7-6 improves the quality of the transmission hologram. The front-surface mirror scopes some of the incident light and reflects it toward the film plate. This reflected beam acts as the reference beam.

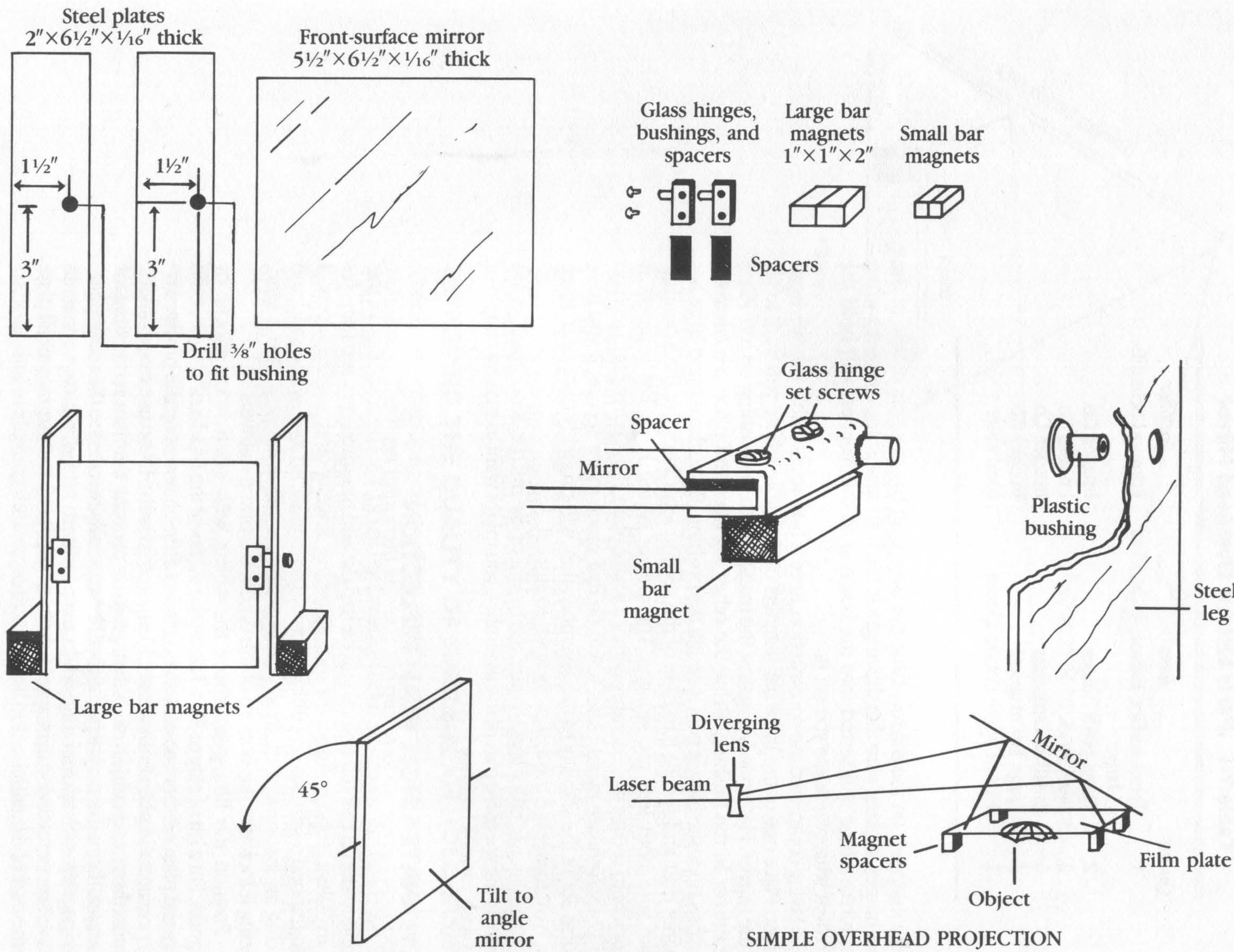


7-6 Setup for improved single-beam transission hologram.

Overhead mirror

I have designed a front-surface mirror holder, illustrated in FIG. 7-7. It can also be used for overhead reference beams in either reflection or transmission holograms. I am calling it an "overhead mirror" because it will likely be used more often in that capacity. See TABLE 7-1 for the parts list. Wear the white cotton gloves when handling the front-surface mirror to prevent oil and dirt from your hands from marring the reflective surface of the mirror.

Refer to FIG. 7-7. Drill a ⅜-inch hole in the two pieces of stock steel as shown. Glue the plastic bushing into the hole. Secure the glass hinges onto the front-surface mirror. Make sure that the pivotal rod of the glass hinge is exactly



7-7 Construction of overhead mirror holder.

Table 7-1 Parts List for Overhead Mirror

Quant.	*Item*	*Supplier*
1	Front-surface mirror, 4″ × 5″ or larger	Edmund Scientific
2	Glass pivot hinges	Images Co.
2	Steel stock 2″ × 7″ × 1/16″	Images Co.
2	Small bar magnets	Images Co.
2	Large bar magnets	Images Co.
1	Pair of white cotton gloves	local store

at the midpoint on the mirror. Glue the two small bar magnets on top of the glass hinges, making sure that the magnets lie flush against the steel legs when the mirror hinge is inserted into the bushing so the magnets will hold the mirror at whatever angle you set it.

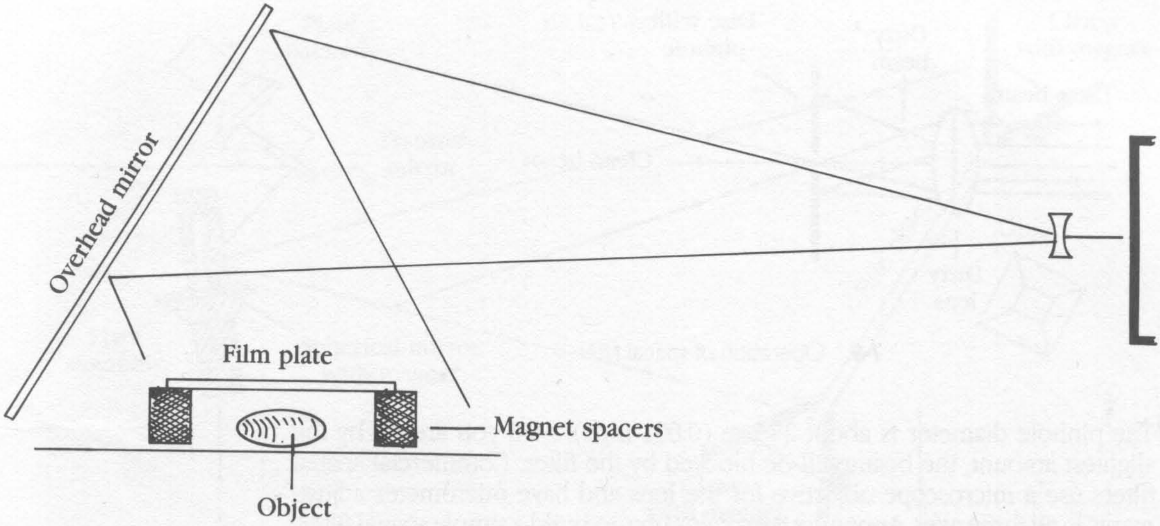
Having completed the construction, here is how to assemble the overhead mirror. Place one of the large bar magnets on the table where you want to set up the mirror. Place one leg against the magnet with the bushing on top. Place the mirror in the bushing. Bring the other leg over and place it so that the mirror's opposite hinges pass through the bushing. Bring the second large bar magnet over and secure it to base of the second leg. Check out the assembly. Make sure both legs are straight. The weight of the large bar magnets is sufficient to secure the assembly without a base plate. If the mirror is placed on the 12-inch-square metal plate, it will be that much more secure. If you have doubts about the stability of the assembly, they will probably disappear when you have to wrestle the assembly apart to store it.

You can use taller legs to raise the height of the mirror. Since the legs are the most inexpensive part of the assembly, you might want to make a couple of sets with various heights.

ALTERNATE SINGLE BEAM REFLECTION

The overhead mirror can be used as illustrated in FIG. 7-8. The advantage of this configuration is that the objects can be laid flat and mounted very securely. It's an excellent configuration for holographing jewelry and small objects. I holographed a seascape by filling a small rectangular tin with white sand and placing an assortment of small shells, coral, and ancient coins in the sand, making it look like the bottom of the ocean. It worked out well.

Position the film plate above the object with small wood blocks or magnets. Put a bit of clay or Fun-Tak on the edges of the blocks or magnets and place the plate on them so only the corners of the plate rest on the blocks. The clay prevents the plate from vibrating during exposure. If you use wood blocks, secure them in position with hot glue to prevent them from moving or vibrating. If you use magnets, they will be naturally secured to the metal plate. The magnets save a lot of time when making these setups, which is the main reason I recommended in chapter 2 that you get the 12-inch-square metal plate for the end of the table.



7-8 Alternate setup for single-beam reflection hologram.

Procedure

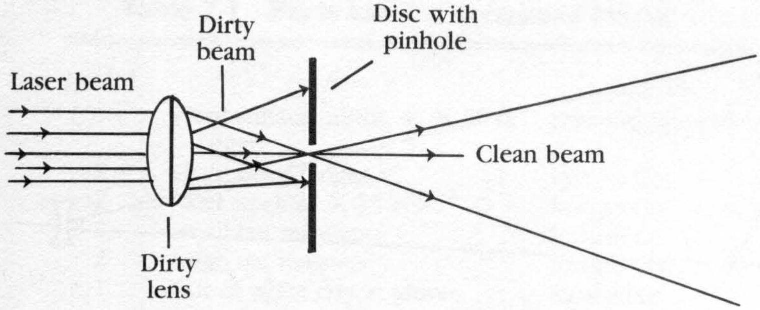
Adjust the diverging lens to spread the beam evenly on the mirror. Adjust the angle of the mirror to reflect the beam onto the plate assembly. It's a good idea to position a white card in place of the plate when adjusting the beam. The white card will allow you to see the beam's spread much more easily. When your mirror is set and the object is in place (don't forget to place a small amount of clay on the edges of the magnets), follow the procedure outlined previously for making an exposure. Since the beam is typically spread out a little further in this setup, the exposure time might be increased slightly.

IMPROVING THE QUALITY OF SINGLE-BEAM HOLOGRAMS

There are limitations as to what can be done to improve single-beam holograms. The most important aspect is the quality of the spread laser beam. You might have noticed when you tested your laser that the spread beam from the lens has whorls and marks. This is caused by dirt and imperfections on or in the lens. Some of them can be removed by cleaning the lens. The most common approach to improving beam quality is to use a *spatial filter*. A second approach, one I use extensively, is a *spherical mirror*.

Spatial filter

The spatial filter is a remarkably simple optical device in principle. Figure 7-9 illustrates a spatial filter. The lens of the filter focuses the laser beam to a point that coincides with the placement of a pinhole. Any light scattered by dirt or imperfections in the lens doesn't pass through the pinhole. The resulting beam from the spatial filter in quite clean and of optimum quality. Although the spatial filter is simple in principle, putting it into practice is another matter. The difficulty lies in aligning the lens so that its focal point is directly on the pinhole.



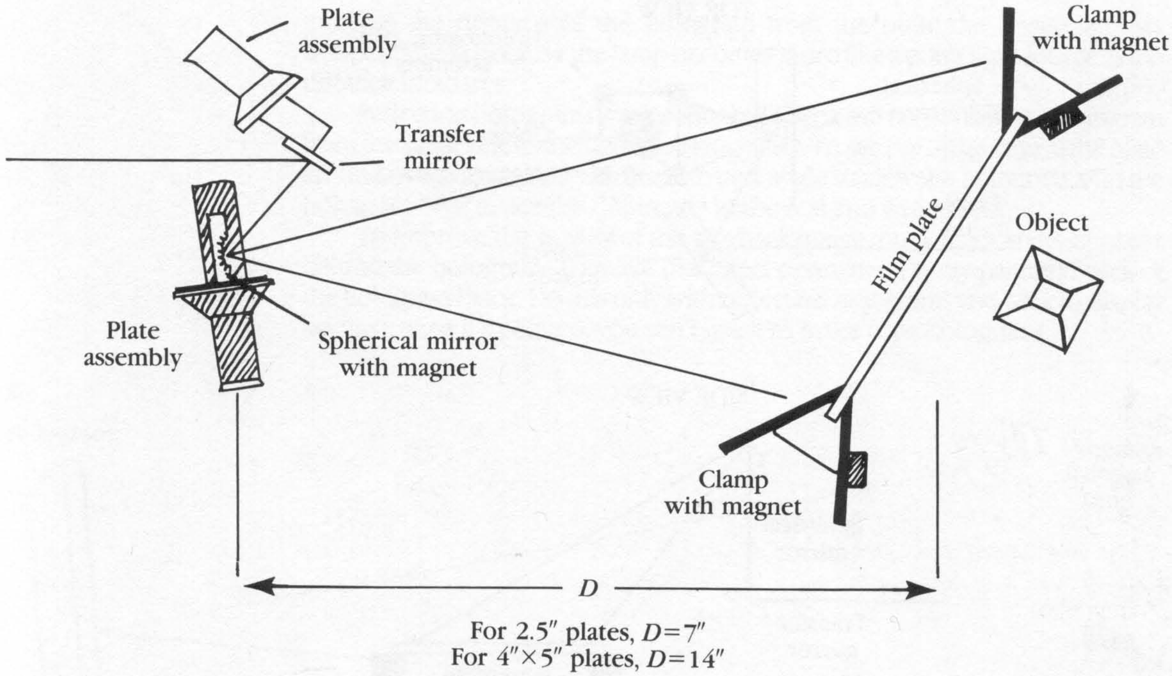
7-9 Operation of spatial filter.

The pinhole diameter is about 25 μm (0.001 inch), so if you are off by the slightest amount, the beam will be blocked by the filter. Commercial spatial filters use a microscope objective for the lens and have micrometer adjustments in all three axes. Appendix B explains how to build a simple spatial filter. The applications of the homemade spatial filter are limited, however, due to its simplistic construction. But it can be used for all single-beam setups using the 2.5-inch plates.

Spherical mirror

The small, spherical mirrors that were mounted on the rectangular magnets offered tremendous improvement over lenses. First, because of its short focal length, the beam spreads so quickly that you could shoot 8 × 10-inch holographic plates on the small table. Also, the quality and clarity of the spread beam is remarkable and is surpassed only by a spatial filter. Hence, I recommended buying three of these mirrors. They are also used extensively in split-beam work (chapter 9). Figure 7-10 illustrates a simple setup using the spherical mirror. Because the beam spreads so quickly, the transfer mirror and spherical mirror are located on the far end of the table with the plate. When you first align the mirrors, the spread beam might appear dirty. Simply move the spherical mirror until you find a clean spot on it. You can use the spherical mirror in all the single-beam setups shown so far. You might wonder why I didn't start using the spherical mirror in the first place. The reason is that it's more difficult to align the mirrors properly. I felt after you have succeeded in making a hologram with the lens, you would have more patience in aligning the mirrors and more practical experience in what you're looking for in a spread beam. The added bonus is that you would see the remarkable improvement in the quality of the hologram when using the mirrors.

Overhead beam The spherical mirror can also be used to project an overhead reference beam similar to the large overhead mirror (see FIG 7-11). Or, it can be used in conjunction with the overhead mirror to produce a greater beam spread for larger film plates. Why bother with the overhead mirror if the spherical mirror can accomplish the same thing? The answer is that they accomplish the same thing, but in limited applications. There are some setups where the overhead mirror will be the mirror of choice. In addition, knowing



7-10 Overhead view using spherical mirror in place of diverging lens.

how to accomplish a specific task a number of ways creates flexibility, versatility, and innovation in your holography setups.

VIEWING HOLOGRAMS

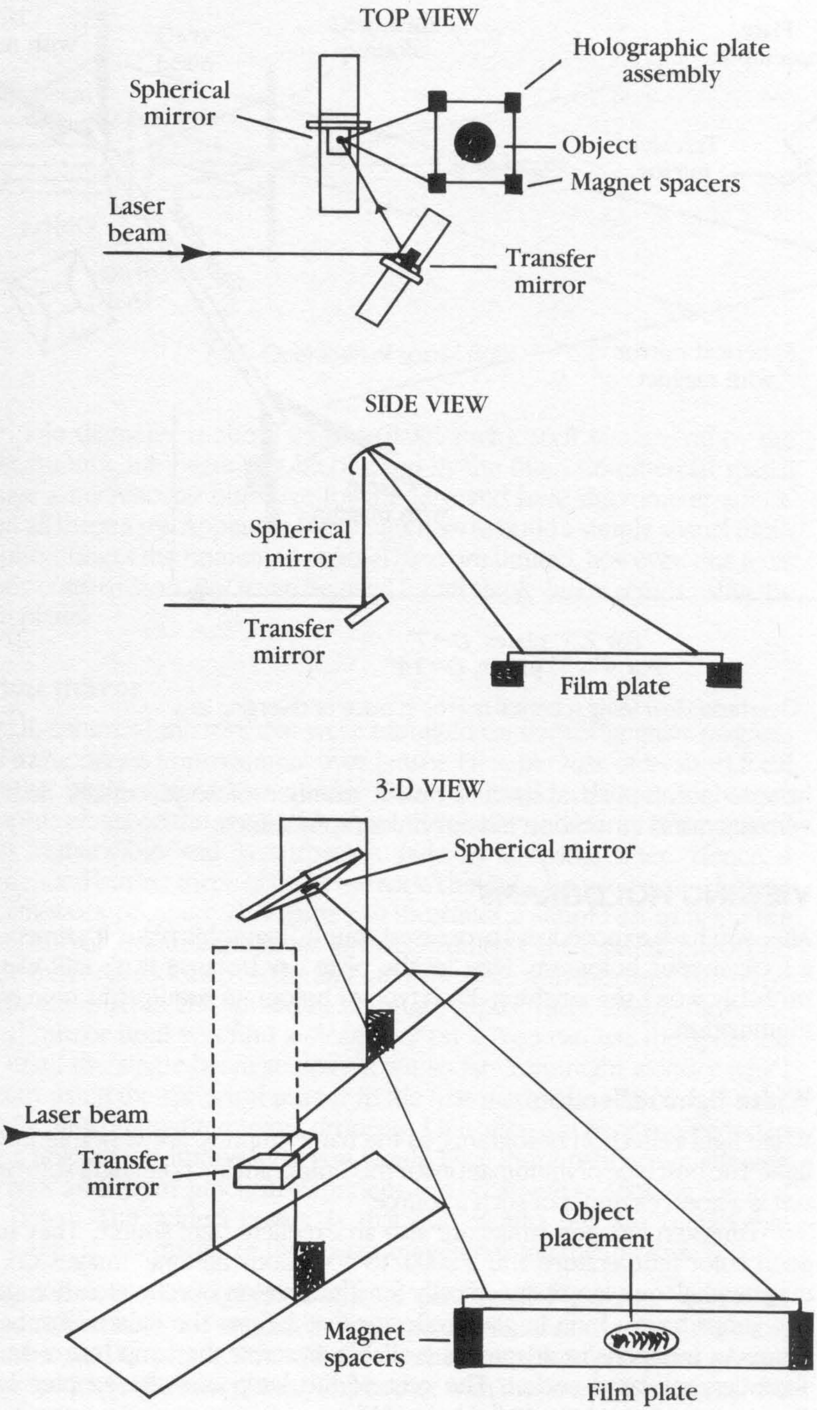
After you have exposed and processed your holographic plate, it's time to take a look at your hologram. First let the plate dry because if it's still wet, you probably won't see anything. Each type of hologram requires its own type of illumination.

White light reflection

White light reflection holograms, as the name implies, are viewable in white light. The best type of illumination for this hologram is a point light source. The sun is a good example of such a source.

Tungsten halogen lamps are also an excellent light source. They have a good color temperature and a 2000- to 3000-hour lifetime. Images Co. sells tungsten halogen lamps specifically for illumination of reflection holograms. The lamps have a built-in glass reflector that focuses the light in front of the lamp. An inexpensive adapter is available to screw the lamp into a standard incandescent lamp socket. The cost of the lamp and the adapter is $25. Replacement lamps are available for $15.

Incandescent lamps can be used, but the image quality isn't as good as with the tungsten halogen. When using an incandescent lamp, notice that if you

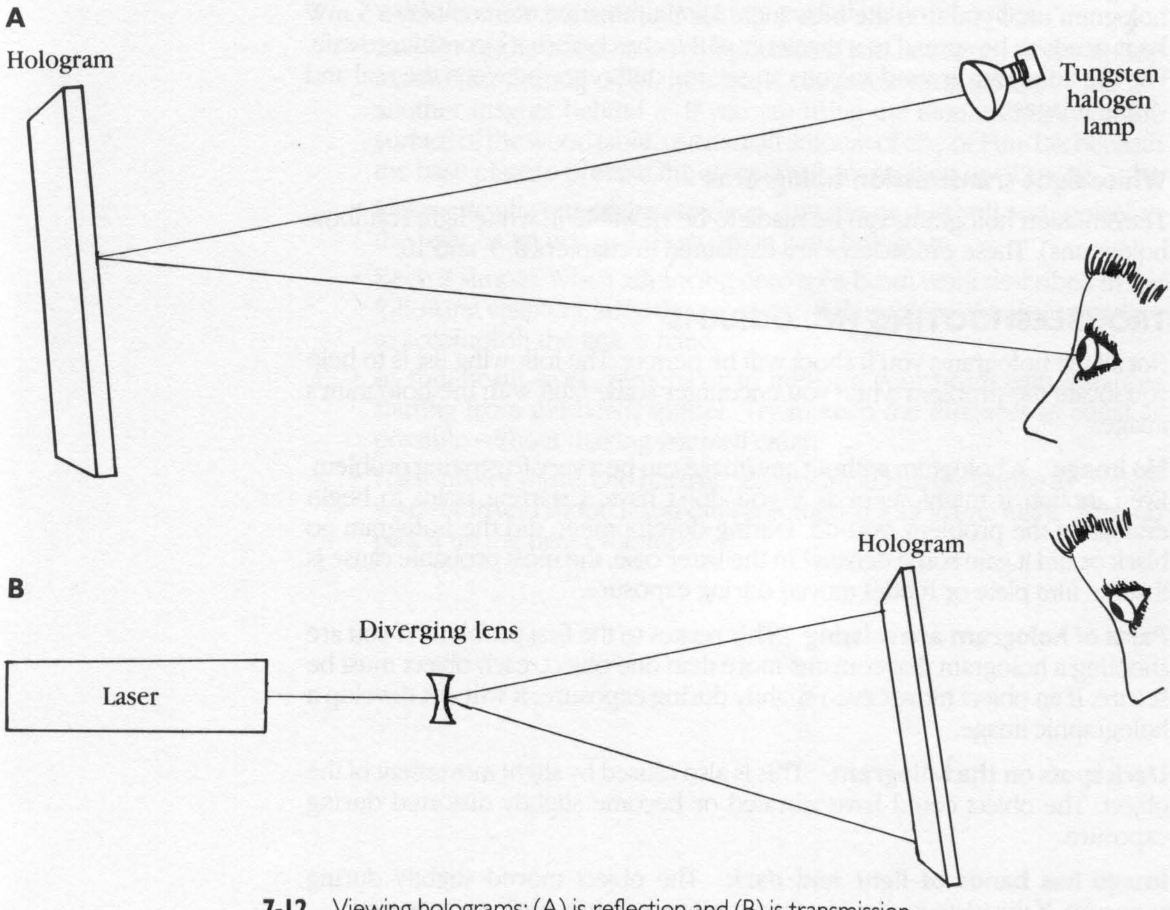


7-11 Using spherical mirror for overhead projection.

increase the distance of the hologram from the bulb, the image appears sharper. This is because the lamp becomes more like a point light source as the distance increases.

Reflection holograms work something like a mirror, so view the hologram from the same side as the light (see FIG. 7-12A). To see the image, move the plate around in the light until you find the best angle to view the hologram. Flip the hologram over to see the difference in the real and virtual images.

To improve the quality of the playback image, put a black sheet of paper behind the hologram. To make this effect permanent, spray paint the back of the hologram black. Do this only with reflection holograms you want to display because once it's painted, you can't use it to make copy holograms.



7-12 Viewing holograms: (A) is reflection and (B) is transmission.

Transmission holograms

Transmission holograms need a monochromatic light source for viewing. Use the laser you used to produce the hologram to view the hologram. A filtered white light source can also be used but requires a special narrow-band filter. Edmund Scientific sells this type of filter. They have a bandwidth of ±−2 nm.

I haven't actually used these filters, so I don't know much about them except that they are available. If you purchase a filter for illumination of transmission holograms, get one that is active at around 633 nm, which matches the wavelength of the laser light used to produce it. If they don't have a 633 nm filter, go for a shorter wavelength, which should illuminate the hologram more brightly than a longer wavelength. However, be aware of the filter's heat resistance, which determines how close to the light source you can place the filter.

With transmission holograms, the light must pass through the film, so you observe the hologram on the opposite side of the light source (see FIG. 7-12B). Spread the laser beam to cover the hologram completely. When looking at the hologram, look at the plate, but do not look directly into the laser. Tilt the hologram until you find the best angle for illumination. Remember, a 5 mW laser needs to be spread to a diameter of 8 inches before it's considered safe. Flip the hologram around so you can see the difference between the real and virtual images.

White light transmission holograms

Transmission holograms can be made to be viewable in white light (rainbow holograms). These procedures are explained in chapters 8, 9, and 10.

TROUBLESHOOTING HOLOGRAMS

Not all the holograms you'll shoot will be perfect. The following list is to help you locate the problem when you encounter some fault with the hologram's image.

No image A hologram without any image can be a very frustrating problem. Even though it might seem as if you don't have a starting point to begin evaluating the problem, you do. During development, did the hologram go black or did it gain some density? In the latter case, the most probable cause is that the film plate or model moved during exposure.

Parts of hologram are missing This relates to the first problem. If you are shooting a hologram that contains more than one object, each object must be secure. If an object moves even slightly during exposure, it will not develop a holographic image.

Dark spots on the hologram This is also caused by slight movement of the object. The object could have vibrated or become slightly distorted during exposure.

Image has bands of light and dark The object moved slightly during exposure. If the plate has bands, then it moved slightly during exposure.

Image faint A faint image can be caused by either overexposing or underexposing the film. The best way to check this is by checking the hologram during development against a neutral density filter. Another possible cause is using tap water that contains chlorides in your stock development solutions. Only use distilled or de-ionized water for your stock solutions.

Image is weak and fades This is the problem I encountered when my safelight was fogging my film during setup and development.

Hologram goes dark after a week or two This is called *printout.* It can be caused by residual traces of triethanolamine left in the emulsion.

It's easy to forget basic information when you are excited about shooting a hologram. But the idea is to generate bright, successful holograms, so it's a good idea to keep the following points in mind.

- Always allow sufficient time for your laser to warm up. This is usually about one half hour. As the laser warms up, the glass expands slightly, which varies the longitudinal mode. So it's important that the laser is stable by allowing for this warm-up period before shooting.
- Stability of the optics is very important. If you notice any of the optical assemblies drifting off of their mark, reinforce the assembly by placing another magnet behind it. If you are using the mount directly on the surface of the wood table, use a small amount of clay or Fun-Tak beneath the base plate to prevent the assembly from rocking or vibrating.
- Make sure all your optics are clean. Any dirt or dust will add "noise" to the laser beam that will show up on your hologram.
- Keep it simple. When advancing onto split-beam work described in the following chapters, keep the geometry of the table as simple as possible to accomplish the task at hand.
- In split-beam work, remember to measure your beam path distances starting from the beam splitter. Try to keep the distances as equal as possible without making yourself crazy.
- Haste makes waste. Old but true, allow yourself plenty of time to arrange your setup and shoot. If you can't accomplish it all in one night, stop and pick it up the next evening.

Chapter 8

Advanced techniques

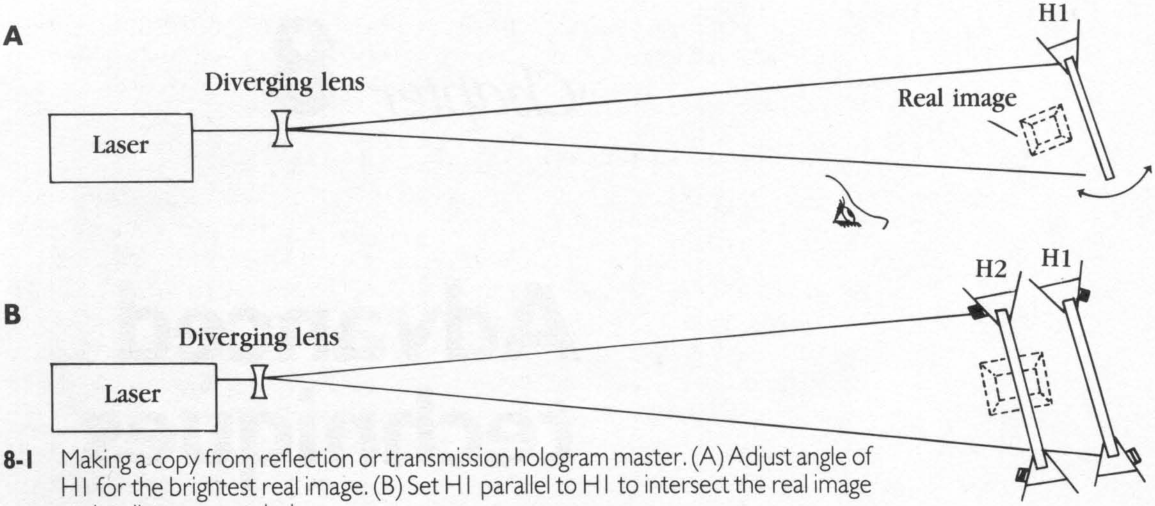
The techniques described in this chapter are illustrated using single-beam holography to allow you a large latitude for experimentation while using simple setups. Inasmuch as split-beam holography improves the resulting image, you can achieve the same positive effect when employing these techniques in your split-beam work.

WHITE LIGHT REFLECTION COPY

As explained in chapter 1, holograms produce both a real and a virtual image. If you flipped a reflection hologram so that you are viewing the real image, you can use it to make a copy, or *transfer hologram.* Because the real image lies "in front" of the plate, you can position the copy plate to intersect the image behind, straddled, or in front of the new hologram, depending on the distance between the plates when making the transfer. You can accomplish the same effect using a transmission hologram, so this same setup is suitable for producing reflection copies from either transmission or reflection masters.

Recall that the real image is pseudoscopic (false), so after exposure and processing, you must flip the transfer hologram to view it. In doing so, you would be looking at a real orthoscopic image. The parallax of the transfer hologram is limited, unless you have used a large master hologram to make the transfer hologram, because when making the transfer hologram, the real image was recorded along with its particular parallax.

Any good quality reflection or transmission hologram you like can be used as a master. Look at FIG. 8-1. The master hologram, hereafter referred to as "H1," is placed in the spread laser beam. The real image is being projected toward the laser. Adjust the angle that the light is incident on the plate to produce the brightest image. Now using a card the exact size of the copy hologram, and position it to be parallel and in front of the master hologram. Position the distance of the plate to intersect the real image where you want it to lie. The shadow cast by the card should fall in line with the edges of the



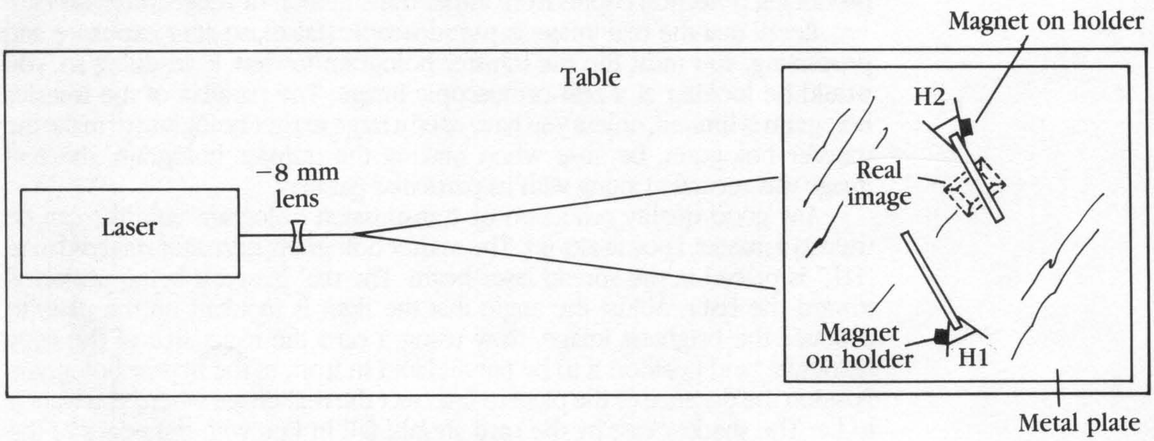
8-1 Making a copy from reflection or transmission hologram master. (A) Adjust angle of H1 for the brightest real image. (B) Set H1 parallel to H1 to intersect the real image at the distance you desire.

master hologram. Position your plate holders at this position and remove the card.

Place a fresh plate, "H2" in the illustration, in the plate holders with the emulsion side facing the H1 master. Make the exposure and develop. Use the same exposure time you used to record the master hologram.

TRANSMISSION COPY

Arrange the geometry of the table as in FIG. 8-2. This setup, when performed correctly, produces a transmission copy that is close to *achromatic* (black and white image) under white light and produces a fine image under laser illumination. Consider it a "cheap and dirty" achromatic white light transmission hologram. Adjust the master hologram to produce the brightest real image. Set up your copy plate to intercept the real image and at the same time have an unobstructed reference beam. Not an easy thing to do, and the



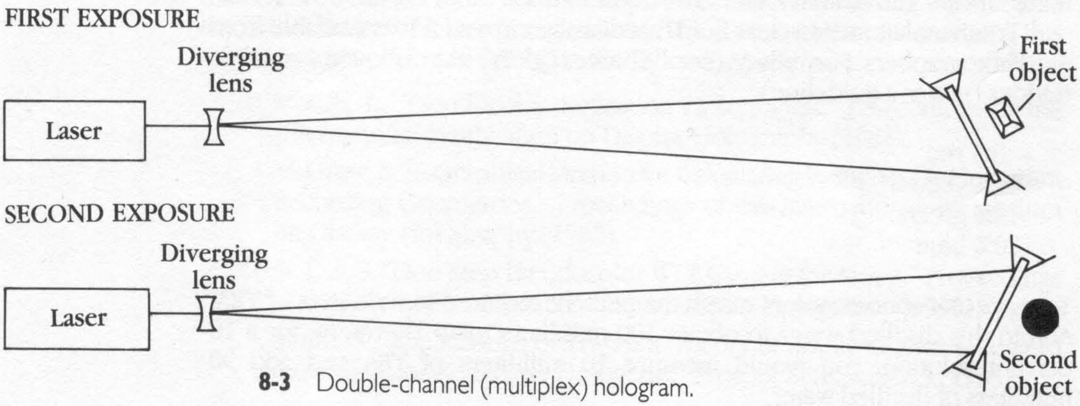
8-2 Making a transmission copy.

geometry would not be perfectly aligned as illustrated. You'll have to make compensations but the results are well worth the endeavor.

Reflection/transmission copy holograms are covered in chapter 9.

DOUBLE-CHANNEL HOLOGRAM

An interesting technique used quite successfully in commercial applications is a *double-* or *dual-channel hologram.* Despite the tremendous amount of information recorded in a single hologram, two or more separate holograms can usually be recorded onto a single plate. Another word for dual-channel is *multiplex.* In dual-channel holograms, the image changes as your viewing angle changes. As an example, one view would be of an unopened jewelry box, and another view would show the same jewelry box opened, revealing an engagement ring. See FIG. 8-3.



8-3 Double-channel (multiplex) hologram.

The easiest method of recording multiple images on a hologram is to vary the angle of the reference beam on the plate between exposures. The technique can be used with both reflection and transmission holograms. Each exposure should be about half of the typical exposure used to record the hologram. By keeping the difference of the reference beam angle large, there is good separation of the images with little cross talk between them.

PSEUDOCOLOR REFLECTION HOLOGRAM

Holograms typically play back their images in the same monochromatic red they were recorded in. To produce color holograms, a number of methods are available. One method requires two or three lasers, each in a different primary color. Aside from the high expense of the lasers, this involves accurately mixing the laser light together at the correct power levels; the emulsion material is not equally sensitive at all frequencies. Despite the cost and difficulty, full-color and naturally colored holograms have been produced this way.

White light transmission holograms (rainbow holograms) can also be used to generate full-color holograms, but it involves complex table geometries that aren't suitable for beginners.

Pseudocolor reflection holograms can be made with an HeNe laser by a technique that swells the emulsion plate with triethanolamine (TEA) before plate exposure. After the TEA-swelled plate is exposed, the interference pattern recorded in the plate as usual. During development, the TEA washes out of the emulsion, which shrinks the emulsion back to its normal size. But the interference pattern is tighter, so the hologram plays back at a shorter wavelength (see more in chapter 13).

Different concentrations of TEA can provide reflection hologram playback in yellow, green, or blue. The method is well suited to single-beam work. TEA has a hypersensitizing effect on the emulsion, depending on its concentration. Reduce the exposure time for TEA-treated plates by a factor of two or three. TEA also begins darkening the emulsion material after about 4 hours without any exposure to the plate, so do not try to make up a batch of TEA plates for eventual use. For the same reason, don't place any of your finished bleach holograms in TEA to shift their wavelength.

Triethanolamine is a clear fluid that dissolves in water. It as available from the Photographers Formulary (see "Sources"). Try the following concentrations (use as a guideline).

0% red
10% yellow
14% green
20% blue

To make any concentration, match the percent required in milliliters of TEA. Add to this distilled water to obtain 100 milliliters total. Therefore, for a 10 percent solution, you would measure 10 milliliters of TEA and add 90 milliliters of distilled water.

Under a safelight, pour the TEA solution into a development tray. Put an unexposed plate into the tray, emulsion side up. Let the plate sit in the TEA solution for about a minute. Remove the plate and squeegee the excessive solution from the plate. Allow the plate to dry completely (about 20 minutes).

Expose the plate using a shorter exposure time than normal; try about half the standard exposure time. Develop and process the plate normally. When the plate dries, check the color shift of the hologram. The percentages of the solution required to bring about a particular color shift vary with the batch of emulsion plates used and as well as the method of swelling and drying the plate.

This is a fertile area for experimentation. Try making a two-channel, two-color reflection hologram. To make a pseudocolor hologram, combine the techniques presented here with the two-channel information. Techniques like this have already been employed with one major difference. In the two-channel holograms, the reference beam angles greatly differed between each channel. To create a pseudocolor hologram, the reference beam is only diverted about 7 degrees between each exposure. This creates cross talk between the images, so they both are visible simultaneously.

If you want to try a three-color pseudohologram, use the following exposure times:

Red ½ standard exposure
Green ½ red exposure
Blue ½ green exposure

Between each exposure, change or move the object you are holographing.

I advise making single-color holograms first to determine the proper TEA concentrations for each color. Then proceed to two- and three-color holograms.

Consider these experiments to be the tip of the iceberg. There are a number of ways to introduce color into holograms. Some use transmission masters. You can get more accurate color registration by reading the article in the below list by S. McGrew on geometry. If you are interested in pursuing this line of holography, read or obtain the following papers.

- Moore, L. "Pseudocolor Reflection Holography." Proceedings of the International Symposium on Display Holography (1982).
- McGrew, S. "A Graphical Method for Calculating Pseudocolor Hologram Recording Geometries." Proceedings of the International Symposium on Display Holography (1982).
- St. Cyr, S. "One-Step Pseudocolor WLT Camera for Artists." Proceedings of the International Symposium on Display Holography (1985).
- Smith, S. "Applications of Tri-color Theory of Additive Color Mixing to the Full-Color Reflection Hologram." Proc. of SPIE, vol. 523 (1985).

If a library in your area doesn't have these papers, the first three are available from the Holography Workshops, and the fourth is available from SPIE (see "Sources").