

## MAS 450/854: Holographic Imaging Lab Notes

### #5: SPATIAL FILTERS & OFF-AXIS “Leith & Upatnieks” HOLOGRAPHY

#### Introduction:

Increasing the angle between the object and reference beams has several important effects on holographic imaging. The various reconstruction components separate, so that only the desired virtual image is presented to the eye. Also, the spatial frequency associated with the image can be high enough to make the recording material function as a “thick” layer, exhibiting volume diffraction effects that brighten the image. The objects also may be front-lit, allowing laser photography of diffusely reflecting solid objects and therefore much more creative freedom. These are some advantages of “off-axis laser transmission” holography, or “Leith and Upatnieks” holography, named after the two University of Michigan researchers who first applied lasers to holography and explored the off-axis domain in the early sixties, and who are considered to be the “fathers” of modern holography. For this very simple first experiment with off-axis holography, we will spread a single beam, use the strongest part of it to illuminate the object, and use a large mirror to reflect a weaker part of it at an angle to the plate to serve as the reference beam.

We will use a lens-pinhole spatial filter, or “beam cleaner” to eliminate the fringes and “bull’s eye” interference patterns that appear in the diverged beam. This is a useful gadget, and learning to align it will be an important part of this lab.

#### Experimental Topics:

1) A series of glass beamsplitters will be set up to feed weak laser beams to several lens-pinhole spatial filters, perhaps of varying types (the sketch below is of the *Jodon* model). Teams of one or two should choose a spatial filter and practice its alignment.

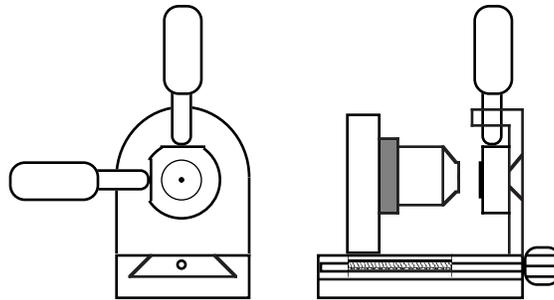


Figure 1: Sketch of a *Lens-Pinhole Spatial Filter* (LPSF or “beam cleaner”)

First, center the spatial filter mount (without pinhole or microscope objective) in the beam as best you can, at a location where the micrometer controls are easy to reach. Then install the microscope objective that your TA gives you (be sure to grasp the mount just around the lens base when screwing and unscrewing the lens!). Refine the mount location so that the diverged beam is centered where the undiverged beam used to be, and the microscope objective is aligned with the beam (so that the beam edge isn’t clipped, and the lens reflections go straight back along the beam to form circles concentric with the beam).

Install and align the pinhole to pass the beam (this is the tricky part!). Aligning a spatial filter takes a certain knack that only experience can provide. It seems to take a long time at first, but soon becomes a routine and rapid procedure. The exact technique depends on the type of spatial filter being used. To begin, rack the microscope objective well back in its slideway (but not so far as to fall out!) and insert the pinhole, in its magnetic mount, between the micrometer tips. If the pinhole is approximately centered, you should be able to see a weak pattern of concentric circles with a bright center, a “bull’s eye,” on a white card held in front of the spatial filter.

Tweak the micrometers to center the “bull’s eye” on the white card in the approximate direction of the original beam, where it should be brightest. The beam will be weak because the lens focus is far from the pinhole. Slowly crank the objective forward, recentering the pattern with the micrometers as you go, watching it get brighter on the way. At some point, the pattern may suddenly disappear, and then reappear as you continue racking the lens forward, and then start getting dimmer again. This means that you have missed perfect alignment, and have gone too far; don’t panic! Back off slightly (there may be some backlash in the focusing gear), and re-crank the lens forward to the disappearing spot. If you slowly tweak the micrometers there, you will soon find a place where an incredibly bright and smooth beam, a Gaussian profile without rings around it, comes bursting out of the spatial filter, ready to make holograms for you. Naturally, you will try to improve the tuning, and perhaps never find quite the same high-

quality beam again. But do it anyway. Of course, if you were incredibly lucky, you will hit that “sweet spot” the first time you rack through the focus, without any fine tweaking at the end. Let your TA guide you through this first time, and save these notes for further practice on your own.

Of course you should learn to do this quickly and easily. Many of the pinholes are very near the center of the magnetic mount, and just visually centering that mount will often produce a “bull’s eye” on a white card on the first try. After that, a little practice will bring the time way down.

#### Symptoms of Problems:

Mis-aligned spatial filter: if the microscope objective is “cocked” to the beam, and not perpendicular to it, the output beam will be “shaved” on one side.

Dirty microscope objective: a really big or dark blot (it will look like a tangle of wool sometimes) in the beam will become a smudge when you put in the pinhole. Unless you can see the dirt on the front surface of the objective (ask your TA to clean it), just change lenses.

Damaged pinhole: if you just can't get a uniform beam through, you may have a dirty or bent pinhole. Just ask for a replacement.

After all this, you may decide that you want a wider or narrower beam, which means starting over with either a higher or lower power lens, or that there are still too many fringes in the beam, so that you need a smaller pinhole. Either case means realigning the system from scratch. Now, on to making a hologram!

2) “Rough out” the exposure setup described by your TA, being careful to keep the object and reference beam path lengths closely matched. Choose your own object for mounting, but use a cross-hatch pattern on the background just behind it. Measure the distance from the plate to a reference point on the object, and to the background.

3) Put the white card in the plate holder, and make sure the reference beam mirror is illuminating the plate location fairly uniformly (there is bound to be *some* intensity falloff at the edges; try to limit it to 2:1).

4) Check the average intensity level of the reference illumination, and then block that off and check the reflected object illumination to estimate the beam ratio. Calculate the exposure time for an exposure of  $600 \text{ ergs/cm}^2$  (or whatever your TA recommends for the processing used).

5) Use a baffle to block the widely diverged beam from exposing the back of the plate. Make sure that the table is floating. Load a plate, draw the curtains, give it a minute to “settle,” and shoot!

6) Process using D-19, stop, fix, and wash. Dry in a graded sequence of 50:50, 75:25, 90:10% alcohol baths.

7) Replace the hologram in the plate holder, with the emulsion toward the object. Place the baffle so as to block the object illumination, but NOT the reference beam. Observe the location, etc., of the virtual image. If you don't see anything, check the orientation of the plate carefully.

8) Move the baffle toward you to now unblock the object illumination, and block the reference beam. Compare the brightness of the object as seen through the hologram to the brightness of the image reconstructed by the hologram in #7. Estimate the “reconstruction ratio.”

9) Re-mount the hologram after turning it  $180^\circ$  around a vertical axis (so that the emulsion is facing you). Look for real image projected on your side of the hologram. Is it bigger than the original object? Find the real image on a ground glass plate, and measure the distances to the best foci of the horizontal and vertical background lines. Find the image magnifications at these distances, and note any differences side-to-side versus up-to-down.

10) Illuminate the rotated hologram with an undiverged laser beam to project a sharper image on the ground glass. Note how it rotates as the beam illuminates different parts of the plate.

11) View the hologram by holding it closer to the laser (maybe from the other side, or upside down) and note the change of magnification of the resulting image. Note the sensitivity of the brightness to the angle of the hologram. View the image with a white light source, and note the spectral effects mentioned in class.