MAS 450/854: Holographic Imaging: Lab Notes

#8: RAINBOW TRANSFER

Introduction-

As a holographic image is moved away from the plane of the hologram, it becomes increasingly spectrally blurred. This can be interpreted as the spectral *dispersion* of an off-axis Fresnel zone plate, or as the spectral *mixing* of a variety of perspective views of the object, which differ because of image parallax. If the illumination beam is vertically inclined, that mixing is between views of differing vertical perspective. If vertical parallax can be eliminated from the image, this blurring is precluded, and the image becomes sharp (to second order, at least). Thus the central principle of a "rainbow" transfer is the elimination of vertical parallax in the projected real image that serves as an object for H2, which becomes the "white-light transmission" hologram, more commonly known as the "rainbow" hologram.

The elimination of vertical parallax is achieved by using only a narrow horizontal strip of the master hologram, the H1, to project the real image to the H2. First, the H1 is "apertured" by masking it down, perhaps with black tape. To reduce the wasted light, the spherical lens that diverges its projection/illumination beam is replaced with a cylindrical lens (with its axis frame-vertical) that spreads the beam into a frame-horizontal fan that just fills the slit aperture.

The reference beam must be inclined from below to anticipate overhead illumination. This is usually a problem, due to the opacity of the tables upon which hologram setups usually reside (although clever holographers have succeeded in arranging mirror periscopes to make overhead beams possible). We prefer to turn the entire experiment "on its ear," so that the reference beam can be made horizontally oblique, parallel to the plane of the table top, and avoid the need for any mirrors after the spatial filter. This means that the H1 strip aperture is now vertical, illuminated by a vertically fanned beam. References to "up," "down," "the left side of the image," etc., thus become fairly confusing unless strict semantic rules are imposed. I have found it useful to adopt an object-centric or hologram-centric coordinate system that is invariant under rotations of the experiment. When referring to locations or directions as they will appear in the hologram as finally framed and presented (as opposed to directions on the table), refer to them as "frame-left" or "frame-up," for example. We encourage you to experiment with your own idiosyncratic object-centric coordinate names, if your imagination takes you that way.

The optical readout of such a horizontal-parallax-only hologram is highly constrained by the laws of diffraction and focusing, so that the exposing layout must be pre-planned more carefully than is the case for full-aperture or image-plane transfers. In particular, the separation of the H1 and H2 during the transfer exposure is generally greater than is used for full-aperture transfers, being closer to the intended viewing distance. For this experiment, you will use the same master plate as for the previous lab, which was constructed to produce the desired spacing. If all this works out well, your rainbow hologram will be optimum for some appropriate viewing distance, probably close to 500 mm. If your master doesn't work out quite right, carry on regardless, and await another opportunity to generate a more carefully calculated master plate.

Experimental Procedures:

1. Rough out the transfer geometry according to your TA's instructions. It is similar to the full-aperture case, except for the substitution of a cylindrical lens in the projection beam and the removal of the collimating lens. Set up the master and transfer plate holders as before, doing what you can to choose an image slice that gives an H1-H2 separation around 350 mm (14").

2. Remove the projection beam's microscope objective and probe the master plate with the raw, undiverged beam by adjusting the steering mirror or beamsplitter. Observe the real image projected on a white card in the H2 plane, noting the amount of motion between image points at various depths. Select a vertical perspective (frame top to frame bottom) that pleases you, and examine the play of horizontal perspective (frame left to frame right).

3. Insert a cylindrical lens where the microscope objective had been. The long axis should be horizontal across the beam, so as to spread the beam vertically and illuminate the strip of the H1. There may be several lenses to try, in order to fill the plate with a reasonably uniform beam and yet not to overfill it so excessively as to waste light. We often use test tubes of various diameters that are filled with oil, xylene, etc., as well as glass rods and lenses. Handle the lens carefully and pick a clean working area on it so that a smooth and uniform projection beam is produced. Examine the real image now produced on the white card. Is the same plane in focus as in the first step? What are the bright streaks? Verify that this image includes the perspective view you wanted, and mask off the unused plate area with black tape to block stray light. (The width of the slit may be increased by using a crossed

(vertical axis) weak cylindrical lens upstream of the strong lens, and far enough away to overlap their foci, if there is time).

4. Introduce a reference beam from as far away as possible. If the master plate "shades" the transfer plate excessively, it may be necessary to cut away some of the unused part of the master plate, so as to bring the plate holder edge nearer the stripe. The H2 should "face" the H1 (its perpendicular should point near the illuminated slit, and *not* split the object and reference beam angles), with the emulsion side out (if emulsion shrinkage during processing turns out to be severe, the perpendicular should be turned a few degrees toward the reference beam). Mark the "frame upper right hand corner," maybe with a scratch on the emulsion.

5. Adjust the beam ratio so that the bright streaks are just visible against the reference beam, when viewed on a white card. Expose to give a good bleached hologram, processed as your TA describes (if you have time, try different processes on various plates, expecially to check the effects of shrinkage).

6. Examine the processed and dried hologram with laser light to see the virtual and real images of the H1 slit. Put your eyes in the H1 slit real image to observe the image of the object in H2. Illuminate H2 with a point-like source of white light, and observe the spectrally-dispersed real image of the H1 slit. Again, place your eyes in that real image, and observe the image of the object. Estimate the size of the "rainbow" viewing zone produced. Check for distortions of the image as you move up and down and back and forth to enjoy the three-dimensionality of the hologram image. Estimate the depth of field (without blur) of the image you see.