True Color Holography on Du Pont Photopolymer Material

by Tung H. Jeong and Edward Wesly

It has been a long and elusive goal of display holographers to produce true multicolored images closely matched to that of the object. Much progress has been reported recently by K. Bazargan[1], T. Kubota[2], P. M. Hubel[3], and A. A. Ward[4]. However, most of the works reported required sandwiches of different materials independently exposed.

During the OE LASE '90, sponsored by SPIE, we reported our recent work in "true color" holography using single elements of silver halide, dichromated gelatin, and the Du Pont photopolymer material. We have succeeded in recording all three primary colors on a single emulsion, AGFA 8E75HD, by using a prolonged exposure on the green. With the helpful suggestions of Jeff Blyth, dichromated gelatin can now record in the red. However, the most exciting results were obtained using the new Du Pont polymer material HRF-705. True color scatter-free images can now be recorded in a single exposure by a single beam of combined primary colors from three lasers. Furthermore, this material requires no wet processing, thus eliminating the hazards that go with chemistry. Because of its overwhelming advantages, we shall concentrate only on the Du Pont polymer material in this report.

Since laser light is required to record holograms, the reconstructed image by an incandescent source will never recreate precisely the image of a multicolored object as it appears in natural lighting. At least two major factors contribute to this problem: the object may fluoresce; and the reconstruction bandwidth will always be wider than laser lines, causing color desaturation. Furthermore, because color perception is subjective, there cannot ever be complete agreement among different observers as to the "truthfulness" of the reconstructed image. Therefore we offer the following heuristic definition of "true color" which is amenable to scientific verification:

A hologram is said to have "true color" if it recreates an image which has the same combination of wavelengths and their relative intensities as those laser wavelengths detected from the object during recording.

Thus the optimal hologram has to be illuminated by the same combination of laser wavelengths that recorded it. The intensity ratios during recording must be readjusted for reconstruction due to the variation of spectral sensitivity of the medium versus wavelength. While this may be realizable in the future when tunable semiconductor lasers become available, we must live in the present with incandescent source and narrow-bandwidth holograms.

For simplicity, only Denisyuk holograms are presented in this report. Split-beam schemes for both transmission and reflection holograms are in progress. In general, we record the holograms using three primary wavelengths from three independent lasers. This is superior to using any single laser with multi-wavelength outputs because it allows us to control the intensities independently. Two argon lasers and a HeNe laser (krypton will be used in the future) together provide the three primary colors. By judicious adjustments, the combined beam can be white or any color the additive primaries can produce.

Among the many methods for combining beams are: 1) a prism, 2) a system of beamsplitters and mirrors, 3) optical fibers[6], and 4) a holographic optical element (HOE)[7,8]. We favor techniques 3) and 4), as shown in Figures 1 and 2.

We have recently succeeded in recording true color Denisyuk holograms on the HRF-705 material using a single combined beam. Except for the relatively long exposures, similar to those used on DCG, the procedures are wonderfully simple.

The material consists of binders, monomers, a photoinitiation system, and sensitizing dyes; and is provided as a layer 20 microns thick (or thicker) sandwiched between Mylar sheets. When the top sheet is peeled off, the tacky material can be attached to glass or plastic substrates. Exposures are made with the second mylar intact.

The absorbed photons polymerize the monomers in areas of interference maximum, causing an increase in local index. Monomers migrate from surrounding regions until hardening occurs and the process stops. Exposure of the entire hologram to incoherent white

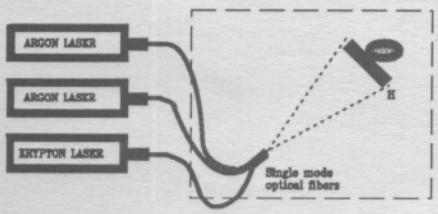

Figure 1:
Optical Fibers for Beam Combining.

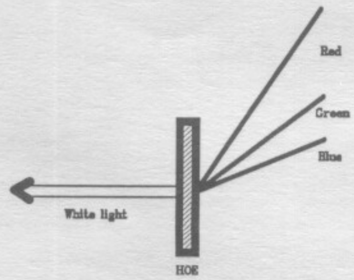

Figure 2:
Holographic Optical Element for Beam Combining.

light (such as sunlight) uniformly polymerizes any remaining monomers. Heating the finished hologram in a oven at 100°C for one-half hour further increases the efficiency.

Because no wet processing is involved, the medium can be of arbitrary thickness. We had made transmission holograms on the 50 micron thick older version of this material over twenty years ago. Not only does it show no degradation over time, but it can be viewed with an incandescent source.

We find that the new Du Pont material represents a significant advance to the state-of-the-art of holographic recording. Its chief attributes are: good storage characteristics before and after exposure; freedom from wet processing; extremely low scatter; high diffraction efficiency; and true color reproduction. One remaining problem to be solved is its low spectral sensitivity, particularly in the red.

References

1. K. Bazargan, "Design of a one-step full-colour holographic recording system," Proc. SPIE Vol. 1051, pp. 6-11 (1989), Editor: S. Benton.

2. T. Kubota, "Image sharpening of Lippmann hologram by compensation of wavelength dispersion," ibid, pp, 12-17.

3. P. M. Hubel and A. A. Ward, "Color reflection holography," ibid, pp. 18-24.

4. P. M. Hubel, "Effects of bandwidth and peak replay wavelength shifts on color holograms," Proc. HOLOGRAPHY '89 (Varna, Bulgaria), SPIE Vol. 1183 (1990), Editors: Y. Denisyuk and T. H. Jeong.

5. T. H. Jeong and E. Wesly, "Progress in True Color Holography," Proc. SPIE 1212 (1990), Editor: S. Benton.

6. T. H. Jeong and S. A. Kupiec, "Fiber Optics in Holography," Proc. International Symposium on Display Holography, Vol. 2, pp. 69-73 (1985), Editor: T. H. Jeong, published by the Lake Forest College Holography Workshops.

7. T. H. Jeong, B. J. Feferman, and C. R. Bennett, "Holographic systems with HOE and optical fibers," Proc. SPIE Vol. 615, pp. 2-6 (1986), Editors: T. H. Jeong and J. E. Ludman.

8. T. H. Jeong and E. Wesly, "HOE for Holography," Proc. HOLOGRAPHY '89 (Varna, Bulgaria), SPIE Vol. 1183 (1990), Editors: Y. Denisyuk and T. H. Jeong.

9. W. K. Smothers, T. J. Trout, A. M. Weber, and D. J. Mickish, "Hologram Recording in Du Pont's New Photopolymer Materials;" IEEE 2nd Int'l. Conf. on Holographic Systems, Components, & Applications, Univ. of Bath, UK (1989). ❑