Technology

SPIE in Los Angeles

Ed Wesly

Two SPIE (The International Society for Optical Engineering) conferences brought holographers to Los Angeles from January 21to 25."Applications of Holography" and "Holography: Critical Review of Technology," chaired by Lloyd Huff of the University of Dayton Research Institute, presented 69 papers to an audience of approximately 500. The conferences surveyed the history and state of the art in virtually every area of holography.

"Holographic Displays" was chaired by Dr. Stephen Benton of Polaroid Corporation and Massachusetts Institute of Technology. The first speaker was Rich Rallison of Dikrotek Inc., who outlined his "holochrome" process for pulsed portraits, the end product of which is an 8 in. x 10 in. flesh-colored reflection hologram suitable for framing. This is no easy feat: it involves recording the pulsed master with a ruby laser (6943 angstrom) on silver halide, and then transferring onto a dichromated gelatin copy plate, recorded at 4880 angstrom. One problem is light scattered from the silver grains in the master when reconstructing at the shorter wavelength; another is minimizing bulbous nose distortion. Rallison showed slides and samples, including shots of his underground lab and pulsed laser studio. There is no good reason to fear having your portrait taken there, since levels of laser radiation are three orders of magnitude below ANSI standard.

The alternative process for human portraiture, holographic stereograms, was presented in three papers. Chris Outwater and Criag Newswanger of Advanced Dimensional Displays discussed the theory, illustrating it with slides of their computerized filming dolly and their lab. These slides were called "Land of the Giants" since the optics used to make 2 ft. x 8 ft. holograms are larger than standard Newport Corporation components. Two of these holographic stereograms were filmed from CRT displays – a computer-generated automobile and an office interior. The holograms are clean, bright and optically well-engineered, providing a very realisitic display. The sharpness afforded by the monochromatic illumination of a mercury vapor lamp also contributes to their effectiveness. Although there is no vertical parallax in this type of hologram, it is visible from many heights without rainbow image collapse. These holograms, along with flat image plane achromatic holographic stereograms, may put the old cylindrical multiplexes to rest. With Outwater and Newswanger's technology priced at only $10,000, we might find a seven-foot ketchup bottle floating in the aisles of supermarkets sooner than we think. Other papers on holographic stereograms represented topics familiar to *holosphere* readers (see. vol. 10, no. 12, p. 1).

The most popular current topic, embossing, was covered in two papers – a third paper was withdrawn. Jody Burns of Holoplate, Inc. demonstrated the entire process of producing large (larger than 6 in. x 6 in.) holograms with a guided "slide tour" of his lab.

Peaking the performance of the photoresist was a paper from Toppan Printing Company. K. Ohnuma showed the results of varying parameters of holographic recording (beam ratio, exposure time, development time and developer concentration) on Shipley AZ 1350J photoresist. He then evaluated the results in three areas: brightness, signal-to-noise ratio (S/N) and contrast.

A silver halide master supplied the real image for a white light transmission copy on a photoresist plate. For each different reference-to-object beam ratio, measurements of S/N and brightness were made for sets of holograms exposed and developed for varying lengths of time. These sets were then processed in different developer concentrations. Graphs were synthesized from the data. For any ratio, the S/N and contrast dropped as brightness increased. Toppan found that their best results were obtained with a reference-to-object beam ratio of 10:1, 40 seconds development time and a one-to-five dilution of developer concentrate to water.

Some outstanding conclusions were:

Brightness depends on the depth of the relief etched into the resist, which is controlled by exposure and development. S/N depends on the non-linearity of the recording material and the amount of intermodulation noise, so it is a function of the reference-to-object beam ratio.

In another paper, Fuji Optical Company showed some exquisite two- , three- and four-layer embossed graphics for record album jackets, magazine covers, and a Sapporo beer advertisement. Although small, they illustrate the graphic potential of the medium for designers. Unfortunately the Japanese are reluctant to export these products to our shores because of the patent situation.

Certainly the holo-embossing industry has been a workhorse in recent years, bringing holography to the attention of the public. Of particular note are the copy-proof "security-grams" on credit cards. Jeff Blyth from England, however, demonstrated that any of us can make a counterfeit embossed hologram that may pass a shopkeeper in poor light, by simply contact-copying the hologram in a Denisyuk mode. A weak, "spurious" transmission hologram is also made in every reflection hologram – and this reconstructs the white light transmission hologram of the card. There may be a surface color on the "bogus-gram," depending upon the processing technique. This is caused by the single-beam reflection "holographic mirror," formed by the reflection from the surface of the original hologram interfering with the reference beam. This may be the give-away to the observant eye, and Blyth recommends shooting for yellow to avoid being caught if you intend to try it! Blyth's process uses controlled differential shrinkage of the Bragg planes, accomplished by dipping a reflection hologram in photo fixer to dissolve some of the silver halide. The hologram reconstructs in a variety of colors, foiling anyone who would try to contact-copy it, even with a dye laser.

Contact-copying of holograms was covered by Smith and Cvetkovich Holography of Chicago. They make editions of multiple-color reflection holograms; Smith showed that the technique of three-color separation as practiced by photographers could be applied to holography. Color separation analysis breaks down a scene into three constituent primaries and can later synthesize the scene from that information. Contemporary color photographic film and paper accomplish this by recording with at least three layers, selectively sensitized by selective absorption of these same colors through the use of complimentary dyes – cyan, magenta and yellow, respectively. However, all that information can be stored in one volume holographic emulsion with three fringe systems à la Lippman.

Smith first perfected processing for Agfa 8E75HD film which reconstructed the reflection hologram of a diffusing glass nearest the laser red (krypton, 647 nm). This color was within the window of the no. 29 red filter. He fine-tuned the colors of other holograms to be within the bandwidth of the standard Kodak color separation filters no. 61 green and no. 47B blue by finding the proper concentrations for triethanolamine pre-swelling of the emulsion.

Smith showed a slide of a hologram which had three overlapping sections of red, green and blue – the intersections reconstructed cyan, magenta, yellow and in the center, white, as predicted. Smith's partner Cvetkovich deserves an award for his equipment designs, foremost of which is a scanning device based on two spinning flywheels. This unit speeds up production by scanning a stripe of light across a contact-copying setup which minimizes spoiled exposures, being more tolerant of local film movements.

A different approach to seeing white, or more precisely, black and white, is through achromatization of transmission holograms by dispersion compensation. The basic principle (following DeBitteto) is to "pre-disperse" a white light reference beam through a grating, the fringe spacing of which corresponds to the mean spatial frequency of the hologram to be reconstructed. This hologram then "un-disperses" the spectrum by diffracting the light in the opposite direction, reconstructing a black-and-white image from what has been traditionally a laser-reconstructed type of hologram. These full-aperture image plane transmission holograms preserve both horizontal and vertical parallax, unlike other white light transmission holograms.

Kaveth Bazargan of New Holographic Design Ltd. showed slides of his research into this area (including full-color experiments), and of the company's commercially available dispersion compensation viewer. This viewer uses a novel grating Holographic Optical Element (HOE) and "venetian blind" system behind the hologram. The reconstruction is as hueless as a black-and-white TV, with doubly dispersed unused orders projecting bright spectra on the floor (see *holosphere*, vol. 12, no. 5, p. 21-22 and vol. 8, no. 7. p. 5).

The sessions on industrial applications covered, among other topics: Measuring the effects of acid rain on stone, inspecting automobile gears for defects, and looking at aerosol particle fields and flow patterns around models in a wind tunnel.

Electronic pickup devices and digitalization of fringe information are more complex, time-consuming and expensive than basic holography. Fringe linearization interferometry or fringe carrier techniques can provide precise determination of holographically recorded displacements.

Undoubtedly the trophy for "most impressive technological tour de force" would go to Brian Tozer and his colleagues of Marchwood Engineering for their remote pulsed ruby laser holograms of the 40-foot deep hot core of a nuclear reactor. Trying to make a successful hologram under the best conditions is not a 100% certainty; imagine the problems encountered in delivering a beam and recording in an environment so full of radiation that it fogs even relatively insensitive 8E75HD film.

After the plate is brought out of the reactor and processed, the reconstructed real image is examined to find defects. Holography's high resolution three-dimensional imagery gathers more information than other techniques for this application. Five-micron deep machining marks on the reactor fuel rods are visible every 2 mm.

Holography is also being used in the search for nature's fundamental particles. A paper delivered by P. Haridas of Massachusetts Institute of Technology offered an update on a bubble chamber experiment at Fermilab (near Chicago). Holographing the volume of the cubic meter bubble chamber is accomplished with a pulsed Neodymium:YAG laser. The holograms are examined microscopically for telltale bubble tracks signifying the presence of a quark called tau-neutrino. The search also goes on in a bigger, 15-foot spherical chamber, and it is hoped that there will be results by the end of this year.

Some papers presented ingenious optical engineering concepts, and applications for HOEs. The Pilkington P.E. Ltd. Labs (England) fabricate HOEs for Marconi Aviation Head Up Displays. They showed a series of color-controlled display holograms – there was not a single streak or smear in the coating, with even, narrow-band reconstruction across the whole plate. Pilkington can produce these items for only 40 pounds.

We will not, however, be able to see the results of a tunable HOE filter, exposed to visible light but reconstructing in the near IR spectrum of laser diodes. A novel recording geometry produces a reflection hologram, the fringe spacing of which varies so that a certain location satisfies the Bragg angle for the infrared wavelength. This type of device finds applications for frequency demultiplexing in optical communications. CGH + HOE= COHOE in the algebra of acronyms.

Computer-generated holograms (CGHs) at the present time are small, inefficient and expensive, encoded with state-of-the-art E-beam lithography. They do not require the existence of any wavefronts, though, for recording – only software. CGHs can be programmed to reconstruct wavefronts that may be very difficult to generate physically with optical components, particularly aspherical wavefronts. So at Kaiser Optical Systems these small, intermediate CGHs are used in an optical setup recording HOEs in a larger scale interferometric mode, explained J.M. Tedesco.

Jack Ludman of Rome AIR Development Center presented a delightul paper on HOEs for energy saving devices. For example, he proposes a 50% efficient grating/window which would diffract a spectrum to a room's ceiling, where a diffusely reflecting paint would ensure that the light would blend back to white by the time it reached a work area. A variation of this idea could be used architecturally as "holographic optical embellishments."

A noteworthy paper in the HOE sessions was delivered by J.J. Cowan of Polaroid Corporation. Entitled "Holographic Honeycomb Microlens," it explored the possibility of making a holographic master for embossing sheets of one-millimeter diameter "fly's eye" lenses into thermoplastic. These microlens arrays would be attached to photographic prints for auto stereoscopic views with horizontal as well as vertical perspective, as in the integral photography of Lippman. More recently, in the integram process DeMontebello used a molded plastic cover sheet – its master was obtained from the impression left by thousands of tiny steel balls embossed into plastic. But now the master can be made on photoresist holographically. The proper lens shape can be made by interfering three beams whose sources are at the corners of an equilateral triangle. Each pair of beams produces a straight line fringe system. The composite of all three systems produces the required honeycomb lens shape. Beautiful graphics illustrated the setup, and stunning electron micrographs of the actual photoresist emulsion showed that this is a workable solution. However, the challenge is to achieve the required coarse fringe spacing, which is approximately one millimeter – a very small fraction of a degree angular separation of the interfering beams.

Running through his company's list of accomplishments in HOEs, specifically Head Up Displays, night vision and laser protection goggles, Gaylord Moss of Hughes Aircraft Company commented that it seems like HOEs have gone further than holography itself.

"Techniques and Other Applications" was a potpourri of interesting subjects. Richard Ingwall of Polaroid Corporation presented holographic performance data for the new photo-polymer material, DMP-128.

Dr. Nick Phillips talked about a possible renascence of Lippman color photography, using it not just for the full-color rendering of scenes, but as a method of evaluating the performance of holographic recording materials. Typically, Lippman's method involves the recording of interference fringes in a black-and-white fine-grained emulsion to reproduce color. Light from a scene focused by a camera lens passes through the emulsion and then doubles back onto itself, forming a standing wave pattern. Traditionally this was done by placing the emulsion in intimate contact with pool of mercury. Dr. Phillips has devised an ingenious method of temporarily laminating aluminized Mylar to the film using 1, 2, 3 - Trichloroethylene. He showed one of his recent Lippman photographs, that of a fringe relief taken under sodium vapor light. It exhibited none of the usual reconstruction problems associated with the process, because of his novel optical arrangement. The most pertinent aspect is the possibility of white light contact-copying for replication of volume holograms. This could possibly solve Smith and Cvetkovich's problems, and give Blyth a run for his money!

In another paper, Dr. Phillips listed the parameters affecting holographic recording materials in silver halide – grain size, gel thickness, gel hardness, sensitivity, ruggedness, the silver-to-gelatin ratio, light scatter, and most important of all, reproducibility. It would perhaps be better for the manufacturers to test out all batches before the material leaves the plant, and to supply the user with figures on these parameters, especially in regards to sensitivity and gelatin hardness.

M.R. Howells of Lawrence Berkeley Lab presented an update of progress in reaching Gabor's goal: optical reconstruction of an x-ray wavefront. Experiments on biological material, diatoms approximately 300 microns in diameter, have been successful in that they do work, but the 100 angstrom intended resolution has not yet been acheived.

At this point, money is being generated by holography, as Dr. Emmett Leith noted in his keynote address, "Holography – Fulfillment of the Promise." A graph of holographic activity based on the volume of papers published each year beginning in 1984 would show a small rise in the '50s, when there were a handful of holographers during the Gabor era. Interest apparently died down in the latter part of the '50s, but actually there was a new "invisible" interest – holography was being applied to synthetic aperture radar (or side-looking radar), which was then classified information. Applying radar principles to optics produced off-axis holography, eliminating many of the drawbacks which had discouraged early experimenters. Utilization of the laser as a coherent illuminating source for recording three-dimensional objects pushed holographic activity to a renewed frenzy, peaking in the mid '60s and then diminishing by the end of the decade.

At that time displays were expensive and not in great demand. Optical memories became popular, but not holography as had been hoped. Spatial filtering was to a limited degree a success, but ran into competition with "user-friendly" computers. Holographic interferometry has always had low visibility, since its areas of application have included industry and the military.

The HOE market is now firmly established – holographic devices for particle sizing and pattern recognition are out in the field, and Leith predicts no more oscillations.

Technique, however, is no longer the major issue. Business now occupies that position, as Dr. Benton pointed out in his review of holographic display technology. In the mid '80s nothing really is new – replication of holograms by embossing and the integration of movies into holographic stereograms have their roots in the '60s, and procedures for multicolored holograms had been successfully attempted by 1980.

Lambertus Hesselink played the devil's advocate with his presentation on non-holographic three-dimensional display of scientific data. Instead of reconstructing wavefronts, depth cues are synthesized by binocular disparity – two different views, one for each eye. The trick is getting each eye to see its own scene. A variety of equipment and techniques exist to do this, almost every one using some sort of eyepiece through which to view. However, these units can easily provide color, as well as a rapid update of infomation.

Of particular interest was Dr. Tung Jeongs's "Holography in Education." He previewed some of the demonstrations that will appear in his forthcoming book, published by The Thomas Edison Foundation. This book illustrates how to explain sophisticated optical concepts with household items. The most ingenious of these, using a pair of rubber bands as an etalon for a vibrating string laser cavity (pumped by a sabre saw) earned him a spontaneous ovation from the audience.

Certainly this summary of the conference could not do justice to all the papers. A complete text is available from the conference sponsor: *SPIE, P.O. Box 10, Bellingham, WA*. Refer to Conference Proceedings no. 523, "Applications of Holography," and no. 532, "Holography: Critical Review of Technology."

Holographic security

Jeff Blyth

The problem of counterfeiting embossed holograms (by single beam contact-copying with holographic film) can be solved by preparing Denisyuk-type reflection holograms so that they cannot be contact-copied.

The system uses controlled variable deformation of holographic fringes over the area of the hologram. If this type of hologram were used on a security card or product label, to the general public it could be an appealing hologram with an apparent permanent color variation. It would differ from the embossed hologram in that it would have a black as opposed to a metallic backing, and it could be fully three-dimensional. To the would-be forger, however, this hologram would present a significant challenge.

Forging with the ubiquitous HeNe laser by contact-printing would result in the following: Only those areas which replayed sufficiently under red illumination would start to produce a copy on a piece of overlaid holographic film, whereas, for example, in the green or blue areas the film would merely "fog" without copying. If the forger then tried to fill in the missing areas with a laser giving green light, the previously formed red areas in the copy hologram would in turn "fog."

A simple way to achieve the necessary effect, making the hologram "forgery-proof," follows:

Place the finished hologram (in an upright position) in an empty vessel and carefully fill it with hypo so that it takes approximately one minute to reach the top of the hologram. If the hologram is then removed and rapidly washed, there can be a variable degree of fringe contraction, depending upon how long the hologram was immersed in hypo.

Patents are pending for the principle of this system, as well as for an improved method of fringe deformation control.