The Royal Photographic Society

HOLOGRAPHY GROUP

Newsletter June 1999

Hologram by courtesy of Applied Holographics / Holograms-3D / Patrick Boyd

Editorial

Another AGM has come and gone, with the usual sparse attendance from non-Committee members. The minutes of the meeting are enclosed with this Newsletter. At the Committee meeting which followed, it was decided to invite Andy Pepper to attend Committee meetings to advise on matters related to the Internet. It was also decided to publish selected excerpts from Newsletters to promote interest in the RPS and the Group. The Website is in fact up and running: the address is http://ourworld.compuserve.com/homepages/rpsholog There will be an article on the way we propose to run it in the next issue of the Newsletter.

John Gates, in a letter to the Committee, tells us that Dr Gordon Rogers has made contact with him. Rogers was a pioneer of holography, one of the few people who pursued the development of holography between Denis Gabor's discoveries of 1947-8 and the invention of the laser in the early 1960s. For historians of imaging this looks like a wonderful primary source. If you are interested, Bob Gibson or I can put you in touch.

A promising way forward for a small Group such as ours is to hold more meetings jointly with other Groups, in view of the success of the meeting together with the Historical Group (reported in this Newsletter), and with the Medical Group some years ago. Other Groups with overlapping interests are the Digital and the Imaging Science Groups, and we hope to arrange further meetings along these lines.

Can I conclude with yet another plea for members to write in? Please don't think your views may be too trivial or parochial to be of interest. Any letter, no matter how critical, will be welcome. You can write in French, German, Spanish or even Latin - if you wish!

Lippmann Photography

Hans Bjelkhagen reveals the secrets of a century-old colour photographic process to a joint meeting of the Holography and Historical Groups.

The lecture room at The Camera Club, Kennington, was unusually full (in fact almost overflowing) for the address by Dr Hans Bjelkhagen of De Montfort University on Wednesday 21 April, on the subject of Lippmann photography, the main area of his recent research.

He began with an historical review of the process. Even before there was photography, he said, there was interest in the recording of an optical image in colour. Early research was centred on the bleaching of dyes: Becquerel carried out some interesting work. But the first, partially successful, attempt at colour photography was by Maxwell, basing his principle on Young’s three-colour theory of visual perception and using an additive method. Eventually, three-colour processes totally dominated other developments. However, true spectral colour reproduction continued in the background. A number of lenticular and diffractive methods were tried; but the only really successful technique was that of Gabriel Lippmann. Born in 1845, he became a professor of physics. In 1891 he made the first true-colour photograph using the interference of light waves, and though his process was difficult, and was overtaken by the Autochrome process of 1907, some fifteen years of extensive research by Lippmann and others resulted in some beautiful and accurate colour photographs - many of them still pristine today. But the process was indeed difficult and beset with associated problems.

Lippmann’s insight was that if light consisted of waves as Maxwell had shown, then if one passed light through a photographic emulsion and immediately reflected it back, standing waves should be set up, producing parallel sheets of latent image one half-wavelength apart within the emulsion. After development, these layers would act like an interference mirror, reflecting only the wavelengths that matched their spacing, i.e., those that were present at any specific point in the image.

Hans compared the Lippmann process with Denisyuk’s reflection holography. In theory, a true-colour hologram records the phase of every spectral wavelength present; but in practice only three discrete wavelengths are recorded. However, because the hologram records phase it can reconstruct an image in depth, whereas Lippmann photography captures only wavelength and position on the film plane. But it does record *every* wavelength, and can thus avoid the distortions in hue and saturation inherent in colour holography.

Lippmann was not alone in his research. The Lumière brothers, Krone, Ives, Valenta, Neuhauss, Lehmann and Cajal all contributed extensively to progress in this field. Edgar Senior in the UK was also a prominent contributor. In particular, the Lumières produced the ultrafine-grain emulsion Lippmann needed to resolve the 0.25 micrometre separation of the fringe planes. Lehmann, working for Zeiss, also made plates, with an absolutely flat spectral response and a sensitivity that brought down exposures from many minutes to around six seconds at f/3, and even marketed them. Around 1893 episcopic projectors were developed to permit public displays of Lippmann photographs. Around 1900 Neuhauss was editor of a photographic journal. He succeeded in making photomicrographs showing the fringe planes at magnifications of X4000, the limit for violet light. [Slides of these were shown.] At a single wavelength, the fringe planes spanned the thickness of the emulsion at regular half-wave intervals. When two wavelengths were used the ‘beats’ were clearly visible. But with a full spectrum, only two or so fringes existed, very close to the emulsion surface and the mirror. As Hans explained, this fits in perfectly with the Fourier model for the behaviour of light, and explains why Lippmann photography reconstructs white and desaturated colours. Lippmann was familiar with Fourier analysis and knew exactly what was going on within the emulsion. [The Fourier model did not reappear until the early 1950s, when it was called in to explain practical lens performance and became the basis of optical transfer functions.]

The important point was that hardly any colours in practice are so saturated (i.e. monochromatic) as to produce interference planes throughout the whole thickness of the emulsion: in most cases no more than two or three fringe planes are produced. The 6-micrometre thickness of a typical holographic emulsion is unnecessary. Indeed, the most efficient recording medium would have a thickness of no more than about 2 µm. Hans said he was already negotiating with Slavich to produce such ultrathin coatings.

Processing was an important part of Lippmann photography. Any deformation of the emulsion changes the fringe spacing and thus the colour of the image. With currently available emulsions it was necessary to use both a prehardener and a tanning developer such as pyrogallol. Fixing was unnecessary, as the grains left behind by colloidal-silver development were insensitive to light.

Lippmann’s original process used a mercury bath in contact with the emulsion. There were some ingenious methods for introducing the mercury, but apart from the hazards of mercury vapour (in those days, nothing compared with the hazards of cyanide fixing baths), and the weight (mercury is heavier than lead), the metal affected the emulsion itself, causing patches and streaks. After some not-very-satisfactory experiments with metal foil backing, Hans did away with the mirror and simply used the light reflected from the plain surface - only about 4%, but enough to produce strong fringes. As the refractive index of air is lower than that of gelatin, there would be no phase reversal on reflection, and the outermost fringe would be on the surface, a considerable advantage.

At this point Hans showed a number of 35 mm slides of copies of Lippmann photographs from all over Europe, including a portrait of Lippmann himself, the Palace of Versailles (there is one of these in the Science Museum, London), and the stuffed parrot which Spirna of Norway [no Monty Python jokes, please - Ed] photographed some 350 times over several months, using his own emulsions. Hans emphasised the very high resolution of the process with one of his own photographs, a panorama of Chicago made on DuPont photopolymer, showing a gasoline station in the far distance in which microscopic examination revealed a list of the prices of fuels.

He had become interested in Lippmann photography largely as a result of his researches into colour reflection holography with Tung Jeong at Lake Forest College, Illinois. He had adapted existing 4 X 5 inch cameras for Lippmann photography; his inspiration had led Ian Pearce, also of Lake Forest, to build a 50 X 50 cm Lippmann camera. One of the main difficulties in viewing the images was that the illuminating light had to be directly behind the viewer. This was solved in the early days by cementing a 10° glass wedge on to the emulsion: this had, incidentally, contributed to the preservation of the originals. He described the making of optical wedges using an angled glass plate and UV-curing optical resin.

Hans concluded his lecture by showing examples of the way in which Lippmann photography could be used for ultra-secure document identification. Lippmann photographs cannot be copied by conventional photography or photocopying machines and, indeed, are virtually impossible to copy by any process at all. Unlike holograms, they cannot be mass-produced, and would therefore be most suitable for identity documents. Hans showed a specimen Swedish passport made using Lippmann photography, using foil-backed material for greater contrast and colour saturation. It bore a Lippmann photograph of himself. The colours shift towards blue if the photograph is looked at obliquely, and when viewed (or illuminated) from a glancing angle the name *Sverige* (Sweden) appears.

The meeting concluded with an opportunity for members to examine some of Hans's impressive work in both Lippmann photography and full-colour holography. Hans has written a number of papers on his research into both these areas of imaging, as well as on the security aspects, and anyone who is interested in these, or, better still, can supply him with information about the early days of Lippmann photography can contact him at The Centre for Modern Optics, De Montfort University, Hawthorn Building, The Gateway, Leicester LEl 9BH,

e-mail: hansholo@aol.com

Department of partly-baked ideas

As I explained in an earlier Newsletter, these articles are fairly loosely based on material I wrote for the journal of the much-missed (New York) Museum of Holography (now, thankfully re-established at MIT after a rescue operation by Stephen Benton). The journal was called *holosphere*, and I contributed a regular article called ‘Jottings from the UK’, the final part of which chronicled the doings of the DPBI. I say ‘regular’, but the timing of the appearance of *holosphere* was anything but regular, and as the editor changed about every four issues the editing varied from the inspired to the shambolic. In the Spring 1986 issue (which appeared some time during the summer) it reached its nadir: pages were misplaced or even missing, and most of my careful report on a special issue of the RPS’s Journal of Photographic Science for Sep/Oct 1985, which was devoted entirely to holography, became a total loss. (Members can, of course, borrow a copy from Bath.) One of the articles, on holographic interferometric tests on turbofan blades, sent me haring off to Derby to interview Ric Parker, then head of holographic nondestructive testing for Rolls-Royce Engines. If you want to study the modes of vibration of a turbofan on a microscopic scale, all you have to do is to make a pulse-laser hologram using a double pulse. The resultant hologram is a contour map of the movement between the exposures, the contour intervals being approximately one half-wavelength, with the bright patches being nodes of no movement. Of course, you need a pretty big plate - you may have actually seen a copy of the Rolls-Royce one, a metre square. But you can get a result on a smaller scale by taking a photograph by laser light, with a reference beam introduced into the camera from behind the lens (a focused-image hologram). It doesn’t have three-dimensional depth, but it records all the out-of-plane movement, which is what matters.

But that is when the shaft is merely shaken along its length. What Rolls-Royce needed to know just as much was what happened at 11 000 rpm. Now,a ruby laser pulse lasts about 25 nanoseconds, and can ‘freeze’ an object moving at something like 8 metres a second for a hologram. But a fan moving at full speed is doing a lot more than 8 m/s, and there is at least a microsecond between the two pulses as well. The obvious answer is to rotate the film at the same rate as the image. No, hang on a minute: you have to rotate the reference beam too.

The answer is to de-rotate the image. But how can you do that? Well, to start with, you have to flip the image. There are three types of prism that will do this: the Dove, Abbé and roof configurations (the last sends the image back again). If you rotate the prism at half the speed of the fan, in the opposite direction, the image will appear stationary (work it out). Rolls-Royce used an Abbé configuration, made out of mirrors for lightness, and obtained spectacular results.

The Department of Partly-Baked Ideas has long been fascinated by the optical effects of such reflecting combinations. Such has been the effect of school teaching by physics teachers who should have known better, that the Department itself is sometimes less than certain as to what it is that a mirror really does. However, after some hard thinking it has decided firmly that the one thing a mirror does *not* do is to reverse images right and left. If you look in a mirror and touch your right ear, your image will touch the same ear with the same hand - the ear and hand that are on the right side of the image as you see it. If you were to paint this ear green and the other one red, matters would be instantly clear. Any seaman will tell you that the terms ‘right’ and ‘left’ have no meaning at sea, as they depend on whether you are facing the bow or the stern: ‘port’ (red light) and ‘starboard’ (green light) remain constant. A mirror doesn’t reverse writing, either. Hold up a piece of paper with writing on it up to a mirror, and it images it without reversal. *You* have done the reversing, as you will see if you look through the paper, which you have spun 180° before holding it up. So a mirror doesn’t reverse laterally; we all know it doesn’t reverse vertically. So does it reverse anything? Yes, it does: it reverses longitudinally. The nose of your image faces the opposite way to your own nose. The image is orthoscopic, as anyone else who looks at *your* image in the mirror sees it with normal parallax. We can coin the term ‘orthoptic’ for the image, too, as it does not reverse the image laterally.

But this term implies that there may be a reflecting device that is *pseudoptic*, i.e., does reverse the image laterally. Is there such a device? Indeed there is: we have described one earlier. All three inverting prisms do if you set them on their sides. You can easily construct a large roof-prism optic by setting up two mirrors touching, exactly at right angles. Front-surface mirrors give the most convincing effect, as you can’t see the join. If you look into this combination, and touch your ear, the image will touch the ear that appears on the opposite side; and a weird experience this is, the first time you see it. Such a mirror reverses laterally but not vertically. If you rotate the combination through 90° so that the join is horizontal the image will be inverted (flipped), but this time the image will touch the ear on the *same* side.

Can we produce a mirror that inverts both laterally and vertically? Yes, we can. Set up your roof prism with the join vertical, then place another mirror on the top, and look into the corner. Your image is now reversed both laterally and vertically. Is it still orthoscopic? Hard to tell; the image of your dominant eye stays stubbornly in the corner of the system, no matter where you move your head. You have created a corner-cube reflector, which always returns light along its original path. Someone else examining your image will, however, be able to confirm that the image is still orthoscopic. In fact, all virtual images are orthoscopic, no matter how complicated the series of mirrors.

You may wonder (a) whether any optical system can of itself produce a pseudoscopic image, (b) what this has to do with holography. Let us answer (a) first. What are the necessary conditions? In a pseudoscopic experience you are looking into a hollow mask of the object. That is, the image is facing in the same direction as the object. All we need is an optical device that produces an image that is *not* reversed longitudinally. The image given by a convex lens is orthoscopic, and you can make a perfectly good one-step hologram of it. But the real image formed by a concave mirror *is* pseudoscopic, and if you make a hologram of this image you will see this. Like the convex lens image it is inverted, but instead of being rotated 180° in its plane it is flipped, the way a master hologram is flipped for transfer. If you flip it or spin it to try to make the image orthoscopic you will finish with an image that is either inverted or laterally reversed. Hariharan’s first full-colour holograms were made by a one-step process using a concave mirror, and he had the same trouble: so all his experiments had to be carried out using symmetrical objects.

So can you combine a concave lens with one or more mirrors to produce an image that can be flipped or spun to produce an orthoscopic, orthoptic image? As the textbooks say, this is left as an exercise for the student.

And the direct connection with holograms? Well, a transmission hologram produces a virtual image, and is therefore a kind of (distorting) concave lens. When you flip it you flip the image, so that it is facing the other way - the necessary condition for pseudoscopy. Similarly, a reflection hologram is a kind of optical mirror, and when it is flipped, the effect is the same. When you make a transfer hologram you simply carry out the process a second time and the image becomes orthoscopic again.