The Royal Photographic Society

HOLOGRAPHY GROUP

Newsletter February 1999

Editorial

So now we are into 1999, the year that sees the end of the Millennium according to our elders and betters (who evidently are unable to count). I have just booked a winter holiday for 1999, ensuring a return several days before the turn of the year. No doubt the airlines have long since zapped their own Millennium bugs, but what of the air traffic systems over Portugal, Spain and France? Russia has apparently grasped the nettle by ordering all its senior airline executives to take an air trip on January the first! And what about your personal equipment? I have no computer - there are far too many electronic gadgets around the house as it is - but I do own two video recorders. One checks out correctly until 2075 (!) but the other, older one appears to be ready to self-destruct at the stroke of midnight on New Year's Eve.

At least the Millennium Dome now seems to be on course. Naturally we want to see holography represented. Via the BIPP I have had enquiries about holography from people concerned with the organisation of the exhibition space. One or two proposals have proved abortive, but our good friend Martin Richardson has now been formally invited to occupy a space in the Dome, so holography will have its place after all.

Holography received a double accolade in the RPS's annual awards this year. Emmett Leith, one of the founding fathers of holography, received the Progress Medal, the Society's highest honour, and Stephen Benton became the first recipient of a medal for progress in three-dimensional imaging instituted by yours truly to celebrate 50 years of membership. Emmett very kindly agreed to address a Group meeting, which was very well attended; there is a report in this Newsletter. I understand that Steve is due to visit this country later this year, and I hope we shall be able to persuade him to address the Group while he is here.

One date already confirmed is certainly one to look forward to. Dr Hans Bjelkhagen will be addressing a joint meeting of the Holography and Historical Groups on 21 April, discussing his research into Lippmann photography, and showing some of his recent work. Details are in the Newsletter and the enclosed leaflet.

Lippmann Photography

Gabriel Lippmann (1845-1921) was a pioneer of colour photography, originating the process named after him in 1891. Louis DuCos du Hauron (1837-1920) had already set out the principles of both additive and subtractive colour reproduction some thirty years earlier, but Lippmann proposed separating out the true colours of the image using the interference principle. The method used what is now termed Bragg diffraction, after Sir Lawrence Bragg, who worked out the theory of X-ray crystallography. Bragg diffraction underlies the operation of a reflection hologram. The reference and object beams enter the emulsion from opposite sides, creating standing waves which are planes more or less parallel to the surface of the emulsion and separated by half a wavelength. If you illuminate the developed emulsion with white light, then light of the wavelength that was used to expose the emulsion will be strongly reflected, as the reflected wavefronts are all in phase. Light of any other wavelength will not interfere constructively and will not be reflected. Of course, you don't have to produce the Bragg planes holographically: you can form them by a repeated surface-coating process, as in the interference mirrors used in lasers.

Now, a Lippmann photograph is a true photograph. It has no reference beam, and cannot record phase. It is thus in no sense a hologram. But it needs an equally fine-grain emulsion, coated on a high-quality plate backed by a reflecting surface. (Lippmann used a bath of mercury.) When a photographic exposure is made, the light reflected back through the emulsion produces the standing waves that record as Bragg planes matched to the wavelength of the light forming the optical image at each point. It's a very ingenious idea, and Lippmann received a Nobel prize for his work.

This was, of course, in the 1890s, and Lippmann photography faced appalling practical difficulties. Panchromatic emulsions were very new and comparatively poorly colour-balanced. Lippmann had to produce his own emulsions and coat them himself. In addition, it was necessary to work out a processing system that would not leave the emulsion shrunk or expanded after processing - a difficult task, as holographers know! Viewing was difficult, too, as you had to have a bright illuminating light directly behind your head. (This was later avoided by mounting the photographs behind a very thin transparent wedge.) Nevertheless, Lippmann and a few other workers did produce some beautiful examples - which, because no dyes were used, did not fade, and, indeed, are as good as new a century later. Most of them are owned by museums in France, but there are a few in the Science Museum, London.

The sheer technical difficulty of the Lippmann process prevented its commercial adoption, and it was forgotten when other processes based on du Hauron's work appeared, such as the additive processes Autochrome (Lumiere, 1903) and Dufaycolor (Dufay, 1910) and the subtractive Kodachrome (Mannes & Godowsky, 1933).* The techniques for making and processing the ultrafine-grain panchromatic emulsions, too, were forgotten until the advent of reflection holography made it necessary to revive them.

*Mannes and Godowsky were not technologists but, surprisingly, professional pianists. Godowsky, in particular, had a technique that made him a legend in his day.

In his early papers Yuri Denisyuk noted the apparent similarities between his invention and Lippmann' s, and he even named his results 'Lippmann holograms'.

In the 1980s Nick Phillips (then at Loughborough University) became interested in Lippmann' s work, particularly the difficulty of obtaining a rigorous theoretical explanation of why they worked even with mixed and desaturated colours. He attempted (with limited success) to make Lippmann photographs using Agfa holographic plates and non-shrink processing techniques.

Hans Bjelkhagen, a leading international expert on the processing of holograms, was working on a three-colour additive method for making natural-colour reflection holograms with Tung Jeong at Lake Forest College near Chicago, when he too became interested in Lippmann photography. He eventually took up a research post within Nick Phillips's Centre for Modern Optics at De Montfort University, Leicester, early last year, since which time he has been researching full-time on Lippmann photography, its past, present and future. Using Slavich plates, he has succeeded in producing beautiful images. He believes that Lippmann photography has a commercial future, particularly in the area of security devices, apart from its artistic value. His talk to the combined Holography and Historical Groups on April 21st will outline the history and continuing development process - with, no doubt, some exciting illustrations.

Department of partly-baked ideas

(Based on articles in *holosphere*, Summer and Fall 1985 issues) Department of Partly-Baked Ideas

Back in the 1980s most of us were having trouble with the stability of our holographic set-ups: we were probably paying too much attention to traffic noise and imaginary laser misbehaviour, and not enough to fluctuations in room temperature and to draughts. Anyway, *something* was playing around with the steadiness of our precious fringes. Around this time, Richard Rallison in Salt Lake City came up with the idea of a fringe stabiliser. A clever but simple optical device diverted part of one of the beams to intersect the other at a very small angle, generating very large fringes (around 1 mm wide), the movement of which could be monitored and corrected by a servo system connected to one of the relay mirrors. Nick Phillips designed one for the RCA, using the piezo tweeter from a Motorola car radio as the transducer. At the time, experiments were going on in psychology labs in the conscious control of brain waves such as alpha rhythms, and Nick suggested, perhaps only half humorously, that by using an electroencephalograph (EEG) connected to an amplifier and feedback system, we could watch the fringes and literally think them back into place. This

PBI led to another, even further out: given enough sensitivity in the system, you could run it purely by psychokinesis. After all, it doesn't take much energy to move a tiny mirror a fraction of a micrometre. It then occurred to me that this might have something to do with our bad days when acres of expensive emulsion are consigned to the bin, and the rarer days when everything comes out right and all our images are dazzlingly bright.

Fourteen years later, this doesn't seem all that much far-fetched. A recent report in *New Scientist* tells of a device which permits totally paralysed persons to spell out words on a computer screen entirely by the power of thought.

In the following issue of *holosphere* I reported an idea by the late Adrian Lines, one of my first holography project students and a dedicated generator of PBIs. After the less than successful outcome of his idea for a holographic sundial (brilliantly realised several years later by Graham Tunnidine), he came up with a bizarre proposal for a holographic image of a keyboard that would actually produce notes when 'played on'. Size was no barrier: he had already made a hologram of (the front end of) a classic American car. Moreover, it wasn't to be just any old piano: it was a concert Steinway he had in mind. The project foundered (he asserted) only because of the impossibility of manoeuvring the aforesaid Steinway into his basement studio. However, the underlying principle was fairly straightforward. When a reflection hologram is illuminated with white light, all of it goes straight through with the exception of the light that is reflected to form the image. If a photodiode connected to a NOT gate is installed beneath the image of each key, and each output is connected to the appropriate key of an electronic piano, placing the fingers on the images of keys will produce the appropriate sound in acceptable, if not concert hall, quality. However, it would be difficult to reach the black notes without covering the white notes and causing them to sound. Pianists with long thin fingers would clearly be at an advantage. Crouching over the keyboard would be discordantly discouraged. Some pieces would go more easily than others: Alkan's fiendish *Allegro Barbaro* from his Op. 35, and Shostakovich's more gentle Fugue in C from his 24 Preludes and Fugues, are entirely on the white keys. Chopin's Etude Op. 10 no 5 in G flat would be altogether another matter.

Oddly enough, although neither Adrian nor I spoke to anyone else about the project, a few years later an eccentric artist (whose name I have unfortunately forgotten) did manage to realise the concept after a fashion, though the phantom instrument was more like a harp than a piano, and could only produce a diatonic tune, one note at a time.

[If anybody out there has any PBIs, please send them in: I should be delighted!]

An address by Professor Emmett N Leith to the Holography Group and guests, at Imperial College, London, 29 September 1998.

The Holography Group and its guests met at Imperial college for a reception in honour of Emmett Leith's award of the RPS's Progress Medal, to be followed by a talk by him on his personal view of the history of holography. Many members will remember a similar meeting several years ago to honour Prof. Yuri Denisyuk, who had also received the Progress Medal.

What follows is a summary of Emmett's talk, slightly rearranged in one or two places for continuity.

Emmett Leith began (as might be expected) with Denis Gabor's discoveries, and listed the less well-known researchers who had kept holography going during the years before the laser was invented, when the remainder of the scientific world had forgotten the subject. These included Haine, Dyson, Mulvey, Rogers, Bragg, Lohmann (who published the first paper after Gabor's, and later wrote the first comprehensive textbook on applied holography), and, in particular, Kirkpatrick and his research students El-Sum and Baez, soon to become professors themselves.

Emmett himself, at 21, had begun studying optics in the same year that Gabor was inventing holography; but he took no active part in holographic research at that time. Instead he became involved with airborne synthetic-aperture radar. The physics underlying microwave imaging strongly resembles that of conventional optics apart from the huge difference in wavelength, but radar has the advantage over visible-light photography of being able to measure distance as well as direction from a single point. The trouble is that the resolution is very low. To achieve resolution comparable with that of a photographic lens your radar 'lens' needs around 10 000 times the diameter (the ratio of wavelengths). The solution is to integrate the readings while flying over a considerable distance using a comparatively small antenna. The data are assembled using an appropriate delay line system, and transferred to film.

As the film plainly contained diffraction patterns, Emmett's team, familiar with the concepts of modern optics, wondered whether optics could be used in the reconstruction of the image. Certainly the mathematical analysis gave a complete replica of the original electromagnetic field. They had read Gabor's and Kirkpatrick's papers and appreciated the way Gabor had solved the problem of recording phase, which codes distance by using a second, reference beam (unnecessary in radar, which can record phase directly). It was apparent that Gabor's difficulties with a spurious real image arose from his in-line optics, and that if the reference beam were simply moved a little off-axis the spurious image would be moved out of the way of the genuine one. Using the best light available they managed to reproduce lettering, then grey-scale transparencies. Then in the early 1960s the laser arrived, and the available coherence length leaped from less than a millimetre to many centimetres. It was now possible to record the wavefront reflected off a solid object. Their technician, who was a model train enthusiast, supplied them with one, which they glued to a heavy steel platform - and made the first off-axis laser hologram. Up to this point it had not occurred to the team that the image itself would have the same depth as the object, and they could scarcely believe what they saw. Soon afterwards (this was 1964) the Optical Society of America had its annual meeting, and Emmett's chief assistant Juris Upatnieks presented their results. They had a demonstration set up in a suite in the hotel, lent for this purpose by Spectra-Physics. When Juris finished his presentation the entire audience made for the demonstration, although the conference was in the middle of a session. The affair generated so much excitement that, as Emmett said, 'We weren't able to get on with making holograms for weeks because we were always on the phone.'

It wasn't easy to make holograms at that time because of the stability needs: people didn't realise that you needed seismic stability rather than photographic stability, and early lasers suffered from frequency drift. But with the adoption of granite tables and the arrival of improved lasers, 'The general the interest in holography just exploded.' Application for grants (and subsequent grants) were everywhere, and all sorts of wild ideas about holographic movies, 3-D TV and incoherent-light holography were aired. Indeed, holography became oversold to the extent that by 1970 research interest had greatly declined, and holography was threatened with the doldrums again.

But much of that research *had* led to viable pathways, and from these came complex spatial filtering, computer-generated holograms, data storage, holographic optical elements and hologrammetry, as well as techniques for non-destructive testing (NDT) and conservation monitoring by means of holographic interferometry.

Towards the end of the 1960s the long haul towards commercially and artistically viable display holograms began. Here the need was for white-light viewing and cheap mass production. Coincidentally, Yuri Denisyuk had developed the reflection hologram at almost exactly the same time as Emmett Leith and Juris Upatnieks had been working on the off-axis transmission hologram. But Denisyuk's published papers were in Russian, and there was a two-year delay before an English translation appeared in the Journal of Spectroscopy - and not a very comprehensible one at that. Denisyuk's work wasn't fully appreciated before 1965, when a fuller report was published independently. [It must be remembered that Denisyuk was unpopular with the hierarchy at the time, and found it difficult to obtain any appreciation of his work even by his fellow scientists.] Emmett related that when the team made their first Denisyuk hologram their processing lab was on the other side of the yard, and as they carried the drying plate back across the yard the image appeared, to their astonishment: they hadn't expected white-light reconstruction. The process was quickly taken up by other working groups, and display holography struggled into life.

In 1969 Stephen Benton with his team at MIT, at the time battling the near-impossibility (then) of holographic video, came up with the white-light transmission ('rainbow') hologram, making possible large window displays, and at the other end of the scale, the embossed hologram, printed on reflective-backed plastic by a process similar to that used for producing CDs. Lloyd Cross invented the holographic stereogram, which multiplexes a large number of photographic images into a hologram and makes possible images with full horizontal parallax of any size object recorded in any light, and with movement, too.

Emmett concluded by looking at current developments. He quoted Charles Townes, inventor of the laser, as saying that whereas you could always predict steady improvements in existing techniques, you just can't forecast really big innovations. No one had predicted transistors, lasers, single-mode optical fibres. Holographic movies? Not in my time, said Emmett. Holography by white light? Likewise. But an enormous proportion of modern optical technology depends on, or depended during its development on, holography. NDT, displays, spectroscopy, optical computing, diffractive optical elements, spatial filters, velocimetry, optical processing, tomography, scanning confocal microscopy, time-gated imaging and imaging through turbid media [two of Emmett's current research areas], photon migration [what?], optical storage, fibre optics, integrated (diffractive-refractive) optics, all make, or have made, use of holography.

Joint Group Meeting in April

The meeting will be held on Wednesday, 21 April 1999 at The London Camera Club, 16 Bowman Street, Kennington, London, 6.30 p.m. for 7.00. p.m., when Dr Hans I. Bjelkhagen will give an illustrated talk on Lippmann colour photography, including his own research. Members of other groups, and their guests, will be welcome. The Camera Club is a few minutes' walk from Kennington Underground station (Northern line).