The Royal Photographic Society

HOLOGRAPHY GROUP

Newsletter September 2005

Editorial

Welcome to another Newsletter. This issue is largely devoted to historical material. Dr Sean Johnston is Senior Lecturer in Science Studies at Glasgow University, and is currently researching the history of holography, so it was a special privilege to have him address a meeting of the Holography Group at the end of April. It is too long to reprint in full, and what appears here is an abridged version (made with permission).
The other speaker at the April meeting was Pearl John, who has been active in the teaching of holography and brought us up to date on her work.

One of our more enthusiastic Group supporters is Dr John Gates (Hon Fellow), who worked at the cutting edge of applied optics during the exciting period when optical methods of measurement were in their infancy, and holography was little more than a few pinhead-sized transparencies and some rather tough mathematics. He has provided some reminiscences of that time, and I hope we will hear more from him to include in later issues.

Another pioneer of display holography has left us. Jerry Pethick, who died recently, is remembered chiefly for his invention of the sand table, a device upon which many self-taught holographers have cut their teeth. He was also involved in the gestation of a number of other innovations, notably in his work with Lloyd Cross on cylindrical stereograms. He was one of the first down-to-earth enthusiasts who showed that you could make excellent holographic images without the need for a PhD and a laboratory full of expensive optical equipment.

Now for some good news. Spatial Imaging has teamed up with Patrick Boyd to run a series of holographic workshops for beginners at the Richmond facility. Two sessions have already been run successfully, and more workshops are planned. For further information e-mail Patrick at info@boydphotoco.uk. Bob and Molly Gibson have also been teaching the basics of holography to schoolchildren, and a report on their first session appears in this issue.

We said goodbye at the end of August to Margaret Benyon MBE (Hon Fellow), who is emigrating to Australia with her family. She is assured of a warm reception from the local holographic community. Margaret has done more than most to elevate creative holographic imagery to a fine art, and we all wish her well in her new home.

Graham Saxby

Scientists, artists and artisans: The making of holographic communities

Like photography a century earlier, holography brought together science and art, military research and cottage industry, hobbyists, artisans and engineers. To become viable, it needed (a) a firm theoretical foundation, (b) the development of practical techniques, (c) a community of practitioners, and, not least, (d) a market. Most of its development was in the years 1964–74, when it established footholds in widely separated areas.

Holography was initially conceived by Denis Gabor in 1947, and he patented some of his ideas the same year. The distinguished scientist Sir Lawrence Bragg brought Gabor's paper to the attention of the Royal Society in 1948; but apart from the work of a few independent researchers such as Gordon Rogers and Hussein El-Sum, nothing further was heard about it for fourteen years. However, in Leningrad during the late 1950s Yuri Denisyuk, unaware of Gabor's work, was researching for the Soviet equivalent of a PhD on a technique for making images of shiny objects by the interference of light waves within photographic emulsions. Having reached their immediate goals, both Gabor and Denisyuk abandoned the area and went on to other work.

The next step came from the University of Michigan. Emmett Leith, working with Juris Upatnieks on synthetic-aperture radar, was evolving the principle of 'wavefront reconstruction' in the optical processing of radar data. They were aware of Gabor's work, and improved his optical layout, producing holograms of continuous-tone transparencies rather than just outlines, using filtered mercury light. The invention of the laser, with its greatly improved coherence length, made three-dimensional holographic imaging possible. In April 1964 the demonstration of the famous image of a toy train to the Optical Society of America astonished scientists. Unfortunately, further research remained largely unpublished because of military security restrictions. But by 1966 communities of holographers, usually consisting of scientists and engineers, were beginning to form. Optical engineering began to include a new synthesis of communication theory and wave optics. Denis Gabor returned to holography, setting up his own lab at CBS Laboratories; Jim Burch headed a small research team at England's National Physical Laboratory (NPL); Ralph Wuerker led a team at TRW in California. The emerging identity of the holographer was promoted by dedicated conferences such as that on holographic interferometry in Glasgow in 1968. Other university labs such as Ann Arbor started the company Conductron to exploit the commercial possibilities of holograms: in 1966 they produced half a million holograms to be included in the Science Yearbook of the World Encyclopedia.

Other audiences were now becoming attracted to holograms. For example, Conductron was approached by the artist Bruce Nauman regarding the possibilities of display holography. Using a pulse laser, he produced a series of holographic self-portraits which were exhibited in small galleries. At about the same time the painter Margaret Benyon, supported by a Fellowship in Art History, taught herself to make holograms in a lab at the University of Nottingham: the results caused a small sensation among viewers. Others, such as Karl Reutersward in Stockholm and Harriet Casdin-Silver in Boston also began exploiting the medium and exhibiting images to small audiences. From merely representational images these artists began to move to more creative and experimental forms and to ‘sculpt with light’. As more artists took to the new medium, exhibitions snowballed. Between the 1970s and 1990s there were at least 500 shows, bringing holograms to a wide public. During the late 1970s, for example, there were large exhibitions in New York (1975), Stockholm (1976), London (1977), and in Berlin, Rome and Canberra (1979). Surprisingly, this artistic movement never reached the USSR. Yuri Denisyuk had overcome the opposition to his research by the authorities, and their reluctant support served to promote the establishment of programmes for the holographic recording of valuable art objects and the availability of these holograms to provincial audiences via travelling exhibitions; but Soviet holography remained stubbornly utilitarian throughout its life.

Perhaps the most important of the individual entrepreneurs of the 1970s was Lloyd Cross, who had worked as a research associate in Leith’s department from the mid-1950s. During a peripatetic three years he collaborated with the artist Jerry Pethick and others in setting up small holography labs and attracting a coterie of followers. In 1971 they set up the first school of holography in San Francisco. In 1974 Cross formed the Multiplex Co, which specialised in animated cylindrical holographic stereograms that could be viewed by white light. These became the most widely seen holograms of the 1970s decade, and had an unprecedented influence on public awareness of the medium. Other private schools appeared soon afterwards in New York, Lake Forest, and, by the early 1980s, scattered throughout Europe. The string and Blu-tack approach was eagerly taken up by young enthusiasts whose individualistic, self-sufficient slant was their design philosophy, and reflected their concerns with alternative technologies, holistic perspectives and opposition to authority.

The countercultural influences of the San Francisco School also promoted wider meanings for holography itself. The distinguished physicist David Bohm mused in print about the analogy between holography, human perception and physical reality itself. Others, such as the psychophysiologist Karl Pribram, took the manifestation of human memory as literally holographic. The San Franciscan holographers largely concurred with these views, seeing making and viewing holograms as a meditative and even metaphysical activity. [See our last Newsletter – Ed.] However, these ideas matured into the more practical ideal of establishing creative holography as an occupation for the amateur, and authors such as George Dowbenko and Fred Unterseher wrote popular manuals on home holography, urging the counter-culture ideas of the early 1970s to mutate to a new dream of holography for public access.

Emmett Leith and Yuri Denisyuk are both still actively researching new applications of holography, though Jerry Pethick and Stephen Benton (who invented the white-light transmission or rainbow hologram and ran a cutting-edge research group at MIT) both died recently. Although many of Gabor's generation of pioneers in coherent optics are no longer with us, most of those who brought holography to its present state of technological excellence are still around. Some of the organisations have had limited lives. The New York Museum of Holography closed a decade ago, though its treasures were saved by MIT. Conductron has long since become a memory. Ilford, Agfa and Kodak have turned their backs on the small market for holographic emulsions. On the other hand, the commercial momentum of holography was revitalised with the advent of embossed holography in the early 1980s, and this has become a worldwide industry, the emphasis shifting from the USA first to Europe, and now increasingly to Asia.

Holography is still a young subject, but it already has an important history not merely for its practitioners, but also for historians, policy makers, sponsors, educators, sociologists and the general public. We can't predict the future, but the study of a well-documented past can help us to organise for success. As Gabor himself said, 'We can invent the future'.

Sean Johnston
(Abridged version of a talk given to the RPS Holography Group on 30 April 2005)

Pearl John discusses holography and education

At the same meeting Pearl John, an RCA graduate in holography, told us of her work in bringing holography to students in the USA and Britain. After graduating she spent some time working with commercial holographers in Britain and teaching photography, as well as organising school projects involving holography displays. In 1998 she gave a paper on her work at an SPIE conference, as a result of which she was invited to run courses at the Columbia Career Center, introducing further education students to laser technology and photonics with a view to continuing for degrees in the subject. These courses proved very popular, especially the parts involving hands-on experience of making holograms. As the college ran a large variety of vocational courses, it was no problem to set up their own gallery: the building course built the fabric, the electrical course did the wiring, and so on. Pearl stressed the importance of teaching laser safety to students: this had been particularly important in the USA, where a teacher can be sued at the drop of a hat From the uncertain world of fine-art holography to that of physics was a transition Pearl found less traumatic than she had expected, largely because many of the students were interested in the creative side of holography as well as its technology and laser work in general. She gave examples of some of the more way-out projects dreamed up by the students. In particular she described a long-term project to make a comprehensive DVD on how to make holograms, at the moment still unfinished, but competent enough to have attracted the support of SPIE.

Pearl had originally intended to spend only one year in the States, but ended up staying for more than five. Soon after returning to the UK she was invited to join Southampton University, one of the foremost research centres for photonics, working mainly with postgraduate students. She is associated with an important project the University is sponsoring is called The Light Express Roadshow. This is a free travelling laser show aimed chiefly at GCSE physics students, and designed to introduce students to photonics, in view of the worldwide shortage of laser and photonics technicians. The show operates in school and village halls, and consists of a spectacular laser show with built-in demonstrations of the principles of photonics, such as trapping a light beam within a stream of water to illustrate fibre optics. Pearl concluded by describing the various Government-sponsored initiatives related to photonics and the way they are being implemented, and showed some of her own recent work.

Graham Saxby

Some reminiscences of the times leading up to holography

Nowadays the term ‘hologram’ covers many different applications, sometimes inappropriate, as with some seaside souvenir baubles that have little or nothing to do with diffraction. The name was coined by Denis Gabor to describe imaging by reconstructed wavefronts, and arose from his research into improving the resolution of electron microscopes. After his first published papers appeared in 1948–9 little further happened in the area, until Leith and Upatnieks modified Gabor’s geometry so that the diffracting structure produced two separated images. In its first edition published in 1959, *Principles of Optics* by Born & Wolf (the optical physicist’s bible) had given an account of holography provided by Gabor himself; by the second edition of 1964 the invention of the laser had made possible the off-axis holograms of Leith and Upatnieks; and by the fourth edition of 1970 the section had been much expanded. (In addition, Gabor himself made a further contribution in the form of an appendix giving an account of the dissimilarity between light optics and electron optics.)

My own university education was deferred by the war until 1946, when I spent three years in the Department of Physics. I was fortunate to be at Imperial College at a time that was to have such influence on subsequent developments. I joined the Physical Society’s Optics and Colour Groups. Gabor was an enthusiastic supporter of both, and I remember several of his presentations on stereoscopy and colour vision.

I had been able to resume university studies owing to my having acquired a part-time job in Ilford’s Research Physics Laboratory under Dr L V Chilton. This had involved the study of the preparation and coating of photographic emulsions. Measurement of the sensitometric characteristics of Ilford material, in particular of special products for the Services, had become increasingly important as the war developed. In 1942 four of us were attached from Ilford to join teams from other manufacturers at the Royal Aircraft Establishment at Farnborough to work on the design of film and print emulsions suitable for processing under tropical conditions. A year or so later there was a new requirement for research into camera technology for both low-level and high-level reconnaissance photography. At the conclusion of the European war, there was a need in the Far East for even lower-level forward-facing photography. At the same time there were demands for aerial surveying in preparation for the replacement of wartime losses and the coming demand for housing. This coincided with the revival of commercial aerial photogrammetry, which for me continued when I joined the NPL (Light Division) in Teddington on leaving Imperial College in 1949. Indeed, one of the first jobs was the calibration of an RAF camera for commercial aerial survey work! In this connection I visited the National Laboratory in Ottawa, which had its own calibration installation – though eventually this project fell through, when funds ran short and alternative methods of calibration were found.

The Division had two subdivisions: mine was concerned with optical metrology, which made much use of interferometric methods, employing Twyman-Green and Fizeau interferometers for the evaluation of optical surfaces to small fractions of a wavelength. The other subdivision, under Dr Walter Stiles, was concerned with photometry and colour measurement, and was involved with the construction of a triple monochromator for the re-determination of the so-called Standard Observer, for submission to the Commission Internationale de l'Eclairage (CIE). Much of the work of the Division was involved with the development of optical measurements for industry. And not only for lenses: one special case was the measurement of the sphericity of glass balls precision-made for the determination of the acceleration due to gravity, to pinpoint their exact centre of mass. All this work was based on measurements of interference fringes either photographed or displayed electronically, and this demanded very stable light sources (there were as yet no lasers).

Around 1950 C R Burch at Bristol University, assisted by J M (Jim) Burch (no relation), was developing a reflection microscope. Incidentally, Emil Wolf (of *Born & Wolf* fame) was at Bristol at this time. Jim Burch subsequently joined Dr Stiles's Colour Measurement Group, and after the successful conclusion of the project he joined the Division Superintendent, Dr L A Sayce, on his own project, the production of optical gratings for engineering measuring machines. He brought with him an interferometer which he had designed himself to measure the accuracy of large concave mirrors by imaging a large scatter plate containing a random array of fine details back onto itself: any errors would show up as interference patterns. Jim and I visited many of the institutions involved with the construction of large telescope mirrors, using this interferometer to monitor their work.

At the International Commission for Optics Colloquium in Brussels in May 1958 there was a broad presentation of the NPL's work, and this was followed in 1959 by the NPL Symposium No 11 on Interferometry, which I was responsible for organising. The NPL's Director Dr G B B M Sutherland presided. Our Distinguished Guest was Prof, F Zernike of Groningen

University, Nobel Prize winner and inventor of the phase contrast microscope, a device that helped to point the way to holography. (Incidentally, his last student, Murk Bottema, was subsequently responsible for designing the successful correcting optics for the Hubble Space Telescope.) Jim Burch was now chosen to set up a team at NPL to liaise with Bell labs and with the Russians. This group (of which I was a member) was part of the team that produced the first working optical masers – or 'lasers' as they became known. This resulted in the whole aspect of metrology expanding and changing into something like its present form. Soon after this I became due for retirement, but continued my association with the RAE and with aerial surveying and optical metrology, first in India and then with University College, London with a Visiting Professorship in Photogrammetry.

John Gates

Holography in Schools

For some time now Jeff Blyth has been demonstrating the making of small holograms using a cheap laser pointer modified by removing the collimating optics. We wanted to give schoolchildren the chance to make their own holograms by this method, so we contacted the teacher who runs the after-school science club at the local secondary school, who was very enthusiastic about the idea. Jeff provided us with one of the little diode lasers, and Mike Medora kindly donated some 4×5 inch plates, which we cut into quarters. After some experimenting we felt we had a system sufficiently safe and robust to use in a school environment, and provided details to the school authorities for checking against Health and Safety Regulations. We then arranged a dummy run with the teacher doing everything the children would be doing.

On the day of the workshop we set up our equipment in the lab well before the children arrived. We began with a half-hour talk covering the wave nature of light and interference, how holograms worked, basic photochemistry and safety precautions (i.e. hold plates by the edges but don’t cut your fingers, keep the plates emulsion up when processing, etc). They did a few practice runs with old waste plates, and then we turned on the safelight, switched off the white lights and began.

The 12–13 year old children were divided into two groups, with each child given a significant job to do: putting the plate onto the frame and arranging the objects on it; operating the shutter for the required interval, or agitating the plate in the various processing solutions. When the image appeared during the drying process they were thrilled! The second group made a similar hologram. Then the holograms were mounted on black card attached at the top edge only, so that they could be flipped to see the pseudoscopic image. After we had shown them a couple of our 8×10 inch holograms they went away with a handout summarising our talk and a hologram similar to the ones they had made.

Bob & Molly Gibson

Department of Partly-Baked Ideas

Every schoolboy knows (as Macaulay was wont to say) that the refractive index (RI) of a material is numerically equal to the speed of light within it divided into the speed of light in empty space. Maxwell showed that the speed of light in any substance was a simple function of its permeability and permittivity, two purely electromagnetic constants. No material can have an RI of less than 1, as that would mean that light within the material was travelling faster than light travels in a vacuum – which is forbidden by relativity theory. But there is no *upper* limit. Diamond has the very high RI of 2.48, but germanium and silicon have RIs respectively of 3 and 4 (to infrared). The RI of a material is an important factor in designing a lens, as it determines the required surface curvature: the higher the RI the less the required curvature. The DPBI has been intrigued to read that it has become possible to fabricate materials that slow down light many thousands of times (you can't actually slow down a photon. What happens is that it is repeatedly absorbed and re-emitted by the molecules of the transmitting material), giving effectively an RI of thousands or even millions. The DPBI has visions of powerful lenses made simply by putting a little stress on a flat piece of the material. One difficulty would be that as the critical angle for total internal reflection would be less than a degree, any light striking the inner surface of such a lens at anything other than a very small angle would never emerge at all! It would seem to be possible, however, to shine a beam of light on an optical flat made from such a material and have the beam emerge, pristine, a week later. The DPBI would welcome suggestions for uses for this remarkable facility.

Even more bizarre is the possibility of a *negative* RI. This is allowed by Maxwell's Laws: both permeability and permittivity can be negative under certain conditions. In fact this has already been achieved for microwave radiation. Doing the same for visible light is likely to be a good deal trickier. However, certain metals have odd optical properties when in very thin films, and some positive results have been indicated with transparent materials coated with a microscopically thin layer of silver. What would a negative refractive index mean? Well, applying the laws of refraction shows that it would still take place according to Snell's sine rule, but as one of the sine terms would be negative the ray would be refracted in the opposite direction to what would be otherwise expected. Carrying this to its logical conclusion means that a flat plate of negative-RI material would act in the same way as a powerful convex lens of conventional material, greatly simplifying optical designs; and, moreover, its resolution would not be limited by the usual laws of diffraction. The only snag is that the effect depends on being able to catch the evanescent wave that occurs at each surface; and as this falls off so rapidly as to be undetectable at distances of less than a wavelength, the object would need to be only about a quarter of a wavelength away from the 'lens', and the image would be formed a similar distance away from the other side. Hmm.