

# Holographics

*International*



**The Australian Dollar: It's Cracking Up!**  
**The Graduates: RCA's New Generation**  
**Danish Focus: New RISO Laboratory**

**Spring 1988 Number 3**  
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# Holographics International

Spring 1988

Number 2

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## EDITORIAL

If you turn your attention to the back page, you will see that the subscription price has gone up. This is to pay for the *The Holographics International Directory and Buyer's Guide* which all subscribers will receive as a supplement to our winter edition for 1989. No doubt you will hear more on this subject at a later date.

In this issue, as you can see, I have given over my editorial space to Jesper von Wieding. I hope you find his opinion stimulating but, whether you do or not, I would like to know what you think of the idea of a guest editorial.

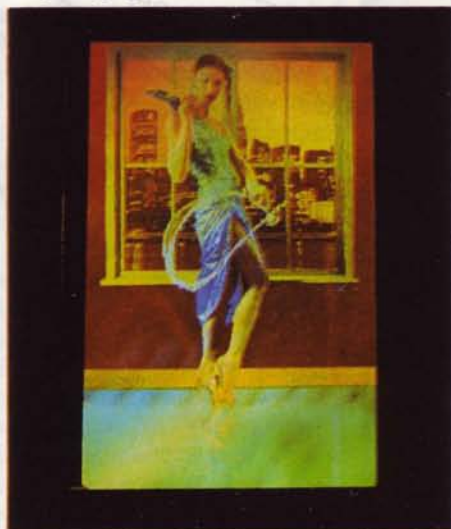
It was pointed out to me that I got Bruce Goldberg's status badly wrong in my last editorial. Bruce is, I am told, a competitive holographer and this makes something of a nonsense of my remarks. In any case, it was suggested that I stop printing reviews in favour of previews. This would seem good advice although my mind is still open on this subject.

Sunny Bains

PSEUDOCOLOUR  
CONFUSION

Dear Sunny,

In order to stop the on-going confusion caused by the suggestion that Mike Medora worked at SEE 3 and may have learned colour control from us (or vice-versa) we would submit the photograph shown.



The photograph shows a pseudo-colour hologram made in 1983 by SEE 3 (Holograms) Ltd. using a planar technique for primary colour mixing using three exposures. We would like to emphasise that there is no connection between the pseudocolour work presently being done by Mike Medora and the early experiments of SEE 3, and that Mike has never at any time been an employee of SEE 3 (Holograms) Ltd.

Many Thanks

Jonathan Ross  
David Pizzanelli

## GUEST EDITORIAL

by Jesper von Wieding

Holographers often talk about the conservative nature of the commercial graphics industry. They cite this as the reason that display holography is not yet an everyday sight in the media or a usual part of the palette of graphic artists and art-directors.

It is my experience that commercial artists in Denmark have a very limited knowledge of the possibilities of holography. This is because many of the producers of holograms have a tendency to mystify the production process, perhaps in order to veil the real costs of production or to exclude commercial agencies from dealing directly with customers.

Since there are only a few hologram producers in the world who have the necessary all-round design skills to meet the needs of customers without requiring the involvement of conventional graphic designers, it is therefore quite common to see commercial holographic displays which show that the designer had little understanding of good design and aesthetics.

Only a few hologram producers have, as yet, understood the necessity of limiting themselves. They have not, so far, taken the decision to choose their identity as either an artist or as a commercial producer. This happens mainly because of the free advertising a producer can get by participating in holographic exhibitions labelled as 'cultural' or 'artistic'.

What the commercial producer should be concentrating on is producing the highest quality holograms at the lowest prices. He should see himself as just one of the necessary links in a long chain within the graphics industry. Assuming this clearly-defined identity would increase the acceptance of display holography in that industry, ensuring its use continues to increase even after the gimmick value of holograms has gone.

My own country, Denmark, is not the only one where some individuals seem more intent on self-promotion and a quick profit than on promoting holography as a graphic tool which could be used to benefit the media.

The reluctance of commercial producers of holograms to see themselves as simply that, limits the development of holography as an art form. The art world has difficulty in coming to terms with holography as art, and art critics are not comfortable in dealing with the medium.

Danish holography, for example, has received international exposure on several occasions,

but the country has only one established holographic artist, Frithioff Johansen. It will be many years, therefore, before the Danish art world fully accepts holography as art.

In larger (and richer) countries, such as West Germany, the new visual medium is achieving a much more rapid understanding and acceptance in the art world. This is helped by individuals who are prepared to buy art for its own sake, rather than as a secure investment which requires art to be in an established form.

One sign of hope is the willingness of some companies, even in Denmark, to invest in new art forms. They have recognised the value for their public image of being seen to have an insight into high-tech art, which encourages customers to see them as companies with substantial resources and with vision for the future.

There is no doubt that holography and other exiting new visual art forms will eventually find a place in the established art world. It is clearly necessary, however, to separate art from commercial design work. Real artists and designers should be given the resources to make an entrance into their respective fields in holography. Then perhaps the individuals who seek fame and fortune by exploiting the novelty value of holograms will give way to those who have the interests of holography at heart.

## About the Author

Jesper von Wieding is a graphic designer, director and investor with the Museum of Holography and New Visual Media in Denmark. The museum, which was founded by Matthias Lauk and is based in Pulheim/Cologne, West Germany, organizes exhibitions of holography and other new media at what they consider to be the highest possible artistic standard. In addition to his work with the museum, Mr von Wieding is representative and spokesman for the art group "Danish Figuration", the exclusive group of Danish figurative painters. To differentiate between his artistic and commercial interests, he has established von Wieding Communications which specialises in delivering complete packages which can include new visual media where appropriate.



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# CAPTAIN COOK IN HALF-BAKED HOLOGRAM

by David Pizzanelli

After years of development, at an estimated cost of US\$14 million, the world's first banknote with a hologram on it has been issued to the public in Australia. For the researchers at the Commonwealth Scientific and Industrial Research Organization, where it was developed, this may have been a dream come true, but for the Reserve Bank of Australia, which is printing and issuing the note, it is fast becoming a nightmare. There is a problem: the hologram rubs off.

The note, a special-issue ten dollar bill to coincide with the Australian bicentennial, has a small picture of Captain Cook, made up of diffraction gratings, in one corner. When the note is crumpled, however, cracks and lines appear across the hologram and Captain Cook soon becomes unrecognizable. When rubbed, the device disappears into a silvery powder, leaving only a clear plastic window.

The disappearing hologram may be an embarrassment to the Reserve Bank of Australia, but it is at the same time not good news for the rest of the holographic community, especially those companies working in the security field who are struggling to find an effective way of putting holograms onto banknotes and paper substrates.

For years the problem of hologram durability - or the lack of it - has prevented the public issue of a holographic banknote, and in recent months the behind the scenes rivalry between the main contenders seems to have increased. Although American Bank Note have been more reticent lately, after their initial enthusiastic announcements in the press that American dollar bills would soon be graced with holographic portraits of presidents. It was clear at the Optical Security Systems Symposium in Zurich (see

last issue) that Landis and Gyr were confident that their kinegrams could withstand anything that the Swiss could contrive to do to them.

However, the bicentennial acted as a clear deadline for the Australian team, meaning that they really had no option but to go ahead

with the public issue of the note, ignoring the progress made by others in the field. The publicity which accompanied the launch reminded Australians that "The costs of maintaining a clean issue fall on the population at large and it is therefore in the users' interests to

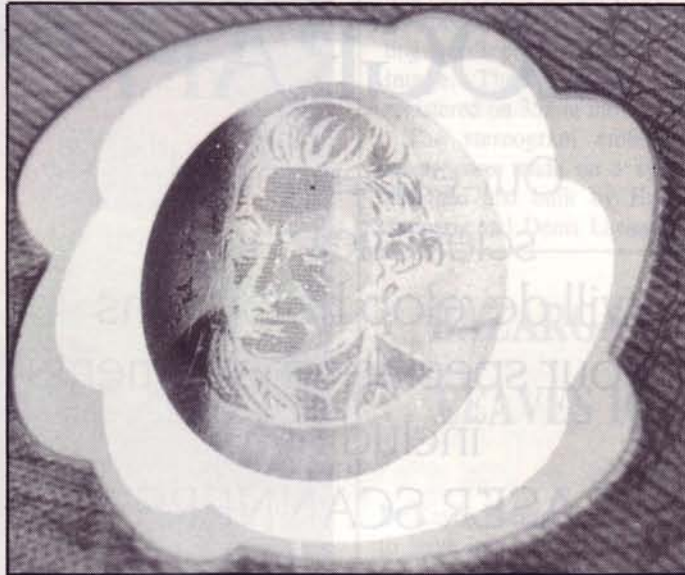
handle currency with some care". But it seems that the notes are not able to withstand the normal rigours of being in circulation despite specific warnings about their care.

From a security point of view, the new note is actually rather more vulnerable than the regular Australian 10 dollar bill. There is no watermark on the new banknote because it is printed on a plastic substrate rather than on a paper base, and there is no metallic thread running through it. The printing consists of four plate off-set on both sides, with three colour intaglio printing on the recto (hologram in top right corner) and just two colour intaglio printing on the verso (hologram in top left). Please see cover.

For shopkeepers with magnifying glasses there is some micro-printing on the recto tucked into a hillside between the boat's sails, and a through the note registration mark within the small diamond shape next to Captain Cook. Neither of these features are really verifiable with the naked eye. Captain Cook's appearance on the banknote, therefore, is far from being purely decorative: the 'Optically Variable Device' really is the feature upon which the note's security depends.

It is important to note that the OVD is not strictly a hologram but a composition formed from different diffraction gratings. This distinction is important because of the growing minefield of holographic patents, particularly in the area of security. Diffraction gratings are beyond the reach of the ABN hotfoil patent, Steve McGrew's 2D-3D patent and even the original 'Granddaddy' patents which cover all forms of off-axis hologram.

After announcing that 54 million of the new banknotes would be put into circulation during 1988, the Reserve Bank's note printing branch at Craigieburn in Victoria has halted production because of "industrial disputes". At time of writing, there was no indication of whether or not production of the new note would recommence. At present, collectors in Australia are said to be paying five times the face value for the new notes in mint condition - so it seems likely that the good Captain will survive unrubbed and uncrumpled in at least a few hands.



*Before...: Captain Cook on a mint note.*



*...and after: The grating after some time in circulation.  
(Photos courtesy of TNT magazine, London.)*



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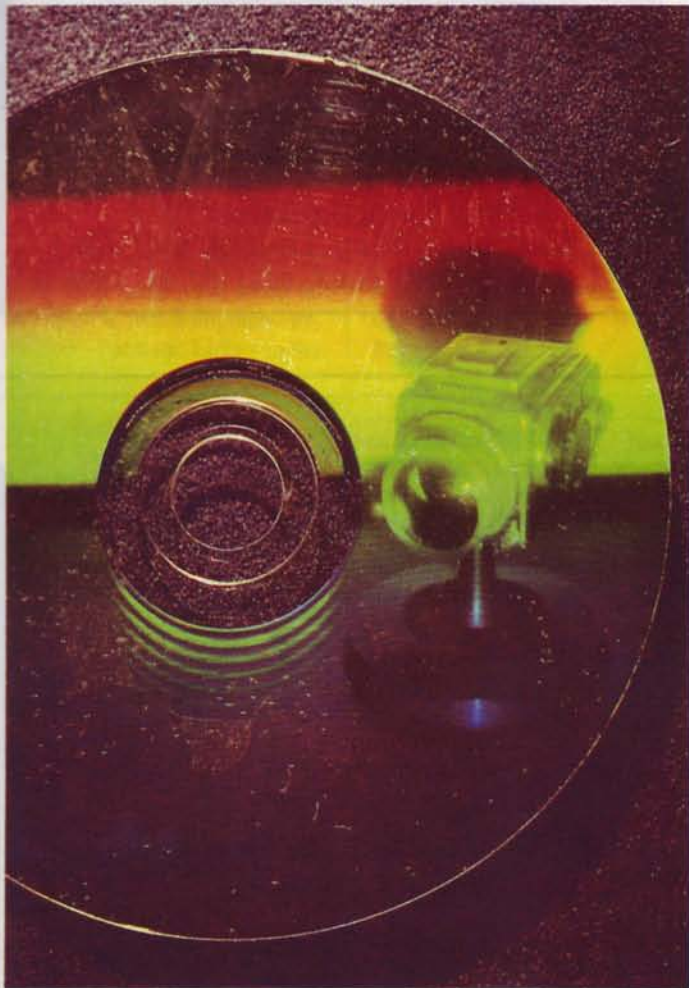


## CD STYLE INJECTION-MOLDING

The Laser Labbet in Linköping, Sweden, has succeeded in producing what is thought to be the first injection-molded hologram.

The hologram was made using a new method borrowed from a technique used in making compact discs. The idea of the project was

sensitivity to lighting angles, even very good holograms can suffer a dramatic decline in quality when glued to a rough surface. The stability and thickness of the new injection molded holograms should ensure that these problems are eliminated. The molded



*An injection-molded hologram in the shape of a compact disc.*

to make a hologram which could combine the high quality of an ordinary glass plate hologram with the low unit price of mass produced embossed holograms.

Holograms on thin foils are often difficult to see because they are attached to surfaces which are not perfectly flat or which are unstable. Because of their sen-

holograms are also more flexible than foil embossed in that they can readily be made into transmission holograms.

Nils Abramson and Ea Jonsson have been working on this project since the beginning of 1987. They are supported by the Hasselblad Federation and the Swedish Board for Technical Development.

## STEREOGRAMS FROM COMPUTER GRAPHICS

This hologram will be the official badge of the *Parigraph* show, one of the most important European trade shows dedicated to computer images, in Paris. It was produced by Hologram Industries of France, which will also be exhibiting its latest work on large format holograms at the show.

The image is a stereogram made from an existing 3-D computer graphic. The only translation needed was the generation of a number of 2-D images representing specific projections of the 3-D image. These images were registered on 35mm movie film.

The stereogram embossing master was made on a system designed and built by Hugues Souparis and Denis Lachaud of



Hologram Industries, which makes it possible to use existing 3-D computer graphics to create holograms.

The computer graphic images were created by Sogitec, and the holographic work was done by Denis Lachaud.

## BAZARGAN LEAVES IC

Dr Kaveh Bazargan has decided to leave Imperial College, London, to set up in business as a consultant in holography, optics and computing. He had been working as part of the Applied Optics group in the Physics Department researching into the use of holographic optical elements for use as interconnects in optical computers.

Arrangements have already been made for him to consult on various projects, but as well as this he hopes to be able to work in areas of holography that he has not been able to work on at Imperial.

One such area is the commercialization of full colour holography, a subject he researched for his PhD. He is surprised at how slowly full colour has developed, especially in comparison with pseudocolour which he sees as more difficult.

## MELLES GRIOT TAKE-OVER

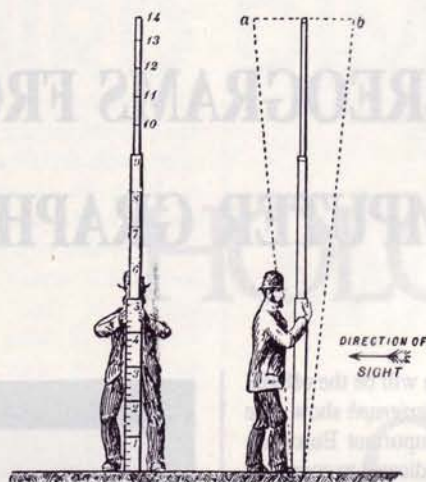
Melles Griot, the US laser manufacturer, has been taken over by the South African controlled company J Bibby & Sons. The deal, which was completed on March 8th, involves the cash purchase of 90% of Melles Griot for US\$38 million.

Melles Griot, previously privately owned, manufactures in six locations in the United States, and in Taiwan and France. It has sales offices in the USA, Canada, Japan, Britain, The Netherlands, France and Sweden.

J Bibby Science Products is already engaged in the manufacture of specialised precision components and instruments for laser and electro-optical applications through its subsidiary, Technical Optics Limited, which is located on the Isle of Man in the UK.

Mr J A Melles, 47, the founder of Melles Griot, will be staying on as president.





FRONT VIEW  
Fig. 234.

SIDE VIEW  
Fig. 235.

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# IRISH EYES ARE SMILING

A new company, Holograms Ireland Ltd, has been formed to promote the sale and distribution of holograms and holographic products in Ireland. The company is equipped to originate creative designs and to cooperate with holographers in the design, production and marketing holographic services and products.

As one of the first promoters of holography in Ireland, Mr Basil Clancy, managing director, has taken an active interest in holography since 1977 when he attended the first holography exhibition - Fantastic Light - in the

Royal Academy of Arts, London, and made contacts with technicians, scientists and artists at the exhibition. It was he who took the initiative in establishing Holograms Ireland Ltd and is now interested in making contact with suppliers of holograms and holographic services.

The other directors are Mr Hugh Fox and Mr Martin Fox who are also directors of Thermfoil Print Ltd, Ennis, County Clare, a company specialising in hot foil printing. Mr Clancy can be contacted at: 1 Hillcourt Road, Glenageary, County Dublin, Republic of Ireland.

## NEW SCIENTIST SPECIAL: REVIEW

*New Scientist*, the popular British science magazine, recently published an issue with a special set of features on holography. The issue, which came out on February 4th, included an articles about art and industrial holography, as well as a book review and a long general article.

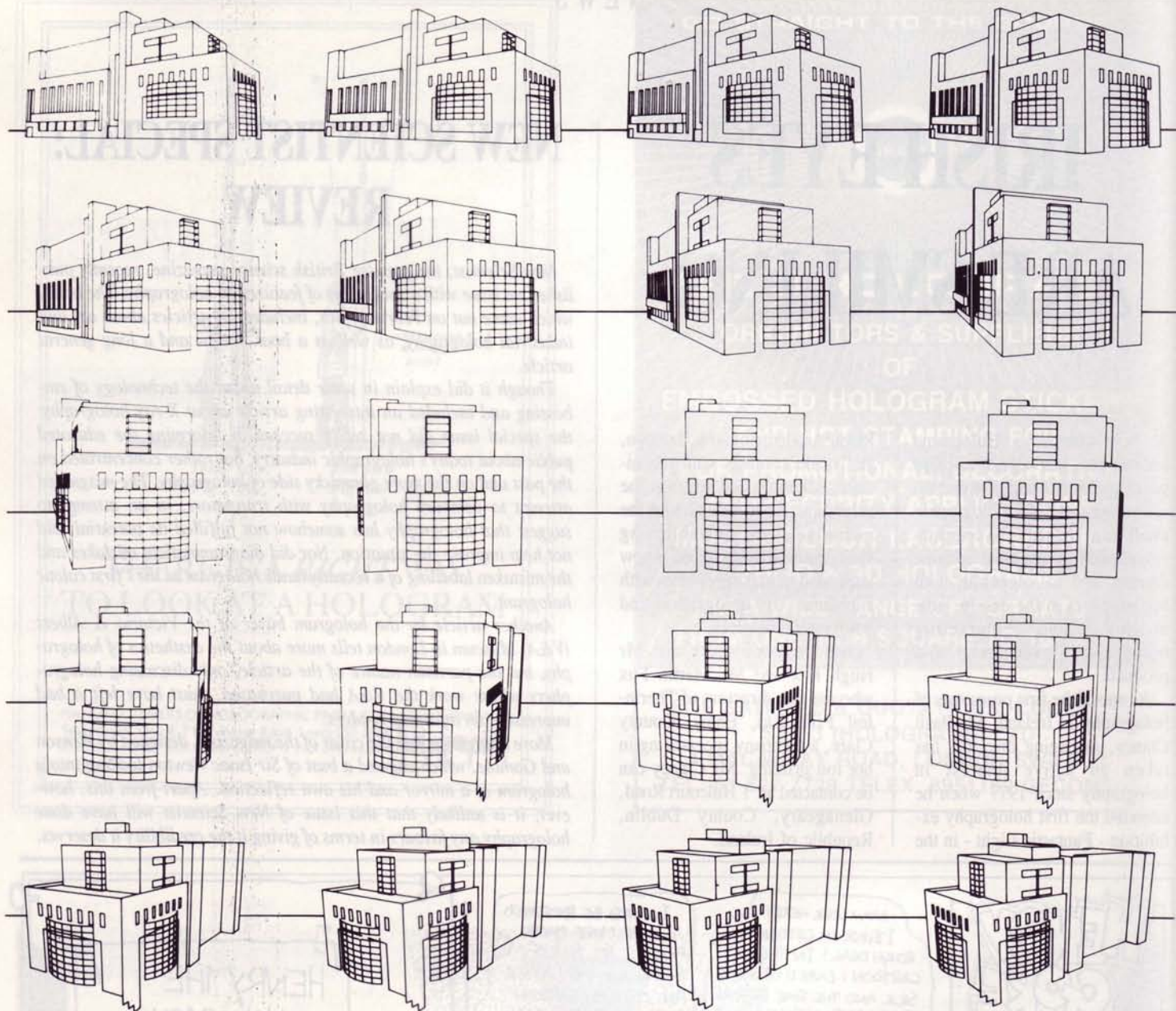
Though it did explain in some detail about the technology of embossing and included an interesting article about X-ray holography, the special issue did not really succeed in informing the educated public about today's holographic industry, but rather concentrated on the past and on the more gimmicky side of holography. The misguided attempt to compare holography with transistors, in an attempt to suggest that holography has somehow not fulfilled its potential, did not help improve the situation. Nor did diagrammatical mistakes and the mistaken labelling of a recently made hologram as the "first colour hologram".

Another article by the hologram buyer at the Victoria & Albert (V&A) Museum in London tells more about the aesthetics of holography, but the partisan nature of the article, only discussing holographers whose work the V&A had purchased, must have left a bad impression on informed readers.

More impressive was the cover of the magazine, designed by Wenyon and Gamble, which showed a bust of Sir Isaac Newton looking into a hologram of a mirror and his own reflection. Apart from this, however, it is unlikely that this issue of *New Scientist* will have done holography any favours in terms of giving it the credibility it deserves.







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# GETTING IT DOWN IN BLACK & WHITE

by Edwina Orr and David Trayner

At Richmond Holographic Studios, we have been researching black and white holography for several years. Aside from the obvious inherent attraction of white, we pursued work in this area for two main reasons.

The first derives from the difficulty of harmonising the colours and textures of holographic images with other materials in the context of holograms incorporated in sculpture. It is well known that the use of colour in sculpture is problematic - any colour other than the natural colour of a material has the tendency to seem incidental and to visually detach itself from the work. The same problems apply to the spectral colours of a hologram when juxtaposed with other materials. The ivory neutrality of a holographic white can overcome this, as the colour is neutralised and the textures softened: a kind of optical "sfumato" (a blending technique for painters developed by Leonardo da Vinci).

Our second reason was the prosaic commercial one of extending our palette for commissioned holograms and to make our holographic portraits more attractive - we all know about the "pickled person" aspect of the majority of holographic portraits and of their cruel rendering of the texture of skin imperfections. Both these drawbacks are largely overcome when the copy hologram is black and white (or even pink or lilac). In the recent pulsed work that we have been doing at our studios in Richmond we have been able to advance the use of these and other techniques in portraiture and we have noticed a greatly increased acceptance of the result by the general public - we now rarely encounter comments such as "weird" and "deathly".

The main content of this article is the detailed description of the production of a white, gold and blue deep-image reflection hologram using an approach developed at Richmond, prefaced by a description of the principal problems involved and a review of some other techniques that have been used to produce white images.

There are two main problems to be solved, achieving the correct mix of colours to produce a white and ensuring that these colours register properly. As will be seen later, there are several types of colour mix which will produce a white.

The registration problem arises from the commonly known fact that in holography the different colours which have to be combined to produce white tend to reconstruct their images in different places, thus giving a chromatically dispersed result or one displaying several iden-

tical but misregistered coloured images. Dispersion increases with the depth of the image, and the simpler of the techniques described here avoids this problem by restricting the image depth to a few millimetres.

Some important techniques for producing black and white holograms are:

1. Broad band reflection holograms - these are reflection holograms where the processing has led to varying fringe spacing which effectively negates the normal filtering properties of Lipmann holograms. Many dichromated gelatin holograms are examples, as are the results of holograms produced by wrongly concocted Russian monobath processing regimes applied to silver halide emulsions, and reflection holograms made with too thin an emulsion layer. Such holograms exhibit severe chromatic dispersion and cannot resolve much useful image depth when illuminated with white light.

2. So-called "open aperture" transmission holograms - here the usable depth is as limited as with broad band reflection holograms, though if a very small angle of incidence and some astigmatism is introduced into the image, the usable depth can be extended to  $\pm 10$ mm or thereabouts.

3. Dispersion compensation - this is a techni-

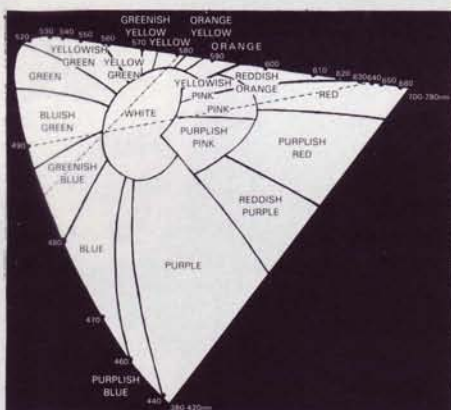


Fig. 1. CIE Chromaticity Diagram - The wavelengths are plotted around the curved perimeter of the diagram. To find the results of mixing two wavelengths draw a straight line between them and the colour zones that it passes through represent the colours that can be produced by the mix.

The dashed line shows that by mixing red and cyan, colours such as white, lilac and pink can be made. The chained line from yellow to blue is the combination discussed for the production of white, blue and gold.

que which when applied to an open aperture transmission hologram will dramatically increase the usable depth. This works by reconstructing the image using a diffraction grating to disperse the white light in an equal and opposite fashion to the hologram which it illuminates, so that the two dispersive effects counteract each other giving a non-dispersed black and white image with full parallax. The disadvantage here is the need for a complicated viewing system. The usable depth is similar to that of conventional reflection holography.

4. Achromatised rainbow holograms - here, as in the case of normal rainbow holograms, the chromatic dispersion does not affect the image. In order to obtain a black and white image, two or more rainbow images are superimposed so that, for example, the red of the first overlaps with the green of the second and the blue of the third, adding up to white. There are a variety of ways to do this. The results can be impressive though they do suffer the disadvantage of loss of vertical parallax and a restricted viewing zone.

5. Colour mixed reflection holography - relatively little work has been done on this. We have been told of some holograms made in the United States, although we don't know who by, and we have seen some excellent DCG work done by Harry Owen at Pilkington (the British glass company). At Richmond Holographic Studios, we have been working on it independently since early 1985, when we produced our first experimental black and white reflection holograms and our first originations for black and white plus two colours. The technique allows for full-parallax deep black and white images in reflection holograms and it can also be adapted to allow the inclusion of two colours. The usable depth is at least 70% of the usable depth of monochrome reflection holograms (around 400mm real image and 800mm virtual image).

## References

- (1) De Bitteto, *Applied Physics Letters*, Vol 9, p1740-1741 (1966).
- (2) K Bazargan, 'A Hologram Viewing Device', *British Patent 8303465*, *US Patent 465620* (Filed 1982).
- (3) eg Benton, *Journal of the Optical Society of America*, Vol 68, p1441, (1978).

## White and 2 colours in reflection holography

Habit leads us to think that a minimum of three colours (namely red, green and blue) must be mixed to produce a white. That this is not necessarily so can easily be seen from the CIE chromaticity diagram (Fig. 1).

As an example of how the diagram is used, consider the straight dashed line. It cuts the perimeter of the diagram at the familiar wavelength of 633nm (wavelengths are plotted around the curved perimeter of the diagram) and



at 490nm. The colours achievable by mixing these two colours in varying proportions are: orange/red, red, magenta-ish red, pink, lilac, cool white, blue, and finally cyan. This can be seen from the zones that the line passes through. Given the area of white in the middle, there are clearly many colour combinations which, when mixed in the correct proportions, will give white.

The necessary colour mix can be obtained using the techniques of pseudo-colour reflection holography, which immediately suggests the inclusion of each of the component colours as discrete elements thus giving, say, a white, yellow and blue image.

The technique of pseudo-colour reflection holography relies on the fact that the reconstructing colour of a reflection hologram depends upon the fringe spacing in the thickness of the emulsion layer. If the emulsion shrinks between shooting and viewing, the wavelength will be blue-shifted. One way of controlling this shrinkage is to pre-swell the layer by a controllable amount before exposure. As the swelling agent is washed out during processing, the end result is a shrinkage in comparison to the shooting thickness. This technique has the advantage of being repeatable, so if two exposures are made with differing degrees of pre-swelling they will come out in different colours.

An unfortunate consequence of the pre-swelling technique is that the angles and forms of the fringes change as a result of the shrinkage. This results in a colour-related image displacement which has to be compensated for in order for the component images to register properly. The compensation is achieved by changing the angles of divergence and incidence of the reference beam on the copy film between the two exposures. Ideally, this should lead to both sets of fringes forming in such a way that they take on the same orientation and forms as each other after shrinkage, thus reconstructing their respective images in the same place.

### Making a black & white portrait

By way of illustration we will describe the making of the portrait of Kate. The intention is to produce a 500x600mm portrait where the skin is black and white, and the hat blue and gold. The two photos (Figs. 2a and 2b) are taken from the two masters we are using (each 500x600mm, shot by myself and David Trayner at our studios in Richmond with a 1 Joule pulsed ruby laser). The one with the hat is to be in yellow and combined on one copy with the other in blue. The chained line on the diagram in Fig. 1 indicates the colour mix to be used, note that it passes through the white zone. The model simply sat still between the recording of the two masters, and the hat was removed for the second shot. Obviously the two masters were well registered in position.

The copy geometry is a conventional reflection

configuration, except that provision is made for two reference beams. One (for the blue reconstruction) is arranged with the maximum possible distance between it and the copy plane at an angle of incidence of (say) 50 degrees to the normal. The other (for yellow) should have a smaller angle of incidence and diverge from a point closer to the copy plane but with a maximum allowance for adjustment of both factors.

Although there are ways of calculating what adjustments are needed to the reference beam angles in order to achieve proper registration, they rely on being able to determine the exact wavelengths of the component colours and as this requires expensive machinery we prefer an empirical approach. The method is as follows:

1. Using the master for yellow (H1y) and the yellow reference beam, set the reference/object beam ratio equal to 3. Compute the normal exposure time and divide it by two - this

is a good starting point from which to judge the balance of the two exposures.

2. Soak the unexposed copy film in the following solution (roughly suitable for current 8E75 T HD film to give a yellow):

Triethanolamine (TEA) 17 parts

Kodak 600 photoflo 2 parts

Water 100 parts

The film should be soaked for more than 60 seconds, squeegeed, and dried in warm (30 degrees celsius) air. Then load (with repeatable registration), expose, unload and box.

3. Change to the other master and reference beam, set ratios and compute exposure time as before (this must be repeatable).

4. Re-swell in (say) a 33:2:100 mixture of TEA, Kodak 600 photoflo and water. Then dry, load and expose.

5. Process using a tanning developer and a rehalogenating bleach. We suggest Pyro and an



Fig. 2a - The master used to make the yellow component of the hologram described in the text.



EDTA bleach. Wash and Dry.

You will now have, no doubt, an imperfect result. There are three types of error peculiar to this procedure. Although they are all inter-related (eg. a simple change of reference angle will cause a colour change) they can be corrected separately until you are near to getting a perfect result. The three types of error are the following;

1. Angular displacement of one image with respect to the other in the vertical plane (vertical registration).

2. Misregistration of the images along the Z-axis (depth registration).

3. Wrong colour.

It is easiest to concentrate all changes on one of the two exposures. In this example we would make adjustments to the yellow exposure, in which case first verify the blue is indeed blue (if not, alter the TEA concentration until it is). Having done that, the following faults should be corrected as described, it is best to work by successive approximations.

Vertical registration: This is controlled by the reference beam angle. If no compensation (ie.

change of reference angle) were applied, a real image point in blue would be below its yellow counterpart. Compensation is achieved by using a smaller angle of incidence for the yellow exposure reference beam as compared to the blue. Thus *under compensation* results in a real image blue point being too low; the correction in this case is to *increase* the compensation - ie. to reduce the angle of incidence of the yellow reference beam. Clearly, the reverse applies when a yellow real image point is seen to be too low.

Depth registration: This is controlled by the distance of the reference beam source (its spatial filter) from the copy plane.

The greater the shrinkage the greater the image displacement in the Z-direction. This displacement is also caused by the usual non-conjugate reconstruction of copy holograms. The mismatch between the reference beams and the reconstructing beams can be manipulated to match the depth registration of the two colours.

The closer the reference beam source is to the copy, the greater the displacement. Also,

the greater the emulsion shrinkage, the greater the displacement. The misregistration caused by the different shrinkages of the yellow and blue components can therefore be compensated for by moving the reference beam source *closer* to the copy. Thus with *under compensation* a real-image blue point will be *further* from the copy plane than is its yellow companion. If this is the case, the compensation should be *increased* by moving the reference beam *closer* to the copy plane. Again the reverse applies if a yellow point is further from the copy plane.

Colour: Use the chromaticity diagram to plot the result of your mix and the two component colours. There are two ways the colour can be wrong: in the balance of brightness between the exposures, and/or in the wavelength of the yellow component. Simple inspection of the diagram should indicate what changes are needed. The balance of brightness is changed by altering the exposure times and a change in the TEA concentration used for the yellow will change the colour.

Repeated application of the above critical approach should give well-registered results after a few attempts.

## Conclusion

This approach considerably extends the palette available in reflection holography and aids in pre-visualization. As well as white there are pink, lilac, and even a pallid orange/pink which approaches the skin colour of sun-starved white Britons.

Though pseudo-colour is merely the holographer's equivalent of hand-toning photographs, it does have more possible applications than many seem to think. For example, it is easy to add another colour and this would give a free range over all colours. If this was then to be applied to colour-separated film footage for multiplexed stereograms with the holographic colours matching the film dye colours, it is easy to see that full colour holograms would result... in fact we really cannot understand why workers in multiplexed holograms haven't done this already.

## About Richmond Holographics

Richmond Holographic Studios is one of the longest-established independent studios in the world. The two main holographers are the authors, Edwina Orr and David Trayner. Since it was founded in 1979 the studio has acquired an international reputation for high quality in both the origination and manufacture of holograms, and their work can be seen in galleries all over the world. Until recently, Richmond offered courses in holography through which almost 500 people were trained, some of whom have gone on to set up their own holographic studios.



Fig. 2b - The master used to make the blue component of the hologram described in the text.



## SHEARWATER SUPPORTS SIX HOLOGRAPHERS

The Shearwater Foundation of New York City has made awards totalling \$60 000 to six holographic artists. Each of the six holographers chosen were awarded \$10 000 to "further their work and encourage the art of holography". Margaret Benyon, Rudie Berkhout, Harriet Casdin-Silver, Sam Moree, Ruben Nunez, and Dan Schweitzer were selected for the award in recognition of their exemplary work in the field.

"The Holography Project", which administers the award programme for the Foundation, was started in 1987 to promote and further the development of art holography by "bringing honour and recognition to the premier artists in the field". The 1987 awards, the first presented by the Foundation, honour those selected artists who have been in the field for at least eight years, and whose work has attained what they feel is the highest calibre of artistic achievement. "These artists have

provided the standard of excellence for the entire field," the Foundation's Board said. The director of the project is Posy Jackson Smith, who has previously been director of the Museum of Holography in New York.

The Shearwater Foundation is one of the few foundations in the United States currently funding artists working in holography. As far as is known, it is also the only foundation in the world which has set up a programme to identify and support what it considers to be the highest artistic achievement in the field.

Margaret Benyon, one of the recipients of the prize, feels that such recognition of holographic artists is a step forward. "This should help to make the art world here (in Britain) a little less biased against holography. The awards will also encourage those young creative holographers who face a chill wind in finding their own personally appropriate survival route."

## HOLOVISION RETURNS

The directors of Hologvision, the British holographic agency which is well-known for its large and aggressive advertising campaign, have recently returned to Britain after having seemingly "disappeared" for several months.

In the latter part of 1987, the company moved from its offices in Pall Mall, London, to a less expensive area of London. Since then it had only been possible to reach them by leaving a message on an answering machine. Alan Rogan of *Creative a la Carte*, a client who had thought that he was working with them at the time, said he had been forced to go to another holographic agency in order to complete his project. Had he not had such an enthusiastic client, he said, he would have scrapped the idea of using holography altogether.

Hologvision says that it had already terminated this project, although it accepted that a misunderstanding might have taken place. The company also claimed that it was contactable, although it admitted that not all calls were returned.

They explained that they had already accepted a contract from a company in the same line as that which Mr Rogan was representing and so had to turn down Rogan's project due to conflict of interests.

Their absence from Britain was, they said, to work on an important project in the United States involving a major toy manufacturer. They expressed full confidence in this project and explained that none of their other projects had been neglected. They also stated that the money raised through completion of the American project would leave them in a good position to continue to operate in both countries.

Another charge which has been levelled against Hologvision is that one of its directors wrote to the managing director of a company which had awarded a contract to a competing holographic agency, stating that the company's marketing manager must have been bribed in order to choose the other agency. Hologvision have acknowledged that this took place, but refused to comment further on the incident.

## CALENDAR

### April 26th

Prof Abdus Salaam FRS, Nobel Laureate, presents the Dennis Gabor Memorial Lecture at Imperial College, London, Britain. For time and location please contact the public relations office, Imperial College on Tel: (+44 1) 589-5111.

### Until April 30th

Phillippe Boissonnet's holograms of sculptures of the figure, shown in relation to paintings and drawings, are at the Interference Fringe Hologram Gallery, Toronto, Canada. For more details phone (+1) (416) 535 2323.

### May 10th

Royal Photographic Society

Holography Group meeting, London. The group has been invited to visit Light Fantastic at the Trocadero, meeting to take place at 7.30pm at the Trocadero, Coventry Street, Piccadilly Circus, London W1V 7FE, Britain.

### May 6th - August 6th

San Francisco's Laser Arts Society for Education and Research (L.A.S.E.R) will host an exhibition of holograms and laser art by its members at Holos Gallery. There will be a reception for the artists from 6 to 9pm on May 6th. For further information, contact Holos Gallery, 1792 Haight Street, San Francisco, CA 94117, USA. Tel: (415) 668-HOLO.

### May 27th - June 17th

Equus/Underwater, a prototype holographic stage set, produced by Nancy Gorglione and Greg Cherry with Laser Affiliates, can

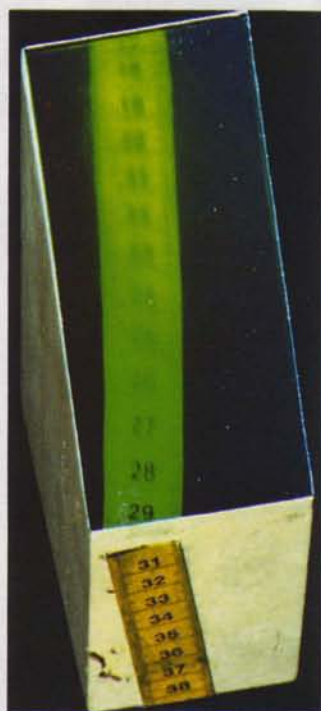
be seen at the Exploratorium, San Francisco, California, USA. Weekend showings will feature additional laser illumination effects. The artists will be present on May 22nd, 28th and 29th, and June 4th, 5th, 11th and 12th.

### June 29th - July 10th

The Royal College of Art in London, Britain, presents its annual degree show, which will display some of the work on which it will judge its students. Work from seven students of the Holography Unit will be on display. Information about the show can be obtained from Tel: (+44 1) 584-5020.

### July 18th - 22nd

Third International Symposium on Display Holography at Lake Forest College. Information can be obtained by writing to: Holography Workshops, Lake Forest College, Lake Forest, Illinois 60045, USA.



By Frithioff Johansen:  
for more see page 25



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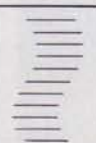
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Caius Hawkins has said that the most positive thing he has gotten out of the RCA is studio time. It has given him the chance to put together a body of work which would have taken years otherwise, especially given how difficult it is to get time to do creative work in commercial studios.

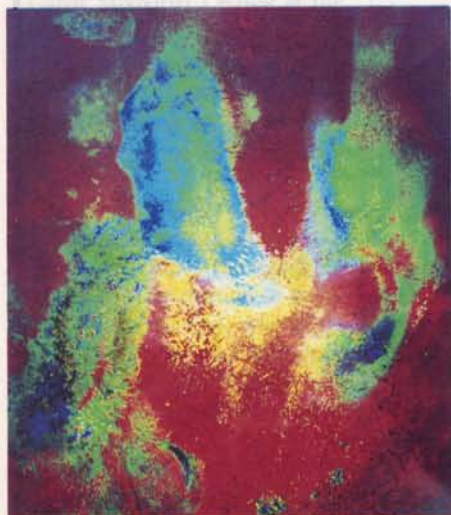
The holograms shown here are from a series, where the intention was to remove the sterility that many holograms display in favour of a more human style. The hologram makes use of a swelling agent which was in one case applied by hand and in the other sprayed on to the emulsion before being exposed by a pulse. He does not want to be pigeon-holed as an abstract artist, however, as he is interested in other areas also.

Although he had been interested in holography from 14, Caius studied for a diploma in photography at the Plymouth College of Art, worked in advertising photography, and did a year studying sculpture at Middlesex Polytechnic before he went to work with New Holographic Design (later Icon Holographics) and finally moved onto the course at the RCA.

Duncan Young studied fine arts before joining the RCA course. He is happy with his work and feels that he has used the two years he has had at the college as constructively he could. This he attributes largely to his art background.

Duncan would like to continue working in holography but says that he doubts this would happen. He would be unlikely to be able to afford to set up his own studio and make ends meet that way, and equally he saw little chance of finding a commercial company to take him on who would be doing the kind of work he's interested in. He does not consider himself as a holographer, but as an artist who happens to work in holography and he says that whether or not he is able to continue his holographic work, he will continue working in art.

Besides his other talents, Duncan Young is Holographics International's cartoonist.



Claudius Moedebe studied physics and then taught holography at a community centre for three years before being accepted on the RCA course.

His main interest at the moment is in using holography in environmental settings, such as offices etc., as a way of making spaces seem larger and more alive. He is also interested in the more commercial end of holography and has ideas about raising the artistic level of mass-produced film holograms.

He feels he took too long to start working properly because he had a lot of inhibitions about the media to overcome, as well as having to learn artistic methods. Now, however, he is happy with his work and would like to continue working along the same line when he leaves. Although ideally he would like to set up his own studio, he realises that this is likely to be impracticable and so he is hoping to be able to continue using borrowed time on others' facilities.

He is optimistic about the future of holography in art. Although he does acknowledge that trying to get work into art galleries etc., he has confidence that good work will be acknowledged and that, after a while, the barriers will start coming down.

The Royal College of Art is based in the Darwin Building, Kensington Gore, London SW7 2EU, Britain. Tel (+44) (0) 1 584 5020. It runs a two year Master of Arts course in the Holography Unit which is part of the Photography Department. The degree is awarded on the basis of holographic work the



Pictured: top left, Caius Hawkins, *Hand*, detail; bottom center, Paul Newman, *Phoenix*; top right, Patrick Boyd, *Breakfast*, detail.

# RCA CLA





*Caius Hawkins, untitled, detail;  
and her Pet Rat, detail; bottom right, Patrick*



In 1980, Martin Richardson was offered a place on the MA course in photography at the RCA, even though his portfolio was a holographic one. In the first term, he worked on a sand table with a 5mW laser which had been set up to teach photographers about holography. The work he did in his second term convinced John Hedgecoe, Professor of Holography, that more equipment was needed. By the time he had finished his MA in photography, Nick Phillips had been taken on to lead the holography unit and Peter Miller was taken on as tutor. The following year, the holography unit acquired a pulse laser, several professional isolation tables.

He went straight from the MA into a PhD as he felt that his work and ideas needed more time to mature, and the RCA equipment gave him the freedom to find his own style and explore his own ideas. Martin has now finished his thesis, which he is very pleased with, based on a personal aesthetic principle which he has developed over the last seven years. It has been influenced by critical essays on sculpture, land art, and photography.

student has completed at college and a short dissertation. A business course is also compulsory. The Unit staff are; visiting senior tutor Nick Phillips, tutor Mike Burridge, technician Rob Munday. The students listed here will be graduating this year. See calendar for Degree Show details.

Patrick Boyd joined the RCA course in 1985, one year before the others. He stayed on in order to pursue work in multiplex holography, which he had been interested in for some time.

Much of the work that Patrick has done this year has been in portraiture, indeed we reported in issue one of his work with Zandra Rhodes, the British fashion designer. Patrick hopes to carry on doing fashion work when he leaves college whether in holography or in photography which he did first.

He feels his progress has been reasonable during his time at college, but obviously wishes he could have had the facilities to do what he wanted to without having to continue into a third year.

Paul Newman Studied Applied Photography, Film and Television at Harrow College of Higher Education, worked at Richmond Holographic Studios and did the Artist in Residence program at the Museum of Holography in New York before joining the RCA course. The hologram shown was made during his summer at the museum.

His recent work has been quite varied including pulse life studies based on his photographic work, as well as more abstract pieces. This latter work tries to avoid the concreteness of some holographic images, and instead portrays objects moving or changing. His work is intended to be spiritual, rather than looking at social issues, although he realises that this is not particularly fashionable in the art establishment at the moment.

Another aspect of Paul's work is that he feels that finding and exploring the artistic roots to his work is very important. He can identify many of the artists, mainly working in other media than holography, who have influenced him confirming that holography, like any other art form, is affected by the same concerns as other media.



SS OF '88



# NICELY DOES IT!

by Peter Miller

Recently, Dominic Welby and I were invited by Margaret Benyon to give a talk at the RPS Holography group about the work that we are involved in at our studio, Laser Lightworks.

At this meeting, we discussed our studio approach to commissions, and we described in detail each of the steps we take to complete jobs successfully. When a job is confirmed and the brief established, we attempt to satisfy their expectations (and so bring in more work). To this end, we: a) discuss the brief with the client; b) have drawings shown to and approved by the client; c) have the model constructed and then approved by the client; d) invite the client and modelmaker into the studio to view the composition and lighting of the model, offer suggestions, and ultimately approve the set-up; e) shoot the master and then send a copy proof or finished hologram to the client for approval, depending on the job.

We find step d) very helpful as it not only allows the client to see the client to see exactly what the lighting and composition will be like in the master, but it also gives them an opportunity to learn a bit about holography and, perhaps, appreciate more what it takes to make one.

Discussion of this sort of issue may not seem very surprising, but other techniques and tips were discussed about shooting masters, sub masters, multi colour shadowgrams, and black



*Detail of 'Bamboo and Maple' by Peter Miller.*

and white achromat type reflection holograms. One topic in particular which generated a bit of interest was the use of a sodium vapour lamp to make holograms which is described here.

After the talk, well meaning people suggested that the sodium vapour copy idea might have money making potential, and that we should, perhaps, keep quiet until we get something out

of it. Now we have nothing against making money, in fact we're in business to do just that. But our reply was that quality and content are the things that are important in display holography and that in order for holography to grow information and support should be freely available.

This may sound pretty naive, especially after shooting a hologram of a pocket watch. But, how many times have you seen a hologram that was interesting and asked the maker how they did it, only to receive the reply, as I have on many occasions, "It's confidential, or else everybody would be doing it."

Everybody? There are probably more brain surgeons in New York City than there are holographers in the world. There is a great deal of communication between holographers, unless, of course, there is the possibility of a pot of gold at the end of the rainbow, or the big chance for immortality by being the first and only. There is nothing wrong with fame and success. Hard work and creativity should be rewarded. But must the price be endless bitchiness?

It is my personal opinion, and others may agree, that if we believe that holography is the way of the future then we should try to set an example for the future, "knowing that in planting the seeds we may never rest in the shade of the trees".



*Detail of 'Elinor's Coral' by Dominic Welby.*



# SODIUM VAPOUR COPIES

Gabor made the first holograms with incoherent light and people continue to make holograms without a laser: the idea is not a new one. There are limitations in using a sodium vapour lamp. The coherence length of the light is extremely short and so objects to be recorded must be in direct contact with or indexed to the recording material. The apparent depth of the image viewed in the hologram is nil. The area we explored involved taking an already existing reflection hologram, made with a laser, and making contact copies of this using the sodium vapour lamp.

The decision to use the lamp to make copies was made almost by accident. Last spring we had borrowed a sodium vapour lamp from Nick Phillips to experiment with. He had suggested that it might be interesting to try using it in some way to produce holograms. Then one day, after Dominic Welby and I had finished a commission we took a look at the bright yellow reflection image plane holograms we had made. At this point I got out the sodium vapour lamp, which we had never had a chance to use, and dusted it off, thinking that the holograms should look pretty good under the bright yellow light. They did.



*Dominic Welby, Peter Miller and Martin Wall in the Laser Lightworks studio.*

*In 1985, Laser Lightworks was formed in the studio that was originally Laser Lines, founded by the late holographic artist Adrian Lines. Peter Miller had been working with Adrian at the time of his death. Peter Miller and Dominic Welby then acquired the studio from Adrian's partner Roy Meyers and set up their own partnership. It was a sad beginning.*

*At present Laser Lightworks is a limited company. Martin Wall has joined Peter and Dominic as a company director to complete the team. They see themselves as continuing their work with the same basic aims that Adrian Lines had: to operate as a business in the area of commercial holography; to produce their own personal art work; and also to contribute to and assist the holographic community.*

It was at this point that we made the connection and took the next logical step, ie. to see if we could make a contact copy. The 4×5 inch hologram was put into the H2 plate holder of the reflection copy set up. Without moving any of the optics, the 35W Gallencamp lamp, with

a one inch circular aperture, was placed directly in front of the reference spatial filter, 91 cm from the copy plate at an angle of 45 degrees. The hologram reconstructed nicely.

An unexposed 4×5 holotest plate was then sensitized in a 1.5% solution of TEA for 2 minutes. The plate was dried and indexed to the yellow copy with white spirit, emulsion to emulsion. The light from the lamp was carded off and the two plates were loaded and allowed to settle for 3 minutes. The card was removed and the plate exposed for 25 seconds. The exposed plate was developed until it was very dense in a solution of pyrogallol and sodium carbonate. It was then washed and bleached in EDTA.

After drying, the hologram was examined. It replayed very well in white light but, because Agfa plates are not very sensitive to yellow light, it was not as bright as the yellow copy. The settling time was also very short, and two of us were standing around the table during the exposure. Another copy was made two days later with the same result. The hologram was of a pocket watch with moving parts projected a centimetre or so from the plane of the plate.

If you give it a try, Good Luck!



*Contact copy made using a sodium vapour lamp.*

**Peter Miller**



# IMAGE BLURRING IN DISPLAY HOLOGRAPHY

## PART II

by Andrew Ward

Holograms recorded in a material which is thicker than a few wavelengths of light are volume diffraction gratings, and will exhibit some degree of Bragg wavelength selectivity to an incident white-light beam (or angular selectivity if the incident light is monochromatic), and there will be only one strong diffracted beam if the hologram grating frequency is high enough. The degree of selectivity—or bandwidth—is related to the thickness of the grating layer, which is 5 micrometres for silver-halide photographic emulsions (about 10 wavelengths). The thicker the grating, the narrower the bandwidth: a very thick grating has a bandwidth approaching zero, when only one wavelength could be diffracted for a given angle of incidence.

The theory of this can be understood by considering the 3-dimensional Fourier spectrum of the grating structure. In directions parallel to

the fringe period, and so the Fourier spectrum in these two directions is a delta function; the Bragg condition has to be satisfied exactly. In the direction perpendicular to the grating (z), however, the grating is discontinuous in a relatively short distance (a few periods), and the Fourier spectrum is a relatively wide sinc<sup>2</sup> function; the distance between the first zeros is  $2\pi/d \text{ mm}^{-1}$ , where d is the grating thickness in mm. This means that there is, in effect, not just one but a spectrum of gratings in the z-direction, which relaxes the Bragg condition for the z-component of an incident wave. (The x- and y-components must still satisfy the Bragg condition exactly.) Thus a range of wavelengths can be diffracted from an incident white-light beam, or a range of angles of incidence can be diffracted for a monochromatic beam. For those familiar with wave-vector diagrams, this is illustrated in figure 2.

Although the Fourier spectrum of a grating in the z-direction is exactly the same for transmission or reflection holograms recorded in the same thickness material, the intensity of the diffracted waves for a given off-Bragg wavelength or angle is different. Drawing the appropriate wave-vector diagrams (like fig. 2) can be used to predict this quite accurately, without having to delve into coupled-wave theory. Reflection holograms have a higher wavelength selectivity than transmission holograms; transmission holograms have a higher angular selectivity. (Which, incidentally, is one reason why surface ripple is more obvious in a transmission hologram than in reflection holograms.)

The fact that a spectrum of wavelengths is diffracted with white-light replay does not necessarily cause blurring, however. Blurring arises only if the spectrum of diffracted waves is angularly dispersed, and the degree of the dispersion is determined by the spatial frequency of the parallel component of the grating (the grating period along the surface of the hologram). This of course varies with position over the hologram, and also with which component grating we are looking at (ie which image point we are looking at); it is fixed at recording by the angle between the reference ray and an object ray where they meet at the hologram.

When an observer looks at the image in a display hologram replayed with white light, the

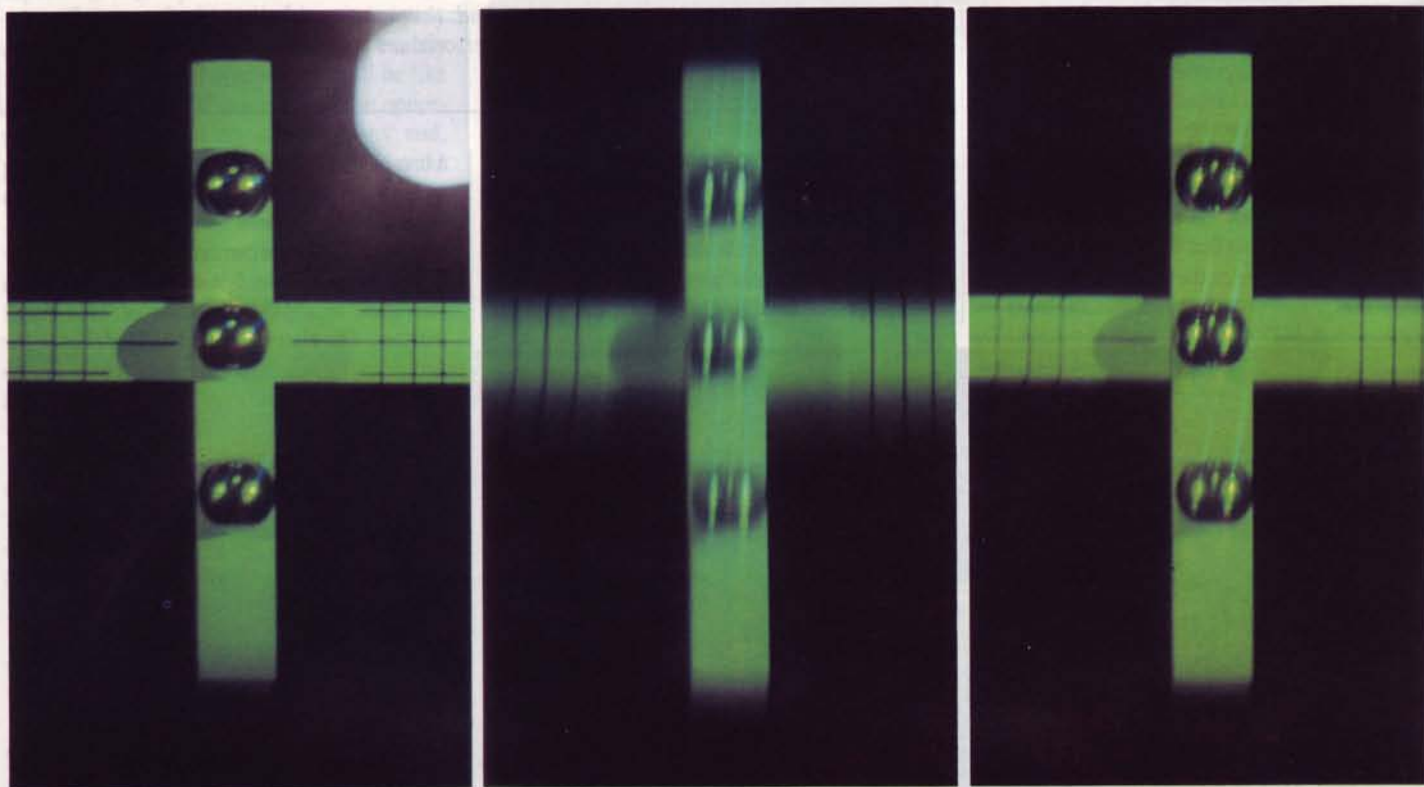


Plate 2: Dispersion blurring in reflection holograms recorded with a reference angle of 45° and varying tilt, replayed with white light (a slide projector 2mm from the hologram). The image is 150mm behind the hologram plate; the bars are 12.5mm wide.

Left: 20° tilt—2.5° away from zero dispersion at the centre. Blurring is minimal close to the specular reflection of the replay light source (which is out of focus in this photograph).

Centre: No tilt. Blurring of horizontal lines is very bad.

Right: 15° tilt. The specular reflection of the replay source is out of the field of view, and dispersion blurring is little worse than source-size blurring (compare the definition of horizontal and vertical lines).



degree of dispersion blurring of any particular image point depends on where his line of sight intersects the hologram, and on the angle this line makes with the reference beam at that point. This is illustrated in figure 3, for one virtual image point (the centre point of an object, say). The image point is in fact dispersed along a line drawn from the replay reference source (or the position of its reflection in the hologram plate for the case of the reflection hologram), though the object-point position and on to the hologram plate. The two ends of this line represent the maximum possible limits of the observed blur; the actual visible length of blur (which will have a  $\text{sinc}^2$  intensity profile) depends on the bandwidth of the hologram: it will of course be less for reflection holograms than for transmission, although the position of any particular wavelength will be the same. Figure 4 illustrates the appearance of the blur for an overhead-referenced reflection hologram of six points objects.

For projected image points, the blurring extends away from the hologram and is inherently larger for the same hologram bandwidth than for virtual image points. Since all of the image points are blurring along a line toward the reflection of the reference source, the overall effect of dispersion blurring in an overhead-referenced display hologram is to blur the horizontal lines in the image. Vertical lines are blurred only by source size effects.

### Reducing dispersion blurring

Figure 3 can be used to see how to reduce dispersion blurring by minimising the angle subtended at the observer's eye by the dispersed image line:

- 1) Reduce the reference beam angle.
- 2) Place the object point closer to the hologram.
- 3) For reflection holograms, tilt the hologram backwards (see below).
- 4) Use a thicker recording material (for reflection holograms).

The first three of these all basically get the image point closer to the line of sight to the replay source (or its reflection), the position of which of course depends on the position of the observer's eye. If an image point is on the line to the replay source, it will not be blurred at all. There is no dispersion then because the observer's line of sight passes through the point on the hologram where the parallel component of the grating spatial frequency is zero. This is the zero-dispersion condition illustrated in figure 5. This condition cannot be used in practice, however, because the observer is of course looking directly at the reference source or its reflection. (And in the case of transmission holograms, there would be some spurious images visible, due to higher diffraction orders appearing.)

For transmission holograms, the zero-dispersion condition can be simulated by the well-known but infrequently used technique of dispersion compensation. A planar grating is

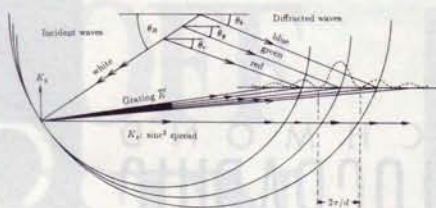


Fig. 2: Wave-vector diagram showing how three wavelengths are diffracted at different angles from a grating of finite thickness,  $d$ .

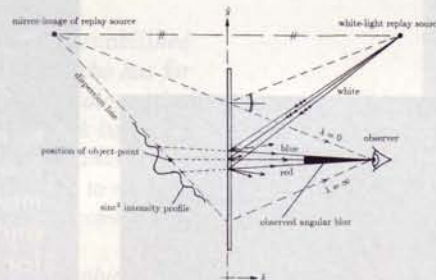


Fig. 3: Ray diagram illustrating dispersion blurring of a single image point.

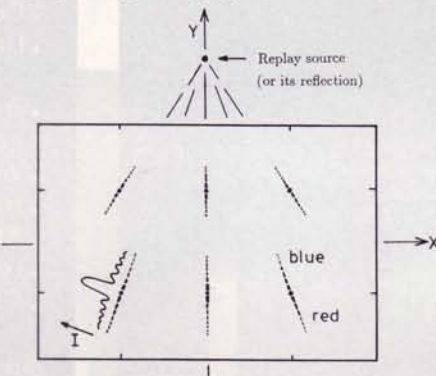


Fig. 4: General form of the dispersion blurring in a white light hologram of six point-objects.

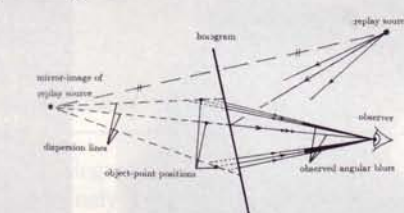


Fig. 5: Dispersion blurring of three image points; the hologram is tilted, and one point illustrates the zero-dispersion condition: when the observer is looking directly at the reflection of the reference source.

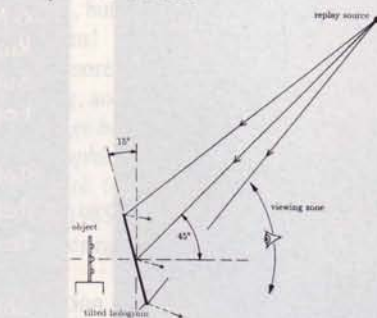


Fig. 6: The best-compromise geometry for reducing dispersion blurring in reflection holograms.

made of the same spatial frequency as the centre frequency of the image hologram (the carrier frequency), but of opposite sign (opposite angle). By placing this in series with the main hologram (usually behind, but it doesn't have to be), the planar grating frequency is in effect subtracted from the main hologram, resulting in a zero centre frequency for the combination, giving zero overall dispersion at the centre, while retaining volume grating characteristics. The only problem with this arrangement is that if the holograms are not 100% efficient, some of the diffracted beam from the first will emerge undiffracted from the second, giving a spurious background. This can be avoided either by not going all the way to zero centre frequency, or by using 3M louvre film between the two holograms. For details of this, refer to Bazargan, British Patent 8303465 (1982).

Plate 2(a) is a photograph of a reflection of hologram made near the zero-dispersion condition: the out-of-focus specular reflection of the replay source (a slide projector) is visible in the top right. The hologram was recorded with a reference angle of  $45^\circ$  and a tilt of  $20^\circ$ , so that it is  $2.5^\circ$  away from zero dispersion at its centre. The zero-dispersion condition in reflection holograms corresponds to unslanted fringes, where the signal beam was incident at the same angle as the reference beam for the object point in question. Overall blurring in plate 2(a) is minimal despite the fact that the image is 150mm behind the hologram recorded with no tilt:  $22.5^\circ$  away from the zero-dispersion condition. The blurring of horizontal lines in this case is clearly unacceptable.

In the images of the metal balls in plates 2(a) and (b), you can see that the dispersion is indeed along a line toward the reflected image of the replay source, and that dispersion increases the further you look away from this line.

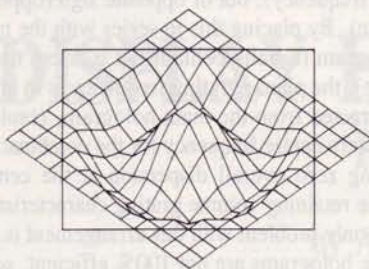
The problem of the replay source reflection could in principle be overcome by anti-reflection coating the hologram, or by sticking a big prism on the front, but these are not very practical solutions.

A dispersion compensation grating could be used in the same way as for transmission holograms, by using either a transmission or reflection compensation grating, but this is not very practical as a parallel reference beam would really need to be used. There could be advantages, though, such as reducing the height of the replay source and increasing the image contrast enormously if a reflection compensation grating was used (the hologram would then be illuminated with near-monochromatic light).

Use of thicker recording materials to reduce the hologram bandwidth and hence the width of the  $\text{sinc}^2$  blur along the dispersion line is only practical for Dichromated gelatin (DCG) recording; suitable silver-halide photographic plates are not generally available in anything other than 5-micron thick layers.

Continued on page 25





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# FRITHIOFF JOHANSEN

*Frithioff Johansen is a well established painter and sculptor in Denmark who has for some time been working with holography. Though his more conventional work continues to be praised critically, Johansen finds it that none of the critics are willing even to mention his holographic work, never mind comment on it.*

*You can see some of his holographic pieces on display from June 10th for two months at the Museum for Holography and New Visual Media, Pulheim/Koln, Germany.*



*Continued from page 23*

## **A compromise: tilting reflection holograms**

The best approach to reducing dispersion blurring in reflection holograms is a compromise solution. Plate 2(c) is a photograph of a hologram recorded with a reference angle of  $45^\circ$  and a tilt of  $15^\circ$  ( $7.5^\circ$  away from zero slant). With this geometry, illustrated in figure 6, the specular reflection of the replay source will be travelling downwards and allows the observer a good viewing zone before he either blocks the replay beam with his head, or sees the specular reflection. The best compromise tilt obviously depends on the size of the hologram and the distance of the replay source. The  $45^\circ$  reference with  $15^\circ$  tilt was used for  $30 \times 40$  cm display holograms during the author's time with Nick Philips at Loughborough University (then under the auspices of Holoco Ltd.). We were originally alerted to the improvements of tilting by reports of tilted Rus-

sian holograms at a Paris exhibition.

The only problem with tilting reflection holograms is that the hologram must of course be tilted at the same angle for display (and must have the correct replay beam angle!). This complicates the mounting technique, and a backward tilt seems to be disliked for aesthetic reasons, but achieving perfection always has its problems!

For more details on the theory of dispersion blurring, and more wave-vector diagrams, refer to: *Image blurring in display holograms and in holographic optical elements*, A A Ward et al., SPIE Vol. 600 Progress in Holographic applications, 1985. A A Ward, Oxford University Engineering Science, 22 December 1987.

## **Distortion blurring**

In Part 1 I said that if a hologram is replayed with a point monochromatic source, then the image would not be blurred at all. In fact, this is only true if we don't look beyond the resolu-

tion of the human eye. The eye has only a very small aperture and intercepts only a very small cone of rays from the hologram at any time. If the image in a hologram is inspected with larger aperture optics, or if a real image is projected onto a screen, we will start to see blurring due to geometric distortion of the spherical waves emanating from each image point. This arises if the replay wavelength is different from the recording wavelength (which for a white-light reflection hologram means any change in thickness or refractive index), or if the replay angle is not exactly equal to the recording angle, or if a real-image hologram is replayed with an inexact conjugate. The glass substrate of the hologram also introduces some distortion at the recording stage (however flat it is), so perfect reconstruction is all but impossible. For more details of geometric distortions refer to: *Image distortions in display holograms*, A A Ward and L Solymar, RPS J. Photographic Science, Vol. 34, 1986, pp62-76.





**ILFORD**

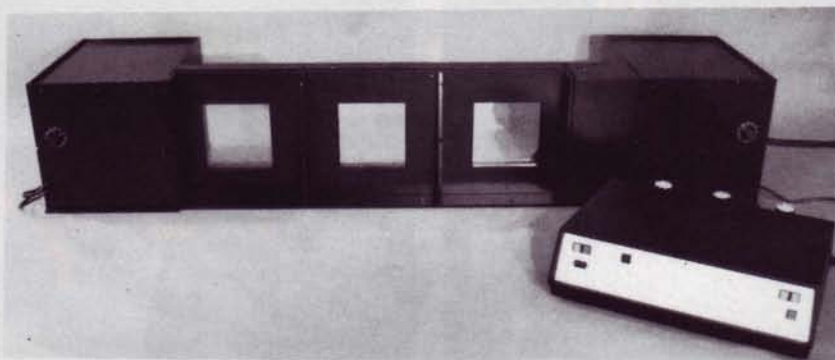


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# ESPRIT DE RISO

by Sunny Bains

In February, the Holography lab at the RISO national Laboratory in Denmark was opened after having been given a facelift worth over £100,000.

The money for the new lab and equipment came from two sources, firstly from the Board of Directors of RISO who approved the plans, and from the Applied Laser Physics Section. Together they provided the £10,000 to cover the construction costs. The Danish Board of Technology put up the rest of the money to buy the equipment. They hand out money for research equipment on the basis that it is not the exclusive property of the institution for which it was bought, but rather it must be a facility which can be used by industry when necessary.

Now the lab has two 1.5x2.4m automatically adjusting tables, a 15W argon-ion laser, a 5W argon-ion laser, a 40mW helium-neon laser, all in a temperature and humidity controlled room.

The project which helped fund all this new equipment by impressing the Danish Board of Technology, was ESPRIT. The project, which has the full title "The Development of a Flexible Automated Assembly Cell and Associated Human Factor Study," is funded primarily by Westland Helicopters. RISO is just one of four partners in this research, the others being the University of Sheffield in Britain, Vrije Univ-



Lars Lindvold and colleagues at the RISO Holography Lab.

ersiteit in Belgium and Dantec.

The RISO work is concentrated on the development of an optical robot visual system, one of the main components of which was developed there. The idea is that an image (initial work is with 2-D objects) is transformed into a form where the position, orientation and size of the object are all given as shift parameters. This means that though the scales on the transformed pattern may change with position, orientation and size, the basic shape of the pattern will not. Thus by comparing the pattern of a given object with the patterns of known objects, the robot should be able to correctly identify the object.

Obviously a vital part of this system is the concept of optical processing which will not vary as rotation and size. This can be done using a so-called geometrical mapping filter. Such a filter cannot, however be made using conventional optics but has to be made as a computer generated hologram. RISO therefore set up a facility to make these on site using a modified satellite picture recorder and a personal computer. The hologram is firstly designed on the computer, then the signal is sent to the satellite recorder which exposes a large piece of film (298x210mm) using a scanning light source. The system has 16 grey levels and a resolution of eight lines/mm. The film is then photoreduced to 36x24mm and is then further optically processed in a Fourier transforming optical processor to scale the hologram and improve the diffraction efficiency.

Though there are some problems outstanding because of the unsatisfactory resolution of the spatial light modulators, the project has been largely successful, to the extent that the computer generated hologram succeeds in transforming the object into a pattern which does not vary with orientation, position or size. The next step is to simplify or squash the pattern so that it is just a line, rather than a 2-D shape. This too has been done with a degree of success although the computer does not yet get it right 100% of the time. Researchers at RISO believe that it is just a matter of time before the computers can be programmed to tell the difference between a circle, a square and a triangle. When they have managed that, then they can move on to 3-D objects. Success in this area could revolutionise industry as robots could then be told what to look for and find it.





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# COLOUR HOLOGRAPHY: NATURALLY THE BEST

by Sunny Bains

It is surprising that graphic designers, who often scream for colour in conventional graphics, are not screaming for natural colour in holography. Perhaps they are, but have been told too many times that natural colour is "too experimental", "too difficult" or "too expensive". One holographer has even remarked that full colour was not possible at all.

It is true that natural colour has not yet caught on commercially, but the reasons for this are, as far as can be seen, matters of investment rather than technology. Both transmission and reflection holograms have been made in natural or near-natural colour using three or two lasers respectively. It is even possible to make colour pulse portraits without too much technical difficulty. The problem of the recording emulsion seems to be not so much of a problem as it was, as Agfa-Gevaert has expressed willingness to double coat film and plates so that they are both red and green/blue sensitive.

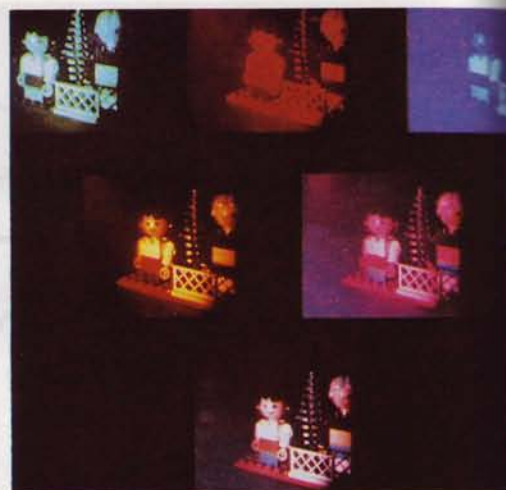
Full colour may also be expensive, in the sense that a studio would need at least two and probably three lasers in order to get the best results. But this initial expenditure would be unlikely to make the unit cost of a hologram much higher, as a large part of the cost of a custom-made hologram is usually labour. Also, some consider the level of difficulty in making holograms in full colour to be relatively low. Dr Kaveh Bazargan, of Imperial College, Lon-

don, recently said that the reason that he had never attempted much experimentation in pseudocolour, as opposed to natural colour, holography because he found natural colour easier.

Full colour holography essentially requires the set up shown, which consists of three lasers emitting red, green and blue light (just red and green will do), and other equipment which is roughly the same as for conventional holography. There has even been work done to produce a system emitting the three colours necessary for colour holography, in a short pulse, from a single laser. This would allow holographic colour portraits to be done easily and could provide the basis for a mass production facility. Initial results from Imperial College, where this work is being carried out, suggest that the system is likely to work well if developed fully.

The only respect in which natural colour differs from monochromatic holography is, then, in the necessity for more than one laser colour. Only one exposure is required (with all of the laser colours exposing the plate at the same time) and the set up could be standardised so that each object could be placed and shot without any specific preparation.

With pseudocolour there are all sorts of complications: swelling agent ratios, changing of reference angles, and more than one exposure.



*The transmission hologram when illuminated.*

At the end of it, what's more, the hologram cannot be copied without going through the whole thing again. It fundamentally cannot be used for mass production and so it is only suitable for one-off or low run custom work. It would be completely impractical to use it for any sort of mass market.

It is in this latter respect that natural colour really comes into its own. The possibilities of colour holography for a mass market are endless, and natural colour, unlike pseudocolour, could very easily be exploited in this way. A machine like the Applied Holographics *Holocopier* could be made to produce hundreds, if not thousands, of colour holograms per hour.

And yet, as far as we know, none of the big holographic companies is actively involved in researching commercial colour. This may have something to do with the fact that many of these companies have invested heavily in thin foil holograms, which cannot be made in natural colour. It is possible that thin foil sales would be hit if full colour film holograms could be made cheaply and easily, thus companies could be damaging their own investments. It might also be a simple unwillingness to invest in something new when it is easier to stick with the old. If the problem is simply that no-one realises that natural colour is potentially so straightforward, then presumably we will now see companies flocking to take up work in this area.

If, however, the reason that companies are not pursuing colour is a commercial one, then only commercial pressure by potential hologram buyers will help. Holographic production companies and agencies will make colour a commercial reality if they are assured of a market.

The informed hologram buyer should now know what to say if presented with the excuse that natural colour holography "can't be done", or "isn't available". In the former case they should find a more honest/informed source of information and in the latter case they should ask why no one is providing the service they want.



*Recording set-up for a full colour transmission hologram using three lasers.*



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# NEW USES FOR HOES

by Lars Lindvold

The objective of this review is to present some new applications of holographic optical elements (HOEs) as opposed to the 'old' ones such as Head-Up Display (HUD) in the F-16 fighter plane, hologons for laser scanning, and holographic spatial filters for optical processing.

Throughout the eighties, a number of interesting applications have emerged for HOEs which seem to be high volume products. The applications that will be reviewed in this article are:

- Viewfinders in cameras.
- Optical read-head in audio disk and CD-ROM.
- HUD for cars.
- HOE enabling white light viewing of transmission holograms.
- Optical sensors.

## Viewfinders in cameras

In 1979, the Japanese firm Canon developed an 8mm movie camera that featured an indicator in the viewfinder to tell the user that the film was about to run out. The limited space in the viewfinder ruled out the use of either LED or LCD. These displays would also obstruct the field of view. Therefore a holographic optical element was conceived, namely the Superimposed Finder Display (1) which fulfilled the requirements of compactness and being transparent when not in use.

The element was an in-plane volume phase transmission hologram. When illuminated by a small light bulb the word "END" would appear in the viewfinder without obstructing the field of view.

In order to get around the time consuming process of sealing the HOE for environmental protection, Canon developed a photopolymer based on polyvinyl carbazole (PVK). This material is not sensitive to high humidity after proper processing.

Some years ago Fuji, the Japanese camera company, made a viewfinder incorporating an HOE for advanced viewfinder cameras with interchangeable lenses. The distance on these cameras is correctly adjusted when two frames are seen to cover each other in the viewfinder. When lenses of different focal length are used in this kind of camera, the frames have to be altered in order to compensate for the parallax error.

Using the angular multiplexing property of a volume phase hologram, the different frames can be stored separately in the hologram. By illuminating the HOE with a small light bulb at different angles, the exact frame correspon-

ding to the lens in question is displayed (2).

## Compact optical read-head for CDs

A number of articles and papers have recently been published on the use of HOEs in the optical read-head for CD-ROM (3) and conventional audio-CD (4). The optics in the optical read-head of any CD system generally have to perform the following tasks:

- Retrieval of data.
- Tracking of read-head.
- Focussing of read-head.
- Correction of the astigmatic output from the laser diode.

This often amounts to about 12 refractive optical elements being used in an optical read-head. The American company Pencom International Corp. has succeeded in combining most of these elements in one holographic optical element plus two refractive optical elements. This is partly due to the fact that the entire optoelectronics has been integrated in one chip.

One of the problems associated with making holographic optical elements for diode lasers is the lack of efficient recording materials for near infrared wavelengths. This can be overcome by using the elaborate two-step recording method originally devised by Lin & Doherty and later refined by Herzig (5).

Pencom International, however, used the inherent aberration free properties of computer generated holographic optical elements which was suggested by the director of Pencom International, Dr WH Lee, a well-known scientist in the field of computer generated holographic elements. The CGHOE was recorded using an E-Beam writer. Similar work has been carried out by Nippon Electronic Corp. Research Labs in Japan for use in audio-CD.

## HUDs in cars

Although a promise was made at the beginning of this article not to mention HUDs, the author cannot resist the temptation to drop a few lines on the latest developments in this area. It appears that several European companies are engaged in developing HUDs for cars, among others the Battelle Institute in Frankfurt, FRG (6). Such a display would provide the driver of the car with information regarding speed, petrol consumption, rpm of engine, etc. while looking through the windscreen of the car at the same time. This should improve road safety as it would lower eye fatigue by avoiding constant eye shifting and refocussing between the instrument panel and the road.

## Viewing holograms with HOEs

One of the difficulties in displaying transmission holograms with white light sources is, of course, the severe dispersion in the hologram. Ways of getting around this problem have usually been the rainbow hologram and reflection holograms of the Denisyuk type. The appearance of the so-called stack holograms for imaging multiple frames from CT scanners has, however, rejuvenated the interest in the use of white light reconstruction of transmission holograms.

Work carried out at the University of Alicante in Spain (7) and Imperial College (8) in the UK has used the dispersive properties of holographic lenses to counteract the dispersion in the transmission hologram in such a way that an almost achromatic image can be obtained with a simple white light source. This makes it very user-friendly for potential users such as doctors.

## Optical Sensors using HOEs

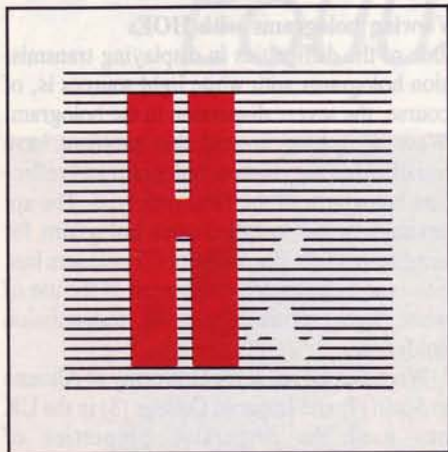
A number of companies and research labs in Europe are working on making compact sensors based on holographic optical elements. It is interesting to note that one group at the National Physical Laboratory in the UK deliberately uses the chromatic aberrations of interferometrically generated zone plates to make fibre optical sensors (9) for measuring mechanical parameters like distance and pressure. These sensors are based on the fact that the coupling of light into an optical fibre is wavelength-sensitive.

Another way of using HOEs has been suggested by RISO National Laboratory in Denmark (10). Here HOEs are used in Laser Doppler anemometry to make sensors capable of measuring rotational speed (vorticity) of arbitrary objects. The advantage of this system is that no alignment of the optical system is necessary as the entire optical system is contained in one hologram. This set-up also makes it possible to use unstabilised laser diodes.

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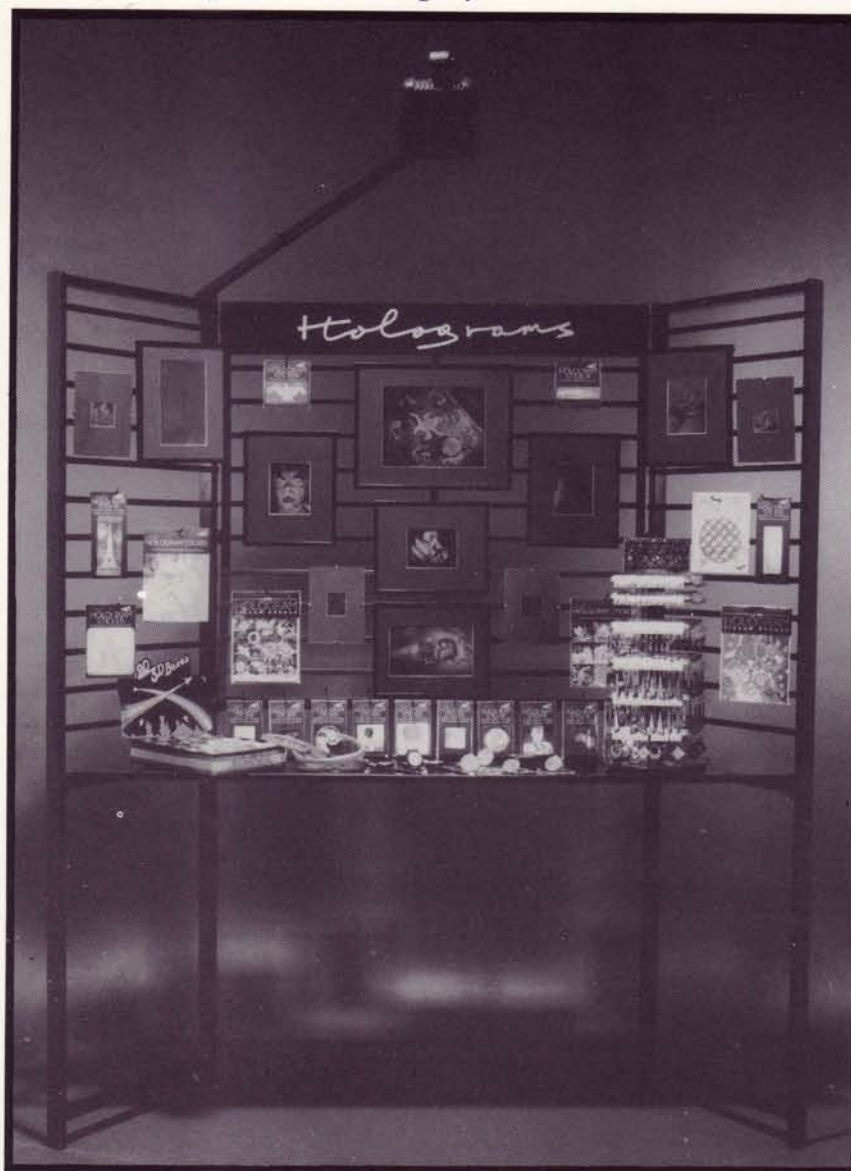
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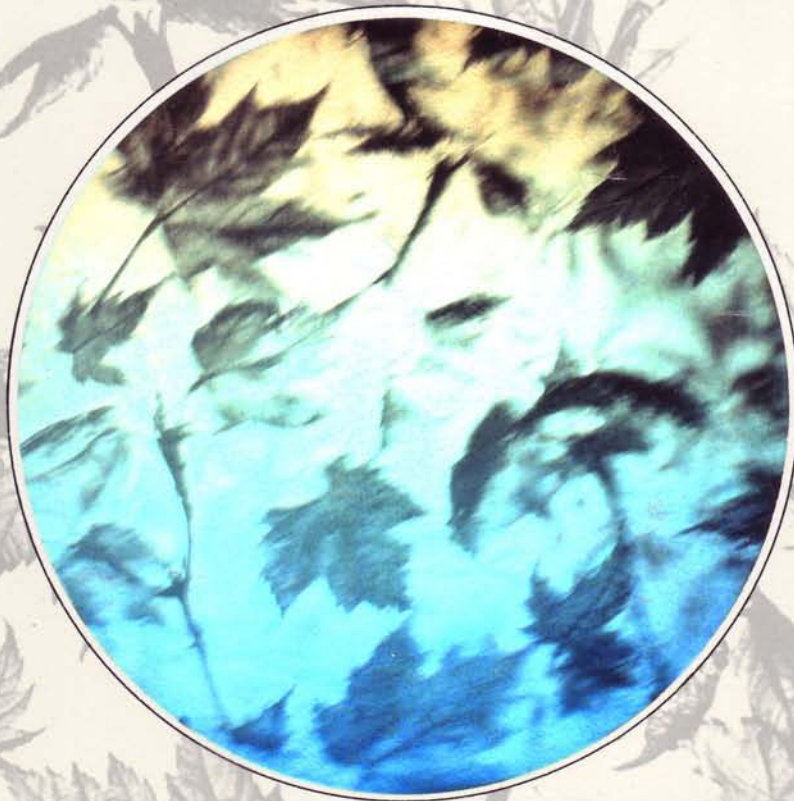


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