Holographics International

Sue Cowles: Educating in 3-D
Holographic Movies: Just a Gimmick?
David Pizzanelli: A Secure Future

Winter 1988 Number 2
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The International Magazine of Holography

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Winter 1988
Number2

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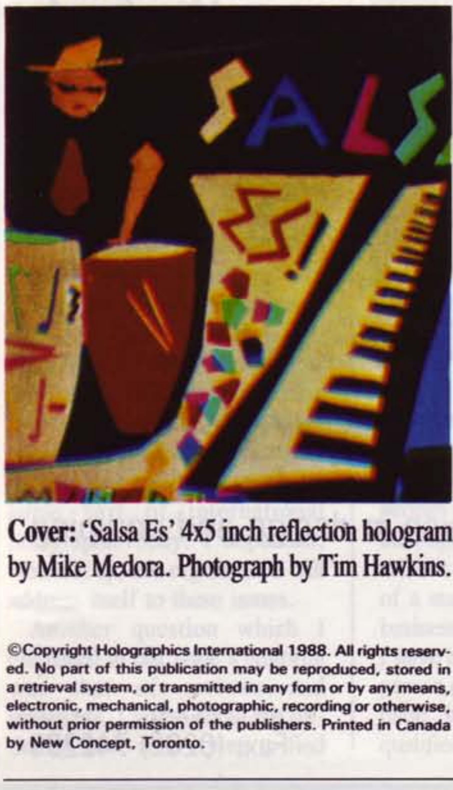


Cover: 'Salsa Es' 4x5 inch reflection hologram by Mike Medora. Photograph by Tim Hawkins.

Winter 1988 **Number 2**

EDITORIAL

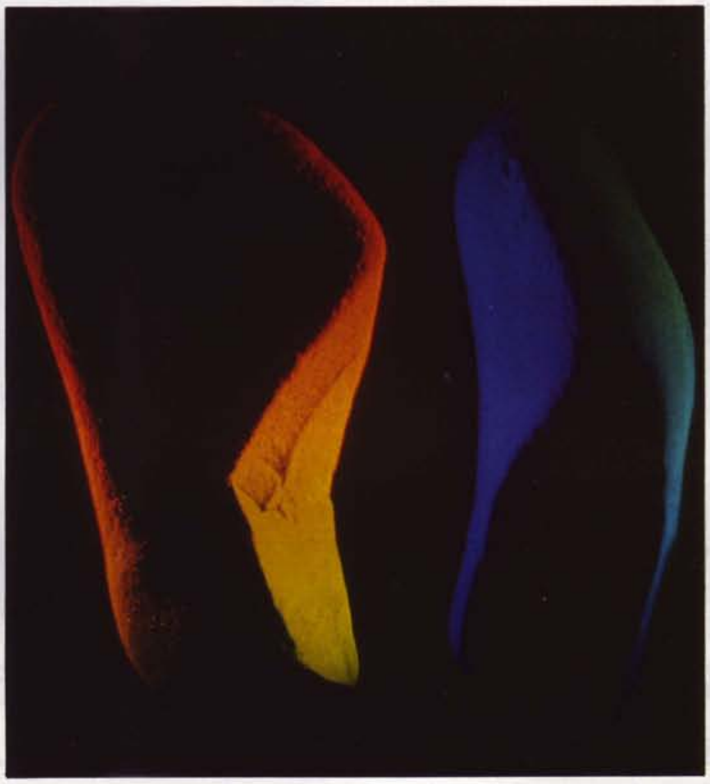
Welcome to our second issue of *Holographics International.* I hope you will enjoy reading the fruits of our labour. I must admit to having been somewhat apprehensive about this issue. For number one I had, what seems now, an incredibly long time to collect information and prepare copy. More importantly, the good reaction I got from holographers was based on comparison with other holographic publications, rather than on any absolute terms. Novelty can be a positive factor. With issue number two, not only does the novelty value disappear, but a new standard is set up, that of the first issue.

It was, therefore, with some trepidation that I realised that with issue two I must not just equal but better issue one! Having worked flat out on the last issue, you can imagine that this would be no easy task. But I needn't have worried. The staff and independent authors provided me with copy which I feel makes this issue much more 'meaty' than the first. I thank them all for their work: Bruce Goldberg, David Pizzanelli, Andrew Ward, Pippa Salmon and Kamala Sen, Kaveh Bazargan and especially Sue Cowles.

On a more serious note, I have been heartened by the reactions I have had to my editorial in the last issue. People seemed to feel, as I did, that a more business-like attitude was necessary in holography, and that holographers should be discouraged from bidding for jobs which they know they can't handle, or quoting lower prices than they actually intend to charge. As I understand it, some plans are afoot to set up some sort of international holographic body. I hope that, when set up, this organization will address itself to these issues.

Another question which I discussed in last issue's editorial was that of reviews and reviewers. I wrote about the difficulty there is in trying to find

"...the more letters I receive, the smaller the editorial rantings will become... there's an incentive for you!"



Bruce Goldberg's favorite at the Kaufman show—'Due Donne'.

people who are qualified to state their opinions about holography as art, but who do not have too much of a stake in the art holography business themselves. On this issue I have had mixed reactions. One person said that only full-time artistic holographers are really qualified to judge another's work.

I am doubtful about this. As I understand it, some of the best art critics are not artists and some of the best theatre critics not actors or directors. My view is that artists *must* have specific ideas of their own about how holographic art should be, for if they didn't have such ideas they would not be able to pursue their own work. Every artist has their own style which, one assumes, they must like or else they wouldn't continue to use it. A reviewer, on the other hand should come to an exhibition with an open mind about what a good art hologram should look like; although they should have enough artistic background to recognise a good piece when they see it, and to know why it is good.

Bruce Goldberg has, I believe, the right qualifications for this job. Though he does still make holograms, he does not earn a living as a holographer and so is not in competition with those whom he reviews. He also has the right sort of artistic background to make informed comments on work he is assessing. This is not to say that we should set him, or anyone else for that matter, up as an authority on art holography. He offers an honest, informed, opinion. That is all.

If you disagree, why not send me a letter telling me how wrong I am. I would be delighted to print it as I have been rather disappointed with the lack of letters submitted for publication. Perhaps HI is not controversial enough. In any case, please do send us letters on issues which we have covered (or failed to cover!) and mark them 'for publication'. The more letters I receive, the smaller the editorial rantings will become... there's an incentive for you.

Also, *please* keep sending us information about you or your company and what you're up to. Relevant colour slides or black and white prints are also appreciated.

If you feel that our coverage of your part of the world is not as strong as it might be, please write and tell me so. If I can (i.e. travel budget permitting) I will come out to visit and find out what's going on. If not, then your letter will make me more aware of your area in future and I'll know who to get in touch with for the latest news.

For those of you who have received Holographics International for the first time, let me welcome you to the magazine and point you towards the back page where our subscription details lurk. At £12 or US$20, we think we're quite good value.

Sunny Bains

PRIME MINISTER GETS A WHITE TIGER

The Dutch Prime Minister, Ruud Lubbers, was presented with a reflection hologram on November 16th, 1987. The hologram was made by White Tiger Holograms of Amsterdam, The Netherlands, its second Dutch Government production.

Mr H Albers, Managing Director of Publinet BV, presented the hologram to celebrate the opening of the world's first computer run business to business databank. This allows businesses in The Netherlands to identify alternative suppliers of products or services and carry out transactions with them through a nationwide computer network.

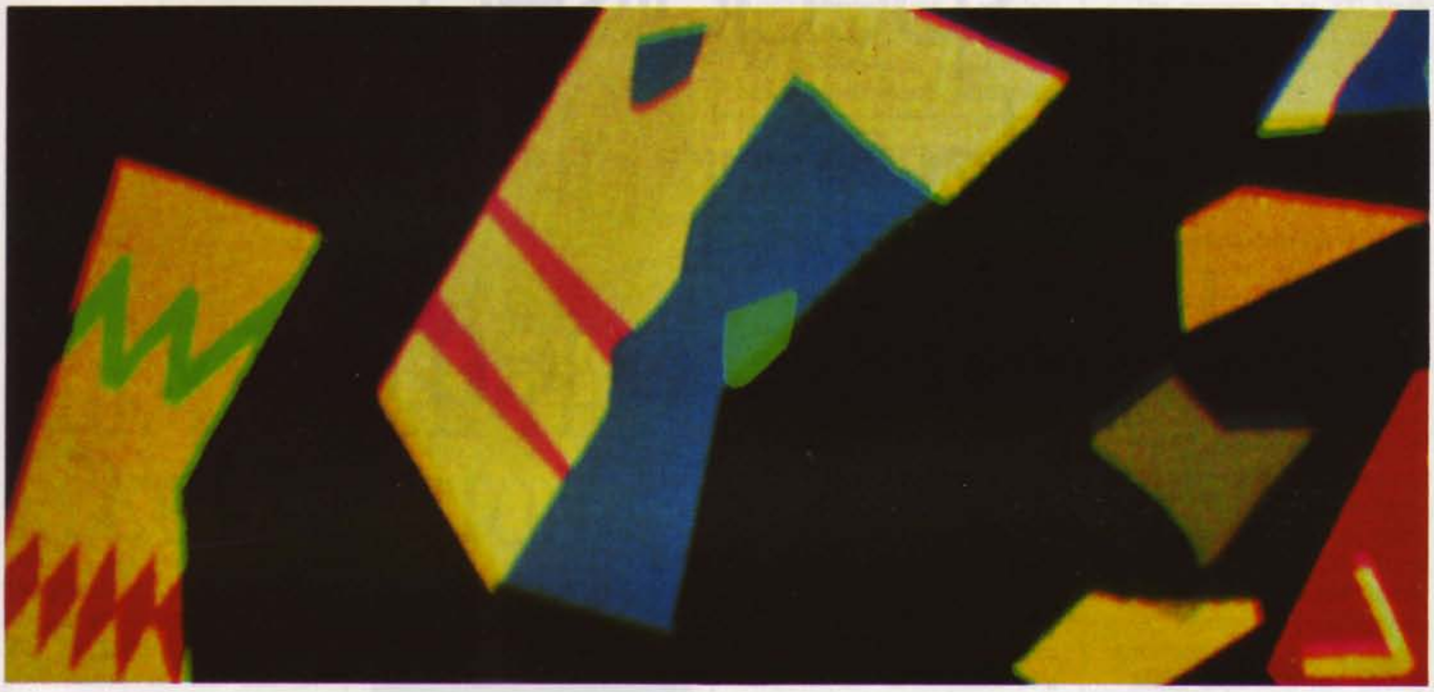
The Advertising Agency, Noordervliet and Winninghoff/Leo Burnett, felt that holography, with its up-to-date look, reflected ideally the image they wanted to create for the new publinet service. To make the holograms, they chose White Tiger, one of Europe's few totally independent holographic design, consultant and production co-ordination agencies. It put together a Dutch/American team who hand-crafted an aluminium model which was mastered and turned into a limited set of 15 dichromates for Prime Minister Lubbers and other Government and business dignatories. The holograms were 7x5 inch dichromates set in a fine, jet-black passepartout and frame.

DIRECTORY DELAYED

The *Holography Directory*, to be published by the Museum of Holography in New York, did not come out in November as planned. At time of writing, a new publication date had not been set.

Staff at the museum say this delay is due to the fall of the dollar which made printing prices in Britain, where the directories were due to be printed, rise dramatically in comparison with prices with the United States.

A new American printer has been chosen, however, at time of writing, the copy had not been finalized.



CREATIVE COLOURING

Mike Medora has taken pseudo-colour holography to a new level by using a planar technique for primary colour mixing.

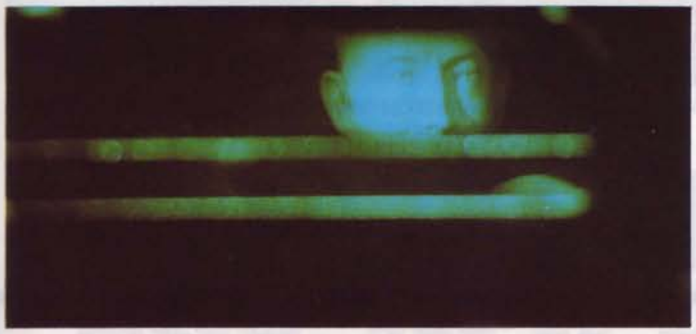
His technique, though not new in itself, involves using a screen as an object, rather than three-dimensional objects. By varying light intensity he can produce *any* colour or combination of colours, including subtle pastels, with only three exposures. Examples of his work are shown above and on the front cover.

The system does have its drawbacks. Although the colours are very bright, the three colours which mix to give the intended colour are actually in three different planes. This can be compensated for, although there are many instances where this would not be necessary.

Medora feels that the planar colour technique will be more accessible to conventional artists, and especially painters, than any other holographic technique yet devised. Perhaps for the first time, painters will be able to create bright multicoloured graphics or logos in three dimensions.

Mike Medora has been working as a holographer in London since 1982. To start with he worked at Third Dimension where in 1983 he took over as the main holographer. He subsequently moved to See 3 (Holograms), and later worked for Richmond Holographics until mid-1987.

Now he has set up in business for himself and has a studio in south London. He looks forward to working with the pseudo-colour technique as well as continuing with conventional holography.



THE FRENCH-THAI CONNECTION

This rainbow stereogram was given as a birthday present to the King of Thailand by the French government at the end of December last year. It shows a specially sculpted bust of the King.

Hugues Souparis of Hologram Industries of Paris was present at the ceremony in Thailand when the hologram, which was made by his company, was presented to King Rama IX. The French had decided to offer a holographic gift for the monarch's sixtieth birthday because of his interest in photography.

Hologram Industries has also produced embossed holograms of an 8th century, life size 'Head of Buddha', which was given by the National Museum of Bangkok to the Guimet Museum in Paris.

LA OPENS ITS EYES

Mayor Thomas Bradley of Los Angeles opened the city's new museum of holography on December 9th, 1987. Known as *Holographic Visions*, the museum is financed by a group of companies and individuals involved in holography, including Advanced Dimensional Displays (ADD) and Holos Gallery.

Holographic Visions features over fifty exhibits, and has been designed to educate the general public about both artistic and scientific holography. In addition to the permanent display, temporary exhibits and commercial pieces on loan from corporations such as General Electric and Toyota will be shown. A selection of pieces ranging in price from $20 to $20 000 is available for sale, and showcases filled with holographic novelties will also be displayed in the museum's gift shop.

The opening ceremonies included the unveiling of a hologram of Mayor Bradley, made in the Mayor's office by ADD. On December 10th the museum held its opening celebration for the general public, which featured 'music, prizes and free admission'.

The five partners in the museum are ADD, Holos Gallery, Technifex, Jerry Preston and Devin Borne. Chris Outwater of ADD is chairman, and Jerry Preston is president of the company.

The museum is at 300 South Grand Avenue in the California Plaza, Los Angeles. Telephone (+1) 213 687 7171.

AH POST-CRASH BOOM

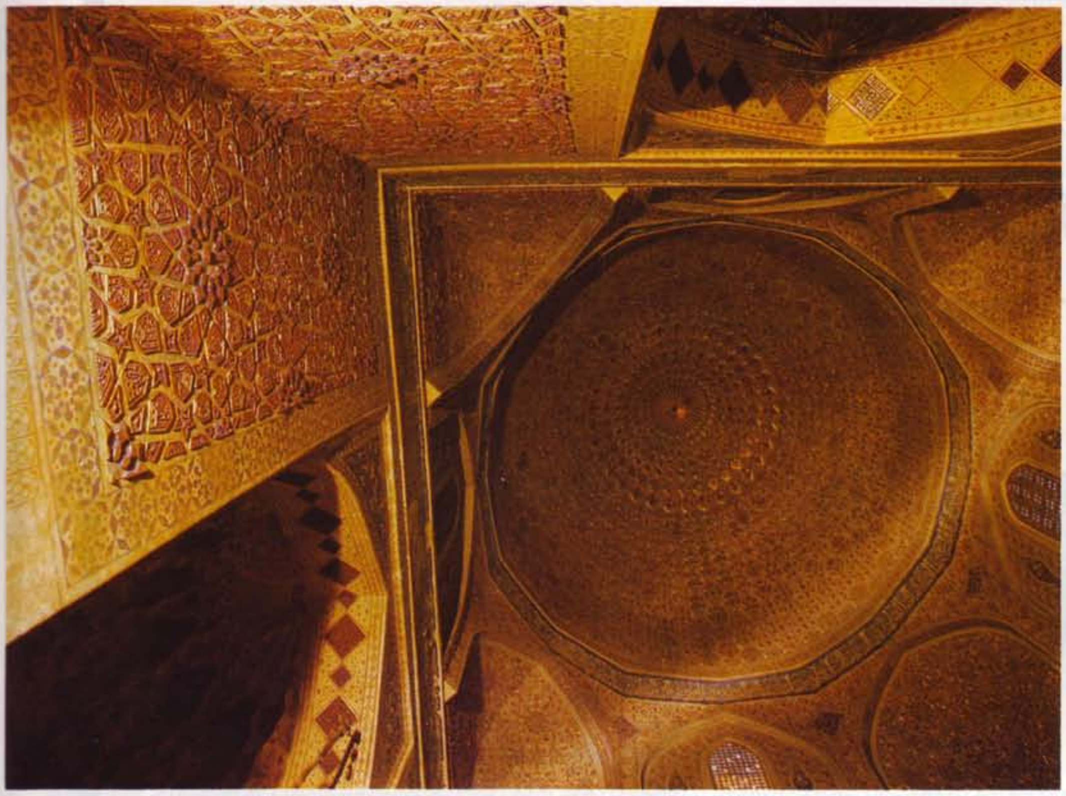
Applied Holographics plc of Britain, a company known for its mass production of holograms, has held a fully-subscribed rights issue of new ordinary shares which has raised approximately £8 235 000 to fund an expansion of its activities.

The projects which the company expects to untertake over the next two years, financed by the rights issue, include the establishment of a new marketing group and the expansion of the sales force both in Britain and other countries, the development of a new multi-channel holographic reproduction system for specialised hologram production, the further improvement of the viewing efficiency of reflection and transmission holograms, the extension of the manufactured range of foils produced by the company's subsidiary Transfer-All Purpose Foils Ltd, and the achievement of greater outputs at lower operating costs from the embossed hologram manufacturing process.

The company regards itself as a leader in the field of mass production of holograms, but believes that in order to maintain its position it must ensure that it has not only the latest technical skills and equipment, but also an active marketing force. For this reason, the Board formulated this two-year development plan.

Applied Holographics anticipates forming joint ventures with other companies in order to minimise costs and increase market penetration. The company says it has already been approached by a number of foreign firms wishing to establish distributorship, agency or joint venture agreements.

Much expansion has already taken place. Applied Holographics Embossed Ltd is now able to offer a complete embossed hologram service at their new factory at Washington, Tyne and Wear, in the north of England. Applied Holographics has also improved and increased its master hologram origination studios at Braxted Park in Essex. It has continued the development of its hologram production bureau at Braxted Park, and a larger bureau is currently being built at Washington, which will become the company's main production facility. Both the bureaux include new finishing processes and equipment.



One of Tom Ang's photographs which will be shown at the Zamana Gallery.

FOLLOWING THE SILK ROAD

An exhibition of holograms and photographs taken while tracing Marco Polo's footsteps, in an overland journey from Europe to China via the Soviet Union, is to be shown at the Zamana Gallery in London. The expedition aimed, among other things, to study the lifestyles of those who live along the 'Silk Road' today.

Tom Ang, a commercial photographer and photographic journalist, took a Holofax holographic camera with him to China in the back of his Land Rover. He also took along sufficient film and chemicals to make 100 holograms. The plan was to travel to China stopping at museums and other sites of archeological interest making holograms of artifacts on the way. The camera ran off the car battery and was electronically controlled, designed to make simple single beam reflection (Denisyuk) holograms.

Faint—but wouldn't you be?

A diplomatic crisis in Iran and Chinese bureaucracy meant that Mr Ang was only able to expose one fifth of the film that he had intended to. All the holograms he did take were made in the USSR, a country which is already known for making holograms of artifacts. The director of the Bukhara State Historical Architecture Museum, Robert Alimeyev, obtained permission for Mr Ang to make holograms, and he was able to take twenty. Though they are not particularly bright, the fact that they were made on a rig which had travelled thousands of miles in the back of a Land Rover makes them remarkable.

The exhibition of photographs and holograms will be open from January 27th until April 10th. The Zamana Gallery is located at 1 Cromwell Gardens, London SW7, Britain.

LUCKY FELIX

Felix, the newspaper of Imperial College Student Union in Britain, has become probably the first student newspaper to carry a hologram on its front cover. The embossed 2-D/3-D holograms of a cat, the paper's symbol, were integrated into the cover of the special Christmas issue.

Four thousand copies of the magazine were distributed free to students and staff. The holograms, supplied by Global Images of the United States, were very popular and copies of the special issue were snapped up in record time.

Judith Hackney, the editor of Felix, expressed her gratitude to Walter Clarke of Global Images for his help with the project.

MICRO-CONTROLE IN BRITAIN

Micro-Controle SA of France is now offering its products direct to holographers in Britain through its new subsidiary Micro-Controle (UK) Ltd.

These include manual and motorised positioners, positioning controllers, optical bench support equipment, and optical components and instruments.

A catalgue available from Micro-Controle at 4320 First Avenue, Newbury Business Park, London Road, Newbury, Berkshire, RG13 2PZ, England. Tel: (+44) 0635 521757.

INSTITUTE ERROR

In an article on page eight of the last issue of Holographics International, we incorrectly gave the new address of the Holography Institute. The correct street address is, in fact, 243 Wilson Street, Petaluma, California, USA, and not 423 Wilson Street as stated.

However, correspondence should not be sent to this address, but to PO Box 446, Petaluma, CA 94953.

Greeting the guests at the new Light Fantastic entrance.

FANTASTIC OPENING

Light Fantastic of Britain have just finished revamping their gallery at the Trocadero in London in order to make it more attractive to tourists.

The exhibition closed down in November and re-opened just one week later. The £200 000 they invested in the refit was spent on a new entrance to the gallery, designed in the form of a mirrored tunnel, with interactive lighting to produce optical illusions. The main exhibition is now smaller and includes more optical illusions and laser effects. The selling gallery has now been extended to include many more medium format holograms than it had. The shop has also been refitted.

The new exhibition is entitled *Come Touch Tomorrow* and is expected to attract more than 800 000 visitors per year. If this expectation turns out to be justified, Light Fantastic will have more than doubled their volume of customers since last year.

Light Fantastic have exhibited in the Trocadero since 1985 when they exhibited a collection of holograms of Soviet treasures. The Trocadero is a small 'galleria' type shopping and tourist centre just off Piccadilly Circus which is the heart of London's most profitable tourist area.

THE NEW YORK EXPERIENCE

by Susan Cowles

In the United States, over the past few years, the State Education Department (SED) in New York has been sponsoring a project called "Holography in the classroom". This was initiated by Scott Lloyd who is currently Director of Educational Services at the Museum of Holography in New York City. It has been through his efforts and the financial and moral support of Robert Reals, the administrative director of the SED, that holography has slowly begun to become part of the education of the young people in selected high schools throughout New York State.

During the summer of 1987, I had the opportunity of working for the State University of New York (SUNY) in Buffalo whilst being employed by the SED. At SUNY I worked as a lecturer and workshop director in holography for a period of six weeks stretching from July through to late August. Following on from that, I conducted additional workshops in creative holography, again over a period of six weeks; yet this time the workshops were carried out as part of an "Artist-in-Residency" programme run by the SED.

The first creative holography workshop at SUNY was part of a summer "Media" Arts Programme which was directed by Dr Gerald O'Grady who was the creator of Media Studies at Buffalo. The summer programme is part of his intentions to make creative "Media" arts accessaible to young people of school age.

This year was the first time that he decided to include holography with full-time tuition into the Media programme. Generally speaking, holography is not widely established within an educational/fine-arts context, therefore the summer workshop, in its own way, set a precedent in this field.

This programme proved to be, in the words of O'Grady, an "immersion experience". This was not only true for the students, but also for the faculty members. Dr O'Grady structures his faculty by employing practising artists who are specialists in their fields. In addition to holography, the other workshops were in film, video, creative sound and photography.

Through an intensive work schedule, a provocative, creative work atmosphere was generated. Workshops in their specialist fields were scheduled between 9:30am and 5pm, Monday to Friday. In addition to that, art history talks were held every morning before the workshops began. Evening and week-end lectures were held involving twenty visiting artists who discussed new technologies, new international devlopments and minorities; needless to say holography was represented here.

As a faculty member I was given total freedom to structure the holography course as I wanted it, but first I had to sort out the practicalities of how to make holograms. When I arrived at the University I discovered that there was very little in the way of equipment available. To start with I had a 5mW laser, a couple of front silvered mirrors, a plate holder and assorted chemicals. At this point there was no isolation table therefore I had to build one.

A suitable venue for the holography studio was found in an unused photography lab. During the first week or so of the programme, with the support of the equipment staff we gathered cinder blocks, bricks, carpet, board and steel plate from the university maintenance department which enabled us to construct an 8x4 inch steel top table.

Whilst materials were being acquired for the table I was busy gathering the other resources we needed; this involved borrowing optics from the Physics department, and getting the holographic film and chemistry. There was a

High School students with their work.

lot of entusiasm and support, not just from within the programme but also from other people outside the summer school. This made it possible to have a workable studio and table complete by the middle of the second week of the course.

I felt that I had been given a great opportunity to put into practise my ideas and thoughts about the teaching of creative holography . As an artist/teacher I wanted the workshop to be a creative environment where the student could learn to explore and develop the aesthetics of holography. In my opinion this should not only include the practice and contemplation of a holographic image, but it should also include the teaching of a practical scientific method. One should feed the other in a true holistic sense.

This was the central theme of the workshop which I consequently developed during the six week period. I wanted the students to find new ways of thinking about and manipulating the holographic image. I felt that holography could all too easily be used purely as a recording medium, ie to show something in 3-D. My aim was to encourage the student to try to reach beyond the initial "novelty" of seeing a holographic image. In retrospect I think I probably managed to achieve this.

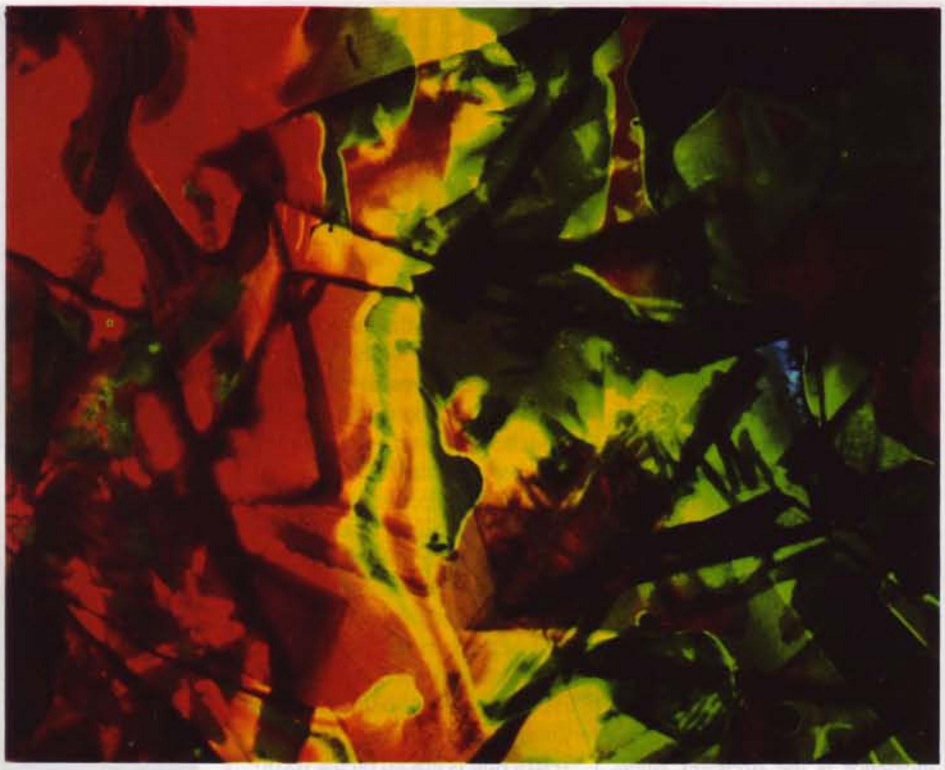
I certainly had no objections to the students making holograms of ready-made objects, although I felt that they had to have a reason for wanting to use them. Otherwise, they would not be using their creative abilities to the fullest extent.

On the whole I found this philosophy did not fail. On the contrary, I found that on the whole the children responded very well to imaginative holographic images. They were full of curiosity about what they were and how they were made. There imaginations became instantly fired - for them it was a "magic" - yet they could play at being magicians.

After the summer workshop was over, I set off on my "Grand Tour" of New York State. I took my experience of the previous six weeks with me and I went on the road. I left Buffalo and headed for Hastings-on-the-Hudson which was my first school stop. Every school I visited had a vibration isolation table and a laser. Not all of them had a vast selection of optics, but I was a travelling lab. I was equipped with everything necessary for doing split and single beam work - right down to the nearest pinhole!

I am aware, as are many other holographers, that holograms do not have to be made from equipment which is entirely shop bought. Therefore, with the exeption of a spatial filter, one beam steering mirror and a crude VBS, bought with the $750 budget from the SED, the optics were improvised.

On my travels through the various school districts, I was surprised by the resourcefulness of schools. Every school had, somewhere, somehting laying idle which could be used to help make holograms. Kids from all academic disciplines had different ideas for making all kinds of images and many successfully managed to translate these ideas into real holograms.



Hologram made at the SUNY summer school.

Throughout the time that I conducted the workshops in the various schools, I became increasingly aware of the wide ranging applications of holography as an educational tool. The most obvious being the way it manages to successfully unify art and science, two subjects which have traditionally been kept separate in schools.

This is not so in New York State. Art teachers and science teachers are now getting together to think of mutually beneficial projects for their students to persue. This is as a result of their exposure to holography. In one school I visited in Clarence NY, holography was being taught as part of Art, Physics, Marketing and Creative Writing, and the Biology teacher was thinking of including it in his lessons too!

This is only one small example of the enthusiasm I encountered in the staff I worked with. They carried their dedication all the way to the point where I felt confident that they were going to carry on with further projects in my absence. At the end of each week in every school, we set up an exhibition of the work that the kids had completed during the week. In all cases these were well publicised, which meant a lot of children were exposed to holograms for the first time in their lives. When they found out that they too could "do it", they wanted to start right away.

Working as an artist-in-residence in those selected schools gave me a chance to be able to begin to de-mystify holography. I was able to show teachers and students alike that it was quite possible for them to make good quality holograms.

The great thing holography has going for it in education is its ability to cross artificial subject boundaries and interest the whole spectrum of people. Perhaps, for some, the very universality of holography is an important lesson itself.

ABOUT THE AUTHOR

Susan Cowles was educated in Britain at the Croydon College of Art & Design, Middlesex Polytechnic, where she was awarded an honours degree in three-dimensional design, and the Royal College of Art, where she obtained an MA in holography in 1986.

Some of her work was shown at the Victoria and Albert Museum in London in a group show called Towards a Bigger Picture. *This was the first collection of holograms to be shown as 'fine art' in a major British museum.*

Sue Cowles has worked with many other holographers in the past, including Adrian Lines, John Brodell, Peter Miller and David Dewar. She is currently writing an educational booklet on 'Holography in Education' for the State Education Department in New York.

PRACTICAL HINT FROM CHRIS LAMBERT

It is generally recommended that front-surface mirrors be used for reflecting light beams in holography. This is to avoid unwanted fringes that would result from the interference of the two reflections from a back-silvered mirror. Chris Lambert of *Laza Holograms* has a tip for using such mirrors successfully to record high quality holograms. His solution is to use a polarisation perpendicular to the plane of incidence, i.e. p-polarisation, to reduce the reflection from the glass surface. The ideal angle of incidence is the Brewster angle (56 degrees) at which point the reflected light is minimum.

Lambert uses a back-silvered mirror 24″ in diameter and 1/4″ thick which he purchased for 10 from a local glazier. This is held 3 feet above a steel table top, and is nearly horizontal, so that any sideways movement of the mirror has little effect on the interference fringes. When p-polarised light was shone onto the mirror, only low contrast, widely spaced fringes could be seen. The set-up was used to record transmission bleached master holograms, which were in turn used to record secondary reflection holograms. No noticeable effects were observed on the reflection copies. The obvious advantages of using a back-silvered mirror are the low cost of the mirrors, and the ease of cleaning the surface - Lambert recommends Windolene! The disadvantage is that a severe restriction is placed on the recording geometry by the Brewster angle requirement.

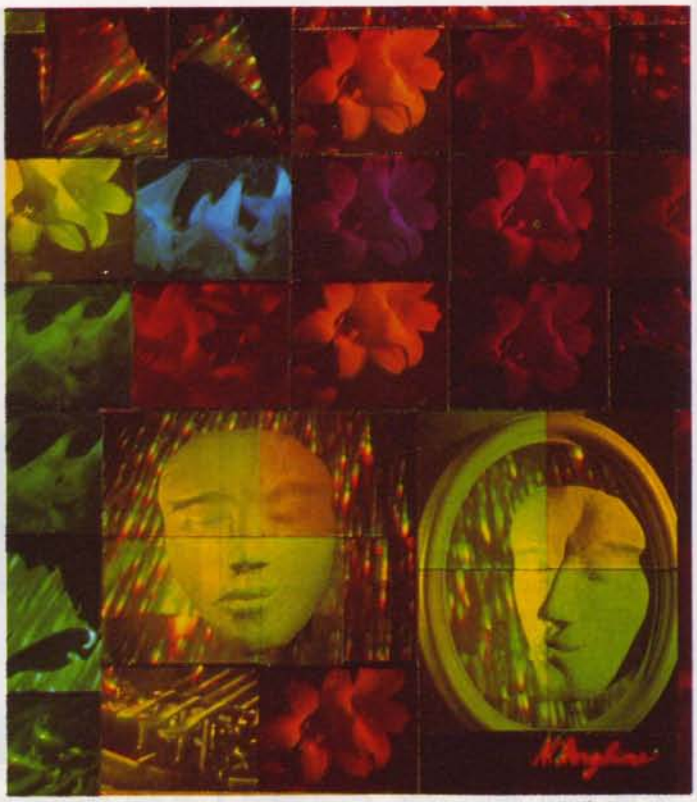
Lambert also uses such mirrors for illuminating the object in recording the H1. This time, the fringes can be eliminated by spraying the front with a light coat of matt varnish. This diffuses the light just enough to get rid of the unsightly fringes.

PROMOTIONAL PRESIDENT

Leon Jay, director of Premium Technology Ltd, a British company concerned with using holograms to add value to everyday products, has recently been made president of the British Promotional Merchandising Association. Mr Jay had been involved with the BPMA for some time before he became involved with holograms but his use of holograms is very much related to his new position.

The BPMA is an organization of companies who provide promotional items bearing corporate logos. Premium Technology provides such items with the added interest that the products are in some way holographic. Examples of these items include paperweights, watches, ashtrays and calculators all adorned with holographic motifs and the clients company name. In June the BPMA awarded Premium Technology a prize for the 'Best New Promotional Product' for a calculator with coins holographically embedded inside.

As well as selling promotional items, Premium Technology have been breaking into the retail market by selling display systems and holograms to retail outlets.



Nancy Gorglione's multicolour refelction composite—'Woman as Music'.

FRUITFUL CHERRY

Nancy Gorglione and Greg Cherry, of the Cherry Optical Company in California, are currently developing a prototype holographic stage set through their non-profit organization, Laser Affiliates.

The stage set, entitled *Equus Underwater*, will feature large-format transmission and reflection holograms designed as a free-standing environmental installation. Sequenced white and laser lighting provides multiple imaging of the holograms.

Funded by a grant from the California Arts Council, *Equus Underwater* is intended to familiarize theatrical artists and organizations with the current technology of holography and its potential applications within the performing arts.

The stage set will be exhibited in non-profit theatres in California from February 14th 1988. Greg Cherry and Nancy Gorglione's work can also be seen at the *3-D Copy Factory*, a new holography gallery which was opened in Los Angeles in December by Rick Pearce.

The thirty holographic pieces in the opening exhibition include one-of-a-kind large format reflection composites (by Nancy), multicolour limited edition holograms by both artists, and Cherry Optical's best selling open edition holograms.

The new gallery features 1800 square feet of exhibition space in prime retail art area of Los Angeles County. The Cherry Optical exhibit will run until February 1988. The *3-D Copy Factory* is located at 13218 Washington Blvd, Venice, California. Telephone (+1) 213 301 6613.

JULIET RIX RESIGNS

The newly elected editor of *Real Image*, the newsletter of the Royal Photographic Society Holography Group, has resigned. Juliet Rix resigned due to pressure of work late last year before she was able to produce her first issue.

Her resignation followed a series of other problems for the publication, which was due to receive a facelift this year. A London company with strong holographic links had offered to fund a new, more glossy version of *Real Image* but, to the dismay of the Holography Group, the RPS committee with responsibility for the group rejected the plan.

After this disappointment and Rix's resignation, former editor Graham Saxby agreed to bring out one more issue of the publication in the existing format. For the future, the group is considering changing the publication to a smaller newsletter format, although no final plans have yet been made.

LLOYD LEAVES

Scott Lloyd, Director of Educational Services at the Museum of Holography in New York, is to leave the museum at the end of January. After five years, he is leaving to set up his own business, called *Holographic Educational Programs and Products* in which he will continue his work in educating young people about holography.

To start with, Lloyd will be doing similar work to that he did at the museum. This will include lectures, demonstrations, and consultancy work in schools, with the aim of making students more holographically literate. But Lloyd has more ambitious plans for the new company which would make holography simpler and more accessible to schools all over the country.

He would like to design and sell holographic equipment, especially optics, which are more lightweight, portable, and easy to use than can be bought at the moment. He also has plans to do make educational programmes on video tape which he would distribute through the State Education Departments all over the US. Consultancy by video would be his next move.

Lloyd gave in his notice to the museum at the beginning of January and, though due to leave at the end of January, he has agreed to continue lecturing until a replacement can be found. He hopes to have the new venture up and running by the end of February.

SAM & DAN MOVE

Sam Morée and Dan Schweitzer of the New York Holographic Labs moved to new premises in January. They can be reached at PO Box 20391, Tomkin Square, New York, NY 10009, and their address in New York is 176 East 3rd Street. Their phone number is still (+1) (212) 242-9774.

CALENDAR

Until March 13th
The Museum of Holography in New York is showing an exhibition on *Californian Holography*, organised by Nancy Gorglione. The exhibition includes, among others, works by Lloyd Cross, Bob Hess, John Kaufman, ADD, Greg Cherry and Nancy Gorglione. For opening times, etc. phone (+1) (212) 925 0526.

Until February 28th
John Kaufman's fifth one man show continues at Holos Gallery in San Francisco (see review page 20). For more information, contact the gallery on (+1) (415) 861 0234.

January 27th - April 10th
The Zamana Gallery in London presents holograms and photographs taken by Tom Ang while travelling overland to China on *The Silk Road*. For details of opening times, etc. call (01) 584 6612/3 (international +44 1 584 6612/3).

January 30th - March 12th
Toronto's Interference Fringe Hologram Gallery exhibits work by Mary Harman entitled *Reconstructions*. This collection of mixed media holographic works includes a number of pieces based on the Magritte illusions. For further details, the gallery can be reached on (+1) (416) 535 2323.

January 31st - February 5th
SPIE presents *Medical Imaging II* at Newport Beach, California. For information call (+1) (206) 676 3920.

February 9th
Royal Photographic Society Holography Group Meeting, London. David Reed talks about the role of holographic design consultancy, in connection with his work at Holographics (UK) Ltd. See page 30 for time and location.

March 8th
Royal Photographic Society Holography Group meeting, London. Annual General Meeting to be held at 6pm. At 7.30pm Peter Miller and Dominic Welby will be talking about their work at Laser Lightworks. See page 30 for location.

March 19th - April 30th
Phillippe Boissonnet's holograms of sculptures of the figure, in relation to paintings and drawings, are shown at the Interference Fringe Hologram Gallery, Toronto. For more details, phone (+1) (416) 535 2323.

April 12th
Royal Photographic Society Holography Group meeting, London. Speaker to be announced. For details of how to get more information, see page 30.

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. For more information about the group, see page 30.

McGrew questions security value of holograms at Swiss conference

COUNTERING COUNTERFEITING

by David Pizzanelli

Since American Bank Note first supplied Mastercard and Visa with security holograms to protect credit cards against counterfeiting, over a billion security holograms have been produced, and not one instance of criminal counterfeiting of a security hologram has been reported. A new type of hologram, the kinegram, was introduced at the International Symposium on Security Optical Systems in Zurich, Switzerland, held in October of last year. The kinegram was devised to allow the high level of security afforded by ordinary holograms to be applied to almost any item at low cost. However, a difference of opinion emerged later in the conference when it was claimed that a determined forger would be able to copy kinegrams or any other holograms.

Dr Jean-Frederick Moser of LGZ (Landis & Gyr, Zug AG), Switzerland presented a paper entitled *The Kinegram, A New High Security Optically Variable Device*. In 1976, Landis and Gyr had succeeded in embossing holograms directly on printed banknote paper. The technique was in close compatibility with the copper plate technique; a scaling down of the intaglio or etched plate print process towards light-diffracting dimensions, in other words, a true hologram printing technique where the copperplate role was taken over by a nickel matrix.

Unfortunately, this system meant that the embossed hologram was uncovered leaving the diffracting microprofile exposed to "external interaction". The crumpling, soiling and abrasion tests which are applied to paper currency to simulate the abuses banknotes suffer in the outside world, "were too severe for the device to survive". So, the kinegram, with its profile protected by a cover varnish, was devised to meet the stringent criteria of Orell Füssli, the Swiss banknote manufacturer

Kinegrams are "computer-generated diffractive micro-structures", their images expand, contract or rotate as the kinegrams are tilted, hence the name. By means of a special projector, delegates to the conference were shown a number of kinegram images projected onto a screen like slides, the images changing as the projectionist pivoted the samples by hand. In this way Dr Moser demonstrated how the images in a kinegram are built up from very basic gratings into amazingly complex and beautiful kinetic patterns, like those generated

Counterfeit copy of the new 'Mastercard' hologram, which is in use in the United States.

on a Guilloche machine and used on banknotes.

Because they are formed of simple gratings, kinegrams stand up to considerable punishment, unlike embossed rainbow holograms with three-dimensional images based on the associative superposition of wavelets. This point will be appreciated by anyone who has seen their embossed hologram ruined simply by being stuck down on an uneven or textured surface. In terms of cost, the kinegrams are clearly something of a luxury item, but Dr Moser was at pains to point out that the "added value" conferred by the kinegram would be greater still. Monetics, the division of Landis & Gyr marketing the kinegram, are seeking approximately 10% of the production cost of the banknote. In Britain, banknotes cost 1.804 pence for the year ending February 1985, the US dollar note cost 2.5 cents and the Canadian dollar about 1.5 cents, so with a production rate of between 6 and 9 billion notes per year made in the US alone, Landis & Gyr Monetics can look forward to a tidy sum.

Later, in his paper, *Countermeasures Against Hologram Counterfeiting*, Steve McGrew stunned delegates with his opening words, "Holograms offer almost no security in themselves: they are extremely easy to counterfeit". Already, non-security holograms made by Light Impressions have been counterfeited in Taiwan, he explained, and went on to give detailed descriptions of methods which he thought might be used to make copies

A Landis & Gyr Kinegram.

Counterfeit copy of old 'Mastercard' hologram shown next to 'real' hologram on credit card.

of security holograms. Although several were surprised by these remarks, no-one contradicted him at the end of the session.

McGrew went on to describe new techniques which could be applied to holograms and OVDs (Optical Variable Devices) to make them less vulnerable to copying. However, his remarks on hologram and, more especially, kinegram copying fuelled heated discussion for the rest of the symposium.

In his turn, Dr David Greenaway of Applied Holographics Embossed Ltd stressed how difficult it was to make holograms. From the recording process carried out on a laser table, to the electroforming steps needed to produce embossing shims, and then to the embossing and finishing operations needed to produce a finished product. The chain of steps is long and the attention to detail is essential if a high quality product is to be achieved. The very length and complexity of the production operation was in itself, he felt, a significant contribution to the security available from an embossed hologram.

Dr Greenaway gave an example of trademark protection in connection with the Swiss watch industry. Inferior imitations of well known brands of Swiss watches were being produced in the Far-East, and to tackle this problem, W Blösch AG decided to incorporate a holographic logo as an integral part of the watchface. The logo is not an embossed hologram, but an actual metallic electroform obtained from an original relief hologram.

On the success of holography as a security medium, Dr Greenaway noted that: "In my previous position with Landis & Gyr we launched tens of millions of embossed pre-payment telephone cards into the public domain and no forged cards which had been used publicly ever landed on my desk".

Simon Brown of Applied Holographics gave a paper entitled *Holographic Technology as a Potential Security Feature (Film and Roll)* in which he pointed out that multicolour reflection holograms offer a relatively high degree of security. As Jeff Blyth has pointed out, this particularly true if the multicolour effect is achieved by treating the emulsion of the hologram before exposure and then treating the surface again prior to subsequent exposures, rather than differential treatment of separate areas of the emulsion surface after one exposure only. By the multiple exposure method, the different hologram images lock at different relative colours, no matter how the emulsion is then manipulated in terms of shrinkage or swelling.

Simon Brown raised some eyebrows with his suggestion that reflection holograms could be diced up into tiny pieces and mixed in with raw paper pulp to make a new kind of security paper, "To incorporate the holograms in the paper, the emulsion will need to be stripped from the carrier base. This is achievable and would give a truly unique product". Brown has taken the step of protecting his truly unique product with a patent application, just in case.

Nick Phillips of Loughborough University was unable to give his paper in person, but it was presented in his absence. Entitled *Holography—Optical Physics or Optical Magic* it detailed his belief in holography as a powerful display medium: "The shock of the sight of a flat picture which looks three-dimensional remains with the viewer almost as fundamentally as a trauma from childhood."

His paper presented a review of the history of holography starting in the 19th century, suggesting that Gabriel Lippmann, "may well have observed holographic effects in the course of his experiments (in 1891) but was probably unable to interpret such observations correctly."

Also of interest was his remark that, "The Gabor in-line hologram is not really a hologram at all but... at best a diffractive shadowgram, albeit replayable by the use of a reference wave." The debate as to the validity of Denis Gabor's hologram is central to the disputes over the 'Grandlady' patents which are raging in the United States at the moment, and any undermining of Gabor's achievement would do much to strengthen the case that Leith and Upatnieks were the first to invent what might properly be termed a hologram. Were such a case to be proved, it would radically effect the position of those wishing to make security holograms in the US.

ABOUT THE AUTHOR

David Pizzanelli has worked for See 3 (Holograms) Ltd in London since 1983. He and his company have been involved with many security projects, especially bank cards, for which they originated the holograms.

They have nine of their originations on the street at the moment, mainly in Britain. Through BPCC Ultracard Ltd, a company set up to market their originations, they have done jobs for Westpak and the Bank of Scotland. They have also done bank cards for the HFC Bank and Hill Samuel.

Other jobs include one for a client from Taiwan, through Banrose Security Print, and a tamper-evident holographic seal for the drug company Glaxo, through Applied Holographics. See 3 have worked with both hot foil and PVC in their security jobs.

JOHN KAUFMAN AT HOLOS GALLERY

Reviewer—Bruce Goldberg

In the last issue of Holographics International we briefly previewed Kaufman's exhibition in San Francisco. Here, our reviewer examines the collection in detail and expresses his opinion on its artistic merit.

The exhibition of holograms by John Kaufman, on view at Holos Gallery in San Francisco, California, until February 28th, proves beyond a shadow of a doubt that holography has reached a point where it can be effectively used as a full-colour medium.

During holography's formative years, the problem of colour control consumed many researchers who generally attacked the problem through the use of multiple lasers of different wavelengths (colours). The resultant hologram actually contained a separate holographic recording (fringe pattern) for each colour to be displayed. Besides the great expense of multiple lasers (usually high powered Argon or Krypton and a Helium-Neon), this technique was limited by the fact that each fringe pattern was of a slightly different scale and therefore shrank to a different degree when dried. This resulted in poor registration between the various colours.

Carpenter Squares—John Kaufman 1986

John Kaufman, along with Lon Moore and others in Northern California, perfected a different technique which requires only a single laser. This approach involves the use of swelling agents, (sometimes just water) to swell the emulsion before each exposure. Each exposure is made onto an emulsion swelled to a different degree and this results in fringe patterns of different scales which produce different colours. Since there are still multiple fringe patterns, registration may still be a problem with some subject matter, but the fact that the process involves only a single laser and that the manipulation of the fringe spacing is an integral, rather than incidental, part of the technique, means that it has much greater artistic potential.

All this is by way of introduction to the superb collection of multi-colour images produced using the pre-swelling technique by its premier advocate John Kaufman. These are surely the most refined colour holograms I have seen to date, displaying a range and subtlety which has apparently escaped all others. The excessive saturation or dimness which has plagued past efforts is gone (although the medium still tends to favour bright colours over muted tones).

Carpenter Squares shows deep blue and yellow steel rules against a red background which fades smoothly to blue at the top of the frame. This kind of colour scheme was unheard of in holography just a few years ago and here it is presented in a controlled, articulate manner. Clearly the period in which Kaufman was experimenting with the pre-swelling technique are gone and we have finally reached the stage at which the experiments are primarily aesthetic, not technical.

Rake combines Kaufman's good colour sense with more spatial conception than some of his other pieces. Here, bright red and green leaves dance at the end of an upturned rake. There is a sensitively chosen play of forms between the leaves and the rake, which seem almost to define a musical score as we watch.

In *Wild Ferns*, a complexly mottled backdrop demonstrates Kaufman's mastery of the medium. Few holographers have been able to achieve the soft, organic look that is evident

Hinged Rock—John Kaufman 1987

here; the look of damp earth, suggesting nature, renewal... Some of Ruben Nunez's work comes to mind, but it is less clarified and resolved.

The two pieces entitled *Pier* and *Pier - Colour Variation* are further evidence of the level of sophistication Kaufman has reached in his colour experiments. I do believe that this level of control and sophistication in colour holography is unprecedented. Subtle blendings and shadings can no longer be thought to go beyond the medium's capabilities.

Hinged Rock is the only really obvious multiple exposure hologram in this group. This piece demonstrates the interpenetration of three-dimensional forms that began to fascinate artists during the Cubist era and which continues to this day in the work of may sculptors as well as holographers. It is fitting that this concern might fade as an issue for holographers as previously unattainable issues (colour) are brought under control.

Two Colour Split Rock is further evidence of the control and mature pallette which has been attained here, but the most lyrical piece in the show is *Duo Donne,* a beautifully chosen and rendered combination of forms in orange, ultrablue and green. Formally, this piece is reminiscent of Henry Moore sculpture. In terms of colour, it is unmistakably Kaufman.

About the only criticism I might have relates not to any particular work, but rather to the overall presentation, which is excessively uniform. In previous shows, Kaufman has presented at least a few transmission holograms. Clearly, he is more comfortable in the reflection mode. However the overall look of the gallery is slightly monotonous, especially in view of the fact that all the pieces are basically the same size. A little more variety in the presentation would have been welcomed.

Rake—John Kaufman 1986

None of this detracts from the works in question, however. Kaufman's earlier shows make sense as both technical and formal exercises, but in this exhibition he has moved beyond these to more purely aesthetic concerns, a move which bodes well for holography.

ABOUT THE AUTHOR

Bruce Goldberg has been involved in holography for eleven years now. He started learning how to make holograms from Sam Moree and Dan Schweitzer in 1976, and went on to follow Moree as the artist in residence at the Museum of Holography in New York.

In 1977 he worked with the pulse ruby laser at the Brookhaven National Laboratory. He is presently on the Board of Directors of the LASER Arts Society in San Francisco.

Goldberg graduated from the Sarah Lawrence College in Bronxville, NY, with a degree in modern art history and architecture.

PRACTICAL HOLOGRAPHY

by Graham Saxby, published by Prentice-Hall

Reviewer—Kaveh Bazargan

Most books on holography fall into one of two categories—academic and practical. The 'academic' books generally concentrate on theory and application, and gloss over the practical details of making holograms. The 'practical' books, on the other hand, contain 'hands-on' advice, but generally do not give the reader a sound understanding of the principles involved, and hence limit the potential creativity of the holographer. What is needed by the ambitious holographer is a book that combines the two approaches, and Saxby has attempted to produce just such a book.

There is no doubt that this book contains far more information than any other on the market for the holographer, and most of it seems to be well researched. The first six chapters of the book are grouped as the 'principles of holography'. Clear diagrams accompany the text to describe the different types of holograms. In most cases the author has taken care to draw the image produced by a hologram or an optical system in the correct 'sense', i.e. mirror-reversed or upside-down—this is rare in both 'practical' and 'academic' books!

The second part of the book—chapters 7 through 22—deal with 'practical display holography', and comprehensively cover the 'nitty-gritty' of setting up and recording holograms, from the details of making an isolation table to optical recording geometries. Again, on the whole the diagrams are clear and accurate. Many references are given, although these are, in general, to more 'popular' publications, and may be limiting for the serious student.

Chapters 23 through 25 review the (mainly non-display) applications of holography, and a number of references have been given. The book contains 12 appendices including background mathematics, processing formulae, optical fibres, fringe stabilization, laser safety, and useful lists of equipment manufacturers.

The book is attractively produced, and contains a large number of colour photographs exemplifying the different techniques covered. There are two holograms contained in the book—an embossed hologram of a live kitten is adhered to the cover (somewhat difficult to see), and a film reflection hologram is stuck inside the book.

Apart from minor errors, perhaps the only serious omission from this book is any explanation of the beam used in recording—one of the most important variables. Saxby relates the beam ratio to the linearity curve of the recording medium, but in practise this applies only to thin amplitude holograms with small interference angles. In any case, all bleached holograms are inherently non-linear. The crucial factor that affects image quality in pictorial holography is, in fact, intermodulation noise.

Saxby has must be congratulated for gathering such a large amount of information together, much of it unpublished before. The book is highly recommended for the practicing holographer, and for the academic who occasionally feels the urge to make an impressive hologram.

IMAGE BLURRING IN DISPLAY HOLOGRAPHY

(AND HOW TO REDUCE IT)

by Andrew Ward

One of the most common defects in display holograms is blurring of the image. This is usually undesirable and is something which we would like to reduce. How can this be done? Is blurring caused by a problem with the way the hologram was recorded, or by a problem with the way it is replayed? The answer to this is the latter: blurring is caused almost entirely by inadequacies in the light source to replay the hologram. Explanation follows.

First, it is very important to appreciate the difference between holography and photography in this respect. A photograph is a 2-dimensional recording of an image formed by a lens, and so can be blurred from the start; when you look at a photograph the sharpness of the image is not affected by the light source used to illuminate it. The situation is completely reversed for a hologram, which is a recording of an interference pattern, not an image. If the interference pattern is blurred at recording, only the brightness of the replay is affected, not the sharpness. The sharpness of the image depends on the direction of the waves diffracted by the hologram, which is determined by the spatial frequency of the recorded interference pattern, and also by the direction, size and wavelength of the replay source. It is not possible to record a hologram of a blurred object. If any hologram is illuminated with an ideal light source (ie. a point source at the correct wavelength, angle and distance), then the image will be pin sharp, no matter how it was recorded. (Nearly: there are limits if we start to look too close, but they are beyond the resolution of human vision.)

This is all very well, but an 'ideal' light source means a laser, so we must accept that display holograms need to be replayed with cheaper, non-ideal light sources which have a finite size and bandwidth (they may even be white). So, is there anything that the creator of the hologram can do to help? The answer is yes.

Most holographers know that the closer the final image is to the plane of the hologram, the sharper it will be; this is related to the size of the replay light source. Most know that if a white-light replay source is to be used, then reflection holograms will normally give a much sharper image than transmission holograms; this is because the diffraction bandwidth of reflection holograms is normally much narrower than that of transmission holograms. However, it is not generally appreciated that the precise geometry of the recording setup can have a dramatic effect on the degree of blurring in holograms replayed with white-light for both reflection and transmission geometries. This is because blurring is caused by angular dispersion of the various wavelength components as they are diffracted by the hologram, and the degree of dispersion depends on the angles between the hologram plate, the reference beam and the object beam.

The primary cause of blurring in white-light holograms is the finite size of the light source; the effect of this will be described first. Dispersion is the second major cause of blurring in white-light reflection display holograms and be reduced by adjusting the recording geometry, as will be described in detail in the next issue of Holographics International.

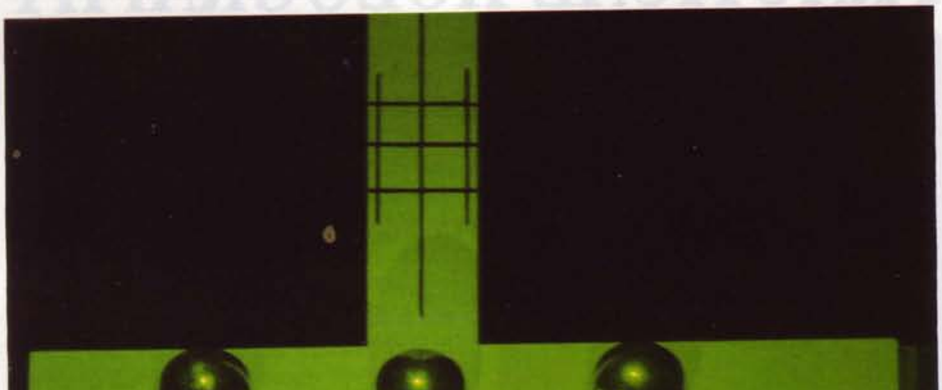


Plate 1—Hologram replayed using a perfect source: filtered mercury lamp.

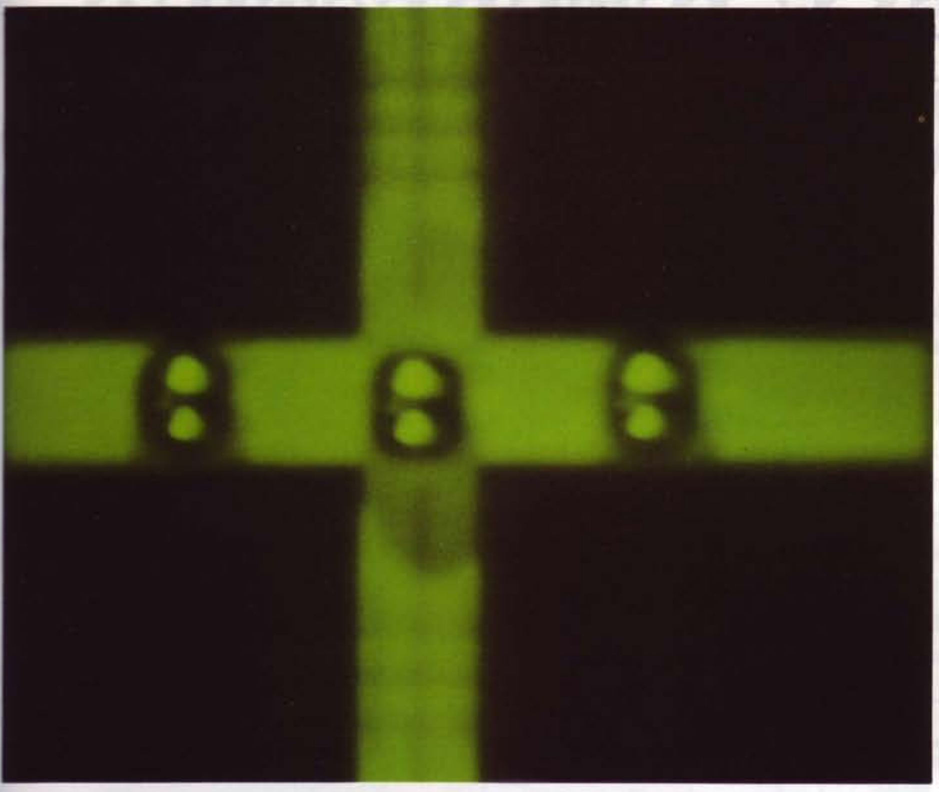


Plate 2—Hologram replayed using a relatively large source: a tungsten bulb.

Source-size Blurring

At the recording stage of a display hologram, the signal beam can be considered to be an array of spherical waves radiating away from each point on the surface of the object. All of these interfere with the reference wave to form a vast superimposed array of holographic lenses or concave mirrors in the hologram.

At replay, each of these lenses or mirrors diffract some of the light from the replay source into what should be a perfect spherical wave which appears to originate from the position of the original object point. In fact, each holographic lens or mirror will form a diminished image of the light source, in much the same way as a conventional lens or concave mirror would, and the final image is actually a vast array of images of the replay source. If the source is anything bigger than a point then the image will be blurred.

The amount of blurring depends on the angle subtended by the source at the surface of the hologram, and on the effective focal lengths of the individual holographic lenses or mirrors. Figure 1 illustrates this for the images of only two object points.

Source-size blurring can be reduced in three ways:

1) Use a smaller replay source and remove any optics which increase its angular size.

2) Move the source further from the hologram to reduce its angular size. (Deviating from the correct reference source distance will not normally cause any noticeable distortion of the image.)

3) Keep object points as close to the hologram as possible at recording to shorten the focal lengths of the individual holographic lenses/mirrors and so reduce the sizes of their images of the replay source. The best condition is, of course, achieved in a semi-real image copy hologram; image points in the plane of the hologram are not blurred at all.

The first and second of these measures will of course also reduce the brightness of the replay beam at the hologram; this is an inevitable consequence of real white-light sources: they must have a finite size to have a useful brightness.

Light Sources

The next best replay source to a laser is a high-pressure mercury or xenon arc lamp, which will give excellent results with transmission holograms if a narrow-band filter is used. Their spectral characteristics can make them tricky to use for reflection holograms, and the tubes and power supplies are quite expensive, so they are not often used. Plate 1 is a photograph of a test reflection hologram replayed with a filtered mercury lamp; the quality is not much worse than replaying with a laser. (The image is 100mm behind the hologram plate.) For comparison, Plate 2 is of the same hologram replayed with a tungsten light bulb at 2m.

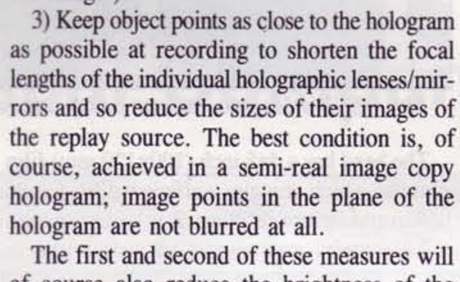


Figure 1

The next best continuous spectrum lamp suitable for reflection holograms is a metal-halide arc lamp without any optics; these are very bright and very small but still expensive and not generally used, except for street lighting.

Next are quartz-halogen filament lamps. These have good compact filaments (especially the lower voltage ones) and are very cheap. Problems, however, arise from the optics put around them to increase the illumination intensity. Doing this inevitably increases their angular size and also often gives very poor uniformity of illumination. The best way to use these lamps is sideways to the hologram with no reflector or lens, when they can be quite close to the hologram to keep the brightness up. A spherical reflector can be added next to increase the brightness, as long as it is of high quality and correctly positioned (with the filament at the centre of curvature). Commercial lamps of this sort are often very poor in this respect, particularly if the lamp is mounted end-on. Display floodlights with rippled or parabolic reflectors and lenses are to be avoided at all costs!

The best compromise between angular size and intensity is a good quality quartz-halogen slide projector fitted with a glass reflector, aspheric condensers, and a projection lens. These have the added advantage of providing very uniform illumination by the action of the projection lens, as well as allowing sharp-bordering. The only disadvantage of quartz-halogen lamps is the need for a bulky and heavy transformer which must be close to the lamp because of the high currents flowing at low voltage. Projectors with mains-voltage lamps are very inferior; their filaments are too big. Direct sunlight, despite popular belief, is actually not as good as a slide projector. The approximate angular sizes of the various light sources are listed below for comparison.

100W mercury/xenon arc lamp at 2m distance: 0.015 degrees.
12V 50W Quartz-halogen bulb at 1m: 0.25×0.04 degrees.
100W Quartz-halogen slide projector at 2m: 0.3 degrees.
Direct sunlight: 0.53 degrees.
Tungsten bulb at 2m: 1.5 degrees.

Andrew Ward is a member of the Optical Holography Group in the Department of Engineering Science at the University of Oxford.

Next Issue: Andrew Ward looks at how to change recording geometry to prevent dispersion blurring.

REMOTELY INTERESTING

One of the most widely used industrial applications of holography is checking engineered components for deformations and analyzing vibrations. To apply these techniques in cases where access to the components is limited, a system of taking holograms remotely is needed. Such systems are already being developed for use in the nuclear industry.

Britain's Central Electricity Generating Board has thirteen nuclear power stations, and has developed the capability to take holograms in radioactive locations. These have included holograms of nuclear fuel elements, of vibrating structures such as gas-ducts and bellows, and of components in reactor cores.

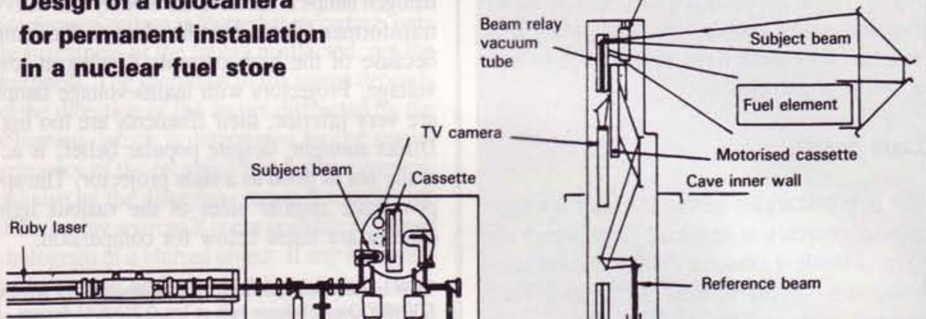
To check for deformations in fuel elements, measurements are taken from the hologram (a process known as hologrammetry) and compared with the original dimensions at the time of manufacture, or with a reference hologram taken earlier. To make these measurements a reconstructed real image must be created from the hologram, and the CEGB team has successfully demonstrated this. For vibrating components in, for example, the reactor's boiler, pulse holography is used to detect deformations using holographic interferometry.

To make these holograms, the CEGB's holographers have developed a compact holocamera. It consists of a transportable laser unit, which remains outside the radioactive area, and a remote head unit, which is compact and robust so that it can be placed near the object using a remote manipulator. The two units are connected by means of a flexible, 45ft (14m) long series of optical relays.

The CEGB's Magnox nuclear power station at Oldbury-on-Severn near Bristol, England

The head has a 4x5 inch (100x120 mm) film cassette which contains sufficient film for 80 holograms before refilling. It is equipped with a TV camera and several photodetectors to enable the unit to be aligned and the correct exposure determined by the operator stationed at the laser unit. The group believes that it is the most compact system of its kind in use anywhere in the world.

Design of a holocamera for permanent installation in a nuclear fuel store



Initially the holocamera used two separate beam relay tubes to transfer the subject and reference beams from the laser unit to the remote head. However, a new system which combines the two beams in a single relay has now been developed. This works by polarising the beams in different planes, combining them to pass through the relay, then separating them again using polarisers.

To make holograms inside the core of a reactor, the remote head was lowered down one of the tubes, through which fuel is inserted and removed, into the region immediately above the core. Here the radiation field is intense and the temperature was above 100 degrees Centigrade, even though the reactor was shut-down. The laser unit and the operators remain in the above core area, which is heavily shielded to create a safe working environment.

Inserting and positioning the remote head in the reactor took about 30 minutes, and since the holographic film can survive in the intense radiation with only minimal fogging for at least

Continued on page 30

Holographic movies bring a fourth dimension to holography—*time!*

HOLOGRAPHY IN HOLLYWOOD?

The concept of moving, three dimensional images remains to most people a figment of a science fiction writers imagination. It might surprise them to learn that it has already been eleven years since the first holographic movie was made.

The principle for holographic movies is the same as for those in two dimensions: a series of still holograms, presented in rapid enough succession, gives the impression of a moving image.

The credit for the first film goes to Professor Victor Komar, a Soviet scientist. In 1976, he successfully put into practice the ideas which had been presented in a scientific paper eleven years before. Professor Komar used eight ruby lasers each producing one image per second, and combined the results to give a film speed of eight images per second. The finished film could be shown on a screen to up to four people at a time.

The next major step forward came five years later, in 1981. In the United States, Arthur Decker used a single YAG laser to produce twenty images per second with low energy pulses. Like Komar's, his film was only seventy millimetres wide so that only very small scenes could be recorded.

In 1983, the first holographic movie filmed in Western Europe was produced at the Institut Franco-Allemand de recherches de Saint-Louis (ISL) by Paul Smigielski, Hubert Fagot and Félix Albe. A small scene, *Holotrain*, was recorded using YAG laser pulses at the unprecedented rate of 24 images per second, on 35mm film. However, cinéholography for its own sake was not the aim—it was envisaged as a tool by which physical phenomena could be observed in four dimensions: space and time. In particular, holographic film could be used in such potentially useful areas as the study of deformation in structures and materials, vaporisation of aerosols and similar processes.

Masks—Alexander 1986

Industries such as aviation should be able to use holographic movies as a method of non-destructive testing.

A new technique being developed at the ISL was especially well suited to such applications. Optical interferometry allows the measurement of deformations on a scale of thousandths of millimetres, and its use in cinéholography was novel and effective. The method requires a double exposure of each frame to the laser, with the time between the two exposures varying according to the process being observed and the required sensitivity. The interference fringes thus formed show any deformation or displacement of the object being filmed. The next few films made at the ISL used this principle to record processes of the sort that scientific research and various industries might find useful; they included *Holocrâne* and *Holoparleur* (1985), the first sequences ever to be filmed in this way.

Holocrâne, produced in collaboration with the odontologic service of the University of Rennes, typified possible medical applications—it was a study of the tiny movements of a bald human head. The time interval between exposures in this case was 10 milliseconds. The industrial applications film-used at even smaller time intervals: 4 milliseconds for *Holoparleur* which showed the membrane of a loudspeaker vibrating at low frequency. Ten interferograms were made per second, with the film being moved intermittently rather than continuously as for other types of holographic movie. *Holofrein* (1986) used a still smaller time interval—50 microseconds—in showing the effect of pressing a brake-shoe against a rotating disc. This kind of holographic movie proves especially useful when non-destructive, real-time testing systems are required, notably for the maintenance of aircraft. Indeed the ISL are at present working on such a system for the Airbus, an application in which the quantity of data needed is so great that the movie is the most efficient way of collecting it.

Meanwhile, work on the more usual types of cinéholography was continuing, and in 1985 *Holomobile* and *Christiane et les Holobulles*, showing a woman blowing bubbles, appeared. These two short sequences were the first to be produced on 126mm film, using a YAG laser at 25Hz. This was also the year in which Paul Smigielski, now head of the Optics department of ISL, and his co-workers were awarded a number of prizes in recognition of their earlier work. Among the awards were the Grand Prix International du Futur, and the Gaumont medal, awarded by the Société pour l'Encouragement de l'Industrie Nationale (founded by Napoleon

Bonaparte in 1801). The latter distinction had been awarded nearly a century earlier to the Lumière brothers for the invention of the cinématograph.

The technique as it is now carried out at the ISL depends on a classical split-beam layout with one beam illuminating the plate directly, and the other being reflected off the object. A YAG laser is used, producing 25 pulses per second of highly coherent green light. Each pulse lasts 15 nanoseconds and has an energy of 50 to 100 millijoules. The camera is synchronised with the laser pulses but keeps the 126mm film moving continuously. This film is of very high resolution. Once it has been processed it can be viewed, using an argon laser for illumination, through a window 1cm high by 10cm wide.

It was this technique which British-Australian artist and sculptor Alexander found extremely restrictive during the production of the first fiction holographic movie, *La Belle et la Bête* (1986). The movie, with a running time of one minute twenty seconds, was one of the longest of its time and was the result of the collaboration of Smigielski, Fagot and Albe with Anne-Marie Christakis of the Museé de l'Holographie de Paris, Alexander and his wife Danielle.

Most frustrating was the cramped set, limited by the volume which could be recorded on film. Besides this, the high power of the laser meant that the actors would have been blinded had they looked closer than a certain angle into its beam.

These restrictions prompted Alexander to investigate other ways of making holographic movies. He drew on the experience gained by working with Australian scientist Dr Hariharan, a short holography course at Goldsmith's College, London and his familiarity with the techniques of wave, pulse, continuous-wave-transfer-from-pulse and integral stereogram holography.

Integral stereogram, or multiplex, holograms seemed most promising and Alexander adapted the technique to suit moving films. He divided each frame of the film into vertical strips, each successive strip being a hologram of a picture taken slightly further round the subject. Although the pictures are two dimensional, the viewer's eyes pick out stereo pairs, forming a 3D image.

The pictures can be taken with an ordinary 35mm camera, avoiding difficulties in using living subjects which could be harmed by laser light. The image size can also be altered easily and, as an additional feature, movement or replacement of subject can be introduced in each picture. This is seen by a viewer who moves from one edge of the hologram to the other.

By the end of 1986, Alexander had made his first film with this method. *Masks* ran at twenty five frames a second for over three minutes. The film was very simple, showing rotating heads of people, masks and models; but it included three dissolves, other subject changes being revealed as the heads rotated. Only twenty or so people can watch *Masks* at once as the film is about twenty five cm square. However, the restrictions played a positive rôle in the development of the movie. Alexander commented: "The limitations of the process prompt scenarios I would never have thought of before." He added that he was "very pleased" with the result.

His next holographic movie developed the method further. Taking as his subject *The Dream*, Alexander filmed the actors and the background separately and combined them on alternate strips on every frame. He was thus able to move their relative positions and adjust sizes easily. Up to four actors appeared in each frame; the film ran at fifty frames a second for eight minutes.

Christiane et les Holobulles—ISL 1985

"I am learning to sculpt with the medium," explained Alexander enthusiastically. "New things are happening each time I make a movie. Nobody knows these things exist—they are unfolding each time."

At the beginning of December 1987, Alexander started filming his third multiplex movie. The movie, whose title is being kept "under wraps", will run at twenty five frames a second since he discovered that a rate of fifty a second was unnecessarily high. Alexander's method has progressed so much since making *Masks* that the new film will include an outdoor scene, movement will be natural and (perhaps most striking of all), the image will appear 'in the air' in front of the film.

Although he has considered constructing a copier so that his films can be seen in different parts of the world at once, Alexander said he was more concerned with producing works of art. "Apart from very important sculpture commissions, which take up about half my time," he said, "my greatest interest is in making more holograms and holographic movies."

The commercial potential of holographic movies is a question approached by Paul Smigielski and Alexander from very different points of view.

For Smigielski the use of classical techniques is the limiting factor for holographic movies at present. With such a small film size, a scene of only ten cubic metres can be filmed, with two actors at a time. And this is for a film with only one colour. If two or more colours are required, as Paul Smigielski pointed out with a rueful laugh, things get more complicated. A white light reconstruction would require a film larger than the object. However, he sees possibilities for filming larger scenes by using optics to reduce the images to a suitable size for the film.

This still leaves the problem of viewing the film, as projecting it onto a screen tends to lose the three-dimensional effect. Attempts at producing holographic screens have not been successful as yet.The present method, by which the viewer looks through the continuously moving film, could be adapted to allow larger numbers of people to view it at one time. But this would necessitate a film 1m high by 10m wide, being moved from one side of a room to the other. This would have the intriguing side-effect that people on the left would see different images from the people on the right. If film makers could exploit this characteristic the results should be interesting.

Alexander, on the other hand, sees the restrictions of technique as less of a problem. In his opinion, holographic films will be the cinema of the twenty first century. At present, copying processes do not exist and holograms currently produced are too small, but these obstacles could be overcome in the forseeable future. He also predicted that full colour movies would be developed.

The difference of opinion seems to stem from the different techniques being exploited. However, a lot depends on the attitudes of those involved. The future of the holographic movie as an artistic medium will be determined by what the individual artist makes of it. One thing seems certain, however: the technique will have a valuable rôle to play in science and industry.

Pippa Salmon
Kamala Sen

DENNIS GABOR: INVENTING OUR FUTURE

Dennis Gabor worked as an engineer, inventor, and scientist for years before holography made him famous in the early sixties. Here, Sunny Bains takes a look at Gabor *before* holography made his name and, using many of his own words, tries to give a flavour of what the man was really like.

Dennis Gabor was born in Hungary at the turn of the century into a strong engineering family, although his father never went to university. From an early age the combination of Dennis' own intellect and the education provided by his father, Bertalan, gave him more knowledge of physics and mathematics than his teachers. He and his two brothers were given all the books and laboratory equipment they needed to excel in both the experimental and theoretical sides of physics. The family

subscribed to all of the popular scientific journals. Through the family, Dennis learned to speak good German, French and English, as well as his native Hungarian.

At school he was often bored by the work, which he found too easy, and was unpopular with teachers. He went on to the Technical University of Budapest to study mechanical engineering. He did well there, but left in his third year after he was called up by the Hungarian government for military service. Because of his dislike of the government, he instead moved to the Technische Hochschule in Berlin where he registered in the electrical engineering department. This he found largely uninspiring:

Though still at its height at the time, I could not call the TH Berlin an ideal institution. There were far too many students and there was hardly any contact between students and teachers. It was a sort of slot machine into which one had to throw no end of machine designs, essays and papers and out came a diploma in the end. But it certainly made one get used to hard work! My real education, and the memory which I cherish most at that time, was the Physical Colloquium at the University, every Tuesday, and the unforgettable seminar on Statistical Mechanics which I had under Einstein's guidance in 1921-22.

Gabor finished his first degree in 1924 and went on to complete a Dr-Ing in 1927. He then joined the Physics Laboratory at Siemens but when Hitler came to power and his contract was not renewed, he returned to Hungary where he worked on the development of a plasma lamp.

In 1934, through Edward Allibone, who was to become a lifelong friend, he came to Britain. For 15 years he worked for the British Thomas Houston Company, and in 1936 he married his wife, Marjorie Butler, with whom he 'lived happily ever after.' His work at BTH was, to begin with, largely based on the development of the plasma lamp. When this project was eventually found to be unworkable, he was given a staff position at the company. With the onset of the war he found himself very restricted in his potential fields of research as he was classed an 'enemy alien' by the British government. For this reason he was not allowed to take part in any project even vaguely involved with defence. He nevertheless decided to pursue his own research on the detection of airplanes using the heat from their engines and an infrared detecting screen but, when the military found out about it, the project was taken over and he was prevented from working on it further.

In 1938, after the advent of television, a worried cinema-chain owner persuaded BTH to develop some way of projecting cinema pictures in 3-D. Gabor patented his ideas in 1940 and towards the end of his time at BTH managed to develop a stereoscopic projection technique. Meanwhile, in the Soviet Union, where a similar system was also being developed, a

> ***"...unlike many scientists, Gabor was no philistine..."***

stereo theatre was set up in Moscow. Dennis, however, realised that this type of system was fundamentally limited. He commented:

Only the Russians could be so disciplined to sit so still.

Unlike many scientists, Gabor was no philistine. Indeed, he was a voracious reader, was interested in art and music, and enjoyed singing. More importantly, he was extremely concerned about the direction mankind was taking, and the role scientists had to play in its progress. In 1941 he wrote, in a paper called 'The

Revival of Utopia':

The pious Darwin and Huxley were completely unaware of the effects of their ideas and writings, and could have protested in good faith that the 'Origin of Species' and even the 'Descendence of Man' had nothing to do with class warfare. But this is the fate of all sowers of ideas. The Encyclopédistes could have as well protested their innocence in the French Revolution. The authors of ideas are traditionally incompetent in judging their effects, but curiously enough, their enemies, usually people with incomparably lesser intelligence, have a very fine instinct for it.

"...Gabor was insistent that he was an engineer..."

Also in 1941, he prepared 'a kind of Hippocratic Oath' for ex- members of the Association of Scientific Workers who had resigned over concern that science should not be abused. It offered advice on how scientists could best equip themselves to play a full part in society. The relevance of this document became most evident after the first atom bomb was dropped on Japan. Later he wrote:

I well remember writing those ten points and I still subscribe to them; we anticipated by five years the shock-wave which hit physicists after Hiroshima when they felt they had to take a stand in a world which had become too dangerous by their own work.

In 1947, Gabor was trying to solve the problem of aberrations in lenses in electron microscopy. He had the idea of recording the phase information of a beam of light on an intensity sensitive plate by interfering it with a reference beam from the same source, and then replaying it by passing light through the photographed image. By mid-1948 he had proved that his theory could work in practise.

At the end of 1948, Gabor moved to Imperial College in London where he had been appointed Reader in Electron Physics. In 1956 he wrote that the preceding 6-7 years had been the happiest of his scientific career.

Eric Ash, now rector of Imperial College, was the first student Gabor supervised for a PhD. He wrote of Gabor:

There was no doubt amongst his students that Gabor should win the Nobel Prize for something - we debated just what it might be. Nor was this a symptom of hero worship of which we were largely innocent. We could assess the magnitude of the intellect but found it harder to discern the direction.

This is, perhaps, hardly surprising. In this period he designed an interference microscope, started experimental work in plasma oscillations and did pioneering work in communication theory.

Throughout his life, Gabor was insistent that he was an engineer and inventor, rather than a scientist. Perhaps is surprising, then, that he did not always like to work with engineers:

My experience with engineering students is that one in two is completely unfit for research, and the other takes a year before he gets going. For this reason I am taking on a young physicist; their starting time is less, but of course there is always the possibility of getting a dud.

When doing experimental work, he tended to design an experiment and then let the research assistants and students get on with it. This left him free to go into his office to write, or rather to typewrite, using his infamous 'hunt and peck' technique.

Communication between Gabor and the students was sometimes difficult. He often found it difficult to get down to the level of the students when trying to explain some idea. Eric Ash wrote:

Holographics International acknowledges the assistance given by Imperial College Archives while researching this article.

Dennis Gabor and his cathode ray oscillograph—Berlin, 1927.

His lecture courses... seemed memorable but hardly capable of assimilation - at least, until the realization dawned that they were not so much lectures but master classes. It was necessary to 'know' the subject before attending these occasions; but then the experience was enormously worthwhile - providing both the long historical view as well as insight in depth and generality.

In 1954, he collaborated with his brother on a paper called 'The Mathematical Theory of Freedom'. Though published in the United States, the political climate at that time meant that the subject matter was out of favour. Gabor explains:

I enclose, with my kindest regards, a paper which I wrote in my spare time over the last two years with my brother André, who is a lecturer in economics at the University of Nottingham, and a fellow of the Statistical Society. The idea of measuring freedom came, of course, from communication theory. It was fun to write something outside physics and engineering, and trying to put a little common sense into this subject which has become so hopelessly confused. I thought also that this would be a good opportunity to get a fellowship of some sort for my brother, to visit the US. But there we had a surprise. I sent the paper in manuscript form to Dr Warren Weaver, the Director of the Rockerfeller foundation, and to Dr Robert Hutchings, director of the Ford Trust. In both cases there was an immediate negative reply; sorry, it is very interesting but we cannot do anything just now! It is very sad that freedom studies have now become a dangerous and suspect business in the States. I am afraid that not only McCarthy must take the blame for this, but also the nuclear scientists.

"...in 1963 ... Gabor's place in history was secured..."

In 1956 Gabor went back to Germany for a visit. Of his trip he wrote:

This was my first visit to Germany since 1933, and it was almost a triumphal entry. I was the guest of Göttingen University and of the Max Planck Institute, to whom I gave a lecture on information theory and physics. They gave a dinner in my honour where I sat between Otto Hahn and Heisenberg, who treated me with more than polite courtesy. These good Germans, whom nobody could ever accuse of nazism, are pathetically keen on making amends for the others.

Between 1952 and 1958, Gabor worked on another of his pet projects, the thin TV tube which could be used for both monochrome and colour. The experimental work was, in fact, successful, but his invention was never taken up since the cathode ray tube had been shorten-

Continued overleaf

Continued from previous page

ed by this time. In 1956, however, the Sunday Times found out about the research and printed an article on the subject. Gabor was concerned for his reputation and wrote to Allibone, who was now head of the Associated Electrical Industries (AEI) research labs at Aldermaston:

You may have seen in yesterday's Sunday Times a short article 'New TV set will hang on wall', mentioning that I am developing such a tube. I want you to know that I neither inspired this article nor authorised it. Presumably it has been released by the National Research Development Corporation, perhaps in the hqpe that the British valve manufacturers would prick up their ears. For my part I am rather concerned about the article, as it could be read as self-advertisement, which can only be harmful to me. I wanted to let you know, in case you have an opportunity to rectify false impressions.

Dennis was appointed to a personal Chair of Applied Electron Physics at Imperial College in 1958. His inaugural lecture entitled *Electronic Inventions and their Impact on Civilization* eventually became the book *Inventing the Future*.

In 1958 he started working on a project involving thermo-nuclear fusion, but illness intervened in 1961 when thrombosis-phlebitis of the legs sent him to hospital. He was forced to withdraw from the project, but recovered.

In 1962 the AEI research facility at Aldermaston closed down. To a journalist from the Financial Times he wrote:

In fact your personal worries are now part of a very sinister development. Do you know that ICI are closing down their fundamental research at Welwyn, and Courtaulds are also shutting down fundamental research? I am afraid what is happening is nothing less than the end of what can really be called research in industry in this country. It is a catastrophic development. When I came to this country 29 years ago and noticed the primitive state of industrial research as compared with that in Germany, I thought, as most people did, that it would be different in a generation, when the people who had themselves done research when they were young would have risen to high management posts. Just the opposite has happened, it is not the research man who has replaced the bluff old production engineer, but the accountant.

From 1963, when Leith and Upatnieks applied lasers to holography, Gabor's place in history was secured. When in 1971 he won the Nobel Prize, Upatnieks sent the first telegram congratulating him, and in 1972 Leith wrote as part of the introduction to the Nobel Lecture printed in the proceedings of the IEEE:

While Nobel awards are given for specific achievements, it nonetheless seems fitting that the recipients of science's highest award should be truly intellectual giants in the broadest sense. On all scores, Dennis Gabor is worthy of this award.

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two hours, bright high resolution holograms were obtained using this equipment.

An exiting new prospect for this work is the possibility of a permanent holographic system installed in a dry store for used nuclear fuel. The CEGB is likely to build such a store for its Advanced Gas-Cooled Reactor fuel, where the fuel elements will be transferred after a period of underwater storage during which their radioactivity has reduced sufficiently for dry storage.

The CEGB's holographers have produced a design and working laboratory models for such a system. All fuel elements arriving at the plant would automatically have a hologram taken of them, which would enable their condition to be assessed. This would involve taking thousands of 10x8 inch (250x200 mm) holograms every year.

The system would be built into the concrete wall of a cell or cave within which the fuel elements would be handled remotely. The laser unit (a pulsed ruby laser) would be on the outside, fully accessible for maintenance. The subject and reference beams would pass through a connecting duct in the cave wall to the head section. Holographic plates would be inserted and removed in a motorised cassette, which would be changed on the outside of the cell.

The financial incentive for such a system is certainly there. Fuel which is not exhausted can be identified, so that it can be replaced in the reactor. Alternatively, damaged fuel elements can be spotted and given special handling to avoid contaminating areas of the store and to reduce radiation exposure to operators.

As a next step, the team would produce a prototype to allow further trials of the system to be carried out. The funding of further work on the idea now depends, however, on the CEGB making a firm decision on whether to go ahead and build the dry fuel store. A decision is expected in the first half of this year.

Martin Taylor

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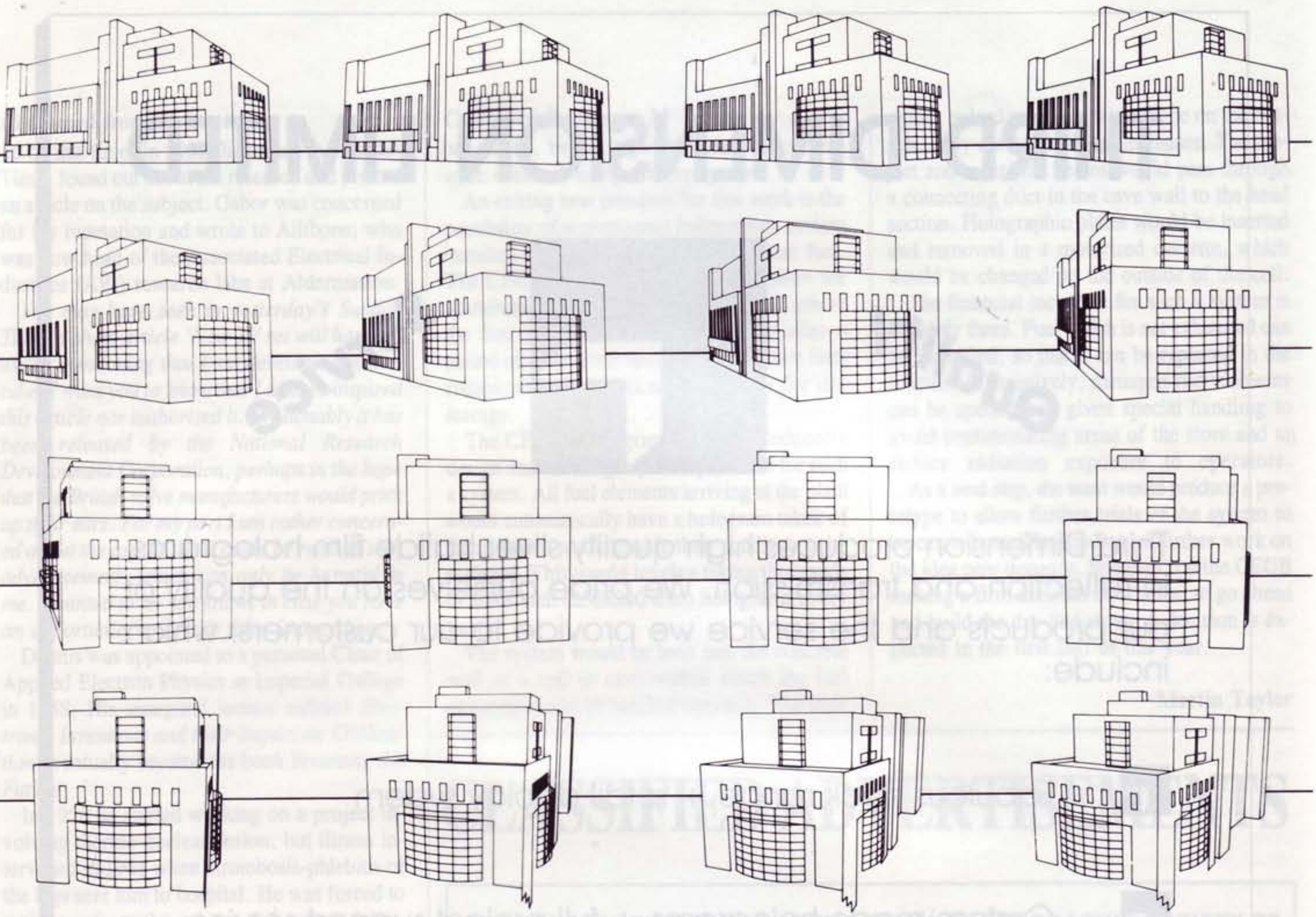

FRINGE LOCKING *PREVIEW*

High quality holograms require that the recording set-up be completely still during exposure. More accurately, that the fringes being recorded be still so that the highest fringe contrast and hence the highest diffraction efficiency can be achieved. When exposure times are particularly long, even the best vibration isolation systems can falter. The answer is, of course, active fringe stabilization (or fringe locking). A couple of interesting papers are about to appear in the literature which are particularly relevant to photoresist and dichromated gelatin recording, in which cases exposures can be very long. (This is, strictly speaking, a 'preview' rather than a 'review'!) To put the new work into perspective, I shall first describe briefly some of the methods that have been used up to now for fringe stabilization.

The simplest method of locking the fringes is simply to magnify the fringes formed by the interference of the beams, using a highpower microscope objective. A small sensitive detector is then placed behind the recording plate, so that it can only see a fraction of one fringe. If any fringe movement occurs, then the reading on the detector changes. This change in reading can be used to change the length of one of the paths so that fringe movement is cancelled. The normal way to do this is to feed the detector reading into an electronic circuit which drives a mirror mounted on a piezoelectric crystal or a loudspeaker cone (1). If the whole system is arranged in a closed servo loop, then the movement of the fringe is continually monitored and corrected. This is called a negative feedback loop, because any change in the output (movement of fringe) results in an input (movement of the mirror) which tends to cancel the original movement.

What are the disadvantages of this method? Well, the amount of light that is used to control the servo loop is very small indeed, because it constitutes a tiny fraction of the total light illuminating the recording plate. Consequently, expensive and cumbersome amplifying systems such as photo multipliers have to be used to detect the fringe movements, and to produce a fast response. Also, the detecting unit itself must be carefully mounted so that it does not vibrate while driving the servo. As the inter-beam angle increases, decreasing the fringe spacing, the method may not work at all. To increase the light available to the detector, we need to use a larger area of the fringe pattern. This was accomplished by MacQuigg (2).

In MacQuigg's system, a normal exposure is first made in the system that is to be used. The hologram is processed, and replaced in its original position. When the two interfering beams are shone onto the hologram, they result in a broad moiré pattern which is formed between the hologram fringes and the real-time fringes produced by the interfering beams. A small movement in one of the optical paths now results in the movement of large, bright fringes across the hologram. Although the sensitivity of the system is as high as if not higher than before, this time we are adding the light intensity from a large area of the hologram, and so we can use less sensitive photodetectors and still get a fast feedback control. Furthermore, small movements of the detector are this time unimportant. Let's look at the disadvantages of using this type of moiré pattern for feedback control: well, the process is now longer because a hologram must first be made in the system and must be replaced accurately. Most people wouldn't want to do this every time.

We can now take a look at the recent work that has been going on in this area. Frejlich et al (3) and Cescato et al (4) have taken the moiré approach a step further to make it more convenient to use routinely with recording materials such as a photoresist and dichromated geletin. When these materials are exposed to an interference pattern, a small change in their refractive index takes place in the area of high light intensity. This change is quite small and must be amplified by subsequent processing to produce a bright holographic image. Even so, a low intensity image can be seen if the holograms are placed in a strong reconstuction beam before processing. In the new method, the faint interference pattern recorded in the first few seconds of the exposure are used to interfere with the real-time fringes, and the moiré pattern produced is used as in the previous technique to lock the fringes. The advantage of this technique is that no hologram need be made before recording the main hologram. It is amazing that fringes of such low contrast can be used for this technique - the authors claim that the fully recorded, unprocessed holograms have a diffraction efficiency of the order of 0.008%.

The technique described can only be used with recording media that exhibit a significant real-time effect, such as photoresist and dichromated gelatin. The latent image produced in photographic materials is so slight that it cannot be detected until the emulsion is processed. The technique has the potential of becoming routine in long exposure holograms that are recorded, for example, as masters for embossing.

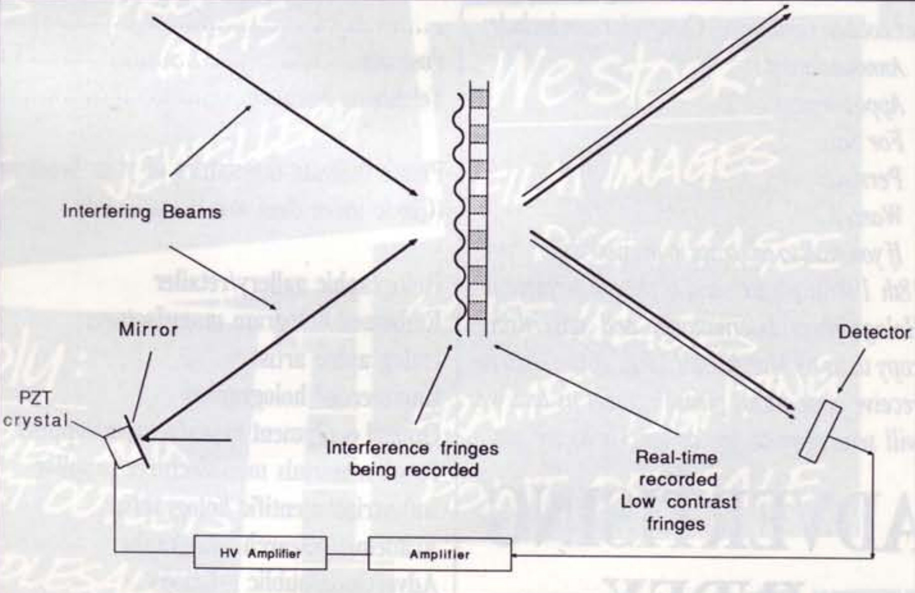

Figure 1: Using real-time recorded fringes for fringe locking.

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(1) DB Neumann et al, 'Improvement of Recorded Holographic Fringes by Feedback Control', Applied Optics, vol 6, p1097 (1967).

(2) DR MacQuigg, 'Hologram Fringe Stabilization Method', Applied Optics, vol 16, p291 (1977).

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(4) L Cescato et al, 'Stabilized Holographic Recording using the Residual Real-time Effect in a Positive Photoresist', Optics Letters, vol 12, p982 (1987).

Kaveh Bazargan

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