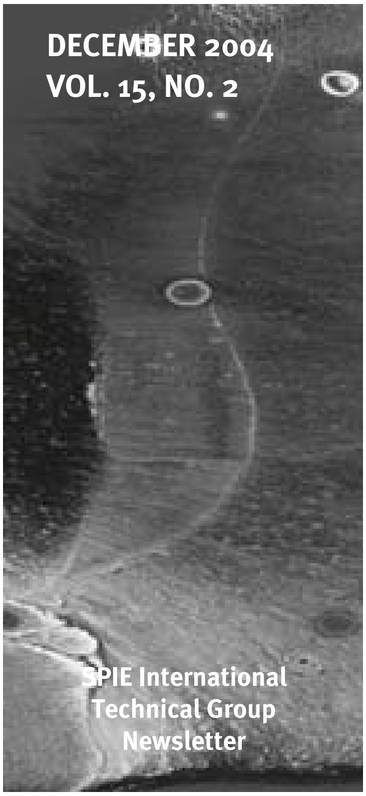
The International Society
for Optical Engineering



DECEMBER 2004
VOL. 15, NO. 2

SPIE International
Technical Group
Newsletter

HOLOGRAPHY

***Calendar**—See page 6.*

***Technical Group Registration Form**—See page 11.*

STOP PRESS: Shearwater Foundation winds up —*See page 7.*

Newsletter now available on-line

Technical Group members are being offered the option of receiving the Holography Newsletter electronically. An e-mail is being sent to all group members with the web location for this issue, and asking members to choose between the electronic and printed version for future issues. If you are a member and have not yet received this message, then SPIE does not have your correct e-mail address.

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Digital holography in real and virtual research: a window into remote places

Holograms have been used in many ways to augment experimental science,[1] but the methods employed have changed significantly in recent years. It is useful to examine analogies to help exploit new technology. For example, a high-quality pulsed hologram of a volume of space is like a window into an actual space, frozen in time, that existed in a different time and place and has now been put before us in the present. Any passive optical measurement—such as microscopy—that could have been made on the actual space through the window can be performed with equivalent results on the reconstructed wavefront/image through the holographic window.

If the hologram is of high-enough quality, the optical instrument cannot tell us whether the image seen is created by a real object or by a hologram. Likewise, recordings made at a high-enough frequency emulate a window into a previous time where history can be observed to unfold in full 3D. Recording the hologram and transmitting the information to another location for wavefront reconstruction produces the equivalent of a window into a remote location. Much more than closed-circuit television, this is the equivalent of having a real window into someplace else.

Electronic holography actually makes this possible, and MetroLaser is examining such applications, their limitations, and their +possibilities. The concept, taken to its fullest, has the ultimate promise of providing scientists with 'eyes' in space. A robot equipped with 'holographic windows' or 'eyes' could provide a better presence in space than actually being there. For example, a scientist looking into a holographic window on earth could effectively see a real Martian surface just millimeters beyond the window.

Started in 1999, SHIVA (Spaceflight Holography

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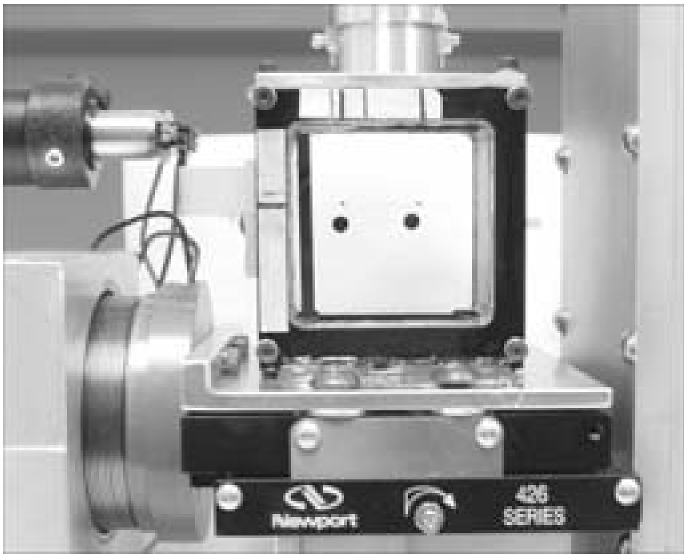

Figure 1. Photograph of the SHIVA experimental cell.

Spherical beam volume holograms as spectral diversity filters for spectroscopy

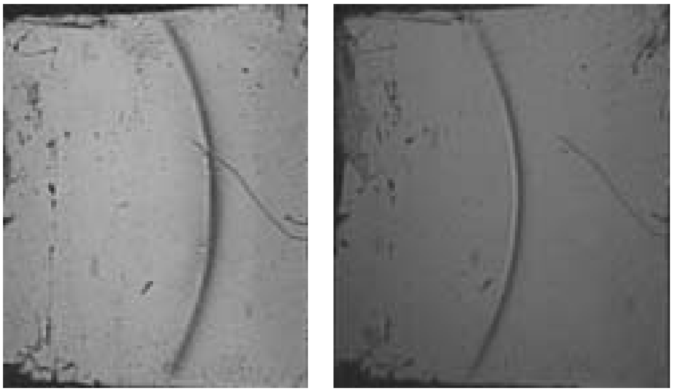

Figure 1. The spectral diversity pattern for single spherical-beam volume hologram with reading wavelength at (a) 532nm and (b) 652nm. The readout wavelength was 532nm.

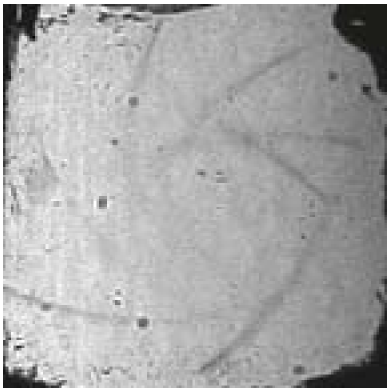

Figure 2. The spectral diversity pattern for eight rotation-multiplexed holograms read out at 830nm. The recording wavelength for all holograms was 532nm.

Holograms (or gratings) are well-known candidates for separation of different input wavelength channels. Most optical spectrometers are built using thin gratings as the wavelength-dispersive device: to be used in spatially-incoherent light, these spectrometers use an entrance slit and collimator to remove the ambiguity between the incident angle and the wavelength. To design more sensitive spectrometers, multimodal-multiplex spectroscopy (MMS) was recently proposed.[1] In contrast to conventional spectrometers, the key element in MMS is a spectral-diversity filter (SDF) that can map an incident optical signal with a uniform spectrum over the input plane onto an output pattern with non-uniform spatial-spectral information.

We recently proposed and demonstrated the feasibility of using spherical-beam volume holograms (SBVHs) as SDFs.[2] The SBVH is recorded using a plane wave (reference beam) and a spherical beam in a relatively-thick polymer material (100μm or more). The spherical beam can be considered as the superposition of several plane waves propagating in different directions: each component forms a hologram with the reference beam. During reading with a collimated beam only a portion of the recorded holograms diffracts due to the Bragg selectivity of the thick hologram.[3]

In our experiments, a SBVH was recorded at 532nm in the Aprilis photopolymer using transmission geometry. To demonstrate spectral diversity, the SBVH was first read using a collimated beam with the same wavelength as the recording beams (532nm) from the direction of the chief ray of the recording spherical beam. As the reading beam was only partially Bragg-matched with a portion of the holograms, it was diffracted in the shape of crescent.[3] Corresponding to the diffracted beam, a dark crescent was observed on the back face of the hologram, as shown in Figure 1(a). This figure indicates that the SBVH successfully mapped the input spectrum (i.e. wavelength equal to 532nm) onto an output pattern (i.e. the dark crescent). Furthermore, Figure 1(b) shows another example of the output pattern, when the reading wavelength was changed to 652nm.

Although the range of reading wavelengths possible in volume holograms was limited by wavelength selectivity, the diffracted beam from the SBVH came from different sets of holograms that were partially Bragg-matched for different wavelengths. The position of the dark crescent therefore changes with the input wavelength as shown in Figure 1(b). We also observed that the crescent motion from one side of the hologram to the other corresponded to a 300nm range of the input wavelength. These results suggest that a good spectral diversity can be obtained from the SBVH because the position of the dark crescent (i.e., the output pattern) is sensitive to input spectrum.

To make the output patterns even more diverse, several SBVHs can be rotation multiplexed. Figure 2 illustrates the output pattern (on the back face of the hologram) formed by multiplexing eight holograms in this way. In this case, the recording material was rotated 45° in-plane before recording each successive hologram. In Figure 2, the eight dark crescents with different tilt angles each correspond to diffraction from one rotation-multiplexed hologram. Comparing Figures 1 and 2 suggests that better spectral diversity (more diverse output patterns) can be obtained by multiplexing holograms in this way.

Since the output is monitored at the back of the hologram, the system is not only compact but allows the effects of multiplexed holograms be observed at the same location. This is the primary feature of the SBVH that makes it a good candidate for application to portable biological and environmental sensing, and the results presented here demonstrate the potential of SBVHs for designing SDFs.

However, all these results are obtained using a collimated incident beam. For practical applications, this spectral diversity should also be presented using spatially-incoherent light. To investigate this issue, we added a diffuser with an adjustable aperture in front of the SBVH to control the degree of spatial coherence of the incident beam. The experimental results for the transmission geometry SBVH show that the width of the dark crescent becomes wider and the contrast of the dark crescent decreases as the beam becomes less coherent.[2] This indicates that there is a trade-off between spectral diversity and the degree of spatial coherence in the input source.[2] However, this trade-off is alleviated for a reflection geometry SBVH because of its lower shift selectivity compared to transmission.[4] The reflection geometry SBVH therefore has better spectral diversity and less sensitivity to the spatial coherence of the source.

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References

1. Z. Xu, Z. Wang, M. E. Sullivan, D. J. Brady, S. H. Foulger, and A. Adibi, *Multimodal multiplex spectroscopy using photonic crystals,* **Opt. Express 11,** pp. 2126-2133, 2003.
2. A. Karbaschi, C. Hsieh, O. Momtahan, A. Adibi, M. E. Sullivan, and D. J. Brady, *Qualitative Demonstration of Spectral Diversity Filtering using Spherical Beam Volume Holograms,* **Opt. Express 12,** pp. 3018-3024, 2004.
3. O. Momtahan, C. Hsieh, A. Karbaschi, A. Adibi, M. E. Sullivan, and D. J. Brady, *Spherical Beam Volume Holograms for Spectroscopic Applications: Modeling and Implementation,* (accepted for publication in **Applied Optics**).
4. C. Hsieh, O. Momtahan, A. Karbaschi, A. Adibi, M. E. Sullivan, and D. J. Brady, *Role of recording geometry in the performance of spectral diversity filters using spherical beam volume holograms,* (accepted for publication in **Optics Letters**).

Photorefractive polymers for optical communications

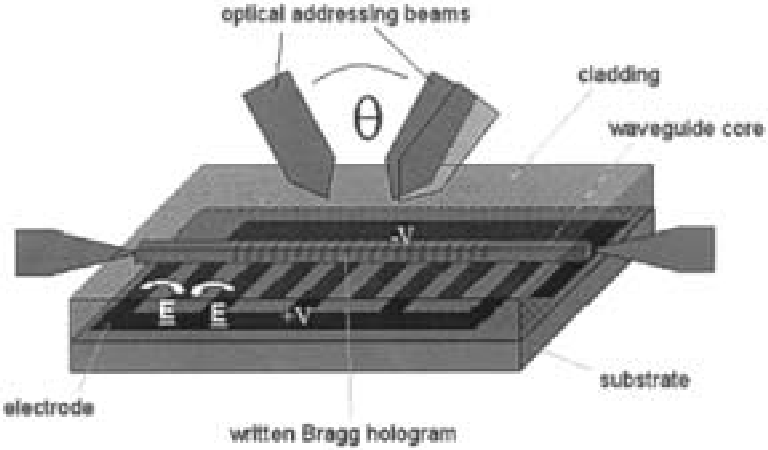

Figure 1. Schematic of a photorefractive polymer waveguide structure, in this case a channel waveguide, showing the electrode arrangement and optical control.

Photorefractive polymer composites are essentially rewritable holographic materials that permit us to record and erase an interference pattern over and over again. Response speeds are typically in the millisecond regime, and it is possible to achieve a diffraction efficiency of 100%.[1] As such, they are an important class of materials for dynamic image processing, digital data storage, holographic imaging and optical communications. In particular, optical communications is an attractive area for photorefractive-polymer researchers as the range and variety of applicable holographic optical functions is immense.[2] Our company—P3 Holographics Ltd, a start-up from the University of Manchester, UK—has made considerable progress towards achieving highly-functional optical components through its research into photorefractive-polymer waveguides.

We are interested in the possibility of forming quickly-rewritable holograms in such waveguides (see Figure 1). Even with the simplest such hologram—a Bragg grating acting as an optical filter—the potential is enormous: particularly if it can be reconfigured in spectral position, bandwidth, reflection coefficient, apodisation, and even chirp. Several filters can also be multiplexed to process channels independently. All this adaptability is potentially mutually independent and simultaneous, in real time, and with remote control.

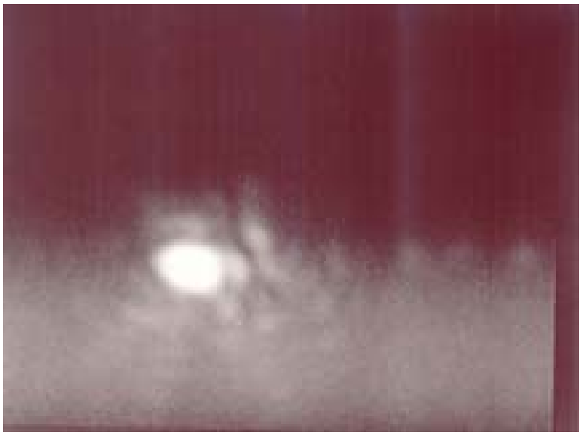

Figure 2. Photograph of the output field emitted from a photorefractive-polymer ridge waveguide. Photo taken at the Centre of Integrated Photonics Ltd..

Control of the optical environment of the device that forms the hologram requires a local red diode laser and a miniature interferometer. The optical interference pattern forms a volume refractive index pattern via the redistribution of charge in the bulk of the material and in the presence of an applied electric field. Charge redistribution leads to a refractive-index pattern due to the reorientation of dipolar chomophores in the composite. The other components in the polymer composite are a charge generator and a polymer matrix: the material favored by P3 Holographics incorporates an azo chromophore, a poly(N-vinyl carbazole) host, and a charge-generating additive.

Researchers have shown that devices made from the material remain functional for at least five years and are reliable in temperatures as high as 70°C. The optical loss at the important communications wavelengths of 1300nm and 1550nm is around 1dBcm^{-1}. Most importantly, 8mm waveguide devices have been shown to be resistant to optical fluences in excess of 0.5W for greater than 500 hours. These are, to our knowledge, the only such reliability data available for photorefractive polymers. Whilst they indicate there is much more work to be done in proving reliability, they show that the strict compliance required with the telecommunications industry standards is certainly a possibility.

As well as long lifetimes when exposed to high-power optical radiation, the devices are also able to support high electric fields. Photorefractive polymer composites typically need an applied field of 50Vmm^{-1} while our waveguide structures easily sustain fields of almost double this.

Though ridge waveguide fabrication can be achieved via several methods, possibly the simplest is through laser micromachining with an ablative excimer laser. First, high-quality 8mm-thick photorefractive-polymer composite films are spun onto a suitable indium-tin-oxide electrode pattern on a quartz substrate. Then, 2mm of polymer material is ablated to reveal a ridge waveguide pattern. The structure is encapsulated by bonding a quartz cover as a superstrate with a UV-curable epoxy adhesive. The entire structure is diced by Disco GmbH to produce high-quality end facets for waveguide coupling.

Tests of these structures show that waveguiding in the ridge is achieved: although currently with a relatively-high optical loss. Figure 2 shows an image of the waveguide emission at 1300nm from the exit facet. Unfortunately, since the optical insertion loss of the ridge waveguide structure exceeds 20dB, neither optical measurements of the filter function in ridge waveguides, nor observation of the photorefractive effect in these structures, has yet been possible. Surface roughness introduced by the laser micromachining of this material is the most likely explanation for the high loss, compared with the low loss in our planar waveguide structures.

Photorefractive polymers are materials capable of rewritable holographic recording and image processing at video rates. When incorporated into optical waveguides, they allow functionality as a tunable filters that are reconfigurable in a wide variety of different ways. Our material has low loss at telecommunications wavelengths, has been demonstrated to work for more than five years, and is stable to heat- and photodegration at power levels of 27dBm for 500 hours. Further work is required to translate these advantageous properties into a ridge or channel waveguide structure with acceptable tunable-filter properties.

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References

1. A. M. Cox, F. A. Wade, R. D. Blackburn, D. P. West, T. A. King, and D. A. Leigh, *Crystallisation resistant photorefractive polymer composite with high diffraction efficiency and reproducibility,* **Appl. Phys. Lett. 68** (20), pp. 2801-2803, 1996.
2. Ph. Dittrich, G. Montemezzani, P. Günter, *Tunable optical filter for wavelength division multiplexing using dynamic interband photorefractive gratings,* **Opt. Communications 214,** pp. 363-370, 2002.

Customization of organic-inorganic materials for holographic recording

Hybrid sol-gel materials have been widely developed for photonic applications in recent years. Many attempts have been successfully made to understand the sol-gel process and develop new materials for particular applications. We study organically substituted alkoxysilanes of the type (R'O)$_3$Si-X-R, where the spacer X is a (CH$_2$)$_p$ (p=2,3) chain and R a functional group.[1] This material combines the advantages of polymers (easy to use, light weight, versatile) and the physical properties of glass (refractive index, optical properties, heat, and mechanical resistance). In addition, since both phases are chemically grafted, the volume shrinkage is minimized and the phase separation is kept below the level of Rayleigh scattering. For this reason, organic-inorganic materials are potential candidates for holographic data storage and for fabrication of optical diffractive elements.[2,3]

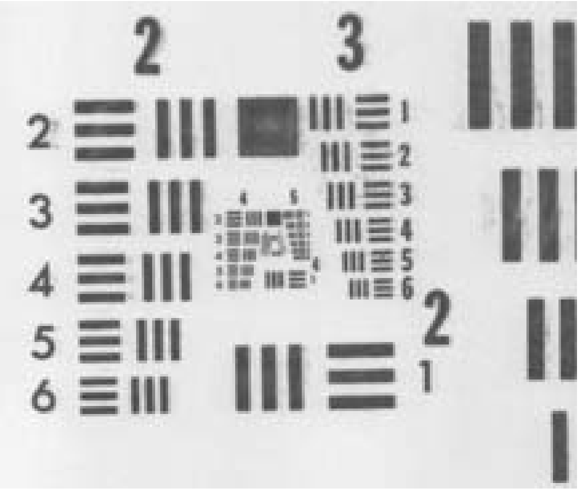

Figure 1. Photograph of the reconstructed image from a volume phase hologram recorded in a hybrid sol-gel with the negative USAF 1951 resolution target as the object. Incident intensity: 26mW/cm^2. Intensity ratio: 2.4. Exposure energy: 7.8mJ/cm^2. Writing angle at 514nm: 30°.

Alkoxysilanes, in which R is a reactive function, are extremely interesting for the synthesis of inorganic-organic glasses by the polymerization of the organic groups. In this approach, an organic network is formed in the matrix of the primarily formed inorganic network. Among the large variety of organic modified silicate precursors, methacryloxypropyltrimethoxy-silane was chosen for this study. The key to success in optical applications is understanding the photo-induced and densification processes of the material, both related to free-radical polymerization of C=C bonds and the condensation of silanol functions. Thus, the structural changes of the hybrid material under irradiation can be investigated using liquid ^{29}Si nuclear magnetic resonance imaging and real-time Fourier-transformed infra-red spectroscopy.[4] This allows us to examine the reaction *in situ* and in real time with excellent temporal definition.

This study also involved the optimization of the photosensitivity of hybrid sol-gel materials. This was achieved by choosing the most efficient photoinitiating system as well as the most appropriate experimental conditions.

Non-uniform illumination induces spatially-controlled photopolymerization of the organic part, leading to a microstructuring of the sensitive layer and a photo-patterning of optical properties. Sinusoidal gratings were recorded in transmission by interference of two coherent plane waves at 514nm. Because the creation of surface relief patterns with an amplitude around 1µm was possible,[5] laminated samples were used. This meant that only index modulation through the entire thickness of the sample was possible. Samples thickness was in the 40-100µm range. The laser incident power density was 26mW/cm^2 with an intensity ratio of the two beams of 2.4. The illumination was held for 5min corresponding to a 7.8J/cm^2 dose.

Gradients of chemical composition result from the spatially-controlled illumination. Consequently, diffusion processes took place from dark areas to the others leading to a periodically-spaced set of regions with various densities, giving rise to a refractive index modulation. After the grating formation, and for storage in the dark at room temperature, the strains resulting from the structural modifications relaxed. This lead to a slow efficiency decrease and sometimes to the appearance of cracks in the layer. Thus, the recording process required some optimization. The incorporation of a plasticizer, which polymerized with the hybrid precursor, enabled the generation of more stable samples after irradiation (see Table 1). Moreover, uniform illumination of the material performed simultaneously around the interference pattern allowed us to avoid the generation and propagation of cracks in the grating.

Table 1. Diffraction efficiency and refractive index modulation for hybrid sol-gel with and without plasticizer (spatial frequency = 1000 lines/mm).

	Thickness	Refractive index modulation	Efficiency after irradiation	Efficiency after 50 days
HSG without plasticizer	98µm	4.1 10^{-3}	95%	65%
HSG with 5% plasticizer	102µm	4.4 10^{-3}	95%	95%

The diffraction efficiencies varied from 30% to 95% for a thickness ranging respectively from 40-100µm and a spatial frequency of 1000 lines/mm. This corresponded to a refractive index modulation estimated to be in the range 4-5×10^{-3} according to Kogelnik's theory (see Table 1).

In addition, the hybrid sol-gel was used to record a hologram of a standard resolution target (see Figure 1). Group five, corresponding to a resolution better than 10µm, is clearly visible.

Future work will include the examination of hybrid materials for data storage applications.

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References

1. O. Soppera, M. Chevallier, C. Croutxé-Barghorn, and C. Carré, *Influence of physico-chemical parameters on the surface patterning in hybrid sol-gel glasses,* **Proc. SPIE 4924,** p. 126, 2002.
2. M. Feuillade, C. Croutxé-Barghorn, L. Mager, C. Carré, and A. Fort, *Photopatterning of hybrid sol-gel glasses: generation of volume phase gratings under visible light accepted for publication,* **Chem. Phys. Lett.** September 2004.
3. G. Ramos, A. Alvarez-Herrero, T. Belenger, A. Nunez, F. del Monte, and D. Levy, **Photopolymerizable hybrid sol-gel materials for holographic recording, SPIE Newsletter: Optics in information Systems 15** (1), p. 8, 2004.
4. O. Soppera and C. Croutxé-Barghorn, *RT FTIR study of free-radical UV-induced polymerization of MAPTMS: Part II – Effect of physico-chemical parameters on photopolymerization kinetics,* **J. of Polym. Sci.: Part A: Polym. Chem. 41,** p. 831, 2003.
5. C. Croutxé-Barghorn, O. Soppera, and M. Chevallier, *Diffraction gratings in hybrid sol-gel films: on the understanding of the relief generation process,* **Macromol. Mater. Eng. 288** (3), p. 219, 2003.

Can holography save physics?

Great Britain is suffering a sharp decline in the number of students choosing to take physics at university. This decline has been described as a disaster for Britain as it will affect our long-term ability to lead the world in applied technology. At the University of Southampton—one of the top five physics research departments in the country—we are trying to reverse the trend and increase student numbers by using holography and a traveling laser-light show to encourage students back into science.[1]

Figure 1. Students observe the Light Express total internal reflection demonstration.

British national newspaper *The Independent* highlighted the problem of falling numbers over the last decade in a recent article.[2] This decline may be due to the fact that there has been a drop in the number of qualified physics teachers in the classroom: the Institute of Physics reports that they are not replaced when they retire due to a lack of trainee teachers. As a result, recruitment of physics teachers in England and Wales has slumped to an all-time low.[3]

The decline in numbers may also be due to a negative stereotypical image of a physicist: generally represented in the media as being 'nerdy'. The University of Southampton's School of Physics and Astronomy is combating this negative image and the lack of trained teachers with a comprehensive outreach program. The university's *Light Express Roadshow*[4] visits schools and colleges throughout the South-East of England, and features a dazzling, professional laser show. A 1W Krypton-Argon laser is used in conjunction with a lecture on the science behind the internet. The show—which reached 3,000 students last year—is designed for 15-18 year-old students and relates to their classroom studies in physics.

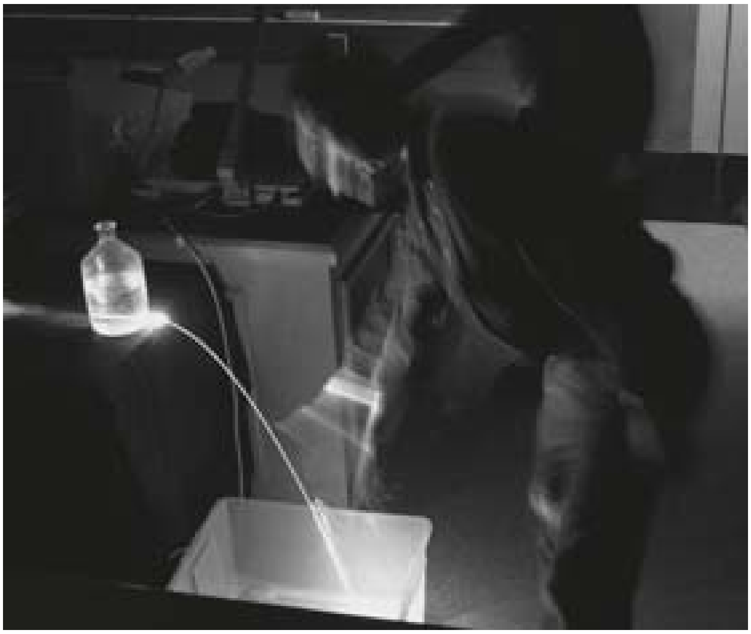

Figure 2. Dr. Bill Brocklesby demonstrates Tyndell's/Colladon's experiment, guiding light down a stream of water during the lecture.

In addition, holography workshops are being offered to local community groups and schools as part of an 'undergraduate ambassador's' scheme that places undergraduate physics students into local classrooms. The program both offers the undergraduate student a taste of teaching and hopes to inspire a new generation of prospective undergraduates by providing role models for school pupils (proving that physics students aren't 'nerdy'!). The undergraduate ambassadors spend weeks with their students in their schools, then bring a select few pupils into the university to make holograms.

The University of Southampton has a dedicated holography studio for this purpose. The equipment consists of four 5-6mW Helium-Neon lasers mounted on vibration-isolation tables. The beam is spread out as soon as it exits the laser—using a microscope objective—to ensure the setup complies with strict safety regulations. The diffuse beam hits a first surface mirror and is spread onto a 2.5"×2.5" holography plate at an angle of approximately 45° to make a simple single-beam reflection (Denisyuk) hologram. We use Slavich plates (PFG-01), currently purchased from Integraf in the USA, and the JD-3 developing regime.[5] This plate and chemistry combination allows us an exposure time of approximately 6-8s, and an extremely short (two minute) development, bleaching, and washing period. The plates are then dried by the school children with a hairdryer. This speed is ideal when working with large numbers of students and a fast turnaround time is required.

The children are split into groups and, while some make holograms, others take part in a number of hands-on labs designed to demonstrate how holograms are made. The labs include 'Lasers and Jelly' (Jell-o) with laser pointers: different colored jelly is used to demonstrate total internal reflection, refraction, diffusion, diffraction and interference. Spectroscopy is also used to demonstrate discrete wavelengths and introduce students to diffraction gratings. A Michelson interferometer is used to demonstrate interference and laser-viewable transmission holograms are exhibited along with holographic interferometry.

Both undergraduate and postgraduate physics students demonstrate these labs and make holograms for the younger ones. This series of hands-on labs was developed at the Columbia Career Centre, Columbia Missouri, by photonics program staff for *Saturday Science*. This event was supported by SPIE and involved students and staff making holograms with visiting 13-year-olds students from local schools. In March 1993, 42 holograms were made in two hours. Saturday Science was an extremely successful recruiting tool for the career center's photonics program and The University of Southampton's School of Physics and Astronomy is recreating this successful approach for its own 'inreach'.

However, there are difficulties involved with evaluating the program's success. Students thoroughly enjoy the light show and workshops, but it will take time to see whether it brings them into physics. It is easy for local schools to visit the University to make holograms, however our marketing and recruitment research has shown that students in Great Britain want to travel at least an hour away from their homes for their University experience. However, we are expecting a change in students' habits in the next year or so. Government legislation set for 2006 will allow universities to more than double their tuition fees, which may well change our student demographic: stu-

Continues on page 9.

The latest on holography's past

The History of Holography and Holographers project, reported in a previous issue[1] is rolling along, continuing to collect information and to publish its research findings. Since the last report nearly eighteen months ago, I have been visiting and interviewing holographers, attending a variety of conferences, and tracking down and corresponding with more elusive practitioners. To date, some fifty interviewees and a further eighty correspondents have contributed—notably Emmett Leith and Juris Upatnieks, Yuri Denisyuk, the late Stephen Benton, Lloyd Cross, Adolf Lohmann, and Tung Jeong. I have visited clusters of holographers in the Bay area of California, the Pacific Northwest, Boston area, Michigan, northern and southern England, and the Ukraine.

Some of these trips have been associated with conferences that attract distinct cohorts of holographers (e.g. SPIE's *Practical Holography XVII* in Santa Clara, CA, the *International Conference on Optical Holography and its Applications* in Kiev, Ukraine, Holopack-Holoprint 2003 in Vancouver, Canada, the *British Society for the History of Science* in Liverpool, UK, and the forthcoming *Royal Photographic Society Holography Conference* in London, UK). These have generated conference papers and fruitful discussions with practitioners from around the world.[2-5]

Research at a handful of public archives has also been important, notably the Bentley Historical Library at the University of Michigan, the Science Museum library in London, the Imperial College archives, also in London, and the MIT Museum in Cambridge, Massachusetts. This work was partially supported by modest and now-exhausted travel grants from the Shearwater Foundation, the American Institute of Physics, the British Academy, and the Carnegie Institute for the Universities of Scotland.

Recent communications have included conference presentations, articles and papers. So far, these have focused mainly on the early period of holography's exploration and consolidation. An edited interview with the late Stephen Benton, and an article on the growth of subcultures of holographers appeared in **Optics & Photonics News** this summer.[6-7] A paper on the influence of George Stroke on the early promotion of the subject during the 1960s, and his contested claims about its early history, was published in the journal **History and Technology** earlier in the year.[8] Another research paper, also aimed at historians of technology, will appear in **Technology and Culture** in early 2005.[9]

Further publications are in the works: notably a paper for historians of science on the varied judgments of 'success' and 'failure' that holography has attracted.[10] The longer-term goal is a wide-ranging history of the subject and of the scientists, engineers, artisans, artists, and entrepreneurs who developed it into the sublime medium that we know today.

Such accounts and analyses demonstrate that holography is a subject with a vibrant history. Nearly 60 years old and attracting several thousand workers, it has influenced science, art and culture more widely than most technologies. Accounts of its contributions—and its contributors—deserve to be more widely known. Readers can assist the project in several ways: by communicating their personal experiences and explanations of the field; by making available documents and other records; by suggesting other sources or links that may not be widely known; and by publicizing or supporting the project. As an African writer said of his continent's oral history, "quand un vieillard meurt, c'est une bibliothèque qui brûle" (when an old person dies, a library burns).[11] The history of a subject does not write itself, it requires active preservation and interpretation.

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http://www.cc.gla.ac.uk/staff/holography.htm

References

1. S. F. Johnston, *Researching the history of holography*, **Holography Technical Group Newsletter 14,** May 2003.
2. S. F. Johnston, *Reconstructing the history of holography*, **Proc. SPIE 5005,** 2003.
3. S. F. Johnston, *Commercial holography: midlife crisis or wise maturity?* **Holopack-Holoprint 2003,** Vancouver, Canada, Nov 2003.
4. S. F. Johnston, *Holoscopes, wave photographs and lensless photography: changing visions of holography*, **Int'l Conf. on Optical Holography and its Applications,** Kiev, Ukraine, May 2004.
5. S. F. Johnston, *From Classified Research to 'Public Access Holography': Equipment as Social Liberator*, **British Society for the History of Science Annual Meeting,** Liverpool, UK, June 2004.
6. S. F. Johnston, *Stephen Benton on holography, Polaroid and MIT*, **Optics & Photonics News,** August 2004.
7. S. F. Johnston, *Holography: from science to subcultures*, **Optics & Photonics News,** July 2004.
8. S. F. Johnston, *Telling tales: George Stroke and the historiography of holography*, **History and Technology 20,** 2004.
9. S. F. Johnston, *Shifting perspectives: holography and the emergence of technical communities*, **Technology & Culture 46,** 2005 (forthcoming).
10. S. F. Johnston, *Attributing scientific and technical progress: the case of holography*, **Isis** (submitted).
11. Voiced by the Malian writer Amadou Hampâté Bâ (1901-1991) at a 1962 UNESCO meeting.

Calendar

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The International Order of Holoknights named and knighted Professor Anand Krishna Asundi presented him with his holoknight sword, and gave him the title 'Anand of Singapore' in August. The ceremony was held at the International Conference On Experimental Mechanics in Bari, Italy. Asundi was knighted by Professor/Holoknight Ichirou Yamaguchi (Ichirou of Kiryu). In attendance for the ceremony were four other holoknights and about 30 optical scientists. The novice holoknight is currently trying to get his sword back from Japanese customs. From left to right: Ichirou Yamaguchi, Werner Jüptner, Anand Asundi, Ryszard Pryputniewicz, and Wolfgang Osten. Picture courtesy of Wolfgang Osten.

STOP PRESS: Shearwater Foundation winds up

I am sad to inform you that, with immediate effect, the Shearwater Foundation is closed.

Since 1987, the Foundation has provided grants and awards, valued at over one and a half million dollars, to support creative holography worldwide. It has encouraged groups and individuals, acknowledged creative achievements and offered help with education, research, international conferences, and publications, as well as assisting with the purchase of several holographic works of art for major museums and collections. It leaves an astounding legacy.

I would like to thank everyone I have worked with on grant applications over the years and all those involved with the Foundation for making this one of the most special and respected supporters in the field. Particular thanks go to Posy Jackson, who instigated the holography program and administered it until 1998. She has remained an active and enthusiastic representative, and point of contact, during my six years with the program.

Please see the statement from the Foundation trustees below.

Dr. Andrew Pepper
Director
Shearwater Foundation
Holography Program

Shearwater Statement

November 22, 2004, Miami, Florida—The Executors of the estate of the remaining Trustee of the Shearwater Foundation have issued a statement today reporting the closure of the Shearwater Foundation, a long-time philanthropic organization headquartered in Florida. The Foundation's officers indicated that this not-for-profit corporation ceased operations on November 15th, 2004, after the sudden death of the last of the Foundation's Board of Trustees. All business by the Foundation will have been concluded by the end of this month.

The Executors wish to thank the office staff of the Foundation as well as those persons who have administered grant programs for their hard work and professional services over the years. The Shearwater Foundation leaves a memorable record of philanthropic achievement in the areas of hospital care, modern dance and the emerging field of holography—a consuming interest of the Trustees for the past ten years. The Foundation has always done its work with anonymity, honoring the wishes of the four people who founded it. As a result, their names will not be disclosed with this notice.

The legacy of their generosity, however, lives on in the support they have given to so many worthy causes over the years.

Digital holography in real and virtual research : a window into remote places

Continued from cover.

Investigation in a Virtual Apparatus)[2] is a fundamental National Air and Space Administration (NASA) investigation of particle dynamics in fluids under microgravity, and makes use of these concepts. Gravity often dominates the equations of motion of particles and fluids, so microgravity provides an ideal environment to study the other forces. Particles are placed in a fluid-filled cell and their precise positions are monitored while controlled forces are imposed upon them by moving or oscillating the cell. Placing a scientist on the Space Station for such a study is not trivial: nor is training an astronaut or even demanding enough of his time to run the experiment.

Ground tests and simulations have recently been completed that establish that the concept and experiment is, indeed, feasible in space, with electronic holograms downlinked to provide near real-time data. Holographic methods developed and tested in these studies can be used to look from our ground-based laboratory directly into the space station experimental chamber, and provide the accuracy and reliability to meet the needs of the fundamental particle/fluid investigation. This will enable the experiment to be transferred from space back to earth in what we call the 'virtual apparatus' for on-earth microgravity experimentation.

When a fluid oscillates sinusoidally, a suspended particle responds by oscillating at the same frequency, but with a different amplitude and phase. The measurement problem is to locate the two extreme positions of the particle in the fluid with great precision and compare that with the fluid amplitude of oscillation. Recording holographically enables microscopic position location without focusing. We can also determine the phase difference between the cell and particle movement by making several measurements and varying the shutter time delay.

Experiments were completed for a full range of frequency and particle types and shapes, including both particle/particle and particle/fluid interactions. Our ground experiments established and quantified experimentally for the first time—with a large amount of high quality data and with a clear margin—the existence of the so-called history drag, which has escaped definitive observation since it was first proposed over 50 years ago. Unlike other forces on particles in fluids, this force, though anticipated through theory, has never been established or even clearly observed experimentally because it is usually masked by other forces and is extremely elusive. Our data also agreed with theoretical predictions based on new solutions to the fundamental equation of motion, which was solved by team members through the use of fractional calculus.[3]

Figure 1 shows the experimental cell, with spherical particles of diameters between 2mm and 4mm, suspended in a viscous fluid. An electromagnet shook the cells sinusoidally at frequencies ranging from 10-80Hz and amplitudes around 200µm. To counteract particle buoyancy and weight, the particles were tethered to the bottom or top of the cell. In-line holograms of the cell were obtained by illuminating it with a collimated He-Ne laser, and recording the resulting near field diffraction pattern on a lensless CCD camera. A sample hologram of two particles—one heavy and the other light—is shown in Figure 2a. The reconstructed image is shown in Figure 2b. Images were reconstructed by first calculating the Fourier transform of the hologram, then multiplying by the transfer function for a plane wave at the appropriate object distance, and finally calculating the inverse Fourier transform of the result.[4]

SHIVA is supported under a NASA flight definition NRA (NAS8-98091) under topic NRA-96 HEDS-02. The NASA management team includes Melanie Bodiford, Project Manager, Dr. David Smith, Project Scientist, and Bill Patterson, Systems Engineer, all from Marshall Space Flight Center.

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References

1. The authors discussed the hologram as a window into other spaces and times at the SPIE Conference on Optical Holography and its Applications, held 24-29 May 2004, Kiev, Ukraine.
2. J. D. Trolinger, D. L'Esperance, R. H. Rangel, C. F. M. Coimbra, and W. K. Witherow, *Design and Preparation of a Particle Dynamics Space Flight Experiment, SHIVA,* **Annals of the New York Academy of Sciences 1027,** pp. 1-17, 2004.
3. C. F. M Coimbra, D. L'Esperance, R. A. Lambert, J. D. Trolinger, and R. H. Rangel, *An Experimental Study on Stationary History Effects in High Frequency Stokes Flows,* **J. of Fluid Mechanics 504,** pp. 353-363, 2004.
4. T. Kreis and W. Jüptner, **Principles of Digital Holography, Akademie Verlag Series in Optical Metrology 3,** Berlin, **pp. 353-363,** 1997.

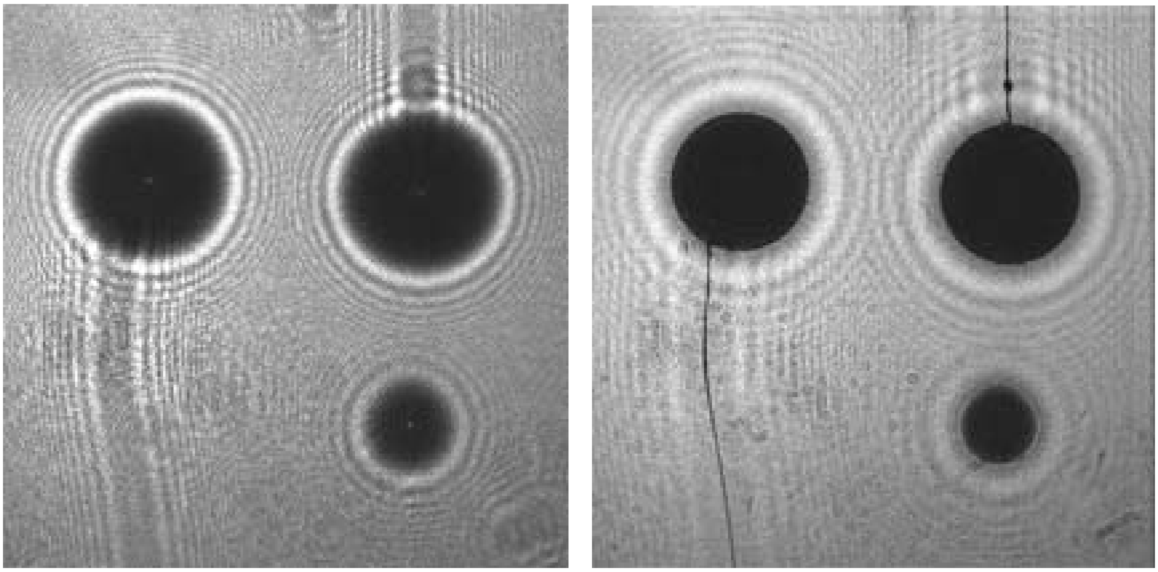

Figure 2. (a) In-line hologram of two tethered particles. (b) Digitally reconstructed image for plane of particles. The small particle in the two images is a reference marker.

Can holography save physics?

Continued from page 5.

dents may want to save money and go to a local University so that they can still live at home and save on costs.

We are currently working on designing curricula for the university's Regional Science Centre, which acts as a training centre for teachers. We intend to teach teachers how to teach holography as an activity in the classroom. We have also been approached by the Institute of Physics to create holography workshops for teachers. The subject has proven time and time again to be a superb motivational activity for students of all ages,[6] and we at the University of Southampton's School of Physics and Astronomy hope that lasers and holography can help reverse the decline in interest in physics.

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References

1. http://www.phys.soton.ac.uk/outreach/index.php
2. A. Mcsmith, S. Cassidy, and S. Carrell, Universities cut sciences as student numbers fall, **The Independent,** London, UK. 22 August 2004. http://education.independent.co.uk/news/story.jsp?story=553864
3. P. Gould, *Wanted: teachers young or old,* **Physicsweb,** Institute of Physics, January 2001. http://physicsweb.org/articles/world/14/1/8
4. http://www.lightexpress.soton.ac.uk
5. http://www.integraf.com
6. P. John and R. Shanks, *Photonics Classes in High School,* Proceedings of SPIE, SPIE, Bellingham, WA, 2000. http://www.pearljohn.co.uk/Education/papers/photonics.html

Figure 3. Students looking at their holograms at the end of a holography workshop.

Figure 4. Pearl John with students and helpers (Dr. James Gates and Dr. Joyce Abernethy) drying their holograms at a holography workshop.

A holographic portrait of Queen Elizabeth II

Continued from page 12.

The Queen, well used to posing for photographs and paintings, adopted her naturally regal pose whilst fixing her gaze on an LED light unit made by Levine. This prevented her from looking at and following the camera with her eyes.

During the first sitting, the Queen's head was also scanned into a computer as a three-dimensional model. A unique head-scanning system was used which was designed and built by British company Wicks and Wilson of Hampshire and operated by Stuart Winsborough. The system has been designed for the production of glass bock 'crystal' three-dimensional portraits however the resultant 'point cloud' data set can be converted into any 3D model format and used to produce other types of images.

After a total of two hours of the Queens time, spread over two sittings, in excess of 8,200 parallax images were recorded for posterity.

In February 2004 Munday used a sequence shot at the first sitting to create the first ever hologram of the Queen using Spatial Imaging's in-house Lightgate digital hologram printer. This small-format 3D holographic stereogram was extremely useful in confirming that the images had been shot with the correct degree of parallax etc., and was also presented to the Queen before the second sitting.

Three weeks after the second sitting, Munday post processed the chosen image sequence using custom software to reverse the effect of several fundamental image distortions inherent in parallax image sequences. He also registered the images with respect to each other so as to achieve the correct degree of projection in the final hologram. The image sequence was then emailed to John Perry of Holographics North Inc. in the USA. Perry further adjusted the images to pre-compensate for the distortion inherent in shooting a blue hologram with a red HeNe laser. He then transferred the images to 35mm film, shooting from a 1200×1600 pixel LCD monitor. The film was processed and placed into his proprietary stereogram printer to produce the master hologram. Four 'rainbow' hologram copies were subsequently created (two artist's proofs and two final works), each 0.85×1.16m (3×4ft) in size. Each hologram is lit using a vertical linear array of high brightness blue LEDs. This illumination configuration creates a sharp, single-color image whilst extending the otherwise restricted vertical viewing aperture of a rainbow hologram.

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Figure 2. Hologram of Queen Elizabeth II.

Figure 3. The VIP (video images with parallax) system.

Contributing to the Holography Newsletter

News, events, and articles

If there are things you'd like to see us cover in the newsletter, please let our Technical Editor, Sunny Bains (sunny@spie.org) know by the deadline date indicated below. Before submitting an article, please check out our full submission guidelines at:

http://www.sunnybains.com/newslet.html

Special issues

Proposals for topical issues are welcomed and should include:

- A brief summary of the proposed topic;
- The reason why it is of current interest;
- A brief resumé of the proposed guest editor.

Special issue proposals should be submitted, by the deadline, to Sunny Bains and will be reviewed by the Technical group Chair.

Upcoming deadlines

21 January 2005: *Special issue proposals.*

4 February 2005: *Ideas for articles you'd like to write (or read).*

25 March 2005: *Calendar items for the 12 months starting* ***June 2005.***

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HOLOGRAPHY ONLINE

Holography Web Discussion Forum

You are invited to participate in SPIE's online discussion forum on Holography. To post a message, log in to create a user account. For options see **"subscribe to this forum."**

You'll find our forums well-designed and easy to use, with many helpful features such as automated email notifications, easy-to-follow "threads," and searchability. There is a full FAQ for more details on how to use the forums.

Main link to the Holography forum:
http://spie.org/app/forums/tech/

Related questions or suggestions can be sent to **forums@spie.org.**

The International Society for Optical Engineering

Holography

This newsletter is published semi-annually by SPIE—The International Society for Optical Engineering, for its International Technical Group on Holography.

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Raymond Kostuk

Technical Editor Sunny Bains
Editorial Assistant Stuart Barr
Managing Editor Linda DeLano

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A holographic portrait of Queen Elizabeth II

Figure 1. From left to right: Munday, Levine and Robb conducting the shoot. Photograph by Nina Duncan.

In August 2003, Rob Munday and Jeffrey Robb of UK company Spatial Imaging were commissioned to create a holographic portrait of Her Majesty Queen Elizabeth II, the first ever holographic portrait of a member of the British Royal family.

The portrait was commissioned by Chris Levine, an independent artist and designer, on behalf of The Jersey Heritage Trust to commemorate the Island of Jersey's 800 year allegiance to the English Crown. The Trust was first attracted to the medium of holography after seeing a selection of Munday's holographic portraits in an exhibition toured by Levine called '*Hypervisual*'. Munday currently operates the only holographic portrait studio in the UK and has produced several holographic works for Levine in the past. A creative collaboration between Levine, Munday, and Spatial's Creative Director, Jeffrey Robb was therefore a natural choice. A fourth key member of the team was holographer John Perry of Holographics North, USA.

Initial discussions revolved around the recording of a 'true' laser holographic portrait using Munday's powerful in-house ruby pulse laser technology. It was unlikely however that the Queen would travel to Munday's studio in Richmond, London. Instead Munday and Robb recommended working with John Perry of Holographics North to produce a large-format holographic stereogram—a combination of stereo-photography and holography. Perry is currently the only holographer in the world able to produce very-large-format holographic stereograms.

A holographic stereogram portrait is made from a sequence of up to 400 images taken of the sitter from multiple angles of view using a specially-designed moving camera. A benefit over 'direct' laser holography is that the resultant image sequences can be used to produce many different types of 3D image. For example, Munday recently created a full color, three dimensional animated portrait of the Queen using the latest auto-stereoscopic 'glasses free' LCD monitor technology.

Prior to the first sitting in November 2003, Levine and Miss Angela Kelly, the Queen's personal assistant, selected the Queen's attire. This consisted of a royal-blue velvet dress, a single string of white pearls and the George IV State Diadem. The Diadem was the crown worn by both Queen Victoria and Queen Elizabeth at their respective coronations and depicted on postage stamps and banknotes. A white ermine cape was also later chosen, as depicted in the final hologram. Levine also chose the name for the piece, *Equanimity*, which means 'the quality of being calm and even-tempered'.

Only six weeks prior to the first sitting Munday embarked on designing, building and testing the VIP (video images with parallax) system—an advanced digital camera linear rail system—investing approximately £50,000 ($90,000) in doing so. Munday took the unusual step of rotating the camera to point towards the subject rather than using the usual 'shift lens/camera' technique that has been employed by many stereographers in the past. Rotating the camera ordinarily introduces undesirable 'keystone distortion', which a shift lens/camera system avoids, however Munday decided to take full advantage of the digital nature of the images and wrote custom software to reverse the keystone distortion and other image distortions after the images had been recorded. This, he felt, provided the ultimate compromise between photographic image quality, angle of view and final holographic stereogram quality.

A state-of-the-art linear motor rotational stage was used to rotate the camera smoothly and at high speed. The rotational stage/camera assembly was in turn mounted on a 2.5m linear motor rail, one of the longest commercially available. Both the linear and the rotary stage were manufactured by Anorad Europe, a Rockwell Automation company. The entire motion-control assembly was then mounted on a rigid-but-portable subframe that enabled easy transportation.

Two royal sittings were conducted at Buckingham Palace. The first was held on the 14th November 2003 and the second on the 24th March 2004. On both occasions several days were spent prior to the shoot setting up and testing the equipment, arranging the lighting, and conducting dry runs. UK photographer Nina Duncan was brought in to assist with lighting, and she also photographically recorded the shoots for the archives. At no time in the past had such an assemblage of high-tech imaging equipment been allowed inside the Palace.

At each sitting Munday, Robb, and Levine were given only one hour of the Queen's time in which to shoot the required image sequences. Munday controlled the VIP system and camera from the computer console whilst Robb checked exposure, focus and composition of the Queen in the frame.

Continues on page 10.

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