Article: Transparent Things through which the Past Shines: Conservation of Holograms in the Collection of the National Gallery of Australia
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Transparent Things through which the Past Shines: Conservation of Holograms in the Collection of the National Gallery of Australia

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Abstract

The National Gallery of Australia (NGA) holds a varied collection of new media, including holograms by artists such as Robyn Beeche, Shu-Min Lin, Paula Dawson and Margaret Benyon. Few artists see the making of a hologram as an integral part of their practice. Paula Dawson and Margaret Benyon are exceptions. Both are pioneers in the area having made and used holograms for many years. While their subject matter and intent are quite different, both artists are attracted by the technical complexities of the media and both use holograms to blur the boundaries between reality and illusion. The theory of holography was established by Dennis Gabor in 1948, with the realisation of light generated holographic images occurring with the invention of lasers in the 1960's. Over the years holograms have evolved, reflecting similar trends to those in photography, incorporating digital technology with applications in science, industry, medicine and art. Until recently the recording materials used most frequently for high quality, large holograms were silver halides due to their light sensitivity and commercial availability. Since the advent of digital imaging these materials have become more or less obsolete. New developments in colour holography have contributed to an entire exhibition created in holographic images being substituted for the fragile originals in 2011. Little is written on hologram preservation and most of that which exists is based on guidelines for photographic preservation. This paper will provide a brief outline of hologram history and development together with an overview of the materials and techniques of a selection of holographic works in the NGA collection and consider some of the implications for the Conservator.

Introduction

Holograms are now commonplace, a familiar feature on credit cards, used on passports, found in magazines and advertising; mass produced and turned out in their millions these commercial holograms are at the opposite end of the spectrum to the unique art holograms on display in galleries and museums around the world. Salvador Dali famously claimed to be the first artist to work with holography in his 1972 New York exhibition. This was not strictly true as there had been two previous exhibitions dedicated to holographic art in the US in 1968 and 1970, highlighting the enthusiasm with which the medium was taken up by artists, almost immediately after the invention of lasers. In fact New York was home to the world's first museum dedicated to holography, which opened in 1976. This collection was transferred to the Massachusetts Institute of Technology (MIT) when the museum closed due to financial pressures in 1992.

By their very nature holographic works are exacting; the challenge for the artist is to maintain their creativity without sacrificing technical excellence. The holograms in the NGA collection are created using a variety of materials and techniques and take different forms. For example the large work (3657mm x 3657mm) by Shu-Min Lin, *Glass Ceiling*, (1997-2001) comprises 12 reflection holograms and 132 granite tiles on which visitors are invited to walk. It was made by a professional holographer on behalf of the artist, and is illuminated with a complex system of lighting held in an overhead grid. Another artist collaborating closely with a professional holographer is Robyn Beeche. She was one of the few women working as a catwalk photographer in the 1970s and 80s with designers such as Vivienne Westwood and Zandra Rhodes. She created groundbreaking images in polaroid, lenticular and holographic format. Beeche's holograms were made by professional holographer, Edwina Orr at Richmond Studios in London; there are three in the NGA's collection, all in excellent condition. These are a rare holographic process which uses a form of colour mixing to achieve a black and white effect. (Orr, 2012). While a number of high profile artists, such as Bruce Naumann, Robert Rauschenberg, Richard Hamilton and James Turrell have exhibited holograms, the physical works are usually made by technicians. There are few artists who see the making of a hologram as an integral part of their practice. Paula Dawson and Margaret Benyon are exceptions. Both are regarded as pioneers in the area, having made and exhibited holograms for many years.

History and development of holograms

The history and development of holograms, together with the rapid advances in hologram technology during the twentieth century, have resulted in a number of different hologram categories, which are already well documented (Bjelkhagen, 1995; Holophile, 2012; Wikipedia, 2012). This paper will deal simply with a generic definition of the two broad groups into which the examples of works taken from the NGA collection fall: *laser transmission* holograms and *reflection* holograms. The Nobel Prize-winning physicist Dennis Gabor made the first holograms (initially called *interferograms*) in the 1940s, announcing his theories and achievements in 1948. But holography had to wait until the invention of the laser in 1960 for its first practical applications, and it was not until 1962 that Yuri Denisyuk made recordings of three-dimensional objects (curved mirrors) in the Soviet Union. The results of these experiments were unsurprisingly named the *Denisyuk, single beam* or *reflection* hologram. Another famous early holographic image was made in the US a little later, 1962–64, by Emmett Leith and Juris Upatnieks. Known as *Train and bird*, it was classed as a *transmission* hologram.

Prior to the invention of the laser there were no light sources of a truly coherent nature – coherent being light comprised of a single wave length, which derives from a single point and is monochromatic. These fixed lasers produce a continuous light wave, whereas pulsed lasers, also developed during the 1960s, emitted powerful bursts of light that made it possible to create holograms of live subjects. Colour holography began with Stephen Benton's white light transmission holography developed at the Polaroid Research Laboratories in 1968. When these *rainbow* holograms are illuminated with a white light, different colours reconstruct different parts of the image at a slightly different angle. As a result the whole image can be seen but its colour varies in a vertical direction, similar to diffraction from a grating.

What is a hologram?

The word hologram comes from the Greek – *hólos* (whole) and *gramma* or *grafẽ* (message or writing). As Margaret Benyon discusses in her work, one of the most fascinating things about a hologram is that if you break off a piece the whole image is encapsulated in that fragment. She demonstrated this by exhibiting holographic jigsaws with straight rather than interlocking edges. These relied on the ingenuity of the viewer to piece them together using the appropriate angle of the image as the guide for reassembly. Early holograms are reminiscent of the first photographs; each is unique providing an image recorded in an emulsion on a photographic plate or film. Recalling the fixed poses of early photography, these holograms required absolute stillness, both in their method and from their subjects. Fine grain, silver halide, gelatin photographic emulsions and dichromated gelatin emulsions were commonly used. These were subject to a variety of processing techniques, which invariably included chemical bleaching – a vital step, since it ensures high diffraction efficiency and, therefore, brightness. A hologram is usually made in low light or a different colour light to that of the laser.

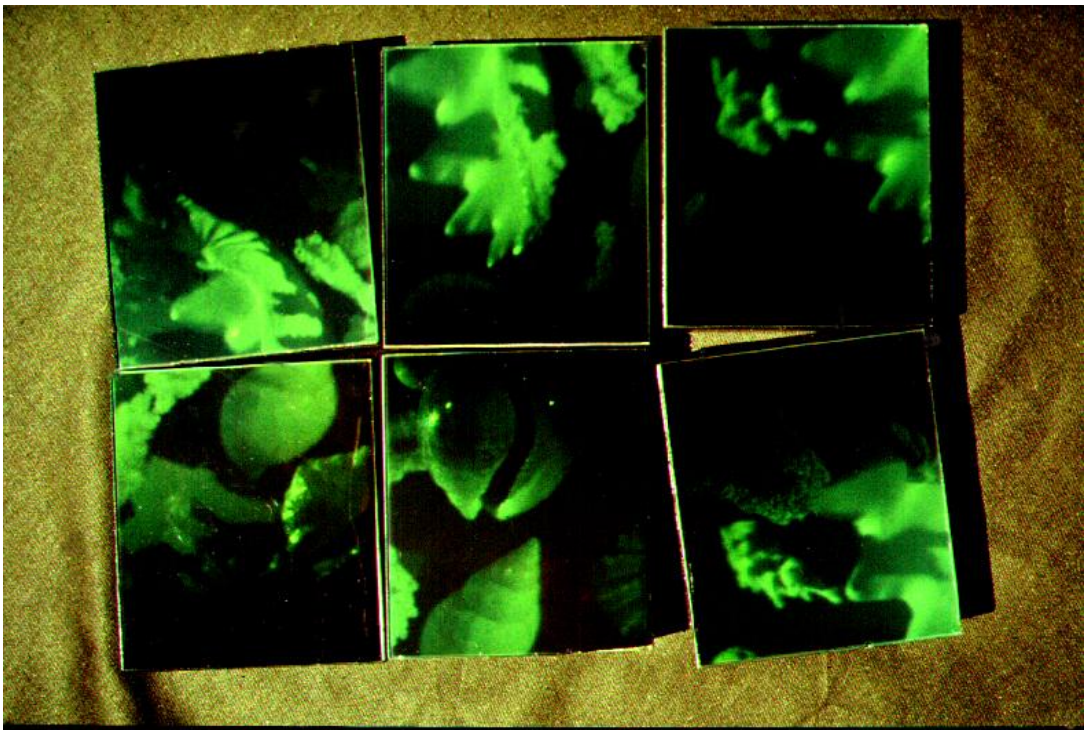

Fig. 1. Margaret Benyon, *hologram 'jigsaw'*, © Margaret Benyon.

To make a hologram, a laser is used for illumination with the single beam being divided in two using a beam splitter. One laser beam illuminates the subject; the subject diffracts this light, which then reaches the sensitised emulsion in scattered form. The other part of the laser beam is the reference beam and falls directly onto the plate or film. The light waves of these two sets of laser beams interfere as they recombine and this interference pattern is recorded on the emulsion layer. Development methods are similar to traditional photographic processing. Once developed, with a reflection hologram an image will be apparent; but in a transmission hologram only a series of soft wavy lines is visible on the plate. This bears no resemblance to the original subject and is not

visible as an image but would be comparable to the compression of sound onto a CD. This holographic image is only decoded when a laser, of exactly the same intensity and at the precise angle to that used when it was made, is directed to illuminate it.

No lens is involved in recording either image, although a lens may be used to diverge the laser beam. Mirrors are used to manipulate the laser beams appropriately. This is a first generation, master hologram where the image is always virtual. Like a photograph printed from a negative, at this point another holographic image can be made or modified through transfer. A reflection hologram is made by placing the sensitised plate or film in front of the subject and illuminating the subject through this. A transmission hologram is made by placing the plate or film immediately behind the subject. Holograms can be made on a wide range of substrates, most commonly glass and film (tri-acetate or polyester) or film laminated to glass, but foil, metal and hard plastic are also used.

Making a hologram

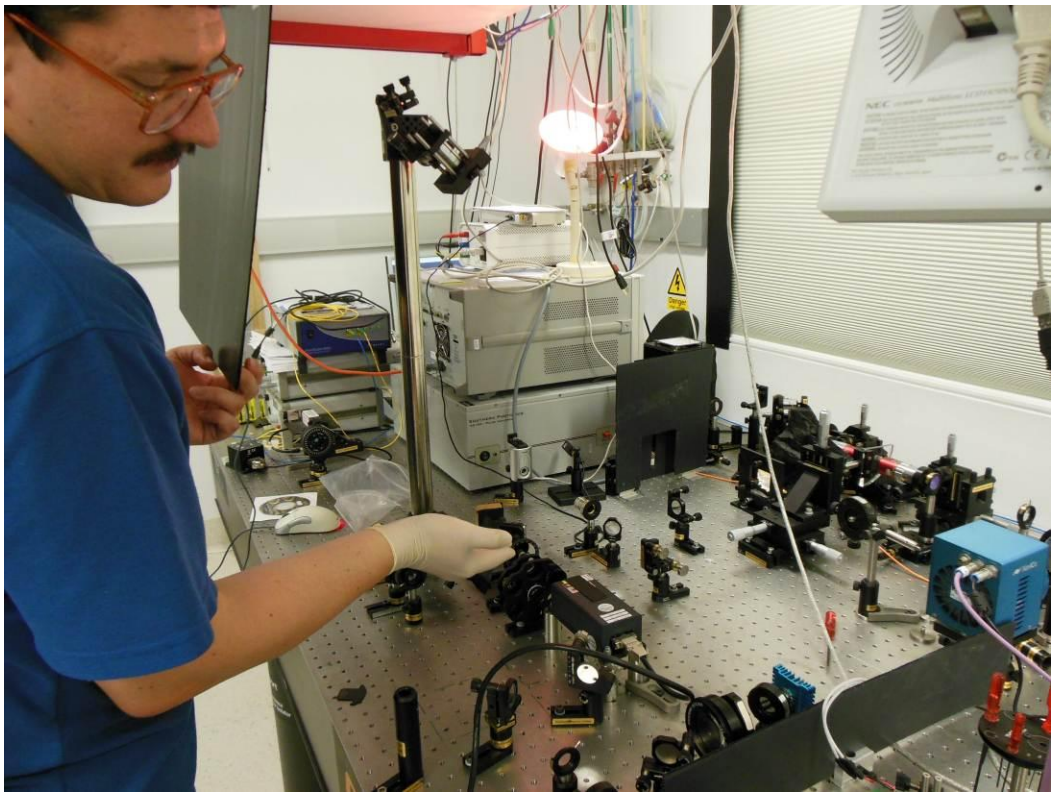

Fig. 2. Dr Alex Minovich, Research Fellow, Nonlinear Physics Centre, Australian National University, checking the equipment used to make a hologram.

To further understand the process, physicist and research fellow at the Australian National University (ANU), Alex Minovitch, was consulted; and with Alex's assistance, two simple Denisyuk reflectance holograms were made. A fixed green laser was directed through a series of filters and an attenuator in order to reduce the intensity of the beam to the correct level. The laser

was reflected by means of a mirror to a microscope objective to diverge the beam onto the subject (a shell). The laser was checked throughout the process using a computer to ensure that it remained cohesive. Paper was placed in front of the plate holder to ensure that the laser was directed correctly. The appropriate low light level for the process was achieved using a traditional red, dark room light. A commercially prepared glass holographic plate was inserted into the holder and placed in front of the subject and exposed to the laser beam for 5 seconds. Once exposed the plate was developed and fixed according to the manufacturer's instructions. This was 2 minutes agitation in the developer, during which time the plate darkened, then a 20 second wash in water, followed by bleaching (and fixing) until the plate became clear; this took less than a minute and was followed by another 20 second wash in water. The plate was then allowed to dry. The chemical bleaching ensures brightness.

Display

Holograms are displayed in either transmission or reflectance states. Transmission holograms, illuminated using a laser, where the laser reconstructs the original image, must have the light source opposite the viewer and thus also opposite the original light source. This means that extreme care has to be taken to avoid having the laser reach the viewer's eyes. This can involve having a specialist such as a physicist on hand to advise. Transmission hologram display was previously complicated by the expensive, fragile, high powered lasers that were required. Lasers are now ubiquitous; small, relatively robust and mass produced at low cost. Reflection holograms are illuminated using a white light source on the same side as the viewer. In addition to considering the nature and intensity of this light source, its height, angle and divergence from the work are also critical. In positioning the hologram on display, correct viewing distance and height, again, may make the difference between seeing the image clearly and not seeing it at all. Most holograms benefit from display in darker-than-usual gallery spaces; this cannot be created by adjusting the lighting on the object, which is a fixed requirement, but conditions can be modified by the introduction of screens, curtains and lowered or absent ambient lighting.

Permanence and deterioration of holograms

Holograms are complex objects. There are a number of factors that could affect their permanence and should be taken into consideration prior to any conservation treatment. Although there is a plethora of literature about the history, development, manufacture and application of holograms there is little written on hologram preservation and much of it is based on guidelines for photographs. Holograms do have many physical similarities to photographs and so comparable considerations can apply. Until fairly recently, the recording materials used most frequently for large, high-quality holograms were silver halides because of their light sensitivity and their commercial availability. Early holograms were prepared individually but, once the technology became more widespread, commercially prepared products became available through the large photographic companies. Since the advent of digital imaging these materials have become more or less obsolete.

The type of support, the emulsion, the nature of the light-sensitive material, and development and processing will all contribute to the quality and permanence of the final work. As holograms are also routinely bleached as part of the processing, this should be taken into account when

considering their longevity. Writers described deterioration in holograms as early as 1986, undertaking testing that relied on similar parameters established in testing for photographic deterioration. Accelerated ageing indicated that there was a change in silver particle morphology and that hologram deterioration was largely catalysed by residual processing chemicals, accentuated by the small developed grain size in the image silver, resulting in a loss of resolution. (Brown and Jacobson, 1986). From this information it could also be anticipated that holograms will react to environmental pollutants in much the same way as black-and-white silver gelatin photographs. Deterioration that can be expected in holograms includes mould, bloom, delamination and cracking in the emulsion layer, changes in the image colour and total image loss; this final point relates in particular to product defects in batches of holographic film. (Orr, 2012).

Consideration needs to be given to whether or not the hologram should or could be taken apart. Holograms are sometimes displayed on a single support layer with the emulsion exposed. The exposed emulsion will then be subject to mechanical and environmental damage, but remains available for interventive treatment such as surface cleaning or consolidation of the gelatin layer. There is much concern amongst holographic artists regarding the potential swelling of the gelatin layer in high RH, which can encourage mould growth and may cause distortion, interference and colour changes in the image. For reflection holograms, colour change is a common problem, particularly a shift from red to blue; while yellow images can change from a gold hue to green. It has been suggested that this colour change is closely related to the thickness of the gelatin layer; swelling can cause a red shift and shrinkage a blue shift. It has been noted that this colour shift can be corrected simply by returning the hologram to optimum RH. (Orr, 2012). However, it has been suggested, that long term exposure to light can also cause this shift from red to blue, and that this change can be irreversible, as a result of permanent shrinkage of the gelatin in the emulsion layer. (Orr, 2012) While on display, holograms require continuous and intense lighting, outside the normal parameters of gallery conditions. In addition to light, heat can also contribute to deterioration, particularly when combined with chemical residues in the emulsion, which can cause instability and result in darkening of the image. (Bjelkhagen, 1995). Heat is particularly a problem for holograms with a black backing, so lighting of negligible heat as well as UV emission should be chosen.

This might explain the preference in the literature for holograms to be sealed in some way after production. At its simplest level this might mean putting the work into a frame behind glazing, but a wide variety of techniques are recommended for this purpose and the conservator should expect to encounter these. Recommendations include covering holograms on glass with another glass sheet – sometimes this is just placed on top, but it can be adhered with a variety of materials, with references in the literature including optical or UV-cured cements, epoxy, silicone, Canada balsam, commercial lacquers and plastic sprays. Improved resolution by reducing interference and matching the refractive indices of the various layers was a consideration. One of the best methods for achieving this was to adhere the still wet, swollen emulsion of the hologram to another cover layer; in the case of a transmission hologram on glass, this would be another layer of glass. In a similar way, holograms on film might be laminated with another plastic film or to glass. (Bjelkhagen, 1995). Reflection holograms often have one side blackened; easily done by placing black card, self-adhesive black vinyl or similar behind the film or plate. However, it was routine to include black paint on the emulsion side or the back of the support or even to use chemical blackening. Proprietary formula paints, or screen-printing inks, matching the refractive index of

the emulsion layer were commonly recommended. Oil paints were to be avoided as it was recognised that these might penetrate the emulsion layer or off-gas chemicals such as peroxides, which would have a deleterious effect on the hologram. (Bjelkhagen, 1995). It has been suggested that darkening in the image, overall or in isolated areas, can result from chemical contamination related to these mounting processes. (Orr, 2012).

Paula Dawson

Australian artist, Paula Dawson is interested in movement, time and memory and it was involvement with her seminal work in the NGA collection, *There's no place like home*, that initiated this investigation into holograms. Her early work was conceptual, combining painting and dance; she trained in classical ballet. Dawson became interested in interference patterns, initially derived from 'sculptural' explosions, carried out using real dynamite, and these experiments led her directly into work with holograms.

Fig. 3. Paula Dawson, *There's no place like home,* 1979-80, laser transmission hologram on glass, National Gallery of Australia, © Paula Dawson.

There's no place like home is a laser transmission hologram. It represents the cluttered interior of a suburban home. The hologram requires a mock room to be built for exhibition, appearing as a window, which the viewer can choose to either look through or walk behind to experience the reality of the empty room. The title refers to the 1939 movie *The Wizard of Oz,* in which Dorothy

clicks the heels of her ruby slippers and wishes herself home. It has been observed that, '*There's no place like home* blurs the boundaries between illusion and reality, just as Dorothy's trip down the Yellow Brick Road happily melded the world of dreams and the people of real life into a Technicolour land of magic.' (Gellatly, 1999). While an enduring fascination with time is central to this work, it also alludes to Dawson's interest in mnemonic memory. The generic objects of the interior (already outdated when the work was made) are there as visual aids to evoke individual recollections; as she says, 'Memory is a soft and seductive thing.' (Davis and Ramsey, 2010).

The work was completed when Dawson was artist in residence at the Laboratoire d'Optique de l'Université de Franche-Comte in Besançon, France, in 1979–80. At the time it was the largest hologram ever made (1500mm x 950mm x 80mm). Lack of other practicing holographers led her to be creative with the technical process and to find different contexts in which to place her art; collaborating with a wide range of scientists and technicians over the course of her career, incorporating new holographic methods and materials as they evolved. Dawson has remained as completely engaged with the technical aspects of her work as she is with the artistic concerns, believing this to be integral to the creative process, writing, 'The sensitivity and dexterity of the holographer's hands are vital…the holographer's craft shares the flexibility and immediacy of physical manipulation with the techniques of the painter, rather than those of other *technology* artists…' (Davis and Ramsey, 2010).

There's no place like home has exceptional resolution and spatial representation. It comprises two sheets of glass, one of which is coated with emulsion and contains the holographic image, while the other sheet is a cover. The two sheets of glass are adhered at the edges with wide black plastic self-adhesive tape. No image is visible, only fine interference lines, similar to moiré patterns, which makes it a little disconcerting to condition report. When the work was called for loan in 2010 it had already been in storage for more than ten years. This is not uncommon for holograms, particularly transmission holograms, as the cost and complications of installation usually condemn them to infrequent display. Unfortunately the foam in the specially designed aluminium crate supplied by the artist had deteriorated dramatically. The work was photographed and documented at this point and the foam and resulting sticky residue successfully removed mechanically. The exterior of the glass on both sides was then carefully surface cleaned with 50:50 ethanol and water, and lint-free cloth, taking care to avoid the very edges and the black tape.

Cleaning made closer examination possible. It was found that three distinct types of deposit could be seen under magnification in between the two layers of glass. These included a whitish bloom with features similar to mould growth, an efflorescence that appeared more particulate, and some small roundish areas, which looked as if fluid was trapped between the layers. As the lead time for the loan was fairly short and our familiarity with this complex work was limited, it was decided to leave it intact for the short term. The magnified deposits appeared largely amorphous in structure and in theory, therefore, should not interfere with the transmission of the image. The major concern was whether or not the work would be viewable once installed in the exhibition – particularly given its significance to the artist and its important place in her body of work. Although a laser is essential for display, the work was acquired without this provision, as at the time, lasers were fairly large, complex, easily damaged, expensive pieces of equipment. So it was not possible to test the image prior to installation. Fortunately, the artist was able to provide accurate installation details, including the intensity of the laser and the exact angle of illumination.

Working together with the artist and physicists from Macquarie University the hologram was safely installed and successfully lit. Problems of potential deterioration and proposed treatment were discussed. The artist opposed the idea of taking the hologram apart. She believed that she had used optical cement between the layers of glass and was not convinced that the sheets could be successfully separated. She was, however, happy to be consulted on any future investigations that took place.

Margaret Benyon

The British artist Margaret Benyon, the first woman to use holography in art practice, spent an extended period in Australia during the late 1970s, making a number of Australian-themed holograms; returning to live here in 2005. Benyon made her holograms during the period 1960–2009. Thirteen are in the National Collection, acquired over a thirty-year period between 1979 and 2012, and include *Hot air*, a significant early laser transmission hologram made in 1970 and acquired in 1979.

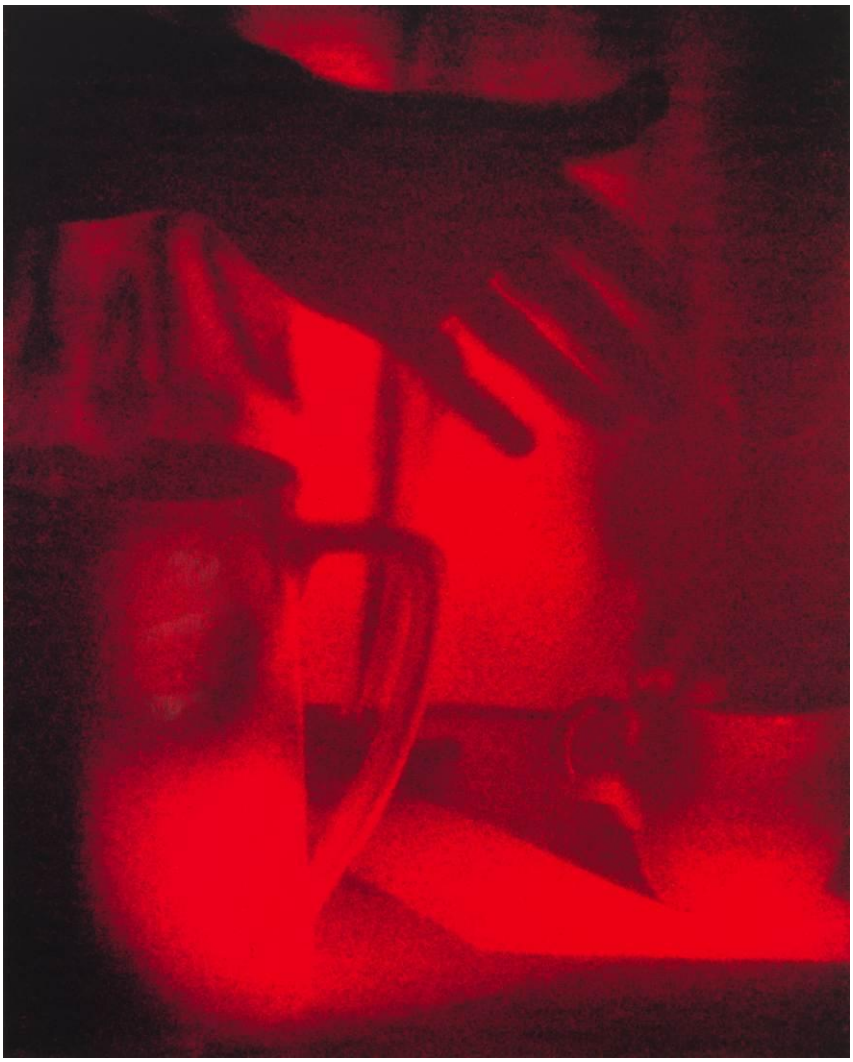

Fig. 4. Margaret Benyon *Hot Air,* 1970, laser transmission hologram on glass, National Gallery of Australia, © Margaret Benyon.

Margaret Benyon trained as a painter and while at the Slade School of Art in London in the early sixties experimented with the Op Art being popularised at the time. Concerned with the representation of three-dimensions on a two-dimensional canvas, she read about holography in a newspaper article in 1967 and was attracted as much as by the technical challenges as the creative solutions it might offer. Working in the medium at this early stage of its development, while exciting, meant that Benyon had to lead the way as both an artist and a technician. Like Dawson, she is fascinated by the merging of reality and illusion, writing, 'We are like Alice, on the other side of the mirror. The hologram serves to remind us that notions such as left and right are one-dimensional and are determined by an arbitrary act of choice.' (Benyon, 2009). She regards making a hologram in much the same way as any creative process; '…it is possible to work through a number of stages. There is the choice of fabrication of objects to be holographed, through test plates to final exposure and even further manipulation of the piece, either in the way it is shown or combined with other media.' (Benyon, 2009).

The other twelve works by Benyon in the collection are reflection holograms, either Denisyuk, single-frame holograms, or multi-frame holograms. They include collage and paint, engraved drawings and integral frames. Two works will be discussed – *Hot air* and *Pushing up the daisies*. *Hot air* is denoted by the artist as a non-hologram, sometimes called a shadowgram. It is a small laser transmission hologram on one sheet of glass; essentially a still life, but capturing the shadow of a hand and currents of hot air not normally visible with the naked eye. These appear black in the hologram because the lasers available at the time could not record subjects that moved even a fraction. The work has had two previous acrylic frames. The original artist's frame was damaged and the artist replaced it when the work went on loan to the US. The second acrylic frame was made by the NGA to the artist's specifications; this has since been lost. Correspondence with the artist confirmed that the work had been extensively exhibited prior to being acquired by the NGA and that it was already showing signs of deterioration when it was loaned to the artist for exhibition in New York in 1980. The artist believed that the surface contamination was due to poor processing, and washed the work prior to exhibiting it. The work is currently housed in an acid-free board folder in a solander box and has never been on display at the NGA. The laser required to exhibit the work, the lighting parameters and OH&S concerns have been a major obstacle to its display. Recently, working with the physicists at ANU the hologram was held in a temporary frame and successfully lit sufficiently to see the image. This work continues in order to establish lighting parameters and look more closely at the work. Initially a new frame will be constructed and then a more powerful selection of lasers will be trialled to establish the most effective way in which to reconstruct the image. As laser equipment is now much more accessible in terms of cost, size and safety, it is hoped that a laser can be purchased so that the complications associated with displaying this work can be reduced. It is anticipated that procedures will also be established for the use of lasers with works of art.

Pushing up the daisies, made in 1996, is a fairly large hologram (800mm x 600mm) depicting a soldier with flowers around his helmet. Gael Newton, Senior Curator of Photography at the NGA, has written that the work is a commentary on modern warfare, inhuman in its scale and complex technologies. The text borrows the well-known euphemism for being dead – 'pushing up the daisies' – from Wilfred Owen's First World War poem *A terre*. It is a collage of two holograms on film adhered to black card with added printed text. It was created by making laser transmission master holograms of a soldier and daisies with a pulsed laser; these were then transferred to

reflection format at a later stage. The artist describes how she removed the emulsion from the edges of the work to allow an optical cement to be used on the film to adhere it to the black card. The frame and glazing arrangement are all original as made by the artist.

Fig. 5. Margaret Benyon *Pushing up the Daisies*, 1996, collage of two reflectance holograms on film with printed text. National Gallery of Australia, © Margaret Benyon.

Pushing up the daisies was called for loan in March 2012. There were a number of conservation questions, affecting both the long-term and short-term condition and stability of the work. Unfortunately a white bloom was evident on the interior of the glazing and the edges of the glass had been ground against the metal frame, so small fragments of glass were apparent throughout the work. The metal frame was flimsy and the backboard was Masonite. The package was unsealed and free to move within the frame. The two holographic films were directly against the

glass glazing. This presented a number of questions for the artist. Could the frame be replaced with an alternative? Could the frame be modified so that better conditions for the work could be achieved? Did the work have to be against the glazing to achieve the correct reflectance? Was glass absolutely necessary or would acrylic glazing have a similar refractive index and behaviour to allow the image to be seen? Could the Masonite backboard be disposed of? What was the efflorescence? Had the film been processed adequately? How had the film been processed? Were the auxiliary elements off-gassing and causing breakdown in the image or film? Would sealing the frame more adequately. exacerbate this deterioration? Once some of these questions were answered, the information could possibly be applied to other works in the collection exhibiting similar problems.

The artist was contacted and insisted that the work remain entirely as is. So documentation and photography were completed and it was deframed. The fragments of glass were removed from the surface of the holographic film with tweezers and a soft brush. The glass glazing was cleaned with 50:50 IMS and water and the whole reassembled to include the Masonite backboard, ready to go back into the frame. Filmoplast P90 tape was used to seal the edges of this package. Further liaison with the artist is on-going as Benyon has suggested this work as the model for framing four new acquisitions – the *Web blue web* series – which are reflection holograms on film. It is hoped that during this process a compromise can be reached, enabling more stable materials to be used, and some answers can be provided to the many questions raised.

Conclusion

While holography may not have blossomed in the manner predicted, it remains integral to art, science and medicine. Holographic exhibitions are unlikely to replace the experience of viewing the original works for many people but the concept remains intriguing and it is possible that virtual exhibitions will be acceptable to future generations who are increasingly at ease with technological simulations. Exhibitions where holograms replace the fragile originals have been attempted previously; most recently the British Museum collaborated with other institutions in the UK, using the latest colour hologram technology, to develop an exhibition, which travelled to a number of locations in Wales. Known as *Bringing the artifacts back to the people*, the project allowed a number of extremely rare pieces, including a 14,000-year-old horse jawbone to be seen (albeit in holographic form) outside their institutions.

There is continuing interest in holographic art in its own right, with an exhibition of holograms in New York as recently as 2012; 'Pictures from the Moon: Artists' Holograms 1969–2008,' at New York's New Museum for Contemporary Art, featured holograms by Bruce Nauman, Louise Bourgeois, Eric Orr, Ed Ruscha, and James Turrell. The exhibition was promoted as offering '…a view of the persistent attempts by artists to wrest something more from technology than that for which it was invented…the enduring hologram continues to mesmerize by expanding the artistic and visual fields that lay before our eyes.' (Moore, 2013). These many fascinations that holograms provoke are perhaps best summarised by Paula Dawson quoting one of her favourite authors, Vladimir Nabokov, who wrote about 'Transparent things, through which the past shines!' (Davis and Ramsey, 2010). The advances in hologram technology, like many areas of conservation, exceed our ability to anticipate preservation requirements, and present constant challenges. At the

NGA we hope to continue to collaborate with artists and scientists to complete further investigation and analysis of holographic works in the collection.

Acknowledgements

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