More than meets the eye: Holographic works in the collection of the National Gallery of Australia

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The National Gallery of Australia (NGA) holds a varied collection of new media, which includes intriguing virtual art such as holograms. Whether the term 'new' can still be applied to holography is debatable; the theory was announced in 1948, with the realisation in images occurring after the invention of lasers in the 1960s. Famously, Salvador Dali claimed to be the first artist to have worked with holography with his 1972 New York exhibition. This, however, was not strictly true as there had been two previous dedicated hologram exhibitions in the US in 1968 and 1970, highlighting the enthusiasm with which the medium was taken up by artists. Over the years hologram materials and techniques have evolved, becoming more sophisticated and, reflecting similar trends to those in photography, incorporating digital technology with applications in art, science, industry and medicine. Holograms are part of everyday life, and extraordinary developments in colour holography have led to artists working exclusively in the medium, producing entire exhibitions created in holographic images. This paper considers some of the implications of these works for the conservator and provides a brief summary of the history and manufacture of holograms, together with an overview of the materials and techniques of a small selection of holographic images in the NGA collection by Paula Dawson and Margaret Benyon. Both artists have been creative with the technical process, collaborating with a wide range of scientists and technicians over the course of their careers, incorporating different holographic methods as these evolved. They have remained as engaged with the technical aspects of their work as with the artistic concerns, believing this an integral part of the creative process; both artists are concerned with the longevity and conservation of their works.

Keywords

Paula Dawson, Margaret Benyon, transmission hologram, reflectance hologram, Denisyuk hologram

Introduction

Holographic media have now confirmed their place in art history, having earlier encountered prejudice as simply a clever technical feat. By their very nature holographic works are exacting; the challenge for the artist is to maintain their creativity without sacrificing technical excellence. It is interesting to note that both Paula Dawson and Margaret Benyon have debated holograms as much at scientific conferences as at art venues. Although a number of high profile artists, such as Bruce Naumann, Robert Rauschenberg, Richard Hamilton and James Turrell (to name a few), have incorporated holograms into their oeuvres, 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. Dawson and 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 National Gallery of Australia (NGA) collection fall: laser transmission holograms and reflectance 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 (a curved mirror) in the Soviet Union. The results of these experiments were unsurprisingly named the Denisyuk, single beam or reflectance 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. 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 *grafē* (message or writing). As Margaret Benyon discusses in her work, one of the most fascinating things about a transmission 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. Early holograms are reminiscent of the first photographs, such as daguerreotypes; each is unique providing an image recorded in an emulsion on a photographic plate or film. Additionally, recalling the fixed poses of early photography, holograms required absolute stillness, both in their method and from their subjects. Fine grain, silver halide, gelatine photographic emulsions and dichromated gelatine 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 darkened room. 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, 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. The 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 the 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 reflectance hologram is made by placing the 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, but foil, metal and hard plastic are also used.

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 a viewer's eyes. This can involve having a specialist such as a physicist on hand to advise. Hologram display used to require complex, high power, expensive lasers – these are now ubiquitous and mass produced at low cost, being much smaller and more robust. Reflectance 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 gelatine photographs.

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 gelatine layer. There is much concern amongst holographic artists regarding the potential swelling of the gelatine layer in high RH, which can encourage mould growth and may cause distortion, interference and colour changes in the image. 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 apparently 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. (Bjelkhagen 1995).

Reflectance holograms often have one side blackened; easily done by placing black card or similar behind the film or plate. However, it was routine to include black paint on the emulsion side of the work 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). Holograms require continuous and intense lighting, outside the normal parameters of gallery display conditions. Light and 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, particularly for holograms with a black backing, is also a problem, so lighting of negligible heat as well as UV emission should be chosen.

Paula Dawson

It was involvement with Paula Dawson's seminal work in the NGA collection – *There's no place like home* – that led me to investigate holograms. *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. 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 (1500 mm x 950 mm x 80 mm). It has exceptional resolution and spatial representation.

Figure 1 – 'There's no place like home' 1979–80, laser transmission hologram, National Gallery of Australia © Paula Dawson

The work 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 the 'too hard' basket. 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 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.

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. The other twelve works are reflectance 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 in a tray of water 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. The emulsion appears intact and currently NGA paper conservators are working with the physicists at the Australian National University (ANU) to establish lighting parameters and look more closely at the work. Initially a new frame will need to be constructed and then a selection of lasers will be trialled to establish whether the image can still be reconstructed. 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.

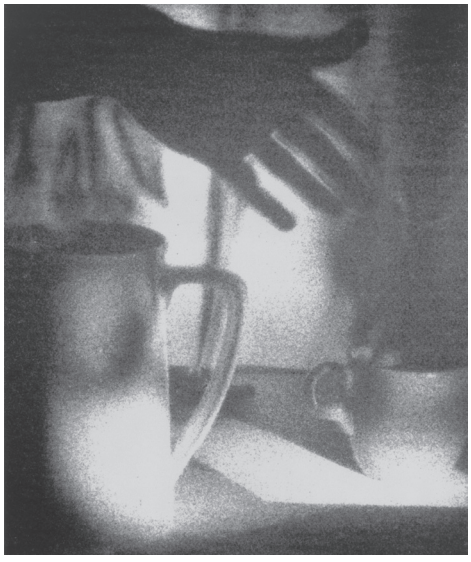

Figure 2 – 'Hot air' 1970, Margaret Benyon, laser transmission hologram, National Gallery of Australia

Pushing up the daisies, made in 1996, is a fairly large hologram (800 mm x 600 mm) 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 reflectance 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 were all original as made by the artist.

Figure 3 – 'Pushing up the daisies' 1996, Maragret Benyon, collage of two reflectance holograms on film with printed text, National Gallery of Australia

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 in the frame? 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. The work was documented and photographed; the frame and glazing were removed. 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 reflectance 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

Holography is now commonplace, used on credit cards and passports, found in magazines and advertising; mass produced and turned out in their millions these holograms are at the opposite end of the spectrum to unique art holograms in galleries. The advances in hologram technology, like many areas of conservation, exceed our ability to anticipate preservation requirements, and present constant challenges. 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, as technology advances, 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. 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.

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