17th-century optics in 20th century art: artists working in Britain's oldest scientific institution

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ABSTRACT

We were the first-ever 'Artists in Residence' at the Royal Greenwich observatory, producing a series of holographic artworks based on our artistic 'researches' there during 1987 and 1988. For the purposes of art we appropriated visual fragments from old optical experiments, including some by Sir Isaac Newton, which we recreated in our studio with a laser. We explain how our experience exhibiting in museums and art galleries since 1984 has influenced the way we make and display holograms.

1. INTRODUCTION

The position of Artist in Residence at the Royal Greenwich Observatory was advertised in the UK national press at the end of 1986. It offered the opportunity to live and work for one year in Britain's oldest scientific research institution (founded 1675), with a stipend and accommodation. Applications were invited from artists working with technology, and one visual artist and one musician were to be appointed at the same time. We jointly applied for the post of visual artist and were eventually successful.

During our residency, the Royal Greenwich Observatory was located at Herstmonceux Castle, Sussex, a restored 15th-century building, as well as in modern laboratories nearby. This environment contained remnants of the institution's past -- busts of scientists, old scientific instruments -- as well as all the necessary tools and equipment for contemporary astronomy.

As artists, we were to seek ideas and inspiration for our work, and to share this process as far as possible with the scientific and other employees of the Observatory. A sharing of the two knowledges or traditions of art and science was to take place, artist and scientist witnessing the progress in each other's work. For this purpose we secured a suitable artists' garret and studio above the castle drawbridge, where we could set up displays and invite the staff to visit (fig. 1). With the freedom of the Observatory, we were able to visit astronomers in their offices, laboratories, telescope domes, workshops and computer rooms, to learn about what they in turn were doing.

We have been making holograms together since 1983 and built a studio at Goldsmiths' College, London in 1979, when we had found it necessary to make much of our optical equipment. From this experience we felt that much of our day-to-day labours were more like old craft skills than the kinds of instant processes people often associate with "technology". Because we realised that similar concerns were also important in the early history of astronomy, we started looking into the Observatory's rare-book archive which contained an impressive collection of early and first-edition scientific books and personal papers from all the former Astronomers Royal. This contact with the problems and practicalities of early astronomers proved to be a

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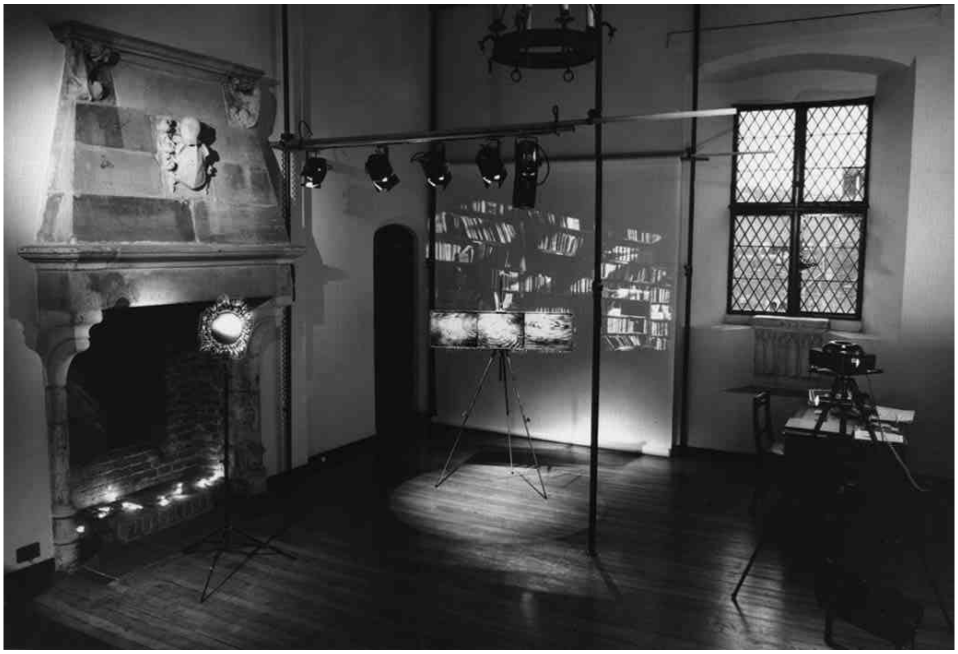


Fig 1. Artists' studio Herstmonceux Castle. Showing Newton's Rings (1987) with projected photograph.

useful source of both written and visual information. In the 17th and 18th centuries presentations of scientific ideas and reports often contained hand drawings by the authors.

We were able to examine an original first-edition copy of Sir Isaac Newton's Opticks, presented to the Observatory at the time of its publication. We found that his experiments were often open-ended, without specific conclusions, sometimes simply an account of way in which he saw light falling in particular patterns onto a screen, as he chose to guide it. Writings such as these revealed a searching thought-process of exploring and trying to understand light which -- despite the intervening centuries -- seemed to have something in common with the practice of the modern holographic artist, where practical experiment, objective observations and imaginative speculations are often fused together. The early history of astronomy and optics seemed to provide us with a common ground where we could seek connections with our own work in holography and explore ideas that related our medium to discoveries in the history of science.

From our readings in the Observatory archives we chose three optical phenomena as the basis for works which are named after them: 'Newton's Rings'[1]; an experiment by Newton that he referred to as 'The Fringes of the Shadows of the Knives'[2]; and 'Airy's Discs'[3].

2. THREE HOLOGRAMS PRODUCED AT THE OBSERVATORY DISPLAY AND ILLUMINATION TECHNIQUES

2.1 Newton's Rings

Newton observed this interference effect when he placed a convex lens on a glass sheet[1], although now the term is often used to describe any interference from glass surfaces in close contact. We recreated such patterns by passing the expanded beam from a 25-milliwatt helium-neon laser through two glass microscope slides clamped together and inserted in the beam just after its expansion by a microscope objective and spatial filter. For our hologram, the image was present both as a projection of the pattern onto a ground glass screen -- the 'subject' of the recording -- and by using the pattern in the reference beam.

In the final white-light reflection hologram you see a field of rings projecting in front of the glass holographic plate as well as apparently receding into the space behind. The holographic plate was exposed twice, once on each side, to produce each of these real and virtual images. The pictorial result is something like an abstract landscape of ringed patterns. This piece was made in 1987, the 300th anniversary of the publication of Principia, the book where Newton used his gravitational theory to account for the elliptical orbits of planets -- another kind of Newtonian ring.

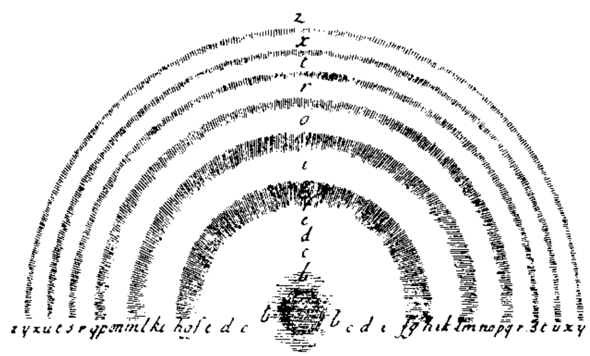


Fig. 2. Newton's Rings, from Opticks (1704)

With all our observatory work we used techniques we had developed prior to this project and we will mention these within our accounts of individual works. Newton's Rings consists of three separate reflection holograms, each 300 x 400 millimetres. These holograms have been framed together to form a piece 300 x 1200 mm. We call these 'triple-plate holograms', a development from our "double-plate" works we have made since 1983. Each plate was exposed to a separate reference beam and the composite hologram requires three lights for display, one above each plate. Since viewers move around a gallery on foot in a horizontal plane, the extension of the image horizontally seems to offer a greater enhancement to the sense of image space than an increase in hologram height. Multiple-plate holograms enable us to overcome some of the limitations in the manufacturer's standard product sizes and shapes. The line between plates does not seem to be visually distracting in our imagery and sometimes acts like the join in a traditional tile design or stained-glass window image.

We use low-voltage tungsten-halogen spotlights fitted with 75-watt 12-volt lamps with integral dichroic-coated faceted reflectors (designation: EYF). Such lamps are 50 mm in diameter, the effective source size of the bare lamp. We designed a snoot 150 mm long for use with a standard fitting produced by a UK manufacturer (Candela Ltd). At the end of this metal snoot is a 35-mm-diameter aperture at the 'crossover point where light from the lamp/reflector is concentrated. This reduces the apparent source size and frames the beam giving an even, circular spot that illuminates the hologram with a small amount of spill light.

Ultraviolet output from these lamps can be high, due perhaps to direct radiation in all directions from the guartz filament capsule rather than reflection from the dichroic coating. We insert a one-millimeter-thick filter of polycarbonate plastic at the snoot aperture to block at least some of these wavelengths. If a wider beamspread or smaller apparent source size is required we place a negative lens at this aperture. We need wider beamspreads when the throw from the spotlight is too short in an installation. A smaller apparent source size can increase angular resolution of the hologram image if it is not already dominated by chromatic blurring, but the price is paid in reconstruction brightness because the beam is more spread out. In practice the standard EYF lamp without lens is adequate in nearly all circumstances. One manufacturer (General Electric Company, USA) has announced plans to introduce a 100-watt version of this lamp in 1990.

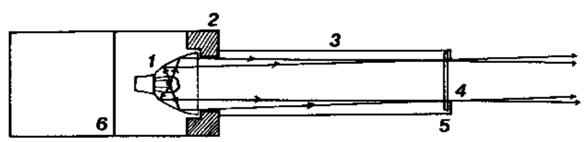


Fig. 3. Low-voltage spotlight fitting:

1. 12-volt, 75-watt reflector lamp 'EYF'
2. support ring/lampholder
3. snoot
4. output aperture, 35 mm diameter
5. ultraviolet filter or negative lens
6. toroidal transformer, 75 VA rating

The three holograms of Newton's Rings are to be seen as one image. With such an abstract image, auxiliary images created by the light spilt from any of the three lights onto an adjoining hologram merely repeats the chosen pattern, at a different angle displaced horizontally to right or left. We can exploit this effect in widening the effective viewing zone of the whole piece because the extra images appear either side of the main image. Aware of this effect in advance, we design imagery either to tolerate it or, better still, to make use of this multiplying effect. In any case, an understanding of spill-light effects is now part of the way we plan and make multiple-plate holograms.

Our three display spotlights are attached by 'adapters' to the same length of light track, in front of the hologram and running parallel to it on the ceiling. The track is longer than the total hologram width, which allows the lights to be moved slightly to the left or right of the center of each plate. We use this to establish a fine degree of control oyer the precise location of the viewing zone of each plate. For example, moving a light along the track to the right -- whilst maintaining it pointing at its corresponding plate -- throws the viewing zone for that plate to the left. We make sure the viewing zones of all three plates coincide usually along the center axis of the middle plate, or the collective viewing zone can be directed to one side to account for the viewer's approach from different directions. In certain cases we mount extra lights at extreme right or left locations to generate a new viewing zone or zones at an oblique angles.

We display Newton's Rings in front of an image from a projected black-and-white slide. In this case, the slide shows a wall of books in the Observatory library. Since a holographic image is made of light, it seemed very natural to us to combine it with another sort of 'light' image in this way. These back projections are part of the entire artwork. For this hologram we are able to show a context for the hologram image of the rings, by choosing an image of the library where we located our source of inspiration. More generally, such installations of holographic imagery and slide imagery have enabled us to create works on a scale suitable for exhibition in large public museums and galleries. A hologram is often better displayed in a large space: walking past a hologram at a distance of ten meters or more is quite a different perceptual experience to viewing it from short range or in a restricted space where free movement is less likely. When imagery is projected some distance in front of a hologram, the scale of the display's surroundings can encourage the viewer to stand away, where the image looks better. Our installations with large-scale photographic back-projections have a similar effect.

2.2 The Fringes of The Shadows of The Knives

This hologram is based on a more obscure experiment of Newton's 5 described in Opticks$_2$. It seems that Newton himself could draw no particular conclusion from the experiment and it has not come to have any special significance in "text-book physics". Newton made his own pencil drawing to document the experiment (fig.4). He allowed sunlight, entering through a 1/32-inch pinhole in a 'paste board' in front of a window, to pass between two sharpened knife blades, held nearly parallel in an acute-angled 'V'-formation.

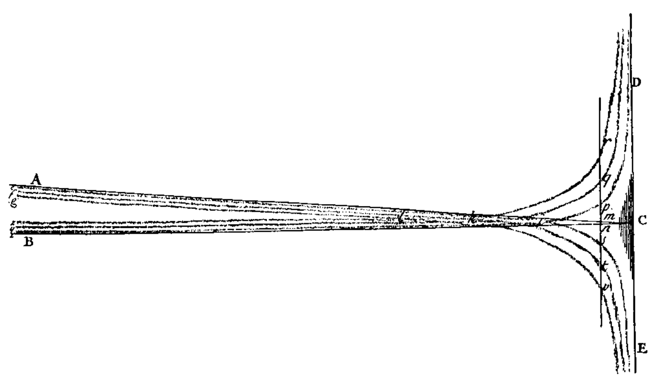
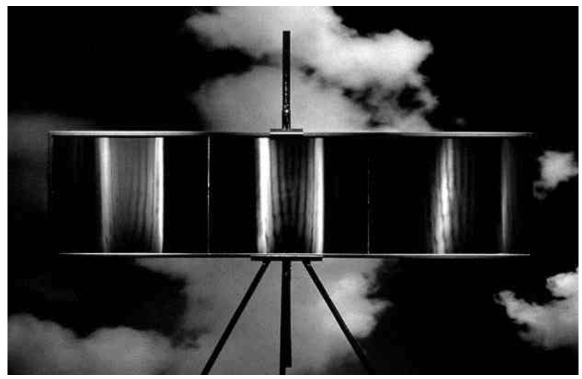


Fig. 4. Newton's drawing of diffraction from knives. AC and BC are the geometric shadows of the blade edges.

The pattern is intrinsically very beautiful, an organic-looking structure formed by the overlap of two distinct types of diffraction pattern. Before we recreated this experiment we had doubted that Newton could have seen such a complex formation from such a simple arrangement. We believe that the two sets of fringe patterns may correspond to what we now call Fresnel and Fraunhofer regimes of diffraction, the gap between the narrowing blades crossing the transition between the two as it converges towards the point of contact.

In our recreation we placed two razor blades in the same V'-formation in the expanded beam beyond a spatial filter. We selected a middle section of the diffraction pattern to produce a white-light reflection hologram. The pattern was present in the reference beam, creating one image exposed directly onto the emulsion, while simultaneously the same pattern (from a second spatial filter and knife-blade arrangement) was projected as 'subject' onto a ground glass screen. We made two exposures of this combined reference beam and subject on each plate, the first exposure with the patterns aimed at the left half, and the second with them aimed to the right. For each exposure we soaked the plate in a solution of triethanolamine to swell the emulsion by a given amount and produce a particular color change[4,5].

Fig. 5. The Fringes of the Shadows of The Knives, Wenyon & Gamble, 1988, 300 x 1200 mm hologram on easel, with photo-projection background.



The color of the image in the final triple-plate piece shifts from red at one end to deep blue at the other, following the spectrum in another reference to Newton's work (fig. 5). The representation of the spectrum as bright vertical lines of color resembles an astronomical spectrograph, used to reveal which wavelengths are present in the light from a star, its chemical composition and red-shifts. Finally, the repeated pattern also suggests the type of decorative stripes popular in Europe during the l7th-century. Thus we see the work as bringing together different layers of meaning. When we exhibit this hologram, the back-projected image shows the sky.

2.3 Airy's Discs

Sir George Airy was the Astronomer Royal at the Observatory from 1835 to 1881. He demonstrated mathematically that diffraction causes the image of a star formed through a perfect telescope to be a disc surrounded by concentric rings. The significance of the observation was that it permitted a rational criterion for the theoretical ability of a telescope to distinguish between two adjacent stars.

In our hologram the image of a disc comes from diffraction by a hole we made with a pin in aluminum foil. We placed this pinhole just beyond the focus of a low-power (x5) microscope objective. The resulting Airy's Disc was projected by the spreading laser light onto a ground glass screen. Our finished piece Airy's Discs is three

3OOmm x 4OOmm plates, each exposed twice to form a real and virtual image of the disc. Each plate was soaked in two different solutions of triethanolomine to give a total of six colors (red and blue, orange and turquoise, yellow and green). Although in making this piece we recorded each disc the same size and at the same position, the resulting holograms display a variation in disc heights and size due to the magnification and shift in angle inherent in reconstructing a hologram at different wavelengths.

Illuminating the three plates with three lights, the effect of spill light creates additional Airy's Discs either side of our main images, an example of how the 'natural' phenomena of the holographic medium can work. We present Airy's Disc in front of an image of the telescope domes at the Observatory.

These three completed triple-plates and back-projections were linked finally by a 30-channel computerised lighting control-board and dimmers produced by CELCO Ltd (UK) which allowed us to continuously control the brightness of the lights and the slide projectors, permitting images to gradually appear or fade away.

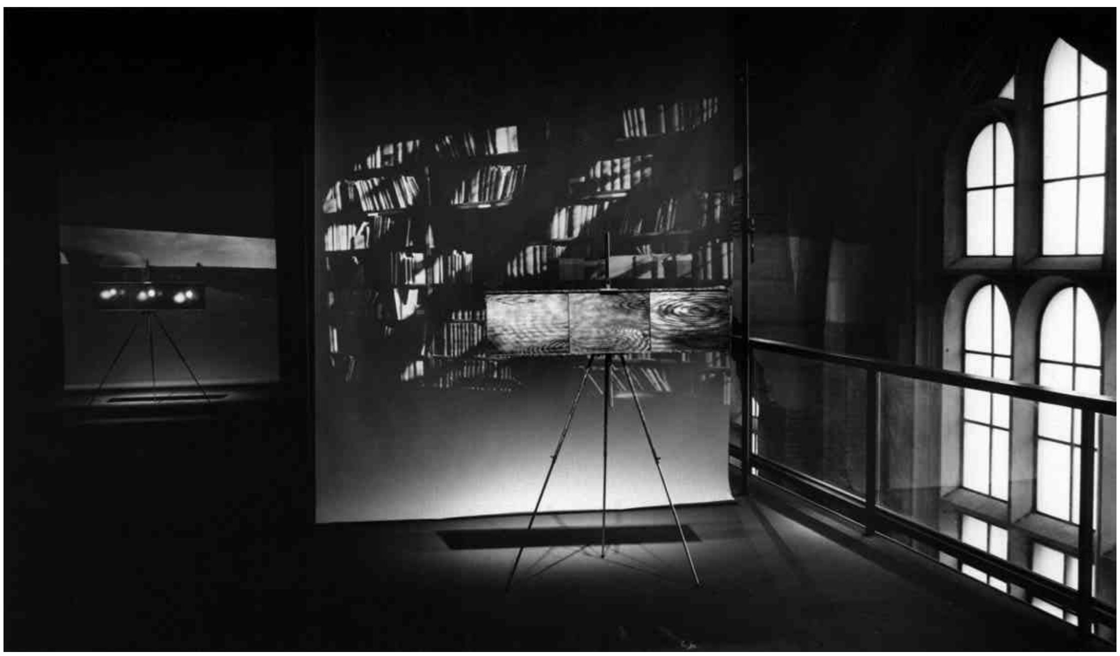


Fig. 6. Wenyon & Gamble exhibition at the Musée des Augustins, Toulouse, France (October 1988), Airy's Discs (1988) left, Newton's Rings (1987) right.

3. CONCLUSION

Whereas 17th-century artists demonstrated their appreciation of a scientist' s work by producing an image of the scientist in the form of a bust or painted portrait, 20th-century artists are able to work with the science itself as subject matter.

The production of each of these pieces spanned a period of about one month. For example, in The Fringes of the Shadows of the Knives, we experimented first with the laser and various knife blades, exploring the optical effects possible. We used drawings to try out different ways of constructing an image with these patterns. We made test strips exploring the effect of different patterns, different locations and image projections as well as more mundane technical factors as exposure and color. Each test strip takes as long to make and process as a full-size plate, one half to one whole day depending on the number of colors and/or exposures necessary.

These works were shown as a group to the Observatory astronomers in February 1988. The first public exhibition was in October 1988 at the Musée des Augustins, Toulouse, France, part of the city's bi-annual FAUST festival of art using new technology (fig. 6). We would like to exhibit these works together again with the original documents that inspired them, in an exhibition at a science museum or similar venue.

We have continued to use optical phenomena as imagery in artworks made since our project at the Observatory. We are also continuing to develop our use of multiple plates and lighting techniques. A recent work consists of five 500mm x 600mm plates (Agfa Gevaert 8E75HD stock from 1983) displayed edge to edge and showing a very simple space with a 'floor' of optical caustic patterns. As fine artists, research and experimentation with the illumination and display of holography is as important as development of holographic recording techniques and offers us as many new possibilities. New lighting techniques can do more than simply enhance the technical quality of a hologram, and may create novel effects in their own right. The lighting and installation of a hologram can become an inherent part of the work itself.

Public museums and art galleries seek high standards of display, and until museum technicians are trained to light holography the artist must often be prepared to provide their work as well as the practical skills to display it if they wish to exhibit in such venues.

Low-voltage spotlights are now becoming more common and less expensive. Many new museums are already specifying these light fittings, making the display of holographic artworks more likely. Further developments in the design and production of new lamps and even diode lasers suitable for holographic display will offer new possibilities to artists.

4. ACKNOWLEDGMENTS

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5. REFERENCES

1. Isaac Newton, Opticks, book 2, part 1, I. Newton, 1704
2. Newton, ibid., book 3, part 1
3. Sir George Airy, Transactions of the Cambridge Philosophical Society, vol. 5, p 283, Cambridge, UK, 1835
4. Lon Moore, 'Pseudo-Color Reflection Holography', Proceedings of the International Symposium on Display Holography, Tung Hon Jeong (editor), pp 163-170, Holography Workshops, Lake Forest College, Illinois, 1983
5. John A. Kaufman, Proc. of Int. Symp. on Dis. Hol., ibid, pp 195-207, 1983