Color holography for museums – Bringing the artifacts back to the people

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ABSTRACT

Color display holography**,** which is the most accurate imaging technology known to science, has been used to produce holographic images for display of artifacts in museums. This article presents the *'Bringing the Artifacts back to the people'* project. Holograms of twelve different artifacts were recorded using the single-beam Denisyuk color reflection hologram technique. 'White' laser light was produced from three combined cw RGB lasers: a red krypton-ion laser, a green frequency-doubled Nd-YAG laser, and an argon-ion laser. Panchromatic ultra-fine-grain silver halide materials were used for the recording of the holograms. During 2009 the artifacts were brought to St Asaph in Wales at the Centre for Modern Optics, to undergo holographic recording. One of the recorded artifacts included a 14,000-year-old decorated horse jaw bone from the ice age, which is kept at British Museum in London. The recorded color holograms of this object and others have been arranged in a touring exhibition, the 'Virtual Artifacts Exhibition.' During 2010-2011, this will be installed in a number of local museums in North Wales and surrounding areas.

Keywords: Holographic Display; Color Holography; 3-D Imaging, Museum Displays;

1. INTRODUCTION

This paper describes how color holography is employed for displaying objects in museums. Presented is: *'Bringing the Artifacts Back to the People'*, a project organized by Crane of Llangollen Museum, North Wales. For the first time this 3-D imaging technique can be used to provide images which are so realistic that they can stand in for the real thing in places where museum facilities are non-existent. The project involves collaboration with a number of major museums including the National Museum of Wales, the British Museum, the Maritime Museum in Liverpool, as well as with the Royal Commission for Ancient and Historical Monuments in Wales. The holograms of all the artifacts were completed by the end of 2009. Everything is now combined into a travelling exhibition that tours around north Wales and the borders. The exhibition opened first at Llangollen Museum in June 2010 and later at the Grosvenor Museum, Chester, Wrexham Museum, Llandudno Museum, Bangor Museum and the Oriel Gallery Llangefni amongst others.

In the early days of holography, holograms of various artifacts were recorded and introduced to museums as a new 3-D imaging technique. The problem was that these holograms were only recorded using one laser (one laser wavelength, and often in red or green light only) which means red or green holographic images. The monochrome 3-D image looked realistic but the poor color reproduction was unacceptable for most potential museum applications. However, in the former USSR and in East-European countries photographic companies were able to manufacture high-quality recording materials which were used to produce large-format monochrome holograms and, in the early 1980s, this encouraged the Ukrainian Ministry of Culture together with the Ukrainian Institute of Physics to develop holographic laboratories in museums to record holograms of unique artifacts. The program included the State Museum of History, the Herson State Historical Archaeological Museum, Ukrainian Museum of Historical Treasures and other museums. Some of these holograms were brought to the West.

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For example, the 1985 exhibition '*Holography – Treasures of the USSR*' at the Trocadero Centre in London displayed many holograms including artifacts from Ukraine, the Northern Black Sea area, Byzantine and Scythian works of art, and objects from the Hermitage. This exhibition was organized by the Academy of the Sciences of the USSR in cooperation with Light Fantastic Ltd in London. Following this, UNESCO published articles on cultural heritage and holography[1] but, because of its expense and the need for special recording laboratories, the technique did not catch on. Markov described early applications of holography in museums.[2,3] Since then, display holography has been developed so that it is now possible to record high-quality color holograms. Today, color holography is the most accurate imaging technology known to science capable of producing 3-D holographic images for display that are almost indistinguishable from the original objects. The holograms recorded on special holographic plates are the closest reproduction that can be achieved being more accurate than photography or computer imaging.

2. COLOR HOLOGRAPHY

2.1 Panchromatic recording materials

In order to record ultra-realistic-looking images based on color holography the key is to have access to special panchromatic recording materials. Since the 1960s, there has been much progress in holography and the recording materials were developed as part of this. In the 1980s and 1990s, for a short period of time, specialist monochrome silver halide holographic recording materials became quite widely available commercially. These products were developed and supplied by major photographic companies such as Eastman Kodak, Agfa-Gevaert and Ilford Limited and were suitable for making high-quality monochrome display holograms on glass plates and film.[4] However the intended commercial applications for these monochrome holographic recordings did not develop as anticipated. This shortcoming became a major factor that led to a rapid decline in the use of monochrome holographic materials and their eventual abandonment for many applications. This in turn resulted in the major photographic companies largely losing interest in the holographic market in general.

To record early color holograms before a suitable panchromatic material existed, a sandwich technique was used to record color reflection holograms. A successful demonstration of a sandwich recording technique was made by Kubota who used a dichromated gelatin plate for the green and blue components, and a silver halide plate for the red component of the image.[5] Kubota's sandwich color hologram of a Japanese doll recorded in 1986 clearly demonstrated the potential of high-quality color holography. Subsequently when panchromatic silver halide materials for color holography became available, Bjelkhagen *et al.*[6] demonstrated the possibility to record color holograms in a single-layer emulsion.

In spite of the volumes written about photographic science very little is specifically known about the making of very small photo-sensitive particles, i.e., the ultra-fine grain crystals in the 10 nm size region needed for color holography. Over the last few years there are some panchromatic holographic emulsions with 10-20 nm grains suitable for color holography. For example: the Russian *Sphere-S* emulsion[8] and the *SilverCross* material.[9,10]

2.1 Denisyuk color recording setup

There have been theoretical investigations carried out which studied the minimum number of laser wavelengths needed to give an error in color rendition that is small enough to be undetectable by an observer. These investigations indicate that more than three RGB wavelengths are needed for very accurate color rendering in a hologram. Four to five optimal laser wavelengths are needed. So far we have used a setup with only three RGB laser wavelengths which is illustrated in Fig. 1. However, the color rendering is already very good, but all colors of the object may not be exactly right with only three laser wavelengths. For realistic holographic images the single-beam Denisyuk reflection hologram is best. For display purposes, the large field of view obtainable in a single-beam hologram is most attractive (180-degree horizontal and 180-degree vertical). The different laser beams necessary for the exposure of the object pass through the same beam expander and spatial filter. The 'white' laser beam illuminates both the holographic plate and the object itself through the plate. Each of the three primary laser wavelengths forms its individual interference pattern in the emulsion, all of which are recorded simultaneously during the exposure. In this way, three holographic images (a red, a green, and a blue image) are superimposed upon one another in the emulsion. Three primary recording laser wavelengths are: 476 nm, provided by an argon ion laser, 532 nm, provided by a continuous-wave (cw) frequency-doubled Nd:YAG laser, and 647 nm, provided by a krypton ion laser. Two dichroic beam combiners are used for adding the three laser beams. By using such beam combiners, simultaneous exposure of

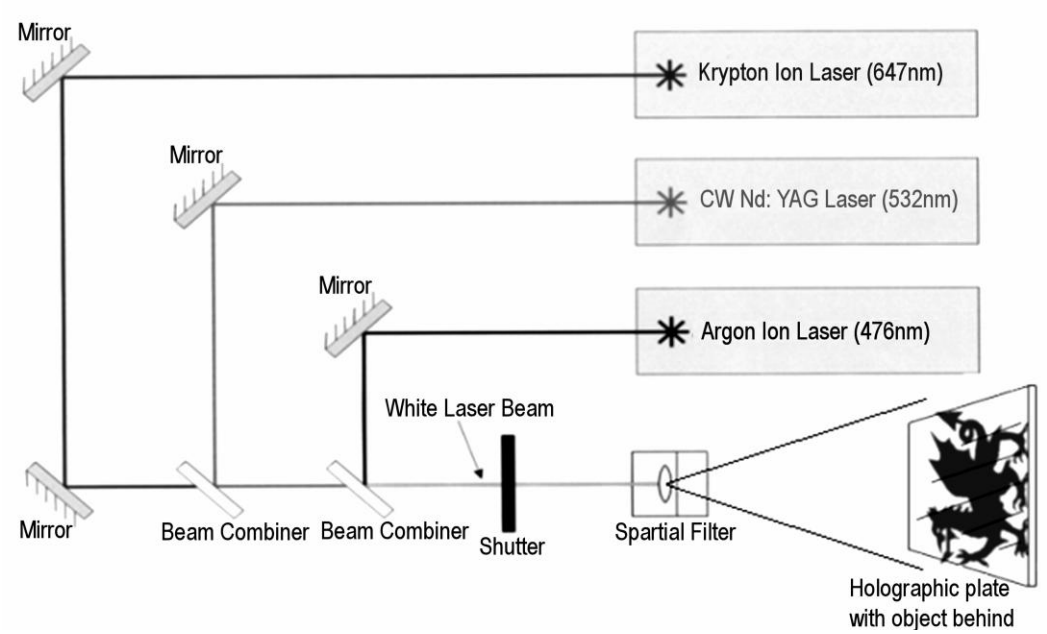


Fig. 1. A schematic of the set-up typically used to record the museum artifact color holograms

the holographic plate can be performed. This makes it possible to control independently the RGB ratio and the overall exposure energy in the emulsion. The RGB ratio can be varied by individually changing the output power of the lasers, while the overall exposure energy is controlled solely by the exposure time.

3. THE MUSEUM COLOR HOLOGRAMS

3.1 Recording of the selected artifacts

Listed in **Table 1** are the artifacts which have been recorded for the touring virtual exhibition. The museum artifacts were brought to Centre for Modern Optics' lab at different occasions during 2009. Each artifact was positioned on a horizontal aluminum plate placed on the recording table. The recording holographic plate was positioned above and very close to the object. During the exposure, the divergent 'white' RGB laser light illuminated the object through the holographic plate at about a 45-degree angle from above. Because of a rather long exposure time (30 to 90 s) the object and the recording equipment have to be stable. Several original holograms were recorded of each artifact to assure that a perfect hologram could be selected for the exhibition. After processing the exposed hologram plate it was sealed to a black glass plate using an index matching optical cement. The 14,000 year old horse jaw bone was the first artifact to be recorded.[11] The jaw bone was positioned on a red-painted aluminum plate placed on the recording table. Shown in Fig. 2 is the jaw bone placed on the aluminum plate with the recording holographic plate positioned above it.

3.2 Museum display of the recorded color holograms

The first museum to host the touring hologram exhibition was Llangollen Museum in Wales. The color holograms were installed in the museum with detailed information of each artifact. A photo of the author (HB) next to the horse jaw bone hologram at the Llangollen Museum exhibition is shown in Fig. 3. In Fig. 4 the author (AO) is looking at the iron axe display at Llangollen Museum and a photo of the axe hologram is reproduced in Fig. 5. Figures 6 – 8 feature photos of the Tudor Owl Jug hologram; the Seal Box hologram; and the Burton Hoard hologram; respectively.

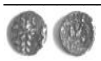
	**Bronze Age Axe Head**	Llangollen Museum
	**Burton Hoard**	National Museum of Wales
	**Iron Age Coin**	Denbighshire Heritage Service
	**Decorated Horse Jaw**	British Museum
	**Seal Box / Roman Beads**	Bangor Museum
	**Llyn Cerrig Bach Plaque**	National Museum of Wales
	**Roman Brooches**	Rhyl Museum
	**Stone Relief of Mars**	National Museum of Wales
	**Tudor Owl Jug**	Grosvenor Museum
	**Sgt at Arms Ring**	Grosvenor Museum
	**Lead Dove** (late 1400s)	National Museum of Wales
	**Bardsey Crown**	Liverpool Maritime Museum

Table 1. Recorded artifacts from different museums

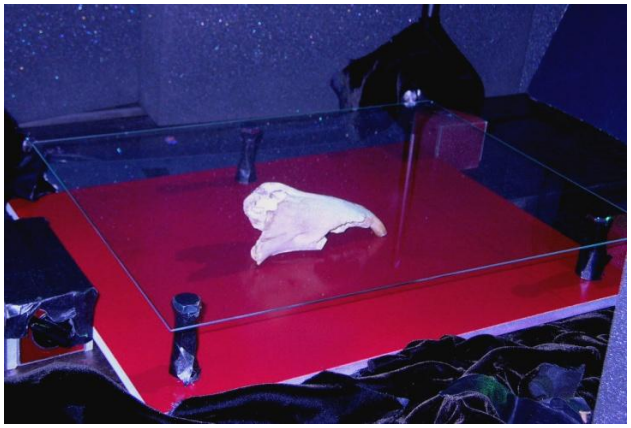


Fig. 2. Horse jaw bone recording setup

Fig. 3. The author (HB) next to the Horse Jaw hologram

Fig. 4. Author (AO) at a Llangollen museum display

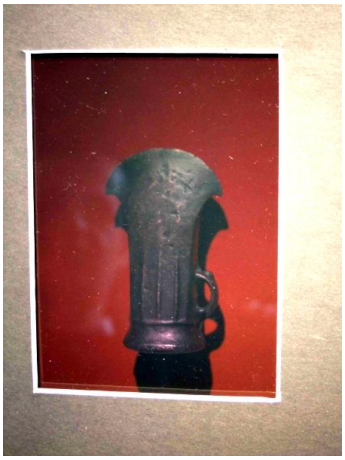


Fig. 5. Iron Axe color hologram

Fig. 6. Owl Jug and Ring hologram

Fig. 7. Seal Box hologram

Fig. 8. Burton Hoard hologram

4. CONCLUSION

The virtual color image behind a holographic plate represents the most realistic-looking 3-D image of an object that can be recorded today. The extensive field of view adds to the illusion of beholding a real object rather than portraying a mere image. Good color rendering can be achieved through choosing the optimum recording laser wavelengths within the visible spectrum. The application of color holography to the '*Bringing the Artifacts Back to the People*' project demonstrates how both museums and the tourist industry alike could exploit this new 3-D imaging technique. Most likely this is the first museum exhibition created entirely from color holograms. The best strategy for the application of this technique on a larger scale would require proactive encouragement of curators and designers to think of using holography in this way. The future use of which will also depend on cost effectiveness and the development of portable recording equipment.

Color holography offers a route to novel display techniques and enables those artifacts deemed too fragile for display to be shown. This technology can also be applied to 2-D objects such as oil paintings.[12] Holograms will not fade even after continuous display, suggesting a potential application for the reproduction and exhibition of vulnerable textiles.

Overall, holography offers a means of reproducing rare, precious or high value artifacts to be displayed, where museum protocols are otherwise prohibitive. Museum objects are both extremely valuable and vulnerable, the reason why so few ever leave a museum. For those that do, the ever-present danger of damage leads to high insurance costs. Keep in mind that air and light itself can lead to damage to some objects over time. Valuable historical items must be highly protected to ensure a safe journey into the future for generations to come. Recording the objects as 3-D color holograms allows the image of an object to leave a museum, increasing the number of people who can experience the history of the object and its place within our culture. You can only have one "real" object -- but you can have numerous holograms of that object being viewed in many different locations, by large numbers of people, all at the same time.

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