**HOLOGRAPHY**

**Recording and reconstructing wavefronts**

In 1947, Denis Gabor invented the technique of recording wave intensity and phase information by means of a background wave, which converts phase differences into intensity differences.

He was awarded the Nobel Prize in Physics in 1971 “for his invention and development of the holographic method”.

A hologram is a record of the interference pattern formed by the signal and the background (reference) wave. The hologram can reconstruct the signal wave.

The advent of the laser made optical holography a reality.

*Left* and *right* side show the optical reconstruction hologram recording in 2012.

These holograms were viewable only by laser illumination.

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**IS IT POSSIBLE?**

A. An observer interacting with the light waves from an object perceives the object in 3D.

B. A suitable storage medium encodes and stores permanently the light wavefronts.

C. The object is removed and the storage medium reconstructs, upon proper illumination, the stored wavefronts.

D. An observer interacting with the reconstructed waves perceives the object as really existing behind the storage medium!
Holograms of cultural artifacts ...

The display case contains a monochrome (yellow-tuned) hologram which is an example of how a hologram can be used in a museum when the real object cannot be on display.

Lindow Man at the British Museum

The Lindow Man was found in the peat bog at Lindow Moss, Cheshire, in August 1984. It was carefully transported to the British Museum and thoroughly examined by a team of scientists. A monochrome (yellow-orange tuned) hologram was recorded by Richmond Holographic Studios using a pulsed ruby laser.

USSR Hologram Exhibition in London

Because of the high-quality of the Denisyuk reflection holograms in the former USSR, museums in these countries were keen to apply and accept holography. A selection of these holograms was brought to the West at the 1985 exhibition ‘Holography – Treasures of the USSR’ at the Treasurers Centre in London, UK.

Soviet scientists used monochrome holography in the 80s to bring “art to the people”

-Russian 1983 Monochrome Hologram

Monochrome Denisyuk reflection hologram on early production PE-2 (Slavich) glass plate. Size 40x28 cm landscape, by M. Slavich

Full Colour

Theoretical and Practical Considerations

- Suitable selection of three or more laser wavelengths
- Panchromatic recording plates with mean grain size well below 10 nm
- Optimized processing of the exposed plates
- Suitable recording geometry to eliminate dispersion
- Mechanical and thermal stability
- Optimized illumination of the colour hologram to enhance depth reconstruction, colour rendition and minimize blur
- Transportable recording system instead of massive laboratory isolation tables and lasers.
Museum Artefacts Recorded in a Laboratory

Bringing the Artefacts Back to the People was a UK project to record colour holograms for a touring exhibition. One of the first artefacts to benefit under this project was the 14,000-year-old Decorated Horse Jaw Bone from the ice age. The bone is the only piece of artwork dated to the end of the last Ice Age or Late Glacial period in Britain. It was dug up by Thomas Kendrick in 1880 and is kept at the British Museum in London.

The OptoClone of the horse jaw bone was recorded at the Centre for Modern Optics (CMO) in Wales on 21 April 2009.

Decorated Horse Jaw Bone Recording

Photo of the OptoClone

Decorated Horse Jaw Bone OptoClone

Photo of the recorded OptoClone plate, size 30x40cm

Tudor Owl Jug and Sergeant at Arms Ring

The recording of the Tudor Owl Jug (16th Century) and Sergeant at Arms Ring. The Artefacts are from Grosvenor Museum in Chester.

Bringing the Artefacts Back to the People

Recording setup

Elisabeth Royles, Grosvenor Museum, Chester

Llangollen Museum Hologram Exhibition
To introduce this new ultra-realistic imaging technique to museums and make it feasible for them to use it, it is essential to use mobile holographic recording equipment.

It would be out of question to bring very rare and expensive artefacts to a holographic laboratory.

Today we have many small powerful lasers on the market which makes such equipment possible to develop.

Our approach: The Z3RGB system

Laser wavelengths

Light sources made up of different mixtures of various wavelengths may appear to be the same color; this effect is called metamerism.

Such light sources have the same apparent color to an observer when they produce the same tri-stimulus values.

Suitable selection of 3 wavelengths would cover a sufficient area of the CIE chromaticity diagram.

We use lasers at 457, 532, and 638 nm.

Why?
Close matching to the emission characteristics of available power LEDs for our HoloFo hologram illuminating device and the spectral response of the human eye.

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Mobile Hologram Recording Principle

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**Transportability**: the Z3RGB system

- Transportable
- Vibration and thermal isolation.

**Light for Illuminating Colour Holograms**

The selection of a suitable lamp for the correct reconstruction (illumination) of colour holograms is much more critical than the selection of lamps for monochrome hologram display.

The colour balance for the recording of a colour hologram must be adjusted with the type of light that is going to be used for the display of the finished hologram in mind.

Colour reproduction in a reflection hologram is only correct when the light is illuminating the hologram at a specific angle.

**Our approach: Stability**

- Electronics, control and monitoring of all exposure parameters.
- Continous laser mode lock monitoring.
- Two-shafts passive isolation platform.
- Specially designed mobile tent chamber that encloses the object/plate space in order to minimize air currents and ensure thermal stability during the exposures.

**Display of Reflection Holograms**

Layout's diagram showing the importance of using a point source light to illuminate a hologram. Here we make an analogy to the shadow cast by a spotlight on a screen. In (a) the spotlight emits light from a small point, resulting in a sharp image. In (b) a large area diffuse spotlight results in a diffuse image. In (c) many spotlights illuminate the hologram, resulting in multiple images.

**Our approach: Illumination**

- No detectable image blur (spatial or chromatic)
- Same scale (vertical / horizontal)
- Very accurate colour rendition
- It looks “identical” to the real object as observed by eye
- Very accurate colour rendition
- Same scale – no magnification
- Resolution corresponds to the eye resolution
- No detectable image blur (spatial or chromatic)
- No field of view limitations
- Image light reflections move like they do on the object

**RESULT: OptoClones™**

- One-to-one size depiction
- Natural colour rendition (RGB)
- Full detail (surface texture) and contrast
- Laser light resolution (nm)
- Full Parallax (vertical / horizontal)
- ±180 degrees viewing angle
- Moving light reflections
- Perfect light shadows
- Full replication of optical properties of object

If accessible only through vision, the object is really present for the human brain with its optical replica indistinguishable from the original object.

**What is an Ultra-Realistic Image?**

- **ONLY HOLOGRAPHY** can accomplish this and is now referred to as an OptoClone
The (Thessaloniki) Museum of Byzantine Culture

On Jan 19th, 2014 the temporary exhibition titled "The Veneration of St. Mamas in the Mediterranean: A Traveler Border-Defender Saint" organized by the Thessaloniki Museum of Byzantine Culture (MBK) as part of the 4th Biennial of Contemporary Art came to a successful end.

Byzantine and Christian Museum

‘Heaven and Earth’: Art of Byzantium from Greek Collections


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The Fabergé Egg OptoClone Project

The Fabergé Egg OptoClone Project in the USA contained nine of the Imperial Easter Eggs. In 2004 these eggs were acquired by Viktor Vekselberg for about $120 million. He brought them to Russia to be displayed to the general public in St. Petersburg. In November 2013 the Eggs were finally put on display at the new Fabergé Museum located in the Shuvalov Palace in the centre of St. Petersburg. The museum contains a total of approximately 4000 works of fine art and decorative applied art, including gold and silver items, paintings, porcelain, and bronze.

A multi-national project

- **Transportable proprietary equipment**
  - ZZyclops
  - Dark room

- **Special holographic glass plates**
  - Panchromatic high-resolution silver-halide

Fabergé Egg and OptoClone

The 15th Anniversary Egg in the museum display
A collection of 13 OptoClones

2-D Art Reproduction

It may sound strange, but actually, recording OptoClones may become an important reproduction technique for 2-D objects as well, such as, e.g., oil paintings – providing extremely realistic-looking images, showing the texture details such as brush strokes and the painter’s signature. In addition, they will not fade or change colour even if they are continuously on display.

This fact is of importance from an archival point of view as well. Insurance companies may require reproductions of very expensive works of art in case they are stolen or damaged. If perfect colour rendering can be obtained in OptoClones, accurate 2-D art reproduction may become important in the future.
‘Seeing is believing’...

... is it really?

Thank for your attention