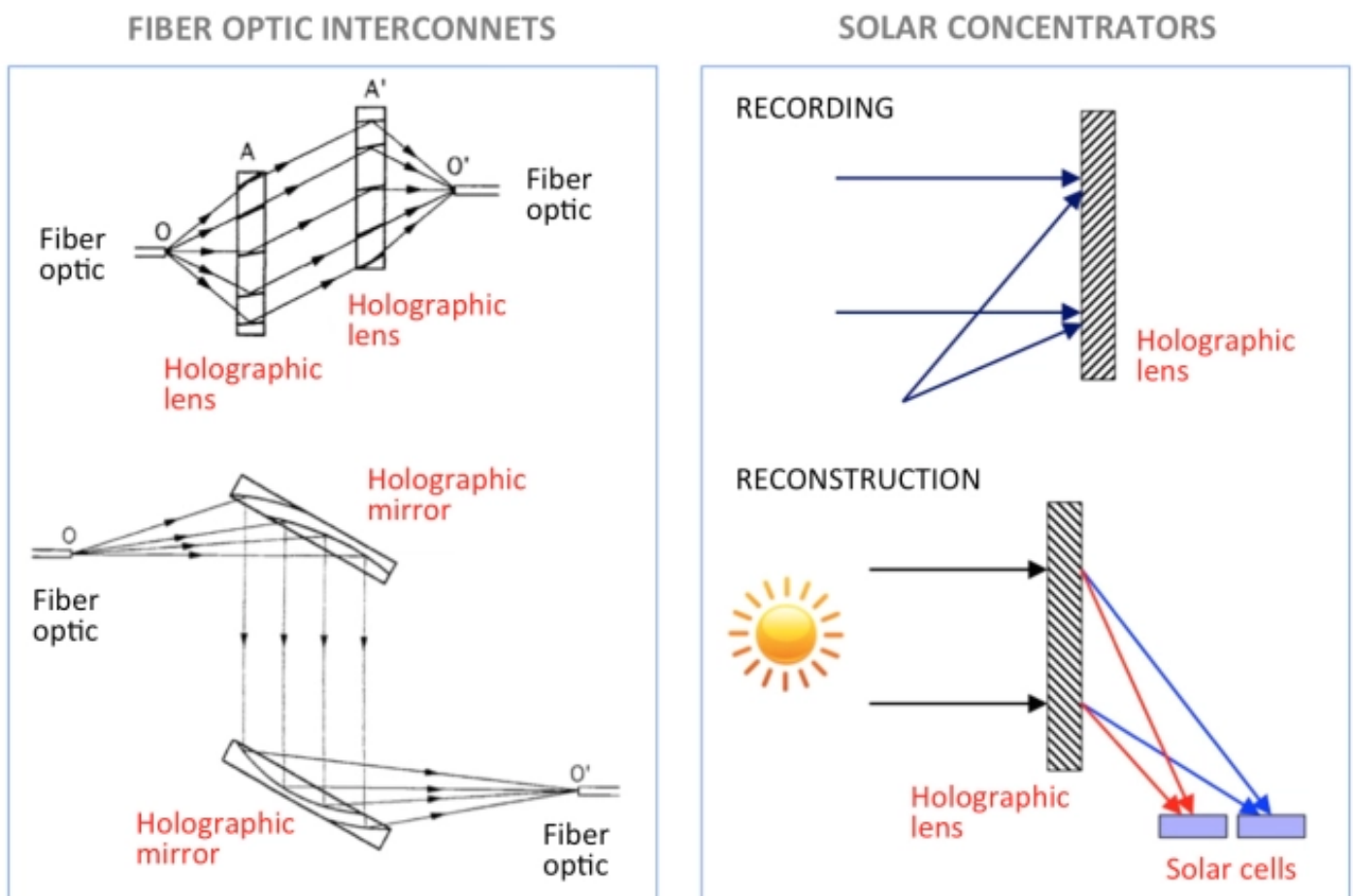


# International Year of Light Blog

## What can be achieved with holography?

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“Holography by itself is a somewhat narrow field, but combine it with others and it makes an area big enough to spend a lifetime in,” stated [Emmett Leith](#) (<https://spie.org/membership/spie-professional-magazine/spie-professional-archives-and-special-content/spie-professional-archives/archived-issues/april-2006/membership/in-memoriam-emmett-leith-1927-2005>) (1927-2005), the “reinventor” of the holographic process and co-inventor of the 3-D hologram. Proof of this is the fact that holography has provided and continues to provide innumerable applications in a multitude of scientific and technical fields. Moreover, it is one of the “rare” scientific fields that has provided a medium for art. It is difficult, if not impossible, to enumerate all the developments and applications based on holography so the following is a review of just some of them.



Holographic optical elements (HOE). Credit: A. Beléndez.

Although reconstructing a three-dimensional image which appears to be in perfect relief is undoubtedly one of the most spectacular and well-known achievements of holography, there are many other applications in very diverse fields. As we know, the first emission laser was obtained in 1960 (<https://light2015blog.org/2015/05/27/55th-anniversary-of-the-lasers-invention/>), the first hologram of a 2-D object in 1963 and that of a 3-D object in 1964. One of the first scientific and technological applications of holography, holographic interferometry (<https://light2015blog.org/2015/07/21/other-anniversaries-celebrated-during-the-international-year-of-light-2015/>), commenced just a year later in 1965, exactly fifty years ago, and is an extremely powerful non-destructive analysis method. With this technique it is possible to visualize the vibrational modes of musical instruments, study the deformation of objects under stress or analyse the temperature distribution, for example, inside a light bulb. Along the lines that appear on the interferogram of the image the temperature is constant. This technique may be applied to study transport phenomena, visualize fluid flow, measure components in hostile or corrosive environments and perform non-destructive testing. It may even be applied in other fields such as orthopaedics to study bone deformations and prostheses, or in studies concerning the conservation and restoration of works of art.

Analysis of microscopic particles distributed in a certain volume is another field in which holography has proven to be very useful. In this case, both on-axis and off-axis configurations may be used and a pulse laser is normally employed. This technique allows the size, position, displacement and velocity of particles to be analysed and makes it possible to study from aerosols to marine plankton. It has even been used to analyze the dynamics of microscopic particles and growth of crystals in conditions of microgravity in experiments carried out on board the space shuttle Discovery twenty years ago, in which over a thousand holograms were recorded, thereby providing a true “virtual” space laboratory on Earth.

Holographic techniques are used to manufacture holographic optical elements (HOE) such as diffraction gratings, mirrors and other more complex devices such as optical fibre interconnectors or solar concentrators using holographic mirrors or lenses. Then there are holographic scanners used to read bar codes which consist of a disk divided into sectors each of which is a holographic lens that deflects the incident light in a specific direction.

Holographic visors form an image at infinity of information displayed on a screen and superimpose it on the outside scene. These visors have been incorporated in fighter-pilot helmets as well as inside the aircrafts themselves. Last year, the firm TruLifeOptics (<http://www.trulifeoptics.com/>), composed of members of the National Physical Laboratory (<http://phys.org/news/2014-07-optical-component-revolutionise-augmented-reality.html>) and the company Colour Holographic, both based in Great Britain, presented some glasses consisting of two holographic optical elements (HOE) which also enable the information provided by an electronic system to be seen simultaneously with the outside scene.

In our society, dominated by information technologies, the use of holography to store information is currently one of its most interesting applications. Multiplexing allows a large number of holograms to be recorded on the same plate and the individual holograms subsequently recovered. This is the principle of holographic memories in which a great amount of information may be stored in a small space. Although the greatest technical difficulties in implementing this technique concerned finding a suitable recording material, the first prototypes of holographic storage systems have already been produced using holographic discs with a storage capacity of 300,000 MB, and there is even talk of terabyte discs.

It is possible to obtain computer generated holograms (CGH) in which the inferential diagram over the surface of the hologram is calculated by computer and represented, for example, in a spatial light modulator (SLM). These holograms are just part of a wider field known as digital holography.

In 2014 a paper was published in the journal *Advanced Optical Materials* ([https://www.youtube.com/watch?v=EAhcEmYF-3k&index=1&list=PLoGFizEtm\\_6gKDenYwsusbmM14L2tsVDk](https://www.youtube.com/watch?v=EAhcEmYF-3k&index=1&list=PLoGFizEtm_6gKDenYwsusbmM14L2tsVDk)) which demonstrated the possibility of using holographic sensors based on the properties of reflection holograms, in particular Bragg's law. When these sensors are illuminated by white light, the colour of the diffracted light depends on the variation in thickness of the hologram since the distance between the stored interference fringes varies. This application has been proposed, for example, to measure pH and even for use in medical diagnosis.

Security holograms are perhaps the most important holographic application from a commercial point of view. The technical difficulty involved in making holograms and the fact that complex sophisticated means are needed to produce a series of copies of the original hologram has made holography a suitable technique for use in security systems such as those found on credit cards, banknotes, identity documents or commercial product labels, including the labels on some pharmaceutical products sold in Southeast Asia, where the sale of illegal medicines is widespread. In all these cases, holograms are used in an attempt to prevent falsification or at least make it as difficult as possible. Likewise, holographic methods are being introduced to authenticate fingerprints.

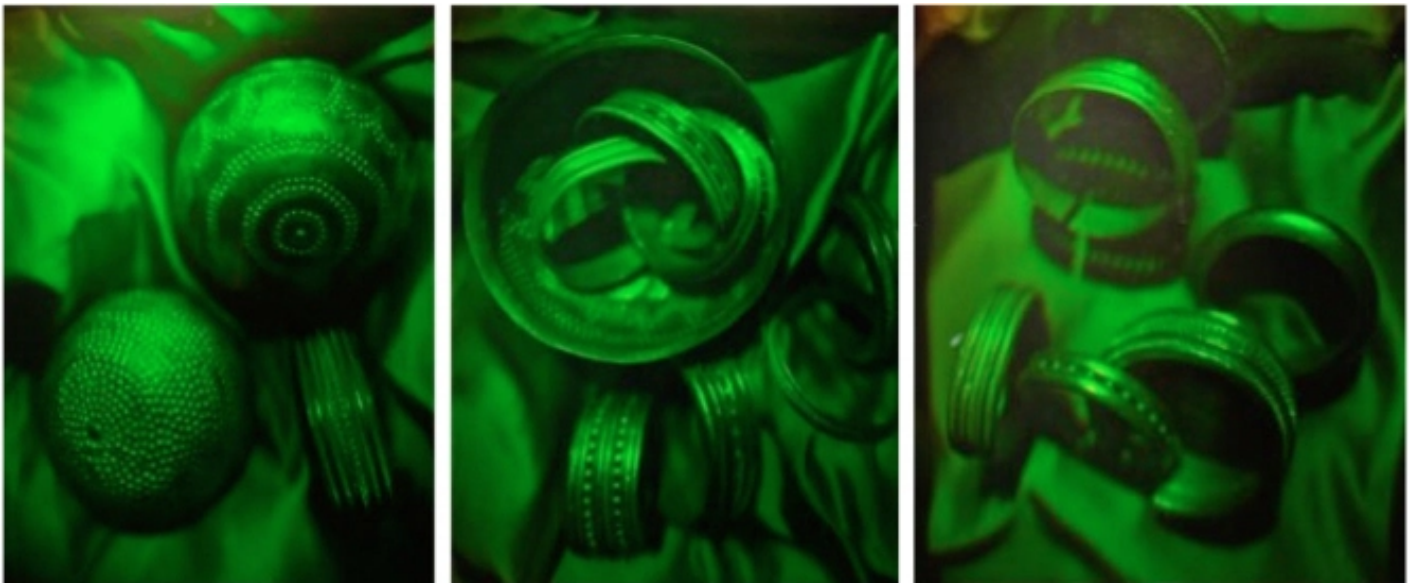


Holograms of the 5 euro note. Credit: Wikipedia.

The problem with holograms recorded using a single colour laser light is that when they are reconstructed they are that colour. However, full colour holograms may be obtained if three lasers (red, green and blue) are used in the recording process. The picture shows the set-up for

recording a colour reflection hologram used by Hans I. Bjelkaghen. The fidelity of reproduction of shapes, colours and brightness is so spectacular that it is difficult to tell whether we are looking at the object itself behind a glass window or at a holographic reproduction.

Holography has been used by museums to substitute certain valuable delicate objects by holograms. This was the case of Lindow Man, a mummy over 2300 years old found in Cheshire, England, in 1984. The original is kept at constant temperature and humidity in a vault in the British Museum in London, whereas a hologram of the mummy was made and put on exhibition so that it could be seen by the general public and studied by various researchers. Making holograms of valuable pieces allows the latter to be viewed in places other than where they are actually kept. Denisyuk type holograms were used in the former Soviet Union and other countries, within the framework of a vast programme of collaboration between physicists and museologists, to conserve works of art considered archaeological treasures. In fact, the Denisyuk technique is often used to substitute the original objects by holograms in travelling exhibitions. In 1984 at the University of Alicante a series of reflection holograms of the treasure of Villena were made.



Reflection holograms of the Treasure of Villena made by J. A. Quintana at the University of Alicante (Spain). Credit: A. Beléndez.

Stephen Benton (<http://www.osa-opn.org/Content/ViewFile.aspx?id=3598>) (1941-2003) stated that creativity does not belong exclusively to the domain of art, it is present in all areas of our existence and one of the most interesting aspects of holography is the symbiotic relationship that exists between science and art. Indeed, holography has been used as a medium for art as we mentioned in an earlier article ([Holography: Art with light](https://light2015blog.org/2015/11/05/holography-art-with-light/) (<https://light2015blog.org/2015/11/05/holography-art-with-light/>)).

Finally, holography may be applied using a large part of the electromagnetic spectrum, from microwaves and radar, through infrared radiation, visible spectrum and ultraviolet radiation to X rays. It is also possible to use beams of electrons or neutrons or even sound beams. There are artistic holograms, holographic portraits and colour holograms. Holograms may be found in gift shops, museums, books, and on greeting cards or postage stamps. Security holograms are big business: in addition to credit cards and banknotes there are holograms on the labels of certain products such as sportswear to ensure their authenticity and distinguish them from imitations. Holographic interferometry is a technique used in very diverse areas; holographic

optical elements are used in a great variety of optical systems; holographic information storage is now a reality, and holography is also present in fundamental physics research such as the theory of relativity or quantum physics. In the almost seventy years holography has existed and despite its somewhat erratic beginnings, there is no doubt that it has a great past and a magnificent present; however, what is certainly undeniable is that it continues to have a most promising future.

### More Information

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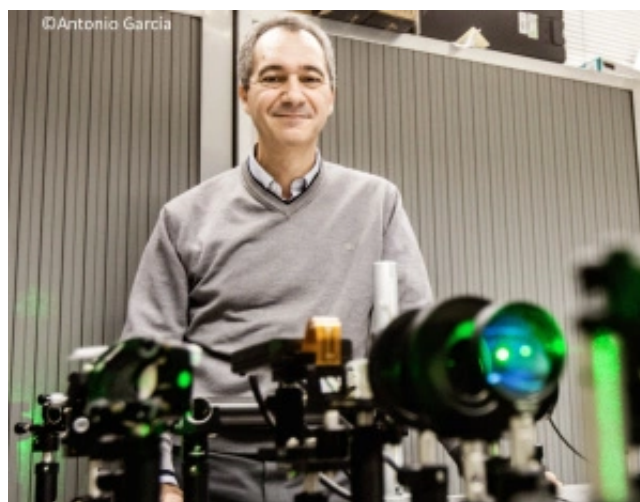
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He is active in public outreach: he has published numerous articles in popular science journals, and in the media. In 2009 he started the blog "[Física para tod@s](http://blogs.ua.es/fisicateleco)" (<http://blogs.ua.es/fisicateleco>), and he has given some talks to general public on science.

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