ADVANCED HOLOGRAPHY – METROLOGY AND IMAGING

Edited by **Izabela Naydenova**

INTECH

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Holoimages on Diffraction Screens

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1. Introduction

What is a hologram? Even if holography was described in a single paper by its creator, there are many descriptions for such a widely divulged phenomenon, known all around the world. Many techniques and elements are entitled "holographic", but they can be classified in two main groups, the "academic" and the "popular" ones. I realized this in July 1989 in a Bulgarian holography meeting when showing my white light holographic screen to Yuri Denisyuk, whom I consider to be the second inventor of holography. He asked if the image I was showing came from a hologram, and my answer was the question "What is a hologram?" His answer was: "Does it employ a reference beam?". My answer was no and then I learned how to introduce the holographic screen techniques in science, not as holography, which is a combination of interference, recording and diffraction, but as a combination of interference, recording, projection of images acquired by any other technique, and diffraction. The projection is made on a fine diffracting structure of about 1,500 lines/mm in such a way that each eye receives a different image which corresponds to the parallax of a 3D scene. But when I showed my projections to people they mostly believed they saw holograms. For them, a hologram is an element which shows 3D in an at least apparent parallax without needing any complementary goggles for the eyes. I call this a popular definition of holography and it can be applied to holographic screens and to auto-stereoscopic systems, provided they reach at least apparent continuity. Non-diffracting auto-stereoscopic techniques are hardly trying to reach this.

A holographic screen, which from now on I will name commonly as a diffractive screen, consists basically of the hologram of a diffuser whose format is designed to create an observation space for the image projected on the screen. This observer's position field is obtained using reverted illumination, i.e., illuminating the screen in the opposite direction to the reference beam. In this way we can generate the more directional screen which is possible nowadays, in large format and employing lightweight and unbreakable materials. Gabor himself tried some ways to make stereoscopic screens without the need of additional goggles or filters (1). The screen obtained by recording an interference pattern, in a holographic manner, is a way for doing that.

2. The hologram as a diffuser

The construction of a surface that generates a luminous distribution at will is not a simple task. Even assuming that, as the light is going to reach a long distance, its distribution in a diffuse light vertically for the observer to see the whole projected image can then be obtained by making the hologram of a rectangular shape diffuser. The converging image which results from illuminating in a direction which is opposite to that corresponding to the reference beam occupies the zone where one observer's eye must be located. And the focusing property of the screen generates another observation zone for the other eye provided that the angular separation of the two projectors to one screen point matches the binocular separation for the observer, obtaining by diffraction the effect of Ivanov's screen by refraction and reflection.

The idea was patented (8), but I do not know if any prototype was made.

It was conceived as a thick (Lippmann-Bragg-Denisyuk) hologram to avoid the simultaneous viewing of more than one image due to the spectral dispersion, so that the proposed solution was purely monochromatic. It still presents two of Ivanov's screen problems: different angular separation for binocular vision at different distances from the screen and the observer having to keep his head at an almost fixed position. While adding the lack of poly-chromaticity, it dispenses with a three-chromatic procedure to be applied for color reproduction.

6. Diffractive screens applied to holographic cinematography

To obtain holographic-like images employing incoherent light it is common to mount a set of discrete images in sequence giving the illusion of a continuous parallax system. The first example was maybe from Lloyd Cross with his integral hologram of 1972 (9), made of more than one hundred pictures acquired by means of a laterally translating movie camera. Many views are necessary to cover a wide parallax angle. We may calculate that by considering that the pupil's eye is about 3 mm wide and that it must pass from one observation region to its neighbor region without perception of a discontinuous jump when following any point in the image.

Holography is the only recording system which provides continuous parallax. A holographic image can be enlarged by means of a concave mirror, for example, but the viewing zone is restricted to only one observer and the longitudinal magnification is always different from the transverse one. The way to cinematography was paved by Komar (10) who succeeded in projecting a large size holographic image by means of a diffractive screen. He recorded a large size scene of about 1 m x 1 m, capable of including a person, through a large aperture objective (200 mm) having also a large angular aperture on a 70 mm format film. Reconstructing by inverting the direction of the reconstruction beam puts the image in the precise position occupied by the object, enabling the correction of distortions and aberrations. But this image cannot be seen by an observer because he must receive the rays in a position from which the image has a reversed depth and can only receive rays coming from the aperture of the lens, much smaller than the whole scene. A conventional diffusing screen would only show a plane image. A diffracting screen made as the hologram of a concave mirror (11) may direct each of the viewpoints on the scene to a continuous viewpoint sequence and, through the proper managing of the diffraction order in the horizontal direction, invert the depth, showing an orthoscopic image. Multiple exposures with changing reference beam angles give the possibility to provide full parallax to more than one observer.

In a second approximation, we can consider the diffractive screen as a diffracting lens, that is, a bi-dimensional grating which puts the light it receives converging to a unique position, as a convergent ordinary optical element. A diffracting lens is obtained directly by a hologram made with two point sources. If we project in monochromatic light, the screen acts as the one of Komar, but, projecting in white light and making the screen with the point sources from the same side of the film, the diffracted transmitted images are affected by a horizontal dispersion. The same basic property that gives orthoscopic and pseudoscopic images with two gratings corresponds now to the same images but seen all over the screen extension. When the observer moves laterally, he receives continuous view sequences of the object. In this way it has been possible to observe the enlarged image of objects on a one square meter screen but an intense reduced size projection lamp and a dark ambience is necessary. To avoid the need of having the observer watching at a very precise height, one point source in the the interference process process is substituted by a thin vertical diffuser. It gives the vertical size of the observation region but with a reduced image brightness. Besides the limited diffraction efficiency, another brightness limitation results from the need of a thin slit on the projecting lens to get maximum focal depth.

9. White light holographic cinematography

The spectral depth coding by diffraction was first discovered in holograms (18) and matches perfectly the projection on diffracting screens generating the image through the diffracting

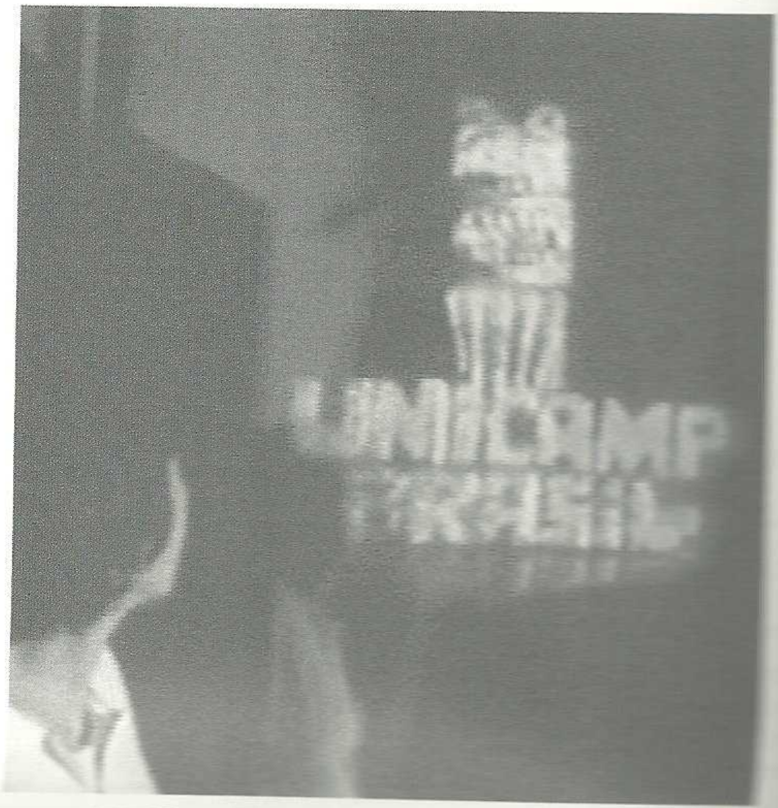

Fig. 6. Hologram made in 35 mm film enlarged x40 by using white light

Fig. 11. A LCD transmission watch as seen in the linear source projection

An improvement of this technique that can be expected would be a way to make the image appear in front of the screen and a way to illuminate from inside of its transparent support, in a similar way to the so-called "edge lit" holograms (29).

12. Not holographic diffractive screens

If the term "holographic" corresponds to Gabor's idea of wave reconstruction, it should be applied to cases in which the interest is precisely the reproduction of waves, like in the case of imaging or holographic interferometry techniques. In that sense, the construction of a diffractive element by interferential means does not give to it the holographic characteristics. If the name "holographic" is given because a three-dimensional continuous parallax image results on the element, it is because the popular sense of the term is being employed. That is why the term "diffractive screen" was widely employed in this text. To reinforce the idea