12

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

plane may correspond to the Fourier transformation of the transmission or reflection surface properties. It is not completely correct to suppose that, because the Fourier transformation can only be applied in a paraxial approximation, and the angles we need to achieve do not always have this limitation. But, assuming the hypothesis, we could obtain the desired surface profile by using the inverse Fourier Transformation of a light distribution that we define as the desired one on the lighted plane.
How can one construct such a microstructure on the surface? Which machining technique would be useful? Could we replicate it in a rapid and cheap way?
We understand that if we make the hologram of a surface of any profile the surface of the resulting hologram is effectively a diffuser with the diffracted light intensity profile of the original surface. It is a fact that diffractive elements made by holography begin to be employed for designing illuminating systems, working with monochromatic or nearly monochromatic light (2). Although the efficiency of an easily replicated hologram is less than 25%, the concentration of the light strictly at a desired region may compensate and even overcome the problem in many cases, and holographic diffusers are on sale by many companies, one of the applications being the internal illumination of computer displays (3).

3. The diffractive screen helping to fulfill the observation field in multiple projections

The surface which, like a plane mirror or a hologram, should generate a light ray distribution which is equivalent to the originally generated by a three-dimensional object must have the capability to emit in a large angular field with directional intensity and color values corresponding to the scene which is being reconstructed. Each ray is the component of a luminous point to be constructed outside the surface, generally, in front of it. The three-dimensional image which floats in front of a screen is the one that most impresses the public, even more when the observer can pass his hand through.

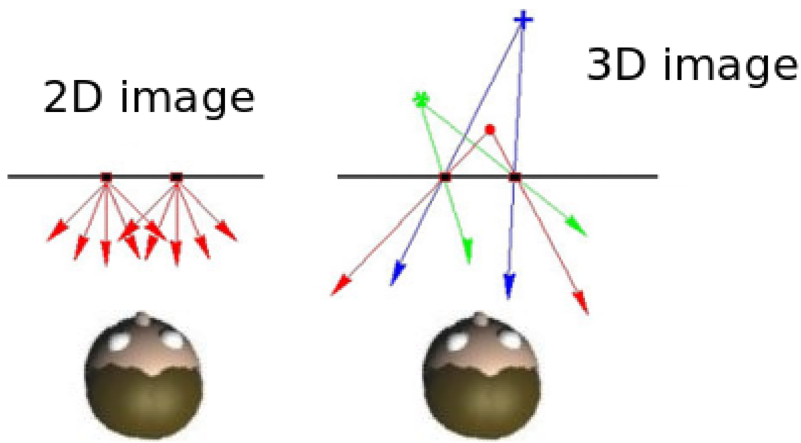

Fig. 1. Left: Ordinary diffusion at a screen. Right: Rays in an ideal three-dimensional display.

The capability to make such an element within a so-called pixel for a TV or computer display does not yet exist. A theoretical way to achieve it was patented (4) based on the location of a 2D micro-display at the focus of a small lens, each micro-pixel element being a ray generator. The number of pixels of a modern display should correspond to the number of volumetric pixels, also called "voxels". Each voxel is the origin of many rays and each ray comes from a sub-pixel of the ideal complete screen, so that we may think these as "ray pixels". An image in a volumetric space with the present pixel display capability for each voxel involves the need for much more pixelation at the emitting surface. The required resolution can be considered as the square of the present capability of 2D screens.

The addressing of those micro-pixels could be facilitated by coding techniques because in each micro-display one pixel's position would always have a corresponding pixel position in its neighbor micro-display, both beginning to a unique three-dimensional display point so that its color and intensity would be very close. Usually, colour does not change with the observation perspective, and the intensity angular change is a relationship which corresponds to a diffusion surface law that could be predetermined and does not need to be received as object information, as it happens in 3D computer drawing rendering.

A fixed relationship interconnects then each family of micro-pixels, each one belonging to one specific micro-pixel display element, and its implementation could be automatic to reduce the need for transmitted information. As such a system is not yet possible, the Holografika company (5) produces one in which a certain number of projectors is located behind a diffracting screen whose function is to produce a diffuse lobe so that as the observer moves, the transition of the light coming from one projector to the light coming from the neighbor projector does not have dark regions. The space region for the observer is then continued and no dark regions are present. The number of projectors must be about 18 and until now only images made by the computer have been shown and animated through simple movements. We can understand that the name "holographic display" given by the company to the system can only be accepted within the popular meaning described above; no light interference is present during the process, neither in practice nor in concept. It is the only commercial system claiming to have the appearance of a continuous parallax. It also claims that the light is directed so that the observer's eye focalizes effectively at the point where the image is represented, eliminating the difference between convergence and accommodation, one important element of visual discomfort.

To support such an assertion, it is necessary to prove that more than one ray exiting from different positions on the screen, those rays converging at the image, are seen by one eye. The commercial system has only a horizontal parallax, so that a certain degree of vertical astigmatism should be present in direct proportion to the eye's aperture. A similar system employing LEDs instead of projectors was proposed (6)

4. Non-diffractive screens for stereo imaging

Dennis Gabor asserted (1) that he and Semioj Ivanov simultaneously studied the possibilities of achieving a screen which could eliminate the need of special goggles. The original idea was developed almost fifty years before by Gabriel Lippmann (1), who employed thin cylindrical transparent elements assembled side by side. Gabor's description is very complete, but it was Ivanov who succeeded in installing the first (and still the only) 3D auto-stereoscopic cinema (7) in 1945.

Based on two cinema projectors placed side by side, the 3 m x 4 m screen was made of a set of thin vertical cylindrical lenses whose surfaces were as shown in the upper part of Figure

2, where the light that is focused at a short distance of the back surface is reflected with different angular orientation due to the different transversal position of each projector and in a multiple way because each lenticular element receives the reflected light with a different angle. Figure 3 shows the conical distribution of the elements necessary to converge the whole scene at the observer's positions. It is to be noted that much accuracy is needed to keep the distance corresponding to the right and left eyes positions so that there are limitations to the positions where observers can be, something common to every stereo system, if mainly auto-stereoscopic.

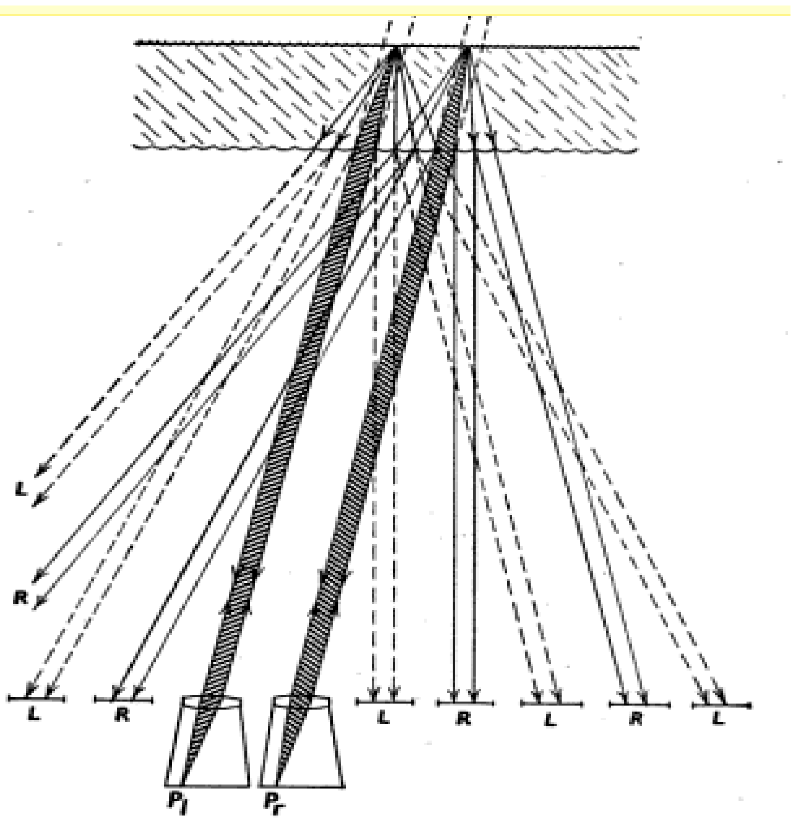

Fig. 2. Surface structure of Ivanov's screen (from Ref.1).

It is reported (1, 7) that Ivanov's theater could receive 180-200 spectators and that some movies were made for it, but it was discontinued because of the fact that the spectator needs to keep his or her head in an almost fixed position.

After Ivanov died Gabor tried to improve the technique by experiencing with mirrored elements with only vertically diffusing properties, eliminating the need for the conical assembly of elements, but he finally concluded that the production of such a screen would be too expensive and abandoned the idea.

After having performed some tests he thought that, if the depth of the scene could be limited, the observer could see the scene normally when one eye is receiving any view or even when the eyes are at positions when inverted views were received. That is, the monocular or pseudoscopic image could be seen as an orthoscopic one.

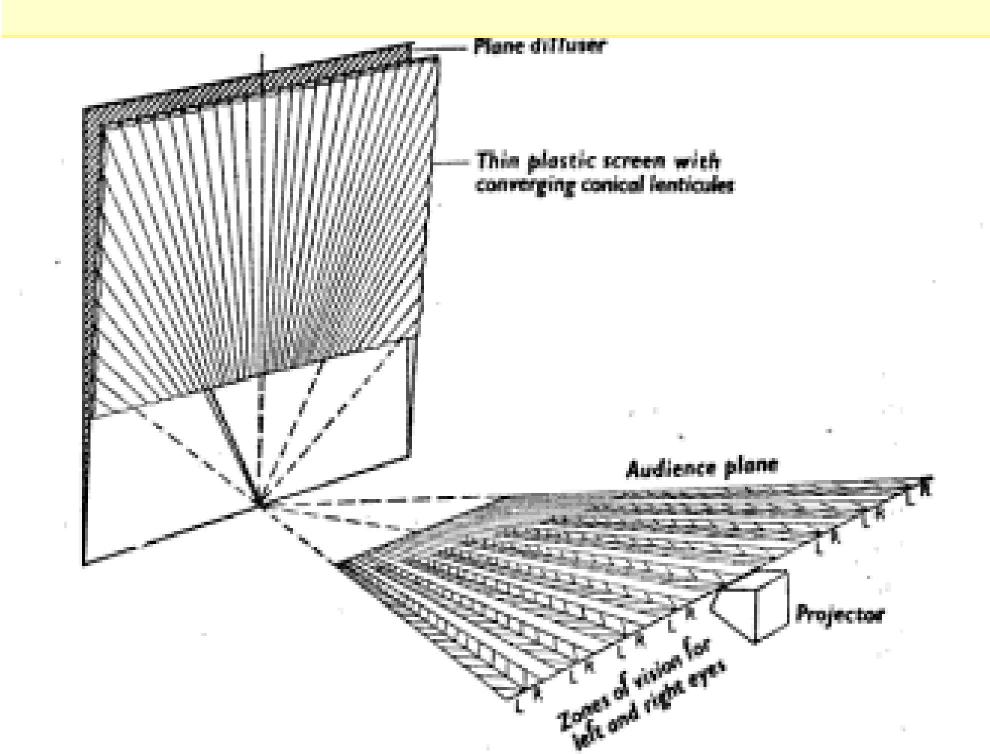

Fig. 3. Elements and vision zones at Ivanov's autoestereopic system (from Ref.1).

In my test of similar situations employing diffractive screens, I could mention a few people who could tolerate those cases. When there is lateral movement of the camera or some relative movement between objects, some 3D perception can occur to be explained by a sort of Pulfrich effect. For people who are very keen on 3D observation, as Gabor would be, it is certainly possible to perceive the depth in such situations.

5. Diffractive screens for stereo imaging

Once holography was discovered and its first practical applications performed, the possibility of employing a hologram not for creating images but for generating vision zones of projected images appeared. The roughness properties that Gabor wanted for the screen to

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 at the precise position occupied by the object, enabling the correction of distortions or 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 a 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 that way a Lippman-Bragg-Denisyuk hologram was made for the screen and its evolution made it capable of rendering color images by means of the three-chromatic procedure. It was discontinued, but constituted the only cinema system that can receive the academic term of "holographic", because recording was made by interference of the object light (a sequence of laser pulses) with a reference beam, recording and diffraction followed, and the concept of a holographic screen was introduced, giving continuous parallax and allowing the observer to move his head. The only visual shortcoming maybe came from the strict monochromaticity of the laser light beams. Living subjects were reproduced. The system cost was, of course, very high. While in need of more precise information, it was certain that at least eight people could watch a twenty minutes movie on the 1 m x 1 m square screen at a few meters distance.

7. On the parallax of a lens image

The very common use of photography has always rendered plane images and that is why it is normal to think that a lens image is plane. But we know that the images are three-dimensional and that it is the detecting system which makes the result to be in a plane. By closing or opening the aperture of a lens, one always captures the same plane scene but the sharpness of those elements not precisely focused diminishes at large apertures. When opening the diaphragm from his smaller diameter, the out-of-focus situation of the additional rays, which do not fit in the image generated by the center of the lens, happens because of the new perspectives added by the lens area being unobstructed. It is important to notice that they correspond to the viewpoint of each area part being unobstructed on the lens. Continuous parallax is then allowed.

One of the first applications of this property was a three-dimensional photography system employing only one camera, opening to light only one area on each side of the lens, one transmitting through one color filter and the other through another, photographing in only one shot a direct anaglyph.

The horizontal parallax transmitted by a slit and placed on a lens may be employed for generating multiple views and even continuous parallax.

Lunazzi (12) projected a scene directly from objects on a diffractive screen of 15 cm x 30 cm employing an ordinary slide projector objective. The 6x enlarged image gives the precise impression of a holographic one, but has more focusing depth limitations. "Direct holoprojection of objects" was a name given to this technique in which the horizontal extension of a lens is the fundamental property (Figure 4).

Son (13) employed this parallax property to project sequentially a set of views from a multimedia projector. Each slit position on the projector corresponded to a vision zone for the screen and the observer could have a different view within a discrete sequence of lateral positions. The image persistence on the retina gives the illusion of simultaneous viewing, but it is necessary for the system to put all views in the time of one ordinary movie frame (1/24s), so that a set of views may be projected. At 24 views per second, for example, the frame capability of the electronic multimedia system needed is about the square value of that of an ordinary projector. In the present state of the art it seems not possible to achieve this at a high definition resolution. Employing many projectors at close lateral positions is a possibility to reduce the frame rate needs and to obtain a brighter image, but it is only possible if the screen has a low scattering level in order to avoid the simultaneous view of all projections.

Fig. 4. Up: Photograph of an object directly projected on a holographic screen. Above: anaglyphic stereo representation of the same scene, with color channel.

8. The continuous parallax

We see the need to approach the perception of a continuous view sequence to have a three-dimensional image with good quality. There is a white-light imaging process whose parallax is inherently continuous, as in holography. It matches depth coding by diffraction naturelly happening when the diffracted light is collected in a small region after a diffraction grating, with its also natural decoding happening after projecting that light on a second diffractive element (14, 15). Each wavelength represents a viewpoint based on a small area of the first diffracting element and as the spectrum is continuous the parallax also is. We can better understand the basic process of a diffractive screen considering it as a primary element, a diffraction grating. If we further approximate the projecting lens to a simple pinhole camera corresponding to its central part, we can see in Figure 5 how the ray tracing based on an object point explains the resulting image by central symmetry (16).

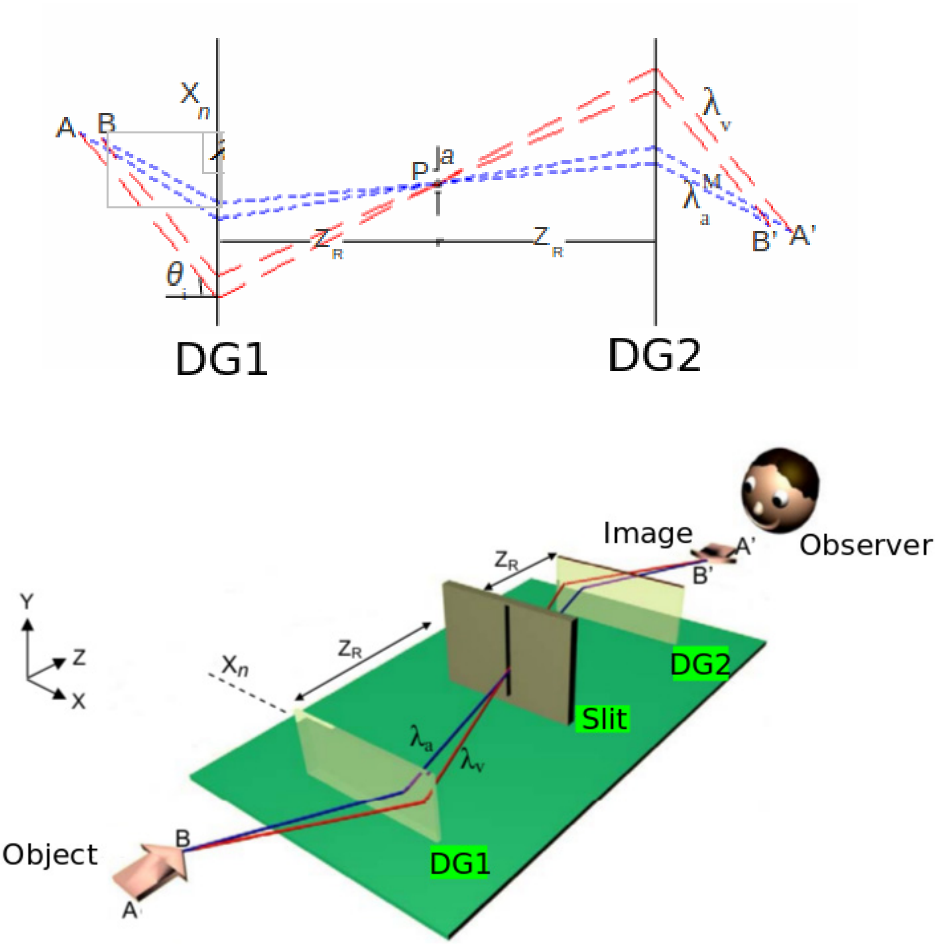

Fig. 5. Symmetry in double diffraction imaging intermediated by a slit.

DG1 and DG2 are two identical diffraction gratings intermediated by a slit. Each object point has a corresponding image point symmetrically to a central point. Because the observer looks to the image from behind, he sees an inverted depth. In this case of perfect matching between two diffractions, it is interesting to notice a property which resembles a holographic one: the diffraction at a symmetric order, on the second grating for example, generates an image with inverted depth. An image in normal depth is so obtained (17).

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 decoding

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

property a second diffracting element may have. Enlargement is the same for all three dimensions of the object. A small transmission hologram made with a lateral reference beam on 35 mm film can be enlarged on the screen by illuminating it with a halogen lamp (19). To obtain a better luminous efficiency the scene was recorded employing a photographic objective covered with a horizontal slit and it was projected by reversing the light path as in Komar's technique but enlarged and in white light. It was possible then to have an image on a 0,84 m x 1,10 m screen (20) at x40 enlargement (Figure 6).

The observer's space depends vertically on the height of the diffuser and laterally on its width and on the screen dispersion. The angle between the object and the reference beams being of 45 degrees, no more than four observers seated in two rows can see the scene simultaneously. A similar system not enlarging holograms but projecting pictures of classic movies was presented to the public (21). There, the images appeared from six meters behind the screen coming closer little by little until traversing it to one meter from the observer, located two meters away from the screen.

The recording and white light projection of holographic movies was not accomplished due to the lack of resources and concentration of efforts in the application of electronic images. The recording of holograms in white light which is based on an interesting proposal (22) was not accomplished up to now.

10. Continuous parallax in electronic images projected on diffractive screens

The depth coding-decoding diffractive principle allows projection of a point source image at any position with respect to a diffractive screen. A computer-controlled figure generator was developed having a thin white light beam being focused at some millimeters from a diffraction grating whose lines were vertical. Because the beam was reflected on a mirror which was made to rotate through a vertical axis, the distance from the focus of the beam to the grating changed. This distance made the necessary degree of coding, which constitutes the horizontal size of a white-light spectrum. The movement was complemented with another two computer-controlled rotating mirrors to generate a luminous point located in any three dimensional position floating in front of the screen (23). A software was in charge of generating animations in the format of line figures. Figure 7 shows that a cube could be drawn without the need to correct any distortion. The image volume is about 100 l, no more is possible due to its reduced brightness. The possibility of white-light laser beams now

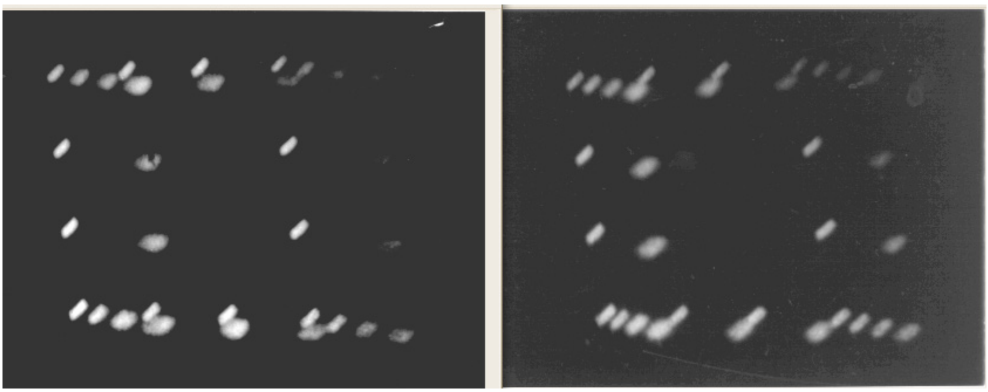

Fig. 7. Luminous points in a cube shape in front of the screen.

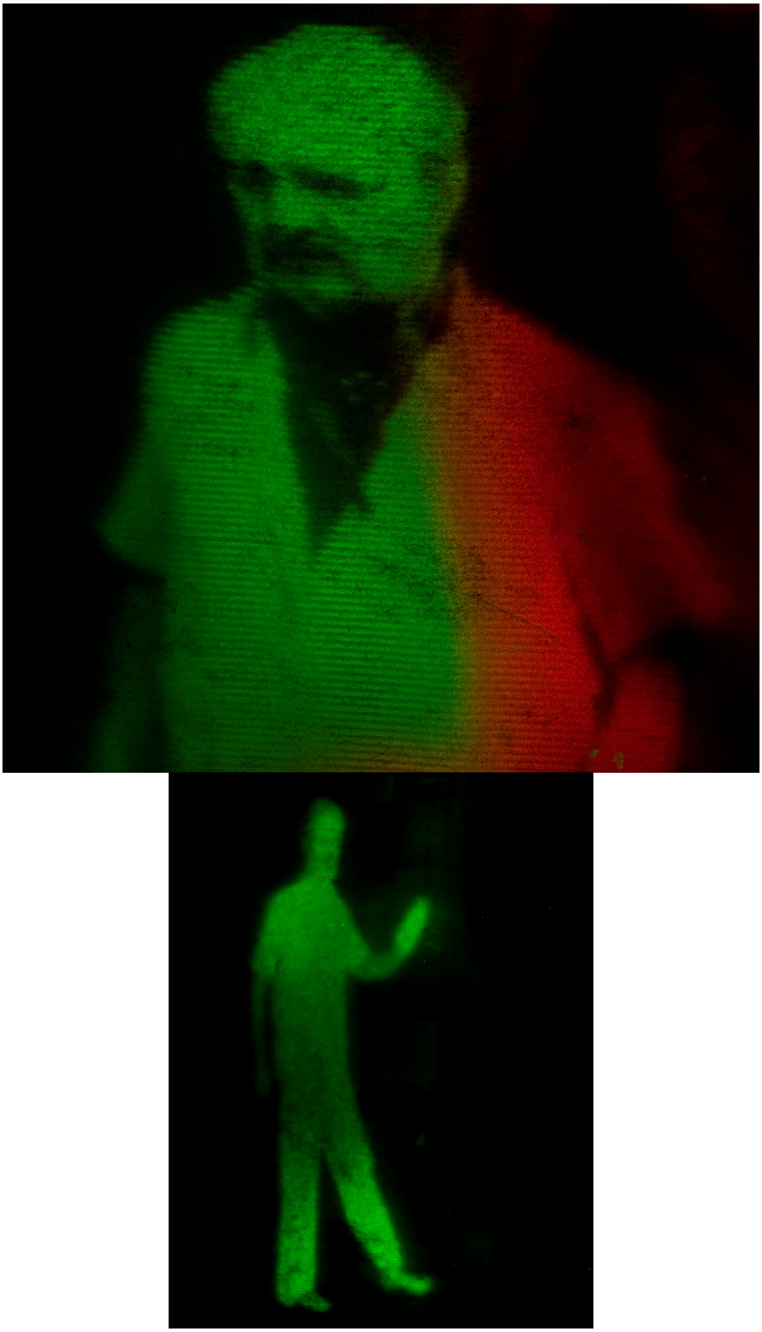

Fig. 8. Vídeo scene appearing in an oblique plane in front of the screen. a) detail. b) complete image, 80 cm high, made of two hundred video lines.

obtained by TiSa lasers whose spectrum is broadened by means of Bragg optical fibers may give to the application of this technique new possibilities.

The depth coding-decoding diffractive principle also allows us to project an electronic image at any plane in respect to a diffractive screen. By choosing an oblique plane in which to position a video image, an interesting approach to a holographic TV was obtained: The scene has depth as well as transversal characteristics, giving the illusion of a perfect 3D to most spectators (24). Although the images we show (Fig.8) shows limited resolution, this is due to electronic equipment limitations. The diffractive imaging process has in principle no resolution limitations but those due to diffusion of the screen or speckle noise.

After some time observing, some people notice the lack of a perfect relief on the image. The scene can generate a volumetric image by projecting many parallel planes in a rapid sequence, each plane having a the image of a corresponding slice in which the whole image was divided. Animated scenes were made by three-dimensional computer drawing from which four slices were made. They were projected through a computer-controlled rotating mirror to make that at each mirror position the corresponding slice was projected (25, 26). Figure 9 shows a vertical sequence of stereo pairs corresponding to how the scene is viewed.

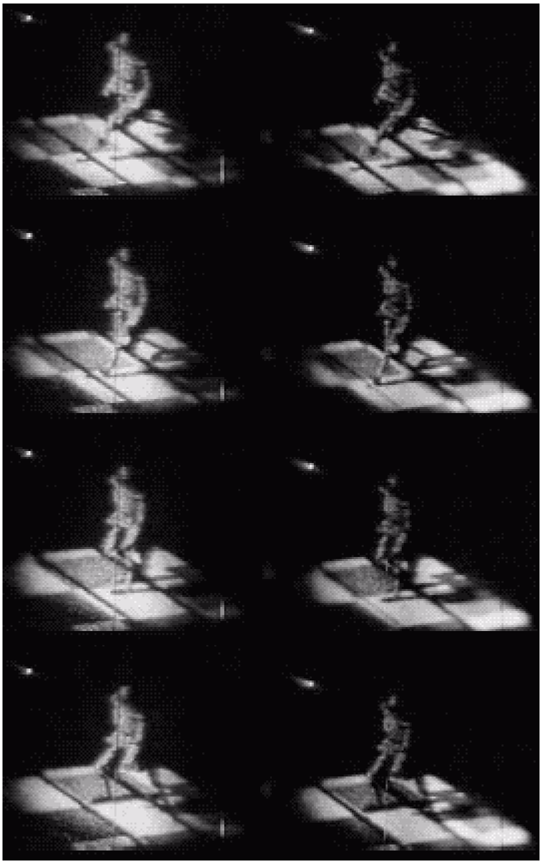

Fig. 9. Four stereo pair frames of a volumetric scene distributed in four assembled slices.

In this proposal discontinuity exists on the slicing, the more slices dividing the scene, the more perfect it appears. Slicing on video scenes should be made by a vertical white-light strip shaped beam sweeping on the scene, but has not been implemented yet.

11. Lensless projection on diffractive screens

The projection by means of lenses or mirrors put limitations in focalization because it is usual to deal with oblique projections. A proposal to solve this problem by elliminating focusing was made by Lunazzi (27, 28) based on employing a linear luminous source, a long filament of a halogen lamp horizontally located behind the screen. The image is a consequence of the shadow projected by each part of the filament. The shadow on the screen can only be seen from a position which is precisely opposite to the filament part. A continuous sequence of shadows is generated rendering horizontal parallax. The angular extension of the filament in respect to the screen center defines the angular field for observation. The image is very peculiar (Fig. 10) because although it does not have inverted depth it shows an object whose closer parts are smaller than those which are farther away from the observer, as in a common shadow. The objects can only be transmission and not diffusing objects, which is not a problem because we can envision its application for elements like liquid crystal displays (Fig.11).

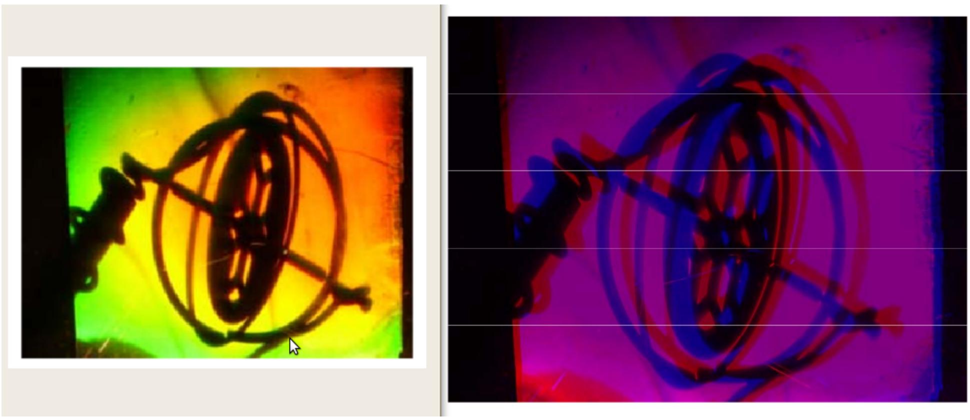

Fig. 10. Continuous parallax image projected with a linear source. Left: original view. Right: anaglyphic stereo representation with no color channel.

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

the fact can be mentioned that similar elements can be constructed by direct recording techniques like lithography, for example. A 5 m diameter diffractive lens was made for an astronomic space project (27), a technique that could be similar to one for the construction of diffractive screens.
It was made in the form of a mosaic, already explored with holographic techniques (10).

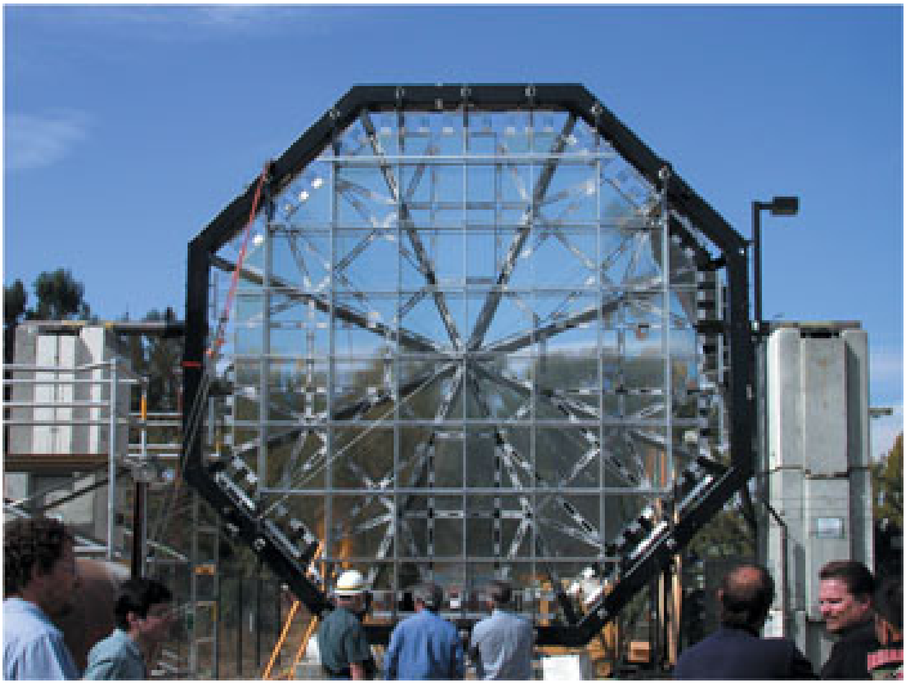

Fig. 12. Picture of a 5 m diameter diffractive lens made by litography (by R. Hyde- S. Dixit).

13. Comparation of electronic image systems employing diffractive screens with other volumetric systems

Non-glasses autostereo systems are not practical for its wide-spread use for commercial purposes yet (30)(31), so that the many systems which has been proposed for it are to be kept under discussion.
Let us consider the following volumetric systems: lenticular, a parallax barrier, a curvature controlled mirror, a rotating screen under projection, a rotating LED display, an electro-optic hologram generator, a fast recording of integral hologram, a laser focalization on crystal, a laser focalization on air, and flying luminous sources.
Among the lenticular systems let us consider only those in which small semi-cylindrical vertical lenses are in contact with a conventional screen. To reach the number of views necessary to produce an apparent continuous view sequence many views must be displayed simultaneously, making a large bandwidth necessary or much processing by very special digital techniques. This is the same as happens for the diffractive screen systems to add several slices or views. Maybe an advantage can be proved in the case of the slicing oblique plane system, because the continuous parallax does not demand electronic processing power.

The parallax barrier system can be disregarded for its long duration presentation applications because of the necessity to maintain the head position during the observation. Relief is inverted when deviating from the right position. Although more than two views can be provided, the adding of views reduces the brightness of the image.
To make large diffractive screens seems to be as easy as making large holograms, while examples of lenticular or parallax barrier screens which are larger than one square meter are not known yet.
The curvature controlled mirror employs fast moving parts, being limited in size to a few decimeters by air resistance and noise generation. The rotating screen systems presents the same problem; its advantage is the ability to show 360 degrees images. The images of the rotating screen systems can not fill more space than the screen does, appearing in fact within a transparent cylinder, never in front or in the back of it, the effect that more impresses the public.
The electro-optic system, already named as "holographic video", developed by Benton, never recorded live video scenes but computer made ones. It has size limitations and consumes much computer processing power.
The fast recording of holograms has been possible in telecommunications with new photosensitive materials. A scanning frame was recorded every two seconds, which is still ten times more than required for video, and not at large size yet. To reach the video velocity much bandwidth and processing capability will also be needed and, if reaching the 1/20s frame speed, the persistence of the images on the retina makes the photosensitive material unnecessary; a diffractive screen can accomplish the task equally.
There are systems creating luminous points within crystals and images can be seen from almost any position, having more than 360 degrees viewing capability, but the images remains within the supporting crystal and it seems neither practical nor possible to have large size images. A new interesting possibility appears to make the same in a liquid, while not employing visible light for that (32).
Other systems focussing intense laser beams on air may generate 360 degrees views, but presents a low resolution and high cost, as well as noise or dangerous luminous or temperature levels. One can think that this systems could be useful for working at large sizes, filling large volumes to be seen from a large distance.
Finally, the same can be said of the recent system made of small flying sources, mini-helicopters whose position can be remotely computer controlled: large sizes could be achieved at a considerably energy cost, low speed and short duration.

14. How to evaluate parallax with ordinary images of a system

It is common to say that holography is the technique allowing to reconstruct the wave amplitude and phase, but if we remain with this sole idea we could not properly analyze the holographic image. Considering that the phase of light cannot be seen, not even a detector with enough capability exists. What our eyes see are rays, directions of propagation. My personal vision of holography comes from my initiation as a 14-year-old photographer making stereo pictures.
This allows me to concentrate on the images and not on a mental visualization of Maxwell equations and their application, in which even complex-conjugated light fields are present. The third dimension can only be clearly perceived through binocular vision, which most popular imaging systems do not permit at present time. To demonstrate the existence of

perspective selective viewing with ordinary cameras it is necessary to show the parallax, something that the photograph of any three-dimensional image, or the video made with the camera at a fixed position, cannot prove. In the case of photographs, a sequence, during which the camera changes laterally its position, allows to observe the relative change of positions of corresponding points at the scene, and also to mount a stereo pair for binocular observation. It improves the knowledge which the photographs offer, but it is not yet enough. A video registering gives more close frames than a series of photographs makes possible, and should detect the presence of dark regions or jumps on the transitions. But this is still not enough: the aperture of the camera lens must be as close as possible to the eye's pupil, about 3 mm to avoid mixing a dark and a luminous region at the same time giving the appearence of not existing dark regions.
In the internet, there are many sites claiming to show three-dimensional or holographic imaging systems, but which are shown from a single viewpoint.
A properly made system must be justified with images that can prove it. The worst case is certainly when simulated pictures are shown without declaring the simulation. It is usual in this cases to see part of the figure exiting the limits of the frame of the screen, what is impossible because light does not travels in curved path.

15. Conclusions

After describing many systems that project goggle-less three-dimensional images on diffractive screens made by recording light interference on photosensitive material, it can be understood that, although these techniques are not the ones which are chosen for the industry at the moment, interesting properties have yet to be explored. Advances in the diffraction and dispersion efficiency of the elements may recall the attention to this subject in the future.

16. References

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