3D shadowgram projection using a simple diffractive screen

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Abstract

We present a new system where a 3D object is projected on a diffractive screen, which is just a simple diffractive holographic lens. The object is illuminated with an extended filament of a white light lamp and no additional element is necessary. The system forms three-dimensional (3D) images with normal depth (orthoscopic) of the shadow type. The continuous parallax, perfect sharpness and additional characteristics of the image depend on the width and extension of the luminous filament and the properties of the diffractive lens.

Introduction

Lunazzi [1] developed ways for obtaining 2D and 3D images with white light using diffractive elements usually through projection by a diffractive lens. The only method we know other authors developed is for 2D images in a system by Hyde [2] named EYELIGHT: Very large aperture diffractive telescopes.

On the other hand, were obtained 3D images that are perfectly symmetric and depth inverted (pseudoscopic) from a double diffraction system using gratings diffraction intermediated by a slit [3-5], in this same system we observed the image with normal depth (orthoscopic images) [6]. The pseudoscopic image appears in the front of the screen as a ghost image and other appears back of screen forming a virtual image. These images are observed in a first diffraction order and they show the following characteristic as horizontal parallax, horizontal magnification and vertical astigmatism. 3D images also can be obtained using two bi-dimensionally defined diffractive elements and an intermediary pinhole [7-9], and the characteristics of the system are: equal horizontal and vertical magnification, possibility of projection because it does not present astigmatism. There is a purely one-step diffractive system for projection of a 2D object illuminated with an extended filament lamp of white light on a diffractive screen to form a 2D image of a transparency [10] that we used to explain a new system of 3D images consisting in the projection of a 3D object on a diffractive screen illuminated with an extended filament of a white light lamp, this image shows characteristics as normal depth, continuous parallax and perfect sharpness.

Experimental Setup

The process for obtaining 3D images using only diffraction is described in the Figure 1. *f* represent the white light source filament from which each point (for example point, f_1) is considered to send white light rays in all directions. Point f_2 represent a point of the filament, f_2 emanates some rays that arrive the object *O1*, making a shadow whose contour rays impinge the *DS* (diffractive screen). The prolongation of these diffracted rays of blue wavelength and red wavelength converges in the observer pupil. The observer is located in the same side that the diffracted rays (blue and red wavelength), in this position may observe the images *i1* with perfect clarity.

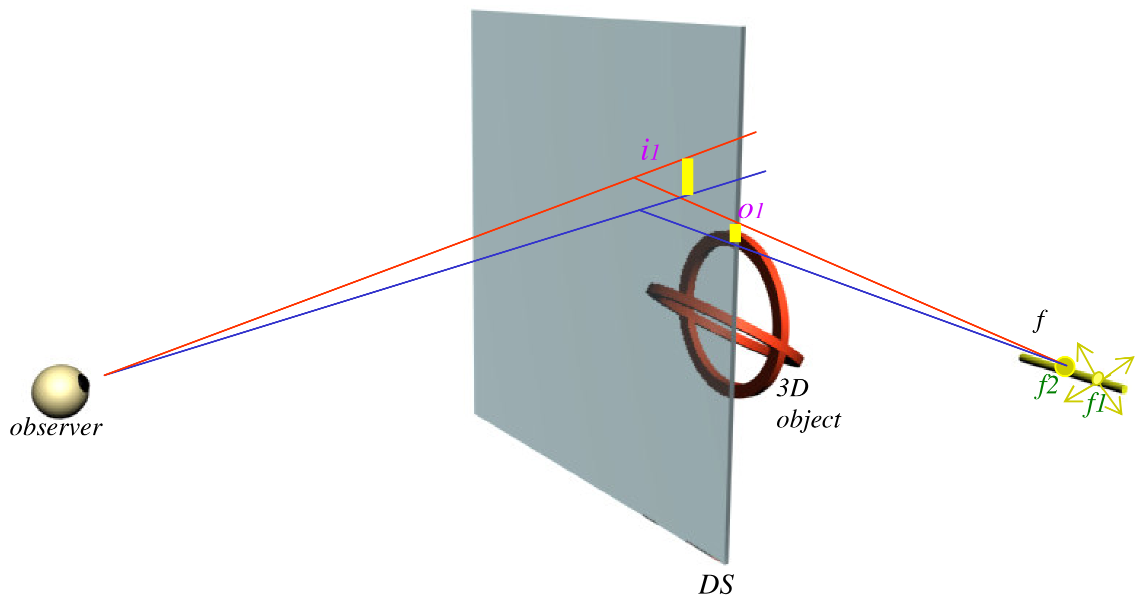

Figure 1: Scheme of a 3D shadowgram projection.

We performed the experience using a common domestic filament lamp (available in USA and Mexico) of 40 W, the length of the filament was 70 ± 5 mm and about 0.3 mm wide. This lamp was placed parallel to the table plane (see Figure 2). The 3D object used has a configuration of two perpendicular rings, whose diameter is approximately to 70 ± 5 mm. As diffractive screen, was used a simple diffractive holographic lens of de 170 x 130 mm located to 430 mm of the lamp. This diffractive lens has a variable spatial frequency approximately of 500 to 1400 lines/mm, being that the frequency is distributed of ascending way from the inferior part to the superior part of the lens.

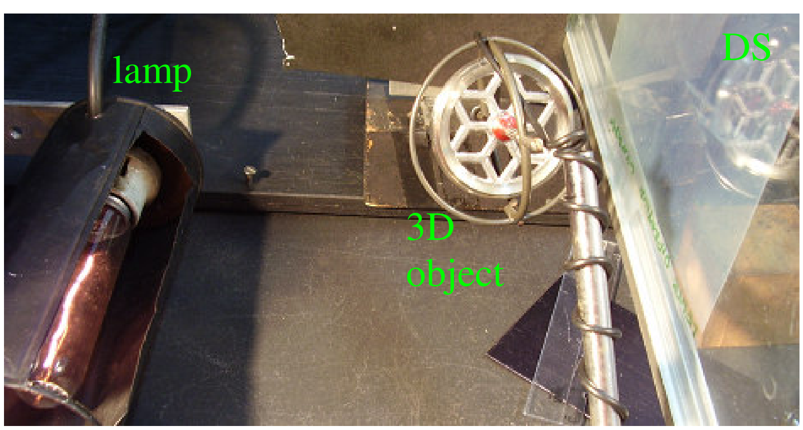

Figure 2: Experimental system of 3D shadowgram projection.

Results and Discussions

We obtained a new tri-dimensionally image of shadow type projecting a 3D object on a screen diffractive illuminated with an extended filament white light lamp.

In the figure 3, we did the ray tracing that demonstrates an orthoscopic virtual image, considering in this situation two points object *O1* and *O2* located at different depth position. ν(x) represent a variable frequency, where ν3>ν2> ν1. From point *f* get out two rays that pass by the extremes of object *O1* (circle *O1*), the same way there are two rays for *O2* (circle *O2*). These rays impinge on the diffractive screen at the points whose frequencies are ν3, ν2 and ν1. Each pair of rays converges in the pupil of observer, this observer sees to the image *i2* closer that the image *i1* of same way that observes the object *O2* closer that *O1*.

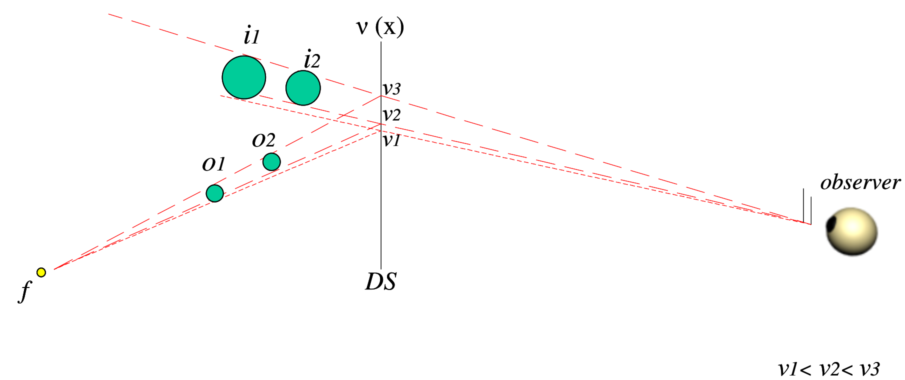

Figure 3: Ray-tracing scheme for the normal depth image (orthoscopic images).

Other characteristic that we observed is the magnification of the image as we showed figure 2, the image *i1* of the object *O1* that is more closer of the lamp and will have enlargement more than the image *i2* of the object *O2* (*O2* more far of the lamp).

As a first experience using a ruler as object, we showed the enlargement the 3D shadowgram of the ruler. In the figure 4 can be observed that when the object is located more far to the lamp its image is less enlarged (at left side) and when the object is located more near to the lamp its image is more enlarged (at right side). This property can be observed for a common shadow too.

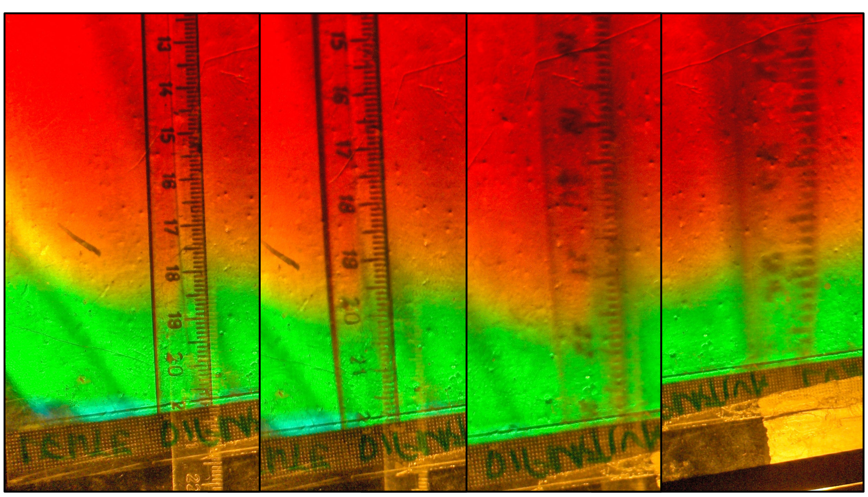

Figure 4: From left to right can be observed the enlargement of the image 3D shadowgram due to the position of the object for a fixed position of the observer.

In the figure 5, show the existence of the depth of a point image, from the points *f1* and *f2* emanates two rays of red wavelength that pass by the extremes of object *O,* impinge to the diffractive screen, each pair of rays converges in the pupil of observer of the left eye and of right eye respectively. The Left eye observes in a perspective different to the left eye, this fact verifies a continuous parallax.

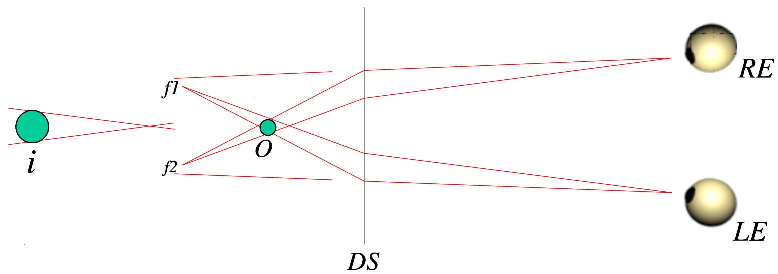

Figure 5: Ray-tracing scheme for a point image seen by the right and left eyes with different perspectives.

In this experience we showed a 3D shadowgram projection using simple diffractive screens of a 3D object (see figure 6), was possible to observe the image with a normal depth, continuous parallax and perfect sharpness.

Figure 6: 3D shadowgram of a 3D object, left: observer is located more far of the diffractive screen that in the right image.

As finish experience was performed a stereogram of the 3DShadowgram, for this we took off two photos in different perspectives, by the left side and the right side of the observer. In this picture we verified three-dimensionality of the image of the object projected on diffractive screen.

Figure 7: Stereoscopy of the 3D shadowgram

Conclusions

Was obtained a new type of tri-dimensional image “3D shadowgram” in a process that involves only diffraction without the need of other optic element. The system can be used as lens, reaching the limit of its capacity of enlargement. Besides, can be used for the building of a stereoscope and for projection of publicitary announces.

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