# Pseudoscopic white-light imaging by means of two bi-dimensional diffracting elements and a pinhole

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## ABSTRACT

Diffracted images with inverted depth were first reported by the authors where a lens or slit intermediated the white-light double diffraction process. The diffracting elements were simple straight line diffraction gratings and the image could be seen but not projected due to its strong astigmatism. The generalization of the symmetry properties to bi-dimensionally defined diffracting elements allows to produce projected images with circular gratings intermediated by a pinhole. Acting as a focusing element, the possibility of enlargement is reported here with experimental results.

**Keywords**: diffractive imaging

## 1. INTRODUCTION

Pseudoscopic (inverted depth) images were only known from stereo photographic or holographic processes but only recently known in diffractive optics imaging. In a previous paper one of the authors [1] analyzed the properties of a diffraction-absorption-diffraction white-light imaging system composed of two diffraction gratings intermediated by a slit. That system can be considered as a magnifier and may have infinite magnification [2,3]. The image was pseudoscopic but could not be projected on a screen due to the difference between the horizontal and vertical imaging processes, which performs astigmatically. We extended the idea to a new system whose diffractive elements are bidimensional, analyzing it with the same theoretical approach, which explains the image through main ray directions. The new image can be projected [4] with equal lateral and longitudinal unitary magnifications. This new kind of images is interesting because could render larger parallax field than refractive or reflective optics. The diffraction properties of ordinary optical disks [5] can be employed as preliminar elements for experiencing this kind of imaging.

## 2. METHODOLOGY

The system is composed of two identical diffractive elements symmetrically located to a pinhole. They are circular gratings (with constant spatial frequency of 658±5 lines/mm) of which only a fraction of less than a half is being employed. The perpendicular to the pinhole pass through the center of curvature of the grating lines. A white-light object is on one side and part of the light, which is diffracted by the first element, goes through the pinhole. Figure 1 shows the ray-tracing situation.

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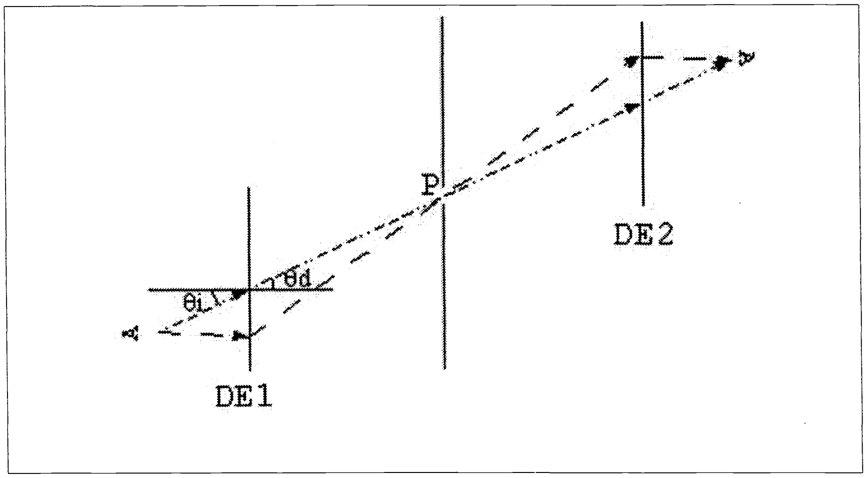


Fig. 1. Ray-tracing situation of the imaging formation.

DE1 e DE2 are the diffraction elements and point P corresponds to the position of the pinhole. From a point of the A shaped object, two different wavelength rays spread and are diffracted at DE1. Neglecting diffraction effects by the pinhole, a completely symmetrical situation can be attributed to the light distribution exiting the pinhole due to the symmetrical positioning of the second diffractive element. We can consider that the pinhole determines the path of every ray and it is evident that there is only one wavelength that, according to the diffraction law, corresponds to each ray direction. That is:

$$\sin\theta_i - \sin\theta_d = \lambda\nu \quad (1)$$

$\theta_i$ being the angle of incidence to DE1, $\theta_d$ the corresponding diffraction angle, $\lambda$ the wavelength and $\nu$ the number of lines per millimeter of the gratings. Rays passing through DE2 diffracting to an order opposite to that of the first diffraction converge to a point symmetrically located in respect to the pinhole and the object. The result is an image after the second diffracting element, whose depth is inverted. To understand that the image is complete one must notice that the selected plane for Figure 1 can be any plane containing the pinhole and the center of curvature of the grating lines so that rays from many directions constitute the image. If a screen is located on the position of the convergence, the image can be focused.

### 2.1. Enlargement by displacement of the second diffracting element

By displacing the second diffracting element (modifying $R_2$), an enlargement of the image occurs to a fixed observer at position ($Z_{ob} + R_2$) and a fixed object put in to $Z_{oj}$. The enlargement is dealt by $L/L_0$ and a relation with the distance of the displacement from the symmetrical point ($R_1=R_2$) is expected to be linear because the rays that found $Z_{ob}$ is just the geometric projection of the ones that has passed through $Z_{oj}$ (in the image after the second DE).
Figure 2 shows the situation:

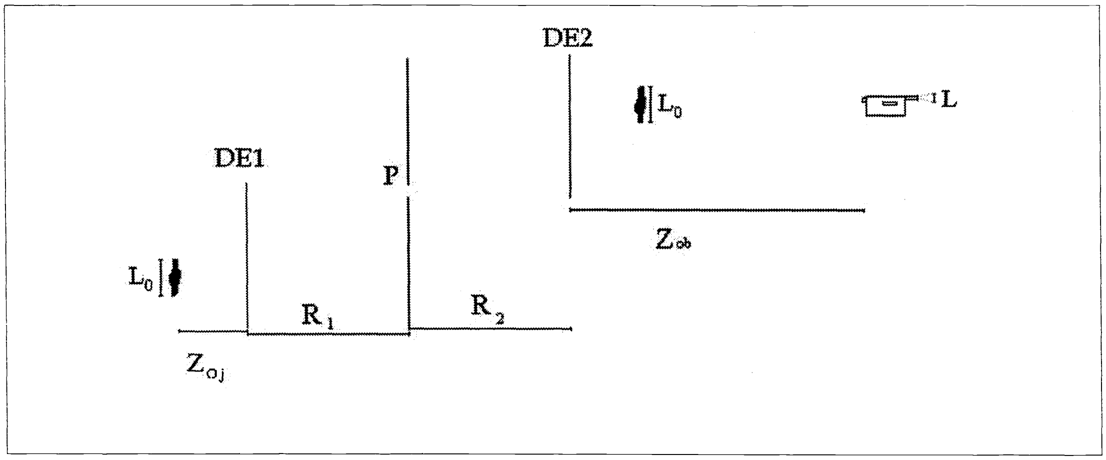


Fig. 2. Notation to be used in the enlargement.

## 3. RESULTS

### 0.0.2.0.1. 3.1. Image of a Halogeneous lamp with reflector

We used a halogeneous 50 W lamp (Figure 3, left side) with a parabolic 46 mm diameter faceted reflector behind it, constituting an extended object. The image is showed in figure 3, right side:

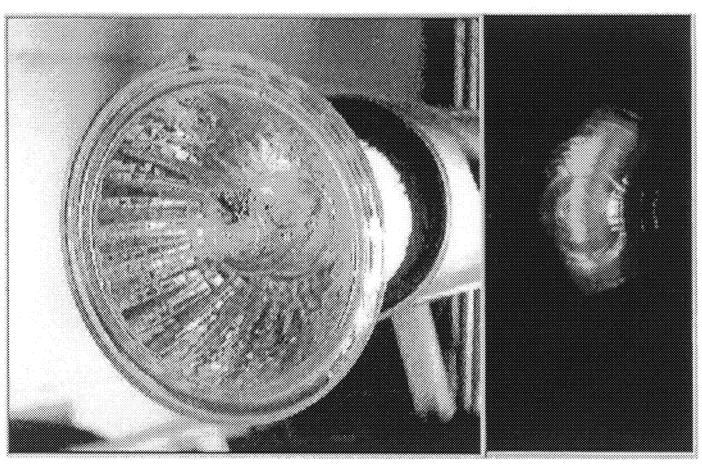

Fig. 3. Halogeneous lamp and its image done by the system

The extension of the image was close to that of the object, but not allowing to see the whole object. From figure 3 we can see the circular distribution of colors, done by the circular diffraction element.

## Enlargement by displacement of the second diffracting element

Using a halogeneous lamp of 20W and ($Z_{ob}$ + $R_2$)=70 cm and the object at 16.5 cm from the first diffraction element we have an angular magnification of almost x2 for the situation where the magnification was x1 . We measured the enlargement of the image when the second diffracting element was displaced, taking with reference this case of total symmetry ($R_1$=$R_2$). Figure 4 shows the linear relation gotten and the Figure 5, some pictures taken from a fixed position of the observer (they are in scale).

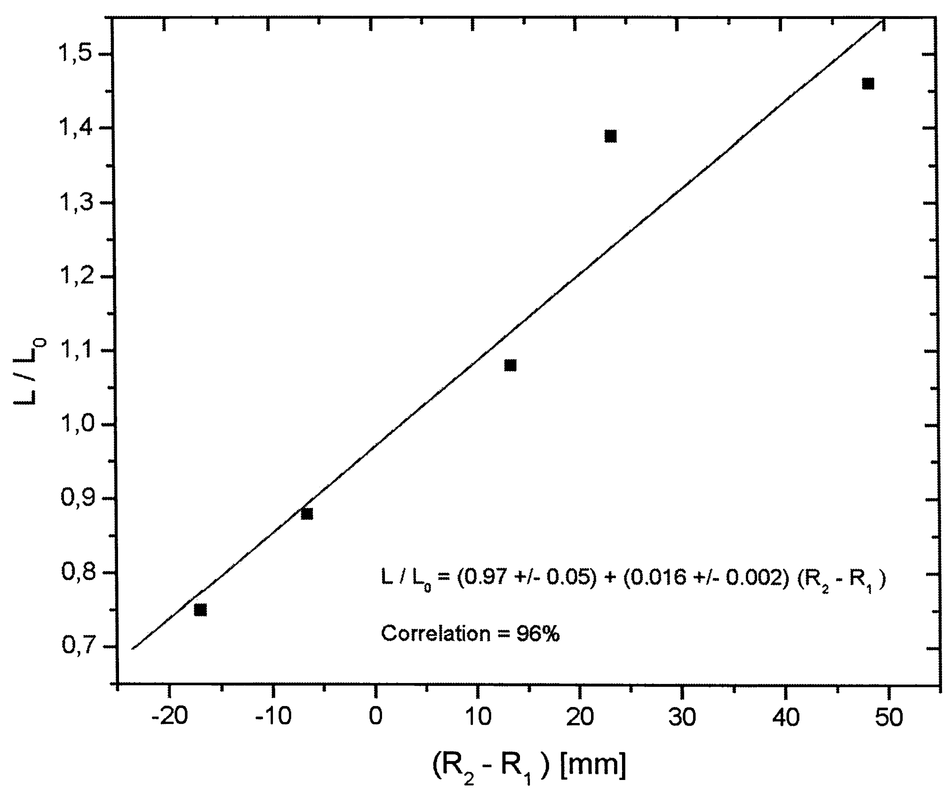


Fig. 4. Linear relationship between displacement of the second diffracting element and magnification.

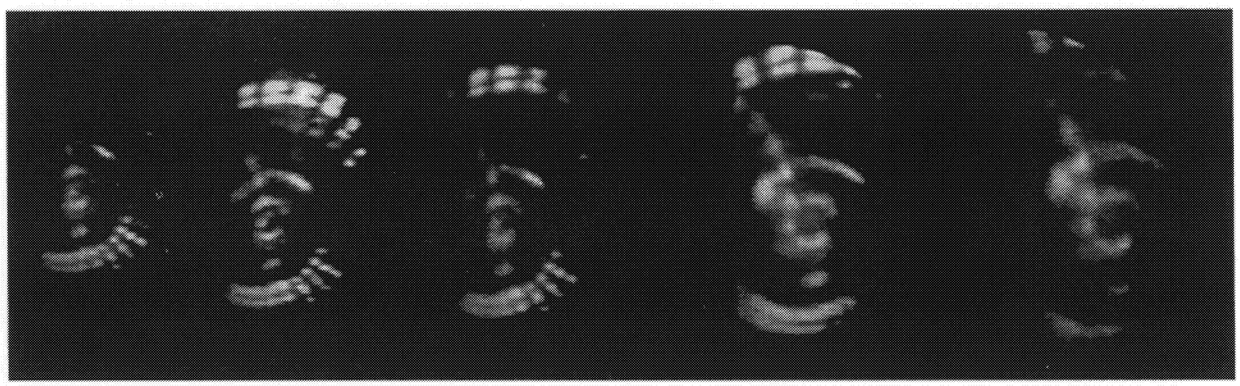

Fig. 5. Magnification at five positions of the second diffracting element.

## 3. CONCLUSIONS

A new kind of images can be achieved using diffracting elements and white-light objects, which resembles very much the conventional imaging of refractive or reflective optics, but having inverted depth and unitary longitudinal and transversal magnification simultaneously. Its extreme simplicity may help in understanding further properties for practical applications.

## 4. ACKNOWLEDGEMENTS

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