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STUDY OF SHEARING AND DEFORMATION OBJECT BY OPTICAL METHOD

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The numerical holography technique is commonly used to measure displacement and deformation of rough surfaces. Despite its importance this technique has not seen much adoption by researchers and industry. Mechanical stability, the need for film development and the difficulty of interpétation fringes are behind this lack of admission. We will study a deformation easy to implement and to analyze: it is the deformation in dome of which it was made state previously. we seek here to develop the technique shearing using a prism. We thus want results easy to analyze. Thus, we can concentrate on the aspects only dependent on the prism and its employment.

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1. Theory

The shearing is an interferometric technique. It is to interfere with object wave itself, but shifted spatially. In practice, this amounts to interfere, by superimposing two images of the object transversely offset.
To this end, there are many devices to create images offset (eg beam splitter, lens Ticket, grating ...).

The advantage of these packages is their low sensitivity to vibration, thanks to their compactness. As we have already mentioned in the introduction to digital holography, the shearing is a technique that allows us to visualize the deformation gradients when it occurs outside the plane of the surface.

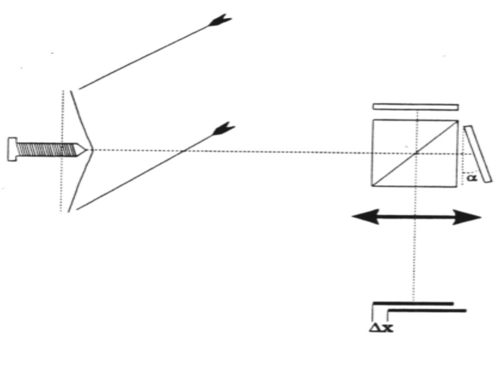

Fig. 1 : Experimental device for shearing.

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To check the aperture of the prism, we proceeded in the following simple way: the beam of the diode, after having passed in a blade half-wave, is sent on the prism. Behind this one, we placed a screen provided with a graph paper. In this manner, we can measure the difference between the two beams.

The blade half-wave is necessary for the following reason:

we saw that the unfolding of the prism is done by separation of the components of polarization. It is necessary thus that the incidental beam has these two components. However, a laser diode is linearly polarized. The blade half-wave enables us to make turn this direction of polarization in order to present it in a symmetrical way compared to the axes of the prism.

Then, we varied the distance between the prism and the screen by step of 5 cm. With each position, we noted the difference between the two beams:

2. Description of prism used

The purpose of this manipulation is to use the technique of shearing mechanism with a double image: a prism.
We want to characterize this prism in order to use it in a later analysis by shearing.
A prism made of a birefringent material that is to say having two refractive indices. This prism is cleaved so as to have the directions associated with these indices in its entrance face. Note that these directions are perpendicular to each other.
The technical characteristics of the prism used in our handling are:
quartz prism, whose refractive indices are:

n_0=1,544
n_e=1,553
Dimensions:
L =1,5 cm
l = 1 cm
d = 0,1 cm

Prism-screen distance (cm)	Shift (cm)
0	0
5	0,05
10	0,10
15	0,15
20	0,20
25	0,25
30	0,30
35	0,35
40	0,40
45	0,45
50	0,50

Table1: Presentation of the shift according to the distance prism screen

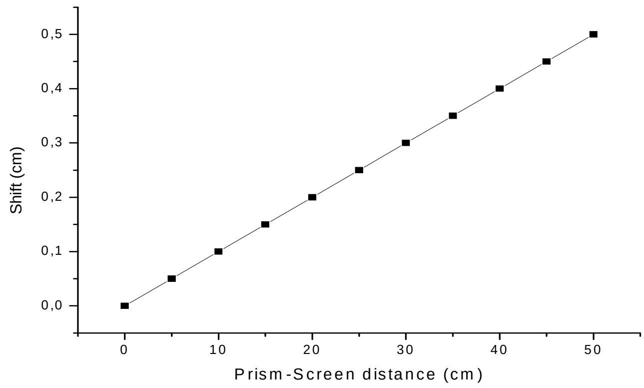

Fig. 2. Unfolding by prism according to the space shift

By carrying out a linear regression, one can express the variation of the beams according to the distance from the prism:

$$Y= x/100$$

Then ;
y = shift (cm)
X = distance prism-screen (cm)
Consequently, the tangent of the half angle of opening is given by half of the slope of this line [1]:

$$tg\,\frac{\alpha}{2} = \frac{0,01}{2}$$

This value is very close to our computed value (33 ' thus ~4% of difference) and a little less that provided by manufacturing (30 ' thus ~ 15% of difference).

2.1. Diagram and description

The assembly carried out is presented in the form of this [2]:

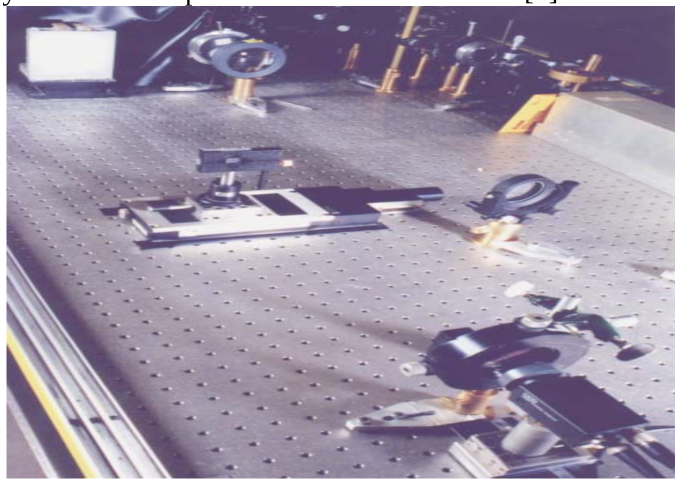

Fig. 3. Experimental device for the control of the deformation of a disk

The beam of a laser diode crosses a blade half-wave. The beam of a diode is linearly polarized and the blade half-wave makes it possible to change this direction of polarization. This blade is assembled on a rotary system and is turned so that the components corresponding to the crystal axes are identical. Then, the beam passes in a lens (focal = 90 mm) to be increased. Finally, it is reflected by a mirror on the deformable disc (deformation in dome). This disc is covered with a diffusing painting.

The diffused light passes then in the prism which duplicates the beams. The light is then collected by a lens (of focal distance 145 mm) diaphragmed by a pupil and sent on a camera CCD. At the entry of this one a polarizer turned is so as to be able to make interfere the two components of polarization. Indeed, we saw that the two beams on the outlet side of the prism have a direction of polarization. Consequently, in order to be able to make them interfere, it is necessary to project these components on a common direction: it is the role played by the polarizer [3].

The prism is placed on an arm of translation so that we can vary its position compared to the lens and thus to control the amplitude of the unfolding.

Moreover, the prism is placed on a micrometric table of translation. This enables us to regulate his position compared to the beam transversely. This table is motorized and managed either by a remote control, or by a computer. The smallest possible translation is 10^{-7} m.

The camera is connected to a computer which takes the images of before and according to deformation, calculates the phase in each case and then the difference in phase.

Handling proceeds this manner then: we take an image of the object, we relocate the prism of a quantity exposed further, we take a second image of the object and so on until obtaining 5 images of the object. Then, we deform the disc and start again this acquisition.

All this part of acquisition was made thanks to macro carried out by HPH. This one asks for the number of images which one wishes to take and the step of translation between each one. The remainder is done then almost automatically [4, 5, 6].

3. Results

3.1. Preliminaries

Before exposing the results, it is necessary for us to make a remark. If one looks at the diagram of the assembly carried out one sees that we laid out a lens between the prism and the camera (this so obviously carrying out an image of the object). This lens affects the unfolding of the image.

We then measured this one in experiments. With this intention, we carried out the image of a graph paper. On this paper, was a quite visible reference mark (a black vertical line). Thus, with the screen, this line was duplicated and it was enough to count the squares between these lines to know the unfolding.

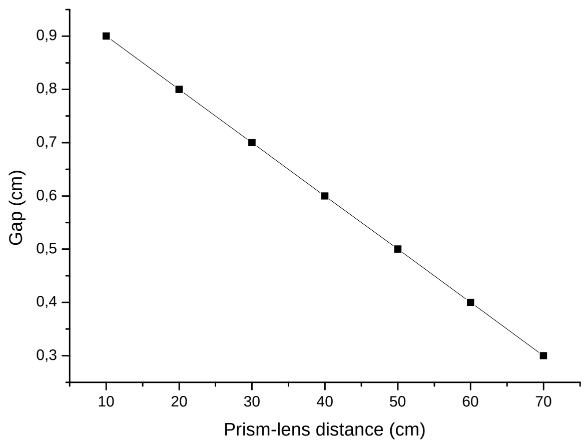

Fig. 4. Variation of the ecart with distance lens- prism

With new, we can express the variation according to the position:

$$y=0,971-0,00938\,x \tag{1}$$

This result is significant because we saw in the theoretical introduction that the value of the shift (the "shear") of the images fixes the sensitivity of measurements.

In the assembly carried out, the distance prism-lens is 61 cm. The shear is worth thus 0,4 cm. A distance distance between interference rings thus corresponds to:

3. 2. Steup used

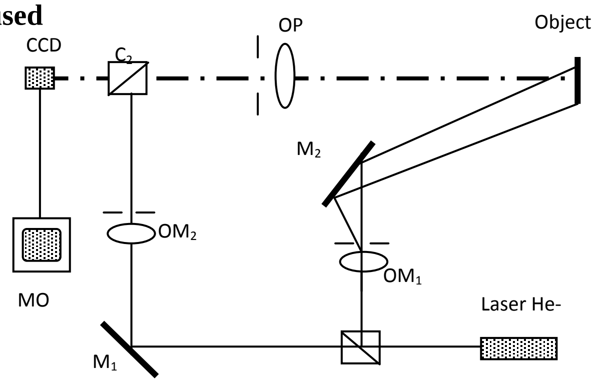

Fig. 5. Experimental setup for measuring travel out of the plane

3. 3. Results

The steps we have made were made in two tenths of a millimeter, from 0 up to 1 millimeter. Below you can find the Fourier transforms for each aperture and for each trip at both the object of the camera.

Here results obtained. On right-hand side, we carried out a median filter (3x3) in order to better distinguish the fringes.

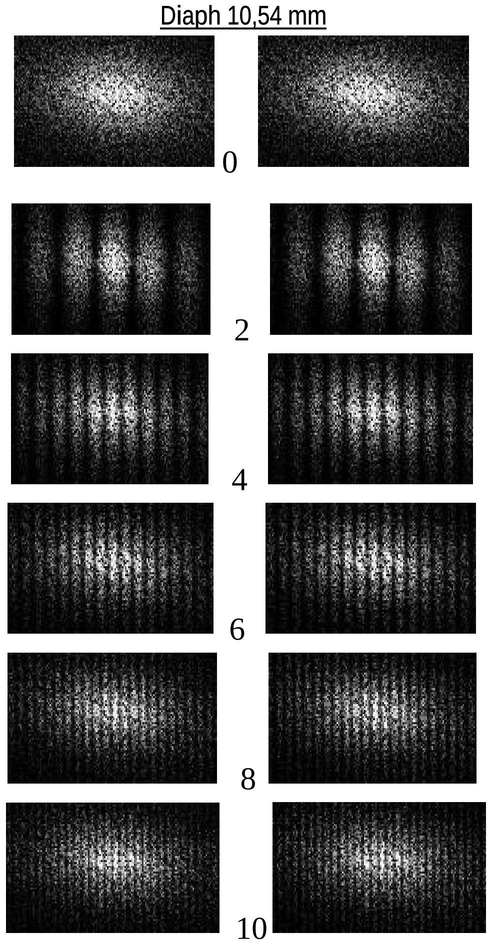

Fig. 6: Representation of specklogramms relating to the deformation for various steps of translation of the prism.

To the naked eye, the loss of contrast is already visible. For the two f-stops, we find that the fringes are virtually indistinguishable for high displacement. The contrast in these cases tends to zero. But to get a clearer picture of this decorrelation and also to take account of the aperture, it is necessary to go to the profile of the Fourier transforms.
To select the maid, we have recourse to the calculation of the jump of phase. Indeed, the software used (IPP-phase) can calculate the jump of phase between each photography.
The result is posted in level of gray. The average value of the histogram of this result informs us about the jump of phase.
For a jump of phase of $\frac{\pi}{2}$, the average value must be 64.

Below, we gathered the histograms corresponding to each step of translation.
This represents the second checking of our calculation concerning the dephasing caused by a translation of the prism. The result obtained is obviously more precise than that obtained with the naked eye on the screen [8.9, 10]

The same procedure is applied to an aluminum plate of dimensions (42 x 42 x 1) mm^3 glued to a sample holder with a circular aperture of diameter 32 mm. Deformation is then applied perpendicular to the center of the plate by the movement of a micrometer screw. Figure (7) represents the four specklogrammes resulting from the technique used. The fringes are concentric with a constant spacing.

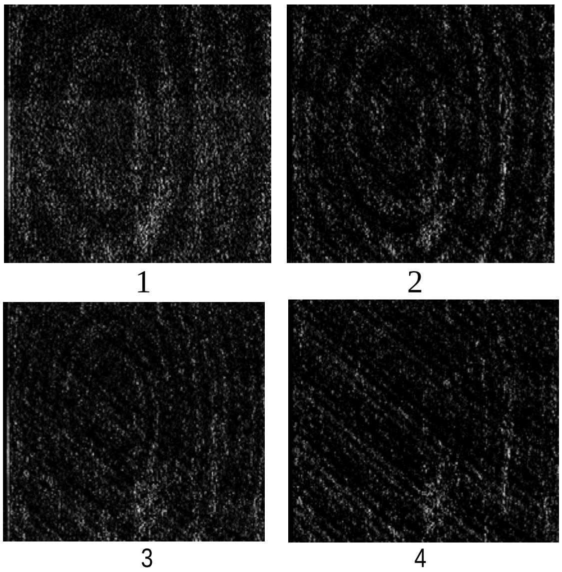

Fig. 7: Figures of fringes on the four states of deformation of an aluminum plate of dimensions (42 x 42 x 1) mm^3.

Note that as far as moving 'of increases, decreases the fringe. We also see that the visibility of these fringes decreases as the displacement increases and becomes almost zero when the displacement is of the order of magnitude of the diameter of the grains. The numerical value of the deformation can be evaluated by the fringe analysis techniques (example: the technique of phase shifting) [6, 7, 8].

3.Conclusions

The Technical numerical holography is a nondestructive technique quickly and accurately. It allows for qualitative measurements of static or dynamic deformations at low frequencies, provided that the deformation does not exceed the diameter of the speckle grain. It is also shown as an arithmetic subtraction is used to generate correlation fringes in real time, similar to those obtained holographically.

We then tackled to check the operation of this technique. We started with the subtraction of image, easier to implement, and we obtained fringes. The first point was thus filled out.

Then, we carried out calculations in order to be able to use the technique of difference in phase. These calculations were checked in experiments with a good precision. The second point also was thus filled out.

Finally, we carried out an assembly in order to use the difference in phase. We saw that we obtained fringes of very good quality and characteristic of the deformation in dome. The third goal was thus reached.

We can thus conclude that this handling is complete. The technique of the shearing by prism is now ready with employment.

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