

## Obtaining the curve “Phase shift vs gray level” of a spatial light modulator Holoeye LC2012

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**Abstract.** In this work, the process to obtain the curve “Gray level vs phase shift” of a transmissive spatial light modulator (SLM) Holoeye LC2012 is described. This work arises from the need that exists for having a new optical surface testing method at INAOE’s Optical Workshop. The SLM was placed in one arm of a Twyman-Green interferometer. The fringe shifts in the interference patterns were produced by displaying the different gray levels in the SLM. The gray level images displayed in the SLM were divided in two equal parts, the upper part was varying the different gray levels from 0 to 255 and the lower part stayed fixed with a gray level of 0 as reference. We show the different phase shifts and the experimental interferograms. From this analysis it was found out that a noticeable phase shift can be obtained from the 50 to the 190 gray levels.

### 1. Introduction

In recent years, the use of spatial light modulators has been applied in several optical applications [1-5]. In the field of optical testing for example such SLM device has been used in the Ronchi test. The purpose in such Ronchi’s method is modifying the structure of the Ronchi grating, either in its classical structure or for producing the so called substructured Ronchi gratings [6, 7].

The used techniques for measuring the phase that is introduced by these SLM are varied, one of the methods for phase “extraction” use the correlation matrix of intensities to determine the phase [3]. For performing the calibration of the SLM, one of the most used techniques is interferometry [8, 9]. In particular in this paper a Twyman-Green interferometer was utilized.

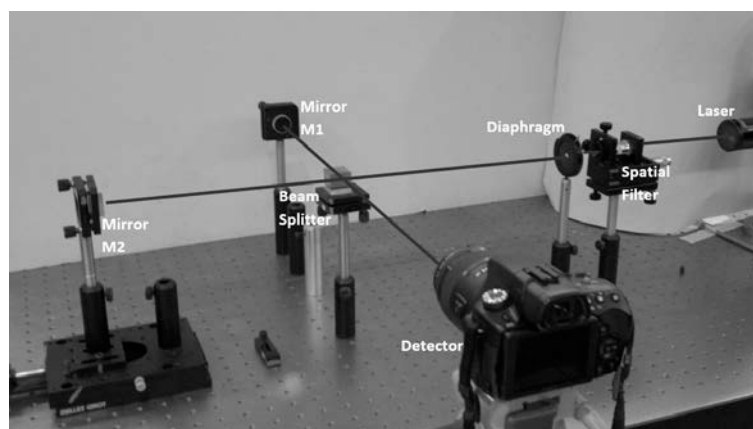
In this work, the process to obtain the curve “Phase shift vs gray level” of a SLM Holoeye LC2012 by using a Twyman-Green interferometer is reported. The main aim was to measure the interference fringes shifts which were produced by modifying the gray level displayed in this SLM. For this, an absolute reference which consists in displaying a gray level image divided in two equal parts was used. The upper part of this gray level image was varying the gray level from 0 to 255 meanwhile the other lower part remained fixed in zero as reference.



## 2. Experimental methodology

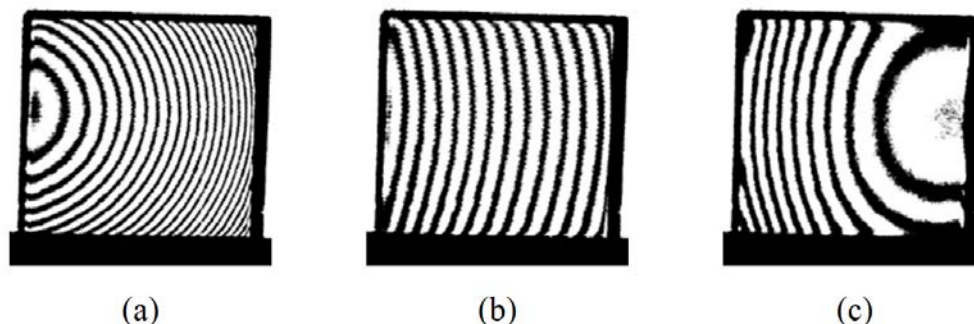
We used for the experimental setup a diode laser of  $532\text{ nm}$  as source light; a spatial filter of  $40\times 10\text{ }\mu\text{m}$ ; a CMOS detector Pixelink PL-B776 with a resolution of  $2048\times 1536$  pixels; a beam splitter 50/50 and three flat mirrors with an optical quality of  $\lambda/4$ . The Mirror M2 was placed in a linear stage with a tilt mounting and M1 was placed in a tilt mounting. A polarizer was used to compensate the visibility in both arms was used.

Before to introduce the SLM in the experimental setup of Fig. 1, the interferometer must be adjusted to have nearly the same optical path for its two arms. In the second step, the SLM is placed into one of the interferometer arms and the optical path produced by its thickness has to be compensated by moving the mirror M2 (in or out) in the other arm.



**Figure 1** Experimental set up.

The first step for matching the optical paths in the interferometer for both mirrors from the beam splitter was to measure the distances with a Vernier as a first approximation. The next step starts by observing the interference patterns. In Fig. 2 are shown three typical interference patterns that can be observed depending of the adjustments done on mirror M2, and keeping mirror M1 fixed. The closer position of both mirrors with respect to the beam splitter is reached when the pattern of Fig. 2b has the minimum number of interference fringes, similar to the pattern of Fig. 3. This process to get the best matching distances can be repeated many times as needed, in order to achieve a better approach to have the same optical path in both interferometer arms.

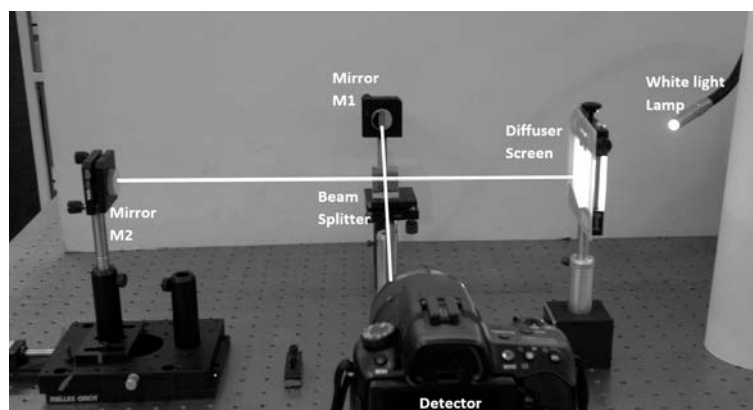


**Figure 2** Experimental interferograms. (a) Right displacement of M2 from the beam splitter; (b) Tilt introduced to M1; (c) Left displacement of M2 from the beam splitter.



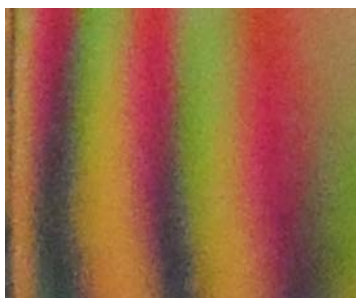
**Figure 3** Interference fringes with practically the same optical path difference.

Because it is necessary to take into account the thickness of the SLM, when is introduced in the interferometric arrangement of Fig. 1, it is compulsory to have in the produced interferograms a reference fringe. Such reference fringe can only be observed if a white light source is used. Therefore, in our experiment the laser was substituted for a white light source as is shown in Fig. 4. The adjustment of mirror M1 must be repeated with this new light source because given its low temporal coherence, implies more fine applied movements. However, with the previous positions with the laser, the task with the white light source is less difficult.



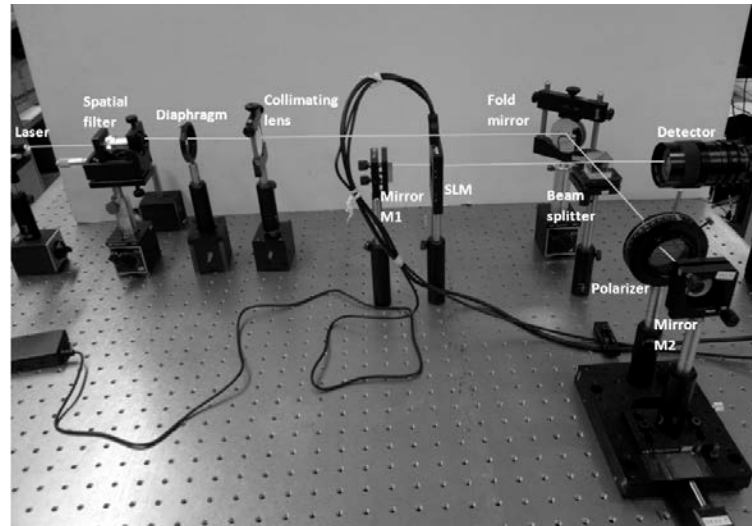
**Figure 4** Experimental set up with white light source.

With the white light source in the setup of Fig. 4, a similar procedure of the previous alignment must be done to get the minimum interference fringes in the observed pattern; when such pattern is obtained a dark fringe is observed, as the one seen in Fig. 5. This dark fringe will be the reference interference fringe. When the SLM is introduced in the experimental setup of Fig. 4, the pattern of Fig. 5 changes because the thickness of the SLM. After new adjustments of mirror M2 (displacements in/out), the interference pattern with a dark fringe is recovered, which means that the matching distances of mirrors M1 and M2 from beam splitter has been properly adjusted.



**Figure 5** White light fringes.

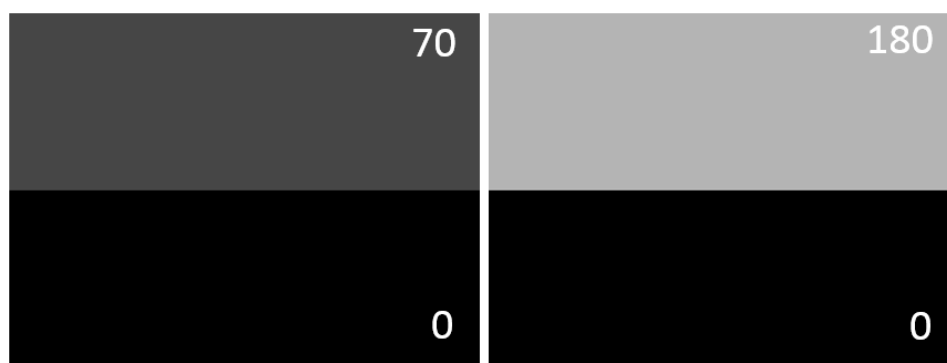
When the SLM is introduced in the interferometer, it produces a reduction in the contrast of the interference pattern that can be compensated by using a beam splitter with a different percent of intensities in each arm, or can be used also some filter. In our case, a polarized was used, Fig. 6.



**Figure 6** Experimental set up.

An algorithm to display the different grey levels in the SLM was developed. This algorithm generates a matrix with the same resolution of the SLM (1024x768pixels); this matrix is divided in two identical parts, the upper part is varying the grey levels from 0 to 255 and the lower part remains fixed with 0 as reference, Fig. 7. This change in the grey level produces a phase shift in the wavefront that can be seen in a fringe shift in the interference pattern which is captured in the detector, Fig. 8.

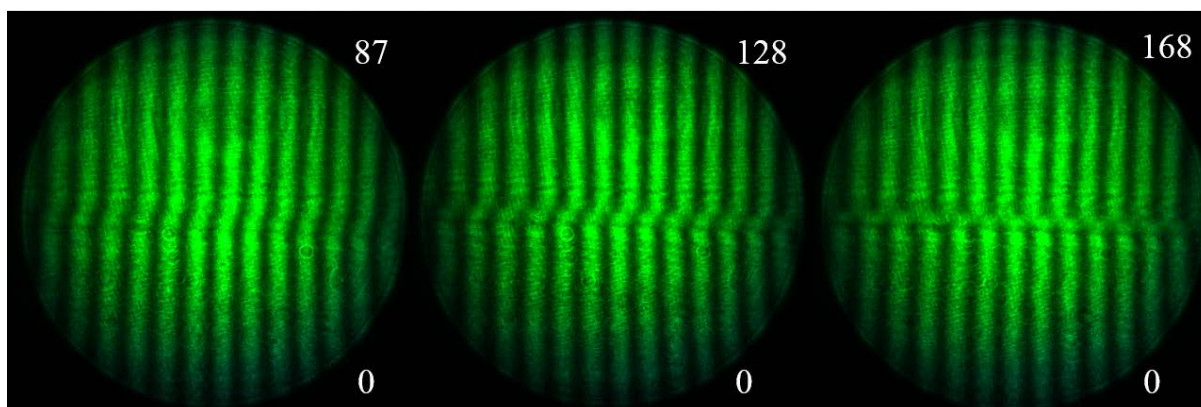
The next step to obtain the curve “Gray level vs phase shift” of the SLM Holoeye LC2012 was to capture the 256 interferograms with phase shift. For this, the 256 images with the different grey levels were displayed in the SLM and at the same time its interferogram was captured, Fig. 8.



**Figure 7** Different grey levels displayed in the SLM.

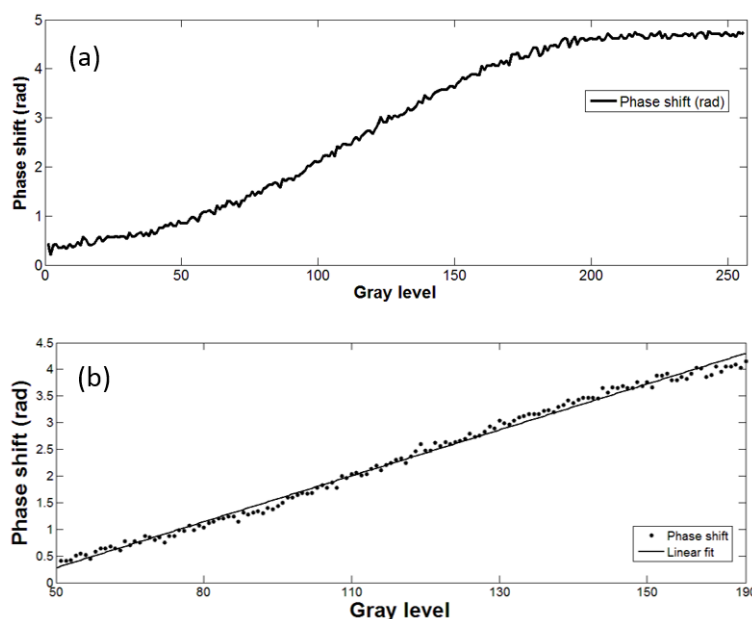
### 3. Experimental Results

In Fig. 8 the experimental interferograms captured with the CMOS detector are shown. A fringe shift in each interferogram that is more remarkable each time that the gray level is increased can be seen.



**Figure 8** Experimental interferograms.

A computational algorithm for measuring the fringe shift in each interferogram was developed. This algorithm finds the value and position of each maximum in the experimental interferograms. After this, the algorithm takes two rows in the interferogram, one corresponding to the part which the gray level was changed and the second row corresponding to the part where the gray level remained fixed. The algorithm makes the subtraction of this two positions giving the introduced shifting by each gray level, Fig. 9.



**Figure 9** Phase shifts. (a) All the gray levels from 0 to 255 and (b) linear fit from 50 to 190 gray levels.

#### 4. Conclusions

It has been shown that varying the gray levels in the SLM Holoeye LC2012 different fringe shifts can be obtained. The best rank of work was found between the 50 to the 190 gray levels. A linear fit between the 50 to 190 gray levels with an error of  $rmse=0.0980$  was found. The fringe shift associated with the different gray levels displayed in the SLM by using a reference in the interference patterns, was calculated. From this analysis it was found out that a noticeable linear phase shift can be obtained

with the Holoeye LC2012 between the 50 to 190 gray levels, Fig. 9. From these initial results we are in the position to do a more complete phase shift analysis of our experimental interferograms.

## References

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