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High optical correction system based 800x600 analog spatial light modulator

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Abstract

In this work, a modern optical system based on modulation technique is constructed to achieve the retrieval of optical defects and distortions of the images behind dark barriers. A 800x600 analog spatial light modulator (SLM) is used in this technique with a 632.8nm He-Ne laser, a circular metallic mesh (CMM) is imaged and disturbed and then dealing with our system. The SLM was confirmed for irregularity improvement such as variable diffracted optical element (DOE) control. The obtained results showed that the effect of distortion has been treated and reduced to be minimum by controlling phase and amplitude modulation of the scattered wave front utilizing the SLM. The obtained images showed identical to the original image with limitation in the intensity distribution due to the pixelated structure of SLM. This technique represents the most appropriate solution to the problem of dispersion in images with the lowest costs and best results. The most important applications of this technology are the ability of providing high-resolution imaging where viewing through a deviant medium is inevitable.

Keywords: Spatial light modulator (SLM), deviation, aberrations compensation, liquid crystal (LC), resolution.

نظام تصحيح بصري عالي يعتمد على معدل الضوء المكاني التناظري 600×800

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الخلاصة

في هذا العمل، تم بناء نظام بصري حديث يعتمد على تقنية التعديل لتحقيق استرجاع العيوب البصرية وتشوهات الصور الموجودة خلف الحواجز المظلمة. يتم استخدام مُعدِّل الضوء المكاني التناظري مقاس 800 × 600 (SLM) في هذه التقنية باستخدام ليزر He-Ne مقاس 632.8 نانومتر، وتم تصوير مشبك معدني دائري (CMM) وتشويب هذه الصور ثم معالجتها حسب نظامنا. تم تأكيد قابلية SLM لتحسين التشويب من خلال التحكم في العنصر البصري المنعرج المتغير (DOE). أظهرت النتائج التي تم الحصول عليها أن تأثير التشويه قد تم معالجته وتقليله إلى الحد الأدنى من خلال التحكم في تعديل الطور والسعة لجبهة الموجة المتناثرة باستخدام SLM. أظهرت الصور التي تم الحصول عليها مطابقة للصورة الأصلية مع وجود قيود في

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توزيع الكثافة بسبب البنية المنقطة لـ SLM. تمثل هذه التقنية الحل الأنسب لمشكلة التشتت في الصور بأقل التكاليف وأفضل النتائج. أهم تطبيقات هذه التقنية هي القدرة على توفير صور عالية الدقة حيث لا مفر من المشاهدة من خلال وسط منحرف.

1. Introduction

Multiple scattering phenomena are the primary cause of incident wave diffusion on a condensed medium, which destroys the original wave within the medium [1]. Some of information about a deflecting object's structure is carried by the amplitude and phase of the diffracted beam [2]. Retrieve dispersed information represents a big and difficult challenge problems in the fields of optics, Bio-imaging, and Microscopy imaging [3], where incoming wave front will be deformed and the information will be lost. These spatial distortions can be improved by an amplitude shaping utilizing spatial light modulator (SLM). The SLM is a device that is utilized in a variety of optical systems for dynamic diffractive optical element (DOE) procedures [4]. It works as a sinusoidal grating with revolving alignment in different phases and control parameters, such as lens, prism, contrast, and brightness, to achieve a visual advantage [5]. It is a key optical component for high-precision displays, sensing, and telecommunication [6]. The SLM has a positive nonlinearity due to it self- focusing, high sensitivity and very low absorption at high intensity imaging [7]. Liquid crystal (LC) cells of the SLM are prepared in two-dimensional arrangements, and developed in a way that forms cells in discrete addressing. As a result, a favorite spatial distribution and a phase or amplitude modulation will be created. When the SLM is inserted between two polarizers it can thus be used as an image source in an optical system, also it can be used as a switchable DOE in Fresnel zone lenses, gratings and beam splitters, which can be altered by means of electronic components. the irregular scattering and reproduction of the light transmission passing through a thin LC segments is studied by [8]. An iterative aspect wavefront compensation technique to recompense distortions have been examined by [9]. The operation of a new SLM-based flexible join platform has been investigated by [10]. In this work, a highly sensitive aberration compensation system is achieved utilizing two-dimensional array (800x600) SLM which programmed as controlling device utilizing high-energy laser for beam profile correction. The investigation of deviation correction is basically restricted by distortion in wavefront caused by random distribution of flecks. This technique can be used in various optical applications, such as biomedical investigations, astronomical imaging and clinical diagnostics [11].

2. Theory

The principle of work of the SLM based on LC function, if light is incident on the LC molecules this produce rotation in LC which causing the change in polarization and amplitude state of this wave front [12]. Figure 1 shows how an externally applied electric field controls the behavior of LC particles, with the direction of these particles changes in response to the direction of the electric field propagation.

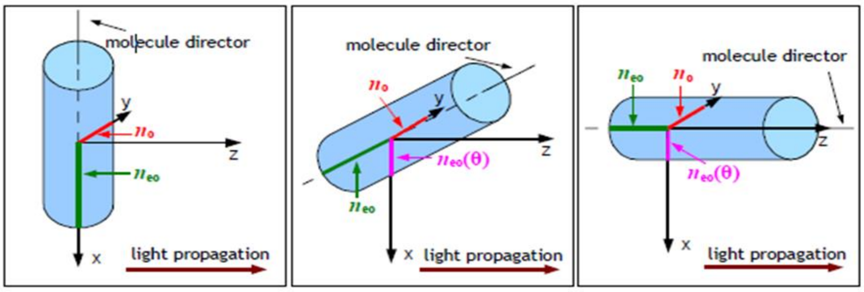

Figure 1-Behavior of the LC particles with respect to the applied voltages, the n_o and n_{eo} represents ordinary and extraordinary refractive indices respectively, while $n_{eo}(\theta)$ is the resulting extraordinary refractive index for each direction of the SLM molecules [13].

The relation between refractive indices of the LC depends on propagation direction and gives as: [13-14]

$$\frac{1}{n_{eo}^2(\theta)} = \frac{cos^2(\theta)}{n_o^2} + \frac{sin^2(\theta)}{n_{eo}^2} \quad (1)$$

where n_o and n_{eo} are the ordinary and extraordinary refractive indices. The angle between the propagation direction through a distance d determines the velocity of exceptional polarized light propagating through the LC, given by the thickness of the medium, is therefore given by:[13]

$$V' = \begin{pmatrix} V'_{eo} \\ V'_o \end{pmatrix} = W_d \begin{pmatrix} V_{eo} \\ V_o \end{pmatrix} \quad (2)$$

where

$$W_d = \begin{pmatrix} exp\left(-i\frac{n_{eo}w}{c}\right) & 0 \\ 0 & exp\left(-i\frac{n_o w}{c}\right) \end{pmatrix} \quad (3)$$

where V_{eo} and V_o are the various velocities of various refractive indices. The Jones matrix of SLM can be approximated as: [13]

$$W_{TN-LC} \approx R(-\alpha)\begin{pmatrix} cos\alpha & sin\alpha \\ -sin\alpha & cos\alpha \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \quad (4)$$

where WTN-LC is the matrix where the LC molecules are arranged in helix structure. When the light is polarized and incident into the SLM, the LCs orientation can be controlled by varying the practical voltage of the SLM segments. So, the amplitude, phase or both will be modified until reach the desired pattern of output wave, Figure 2. As a result, the amplitude of an incident light with polarized wave shows a deviation correction and the modulation in phase can be written as: [15]

$$\varphi(x, y; V) = \delta\varphi(x, y; V) + \varphi(x, y; 0) \quad (5)$$

where δφ (x, y;V) represents modulation part which depending on the applied voltage and the position of pixels, φ(x, y; 0) is the distortion compensation achieved by modifying the incident wave front.

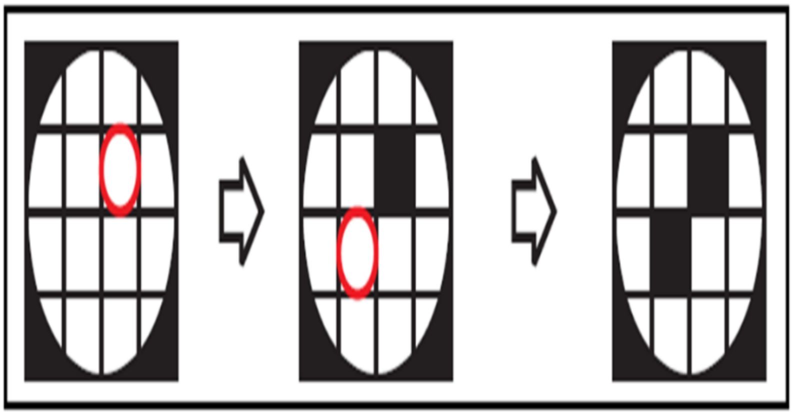

Figure 2-controlling of amplitude modulation according to the voltage applied into the SLM segments, parts of these segments are turned off (red circles) as algorithm proceeds to next segment and so on. This leads to real time aberration deviation by sensing the incident light wave and altering the phase difference of the SLM to compensate aberrations [16].

The high intensity of the laser is excellent for examining cases of optical dispersion correction [17], in addition to the fact that the principle of the SLM's operation requires a polarized light source.

3. Experimental work

Figure 3 shows the experimental setup. In this part, we distorted an optical image and then studied the effect of the SLM in distortion correcting. A polarized He–Ne laser is expanded with a diameter of 1cm by an objective lens, then passing through a circular metallic mesh (CMM). A high-condense diffuser acts as a dispersal medium, scattering the light beam. So, the incoming wave front is diffracted and the information of the CMM are dispersed. The distorted wave light is then passed through a 600×800 SLM and controlled by an adapted electronic mesh which determines the applied voltage to the LC as grey level values (0-255). The phase of the CMM distorted wave will be modified and shaped until reach the desired pattern.

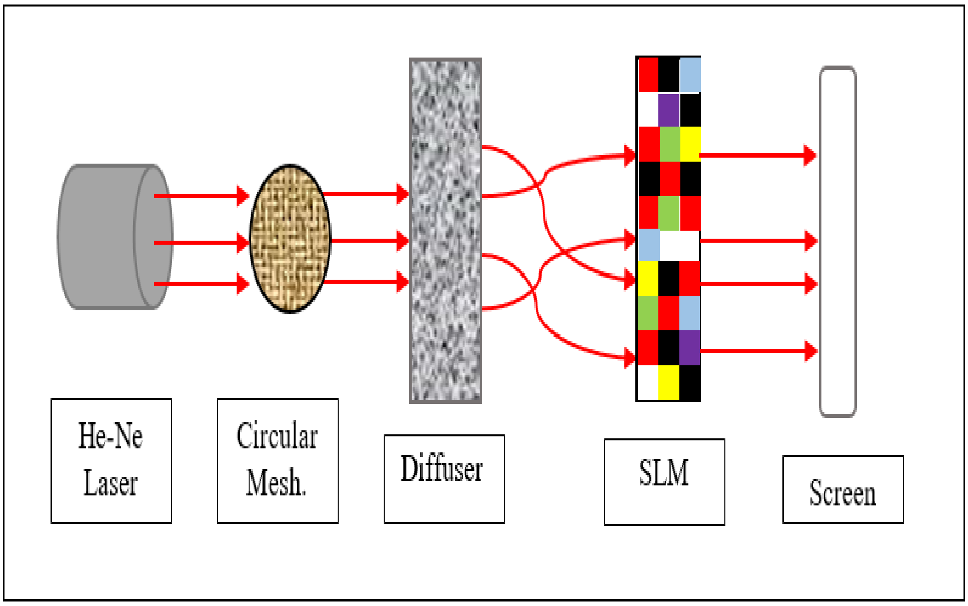

Figure 3-The experimental setup.

A charged coupled device (CCD) camera is used to show the obtained results.

4. Results and discussion

In this section, we studied the images obtained by our system and we noticed the effect of diffuser and SLM respectevely. When the SLM is illuminated by a coherent light source, various diffraction effects that are based on phase modulation effect can be observed. In this case, the SLM is divided into 480000 segments, Figure 4. Before the optimization, all segments were on and the transmitted intensity pattern was random speckle.

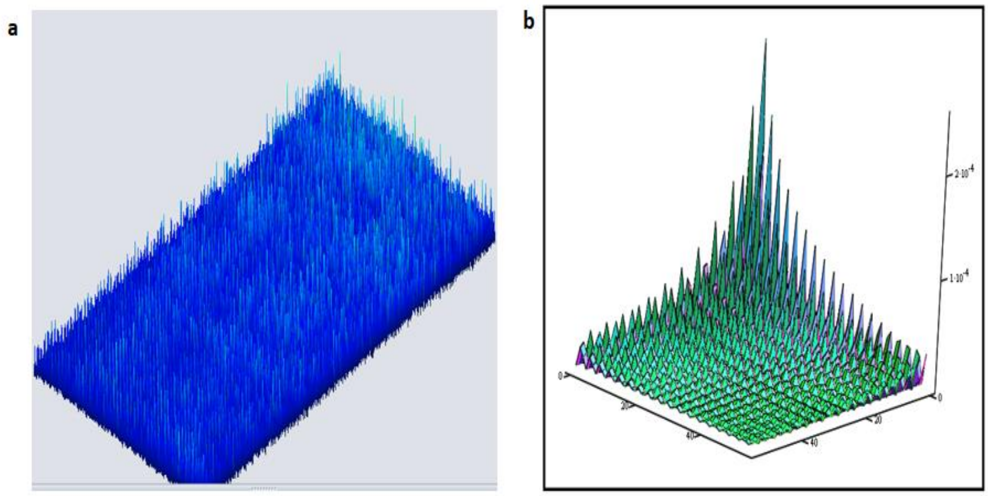

Figure 4-Pixelated structure of the SLM: (a) far field diffraction patterns of illuminating SLM with an expand He-Ne laser, (b) simulation of the 800 × 600 pixels for the SLM which refers to the high performance of the SLM.

The creative image of CMM before placing the dispersed medium is shown in Figure 5.

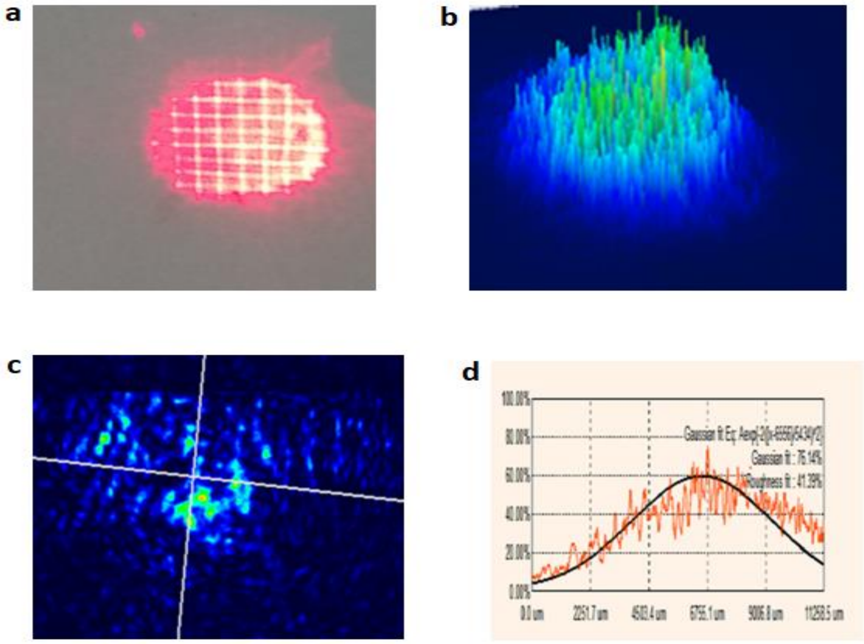

Figure 5-(a) The real image of CMM before being blurred by the dense material, (b) 3D, (c) 2D, (d) XY Graph.

The CMM image is blocked by the diffuser and an arbitrary speckle pattern produced on the CCD device as shown in Figure 6, where the subtle lines of the CMM image is unclear.

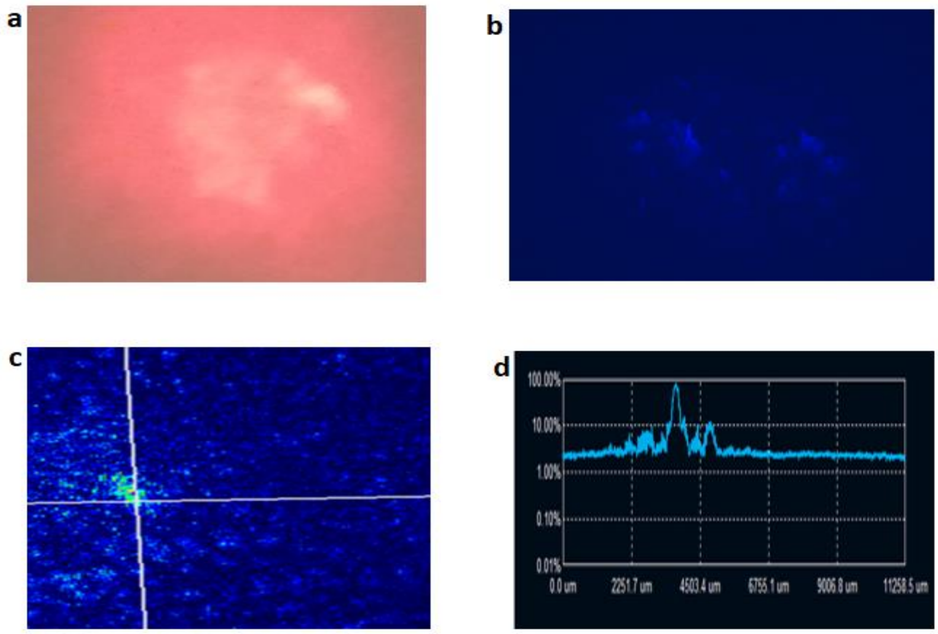

Figure 6-Distorted images of the circular metallic mesh (CMM) due to the diffuser medium, the images from left to right: screen image, 3d, 2d and XY intensity profile images.

When the distorted image is passed through the SLM, the segments of the CMM is imaged to the SLM plane of a 600×800 segments, means that the SLM segments had transformed the CMM image into 600×800 pixels at the improved wavelength. So, each pixel will be controlled and rotated in different directions, the amplitude and phase are changing to produce the image with various range of intensity. As aresult, the disperted wave front will be enhanced and shaped utilizing SLM (Figure 7).

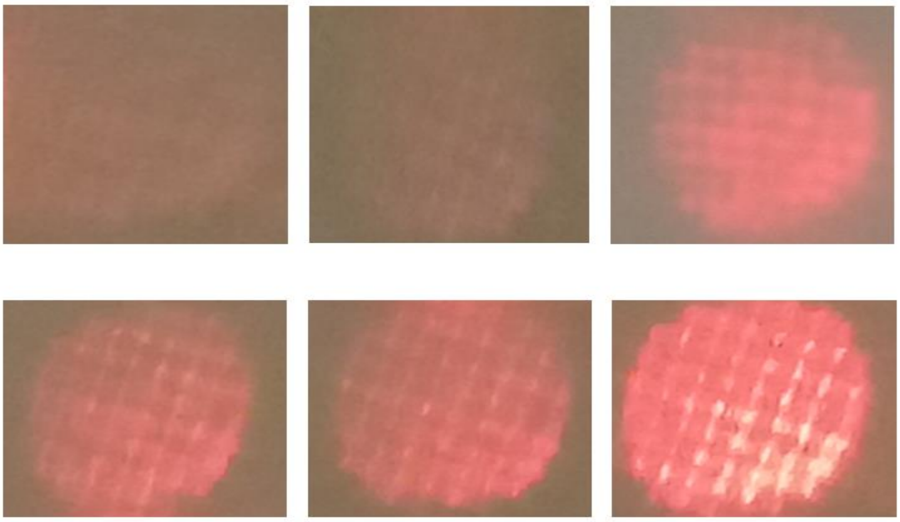

Figure 7-Deviation compensation of the CMM image utilizing SLM, the optimization procedure from left to right is due to phase diffrence.

The change in the polarization of the SLM's molecules led to a change in the phase of the incident light wave into several phases and intensities (Figure 8), which allowed us to choose the appropriate pattern and the closest to the original image. The increase in intensity is maybe caused by an intrinsic birefringence of the LC particles which compensate this inherent refractive index difference and cause the intensity to rise.

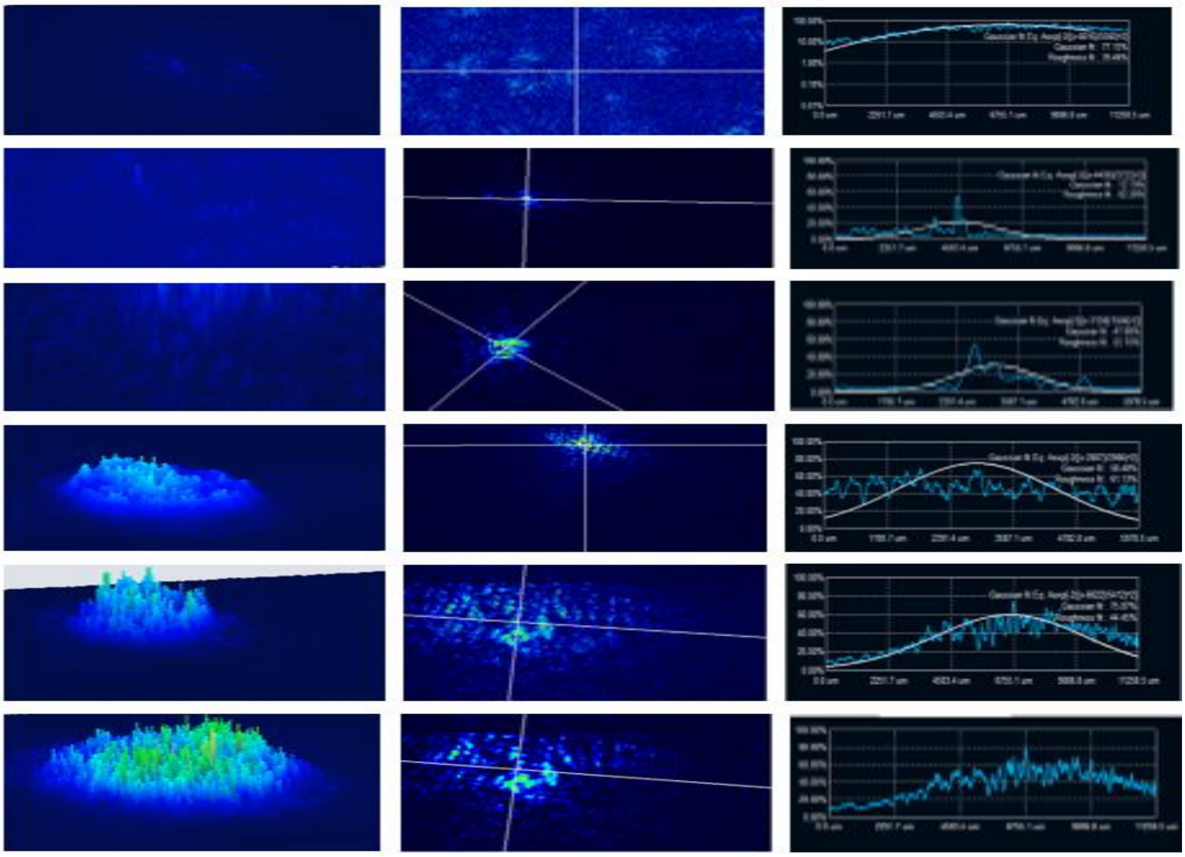

Figure 8- The patterns of the CMM image after enhancement, there is an increasing intensity as a result of phase delay effect where the light is focused behind the diffuser.

The intensity distribution of resulting images is limited by the accuracy of the LC distribution within a 2d matrix inside the SLM. So, the variation in the resulting intensity distribution, Figure 8, is due to the structure of the SLM where the distribution of the intensity for the LCs arranged in 2d layer show variance distribution as shown in Figure 9.

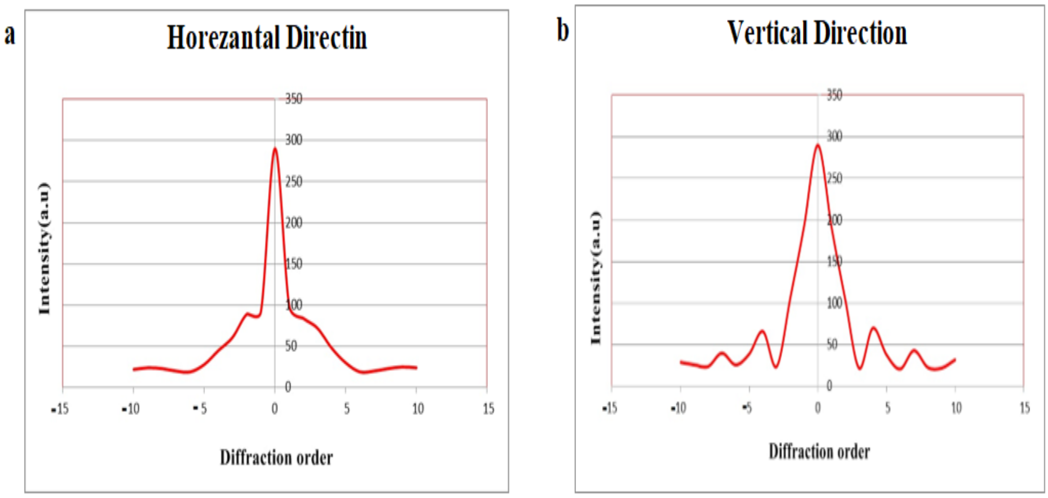

Figure 9-Gaussian of intensity distribution for the LC molecules in the SLM: (a) in horizontal row of the SLM matrix, the distribution of diffraction orders show symmetrical, (b) The vertical distribution of diffraction orders show asymmetric. This structure is affecting the image results by the SLM.

The vertical distribution of pixels is less accurate than the horizontal distribution. The orders of diffraction for both the horizontal and the vertical show that there is a slight variation in the vertical distribution, as indicated in Figure 9.

5. Conclusions

In conclusion, we have demonstrated a high optical correction based SLM system to deviate the aberration of the CMM image passed through a medium with high scattering density. The SLM is used to alter and shape the optical characteristics of a complex distortion imaging. The losing of dispersion information was compensated successfully by phase modulation produced by controlling the applied voltage and thus the incoming light to the surface of SLM. The obtained results showed agradual increase of image intensity due to the modifying in the coupled phase and amplitude (a natural birefringence of the SLM). However, the distribution of intensity was asymmetric because of the SLM designing where the gaussian distribution is not equally for both vertical and horizonal LCs pixels. The SLM worked as an DOE which can be used to introduce an individual phase shift to the light pathes of wave front incident on the LC cells. This system of great interesting in biomedical photonics and microscopic imaging applications.

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