Implementation of Spatial Light Modulator(SLM) using a Commercial LCD Beam Projector

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Abstract

In this paper, a new high resolution XGA-SLM is implemented through modification of a commercial TFT-LCD beam projector and its optical modulation characteristics as a spatial light modulator(SLM) is also analyzed.

First, the optics module, projection lamp and fans are removed from a commercial beam projector and instead, some electric circuits to compensate their removal are manufactured and then, by inserting them into the beam projector, a new XGA-SLM is finally implemented.

Second, from some optical experimental results, this TFT-SLM is found to have a good optical linearity in amplitude and phase modulation characteristics as a function of the input gray levels. Especially, through implementation of a binary phase-type correlator such as BPEJTC by using the suggested TFT-LCD panel, the implemented SLM is proposed as a new relatively low-cost and high resolution SLM for optical information processing.

Key Words : SLM, LCD Projector, TFT-LCD, Mach-Zehnder Interference System, Optical Module

1. Introduction

The information and communication industries having high power in 21st century, currently has been experiencing the innovative change due to spreading of information and communication network, including the internetwork, and rapid development of digital multi-media

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Particularly, the research and development with respect to the technology based on the kernel that can synthesize and process, transmit, and record more effectively the diverse digital multi-media information that expect to be increased by geometric progress has been vitally progressed on the center of the developed countries [1]. The most competitive candidated technology able to commercialize in the short term among these research and development fields in the future is the application utilizing light hologram technology.

The light element able to use as the most core in the technology processing the light by using the hologram is just spatial light modulator (SLM). This SLM is not only used for inputting device of light image in the system processing the light information but also into spatial matched filter.

When such SLM would be utilized into the system processing light information, the character to be required usually must be high in the resolution, and be possible addressing the pixel unit, and modulating in amplitude and phase as well as general purpose commodity at low price.

Currently, the SLM used broadly is the LCD (liquid crystal device) spatial light modulator [3-10]. However, the LCD SLM currently widely used has, in general, the resolution like the grade of VGA(640×480) or SVGA(800×600). Besides, it is quite expensive.

Recently, the dedicated SLM having super resolution of XGA(1024×768) grade has been commercialized, but the price is very expensive. The conventional LCD SLM has been used for amplitude modulation, but the SLM for modulating the phase or complex number that have been demanded in light pattern recognition or light security field has been hardly reported.

The present paper has verified all the possibilities that are not only able to replace the unique SLM developed for modulating the phase and expensive, but also able to modulate the phase and amplitude through implementing the LCD-SLM having super high resolution of XGA grade and low price by using the commercial LCD beam projector.

Again, through character analyzing of the light modulation of commercial LCD-SLM newly proposed, it has been verified that the proposed SLM is widely and acceptably good in usage, and that it has excellent performance in a lower price than the conventional and expensive SLM. Hereafter, by using this fresh LCD-SLM, very effective experiment of the spatial light modulation will be possible.

2. The structure of commercial LCD beam projector

The LCD panel of LCD beam projector produced by SHARP Co. consists of three(R, G, B) of LCD panel(LCX029CNT) produced by SONY, The the diameter of each LCD panel is 0.9″. It is constituted by the pixel of 786,432(1024×768) that is XGA grade.

Figure 1 shows the block diagram of an internal system of LCD beam projector used in this paper. The main board of the beam projector controls each driving part and it actuates the power lamp part of high output and, therefore, the power source for this is structured independently.

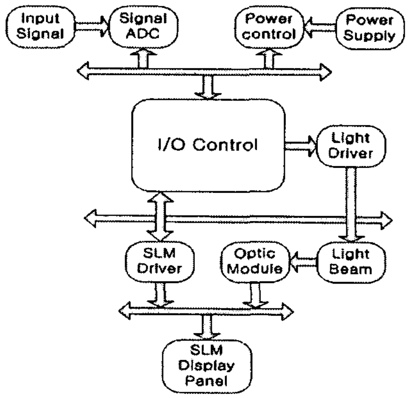


Fig. 1. Blockdiagram of LCD beam projector system

The main board mentioned in figure 1 has the function of self test - designed uniquely to protect the beam project from high temperature and high voltage, and to guarantee the stable operation from external impact. That is, the beam projector unit is very complicated and it has high precision, that is, when there happens any trouble in the internal circuit or on the module, it has the function that puts its operates into stop and, hence, enter the function to check the trouble.

To modify the SLM in accordance with this, many optical systems and projection modules are needs to be removed. At this time, because the function of trouble-check exists in each circuit or module, even since the SLM has been modified, all the functions are not actuated unless the SLM is made into original state before being modified. Therefore, extreme carefulness is required. Again, because the lamp of the projector is operated with high voltage and electric current, and a high temperature is generated by 150w of large output, all the actions that beam projector must take are to stop at once an external cover is opened.

Accordingly, to modify a commercial beam projector such a SLM, the modules should be removed very skillfully and carefully, and requires to be substituted with the fine compensation circuit.

3. Implementation of LCD-SLM through modifying a commercial beam projector

3.1 The character of LCD panel for beam projector

In this paper, the TFT-LCD panel XGA grade (Sony, LCX029CNT) used in the commercial beam projector(PG-C20XE) produced by SHARP Co, was investigated on the optical property. It was then modified into an input of the system processing light information and SLM optical element for spatial filter.

That is, as the principle of TFT-LCD XGA grade built in the inside of commercial beam projector and of projection optics system was effectively used, we had performed the procedure to convert into the LCD SLM for processing light information with no usage of the projection.

As the LCD used for Beam projector was the Active Matrix type of TFT-LCD XGA grade whose diameter is 0.9″ and 786,432(1024×768) of pixels, its contrast ratio is 1 : 350. The size of each pixel is 17.99×17.99[㎛], and the frame size (length×width) is 18.43×13.82[mm].

Table 1. Specification of LCD panel in the beam projector

LCX029CNT Panel by Sony			
Panel Size(Dig.)	0.9″	Contrast	1:350
Number of Pixel	786,432 (1024×768)	Mode	TN
Pixel Size	17.99×17.99[um]	# of data lines	32
External size of SLM	18.4([H])× 13.8([mm])([v])	Optical transmittance	30[%] (typ)

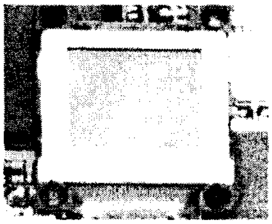


Fig. 2. External photograph of TFT-LCD panel in the beam projector

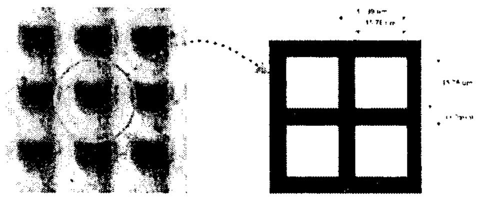


Fig. 3. Pixel structure's photograph of LCD panel

Figure 2 shows the appearance of LCD panel used in the commercial beam projector. The structural form of pixel by magnifying the panel is shown in figure 3. The LCD panel shown in figure 2 is a piece separated from three panels for synthesizing the RGB images. In addition, figure 3 displays the size and the structure with respect to each pixel by photographing closely with a microscope after the internal panel of a beam projector is dissembled.

3.2 Removing the optics module and Lens module

The optics system of beam projector shown in figure 4 consists of an objective lens for projection, a general optics lens, a reflection mirror, and a color filter, among the important parts.

Although such an optics system is a very critical system in the conventional commercial beam projector because it carries out the function projecting into a screen the images on the panel by passing the beam of lamp into the LCD panel within a beam projector, when it would be modified into SLM, this optics system becomes useless at all. Therefore, an effective removal is very important.

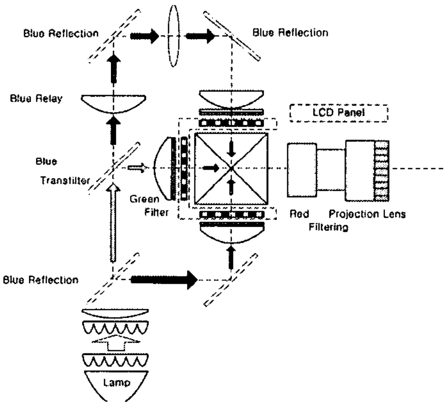
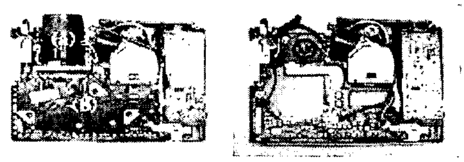


Fig. 4. Internal structure of a commercial beam projector using a prism

The procedure to remove the optics module is classified into two parts: the part of forming color image after the light of lamp. The white color light is divided into three - Red, Green, and Blue. These three color lights are passed into a panel opposing them, and they re united into a color. The other is the part of the projection lens module projecting into a screen such color images.

These two parts are a net optics system, not at all containing the electronics controller, and are removed easily by releasing the tightened bolt of optics module after the removal of the main circuit board.

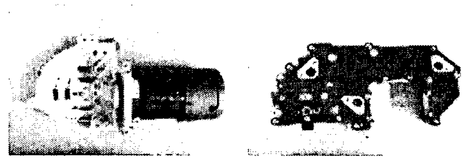
The dotted lines in figure (a) shows the projection lens module (a) inside the projector, and (b) the region of each optics module.



(a) (b)

Fig. 5. Figure of removing before and after of the projection lens and optical module

Figure 5 displays the beam projector before and after they are removed. Figure 6 illustrates the projection lens module and the optics module removed from a commercial beam projector.



(a) (b)

Fig. 6. Figure of a removed optical module and projection lens module

3.3 Removing the fan of beam projector and lamp module

The projection lamp, which outputs 150[W] power, emits much heat leading into putting out light. At this time, the heat emitted has as much high temperature enough for burning the internal circuit and the PCB board, particularly. This is because the color filter among internal optics systems and the SLM are very vulnerable to heat. Therefore, it requires a device able to expel the heat out effectively. To emit this heat, the commercial beam projector employs four fans. These internal fans within a commercial beam projector are connected to the main board by the means of three wires(Red, Black, White) or two wires(Red, Black).

Table 2 shows the power source data used to input into each fan.

Table 2. Fan's usage power data

	Red	Black	White
Power OFF	0[V]	0[V]	0[V]
Power ON(2wires)	5[V]	GND	Non
Power ON(3wires)	15[V]	GND	0.7[V]

When table 2 is analyzed, we can observe that the 5 Voltage fan is connected to the main board with two wires(Red, Black), and the 15 Voltage one connected with three wires(Red, Black, White).

While the 15 Voltage fan connected to the main board with three wires, among these the white color wire is the line for checking whether the operation of fan is normal or abnormal, and it is used into a part possible to give great impact among the operations of beam projector according to whether the operation of fan is normal or not. This is because much heat is produced within a beam projector.

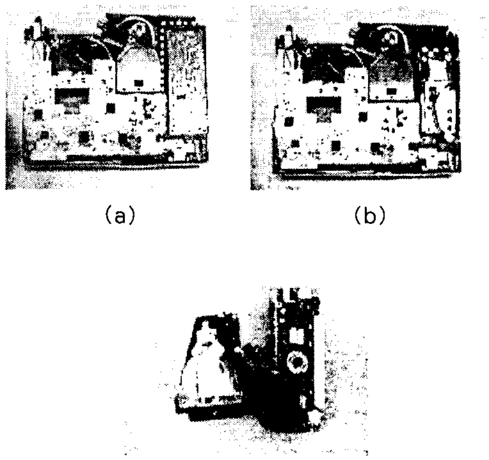
For such a wire to check the operation, the signal or voltage is encountered into kind and property of fan that is applied. Accordingly, the 5 voltage fan may be removed easily because it has no wire for checking, while the 15 voltage fan connected to main board by the means of checking wire is needed to be set at the operational condition into the same condition before being removed to make the beam projector into normal after the removal.

Since the LCD SLM that we would use is not for the use of projector, rather for optical element for information process by a ray using laser beam majority in the darkroom, the 150[W] of lamp having high voltage and high power must be removed. The power source for turning on the projection lamp is kept at 15[V] DC in the normal state, but as soon as the operation starts, the high voltage of more than 300 voltage is formed, and on the inside of the lamp circuit the voltage greater than 1[kv] is created at that time.

The projection lamp circuit is connected to the main board by the means of the four wires: a lead for operation check, the other for power source check, and the two lead wires for grounding. Since the circuit is not operated unless these data of each lead wire are matched, When the projection lamp having high voltage and high power would be removed effectively, the operational condition, like the ones illustrated in table 3, must be formed.

Table 3. The active conditions of main board after the projection lamp removed

ON/OFF	Ground	Action Cond.	Input voltage
Lamp OFF	GND	0	4[V]
Lamp ON	GND	1.6[V]	0.7



(a) (b)

(c)

Fig. 7. Figures of removing before and after of lamp and figure of removed lamp module

To make it into normal state and at the same environment before the projection lamp is removed, the voltage of 0.7[V] should be applied when the lamp is "ON" and the voltage of 4[V] be applied when it is "OFF". We could implement the situation possible to operate normally without the lamp by designing and manufacturing a new power source circuit by considering these conditions.

Figure 7 (a) and 7 (b), respectively, show the projection lamp before and after being removed while figure 7 (c) shows the lamp module region within projector.

3.4 Implementation of data lead wire and LCD panel holder

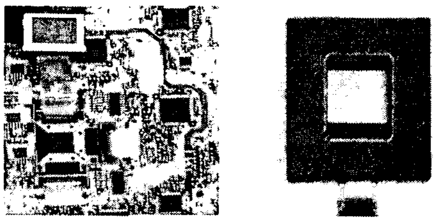
The lead wire for data of LCD panel within a commercial beam projector consists of 32 pins, and it is connected to the main board with short space of about 5[cm]. To use freely such an LCD panel with the SLM for processing information by light, it is needed that the length longer than 50[cm] be designed.

For the sole purpose of protecting the long data lead wire having 32 pin, and to prevent LCD panel from the damage in the procedure of information process by light, the design for a holder to fix the LCD panel is also required. Figure 8 shows the appearance of LCD SLM newly implemented by applying the panel holder. Besides, 32 pins of data lead wires designed and manufactured in the present study are represented in the respective figure of original LCD panel.

As seen in the figures, the present study could implement the SLM by connecting each LCD as designed and manufactured in real to the lead wire for data whose length is 1.5.

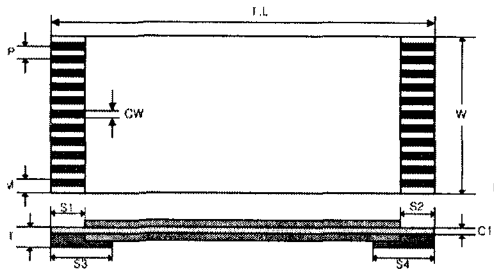
As the lead wire used in this paper was an FFC (Flexible Flat Cable). It was designed as the lead wire for data meeting the best condition by considering the characteristics of signal and noise under AC 500[V/min], 266[Ω/Km-Min], without being interrupted by heat and noise generated within the conducting wire under the temperature below 105[℃] by using PET/PVC material.

Figure 9 (a) shows the structure of the lead wire for data considering such characteristics, where P is the pitch size(0.5[mm]), TL is the total length (1.5[m]). In figure 9 (b) the connection structure for connecting to a cable has been shown.

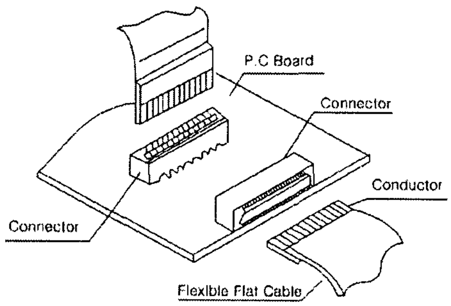


(a) (b)

Fig. 8. Figure of removing before and after of the original LCD panel



(a) Structure of data reed wire



(b) Connector's coupling method

Fig. 9. Structure of data reed wire and connector's coupling method

4. Experiment and Consideration of results

4.1 Analysis of the characteristics of amplitude modulation of LCD-SLM implemented

To analyze the possibility of application for processing the information by light with respect to the XGA grade of LCD SLM implemented in this paper, the character of modulation by light, such as the character of amplitude modulation and of phase modulation was analyzed. Firstly, the character of amplitude modulation by light of LCD SLM implemented was analyzed by constituting the experimental system as in figure 10.

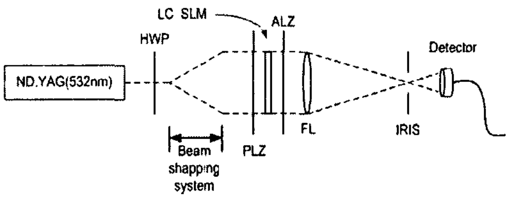


Fig. 10. Experimental diagram for characteristic analysis of the amplitude modulation in the modified LCD-SLM

In the experiment under discussion, the direction of polarized light was tuned into the traverse wave by the ND: YAD laser having an output power of 200[mW] and its wave length being 532[nm] made by Crystal Laser company. The wave plate whose wavelength is λ/2 and the parallel light more than one inch in its diameter was made through the collimator and beam expander(10X) system made by New pot company. Also, a polarizer and an analyzer were installed at the front and rear of LCD panel. The image, according to grey level on the LCD panel, was displayed, with the light intensity transmitted to the LCD panel according to grey level being measured using a photo-detector[5-7]. Figure 11 shows the experimental results of the character of amplitude modulation by light of LCD SLM newly implemented in this paper. In figure 11, the grey level is set into 0, when all the pixel of LCD panel is in "OFF". It is set into 255 grey level when all pixel is "On". Under such a condition, when the grey level of the image displaying on the LCD SLM is changed from 0 to 255, figure 11 shows the relative number by detecting the light intensity matching to each grey level.

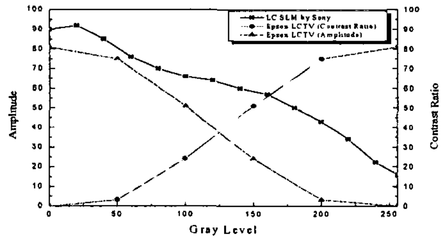


Fig. 11. The characteristic of optical amplitude modulation in accordance with gray level

Figure 11 shows, the schismatizing of the numerical value with respect to the character of amplitude modulation of LC-SLM proposed in this paper, and it was compared with Epson LCTV(320×220)[8]. The Data to LC SLM in the figure is displayed after being converted into a hundred percent of transmitting efficient with respect to grey level of inputting image. An Epson LCTV showed the converting into a hundred percent of light intensity of illumination on the panel according to each video level, Since these two data have a relative concept that is opposed to each other, where they are compared to one hundredth rate they become the same data. When the character of amplitude modulation of LC SLM implemented in this paper is compared with the commercial spatial light modulator at the current, we could know that the curve line of character is distributed linearly even though high resolution and small pixel exist.

4.2 Character analysis of phase modulation of LCD-SLM implemented

To analyze the character of phase modulation of LCD SLM XGA grade newly implemented in the present paper, we constituted an interferometer of Mach-Zehnder like in figure 12. In the present test, we used ND: YAG Laser(DPSS) whose wave length is 532[nm], and its maximum output power is 150[mW] as laser source, and made by Coherent company. To measure the character of phase modulation, the same LC SLM panel that had been used in the amplitude modulation was used. The differing from that experimental setup of amplitude modulation was done, and its experiment was carried out after removal of the PLZ and ALZ that had existed at the front and the rear sides of the panel.

We let the linear interference pattern obtained through the interferometer of Mach-Zehnder be located traversely by adjusting M1 and M2. Such an interference pattern was detected using the high resolution color CCD camera whose pixel size is 1/2 inch(SCC347-1/2″).

Also to analyze the character of phase modulation of spatial modulator, we manufactured and used the 256 pieces of image of the stripe pattern type and applied the grey level 0~255 as the input image.

The inference pattern was constituted by two dividers of beam and the polarized direction of beam inputting into the panel of LC SLM was adjusted into parallel with the direction of arranged structure of molecular located at the front side of LC SLM panel.

In this paper, we constituted the test system like figure 12, and by using this, the stripe image like figure 13 as input image into LCD SLM to investigate the character of phase modulation of LCD SLM, newly implemented, was formed.

The stripe images were made into four arrangement of stripes having the size 256×768 to divide the LC SLM panel.

All the even low of grey level was fixed as 255, and the odd low of grey level were constituted as 256 stripe images varied from 0 to 255. We let the images of strip window shape make upright with respect to the interference pattern generated by the Mach-Zehnder constituted. Figure 13 shows the example of stripe image constituted.

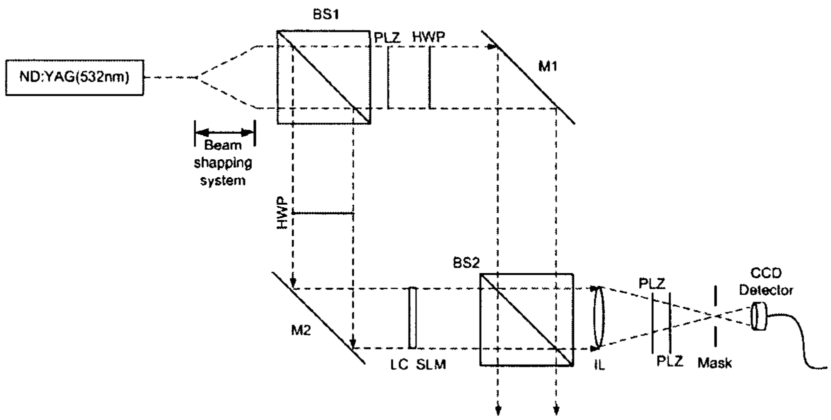
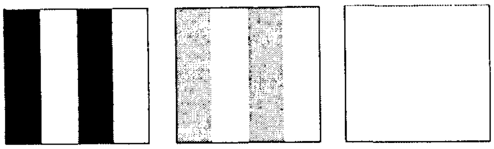


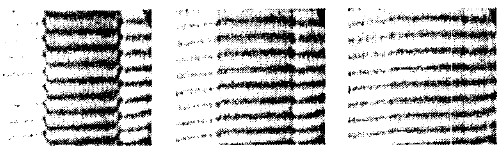
Fig. 12. Experimental diagram for characteristic analysis of the phase modulation in the modified LCD-SLM



(a) (b) (c)

Fig. 13. Examples of stripe image in accordance with gray level

As measured by the photo detector, the interference pattern between the reference beam and stripe image beam after being inputted into the LCD panel can be compared. The stripe image in the test system of figure 12 and the phase variation of LCD SLM according to the grey level were measured.



(a) (b) (c)

Fig. 14. Experimental results for phase variation of LCD SLM in accordance with gray level

Figure 14 shows the test result with respect to the stripe pattern of figure 13.

In the presented test, we have used the same LC SLM panel as that of the test of amplitude modulation, and controlled in hardware to cause the applied voltage to be uniformed over each pixel on the panel. The same condition as the amplitude's of the brightness and contrast of panel was made.

Through the condition like this, we constituted the test diagram as in figure 12. The maximum variation of phase character where all pixels were exactly in "ON" state, and "OFF" state was measured by shift distance of the interference pattern. These values were expressed as phase angle of PLZ. The maximum phase variation through this was measured as 1.88[π] or 340[°]. The measurement results with respect to each grey level were shown in table 4.

Table 4. Experimental data for characteristic of the phase modulation in the modified LCD-SLM

Gray Level		Phase Shift			
		Degree([°])		ω([π])	
0	140	0	240	0.056	1.389
10	150	10	250	0.167	1.44
20	160	30	260	0.25	1.44
30	170	45	265	0.33	1.47
40	180	60	275	0.417	1.52
50	190	75	280	0.47	1.55
60	200	85	290	0.67	1.61
70	210	120	305	0.83	1.69
80	220	150	310	0.94	1.72
90	230	170	315	1.08	1.75
100	240	195	325	1.167	1.80
110	250	210	335	1.22	1.86
120	255	220	340	1.28	1.88
130	-	230	-	1.33	-

Figure 15 shows, with a graph, the test result of the character of phase modulation obtained by using the test system like in figure 12 by varying the grey level from 0 to 255, and these results were compared and analyzed with the data of Crystal LCTV panel made by Epson company whose resolution is 320×220 and that is which our laboratory possesses.

As seen in figure 15, the LC SLM panel proposed in the present paper has little standard deviation according to each level, comparing with the conventional SLM that is already commercialized, and it has excellent linearity. When other characteristics of a panel are considered, we can know that this can be applied enough into the displaying system and photo security system, etc by using the photo-element of the system processing the information by light.

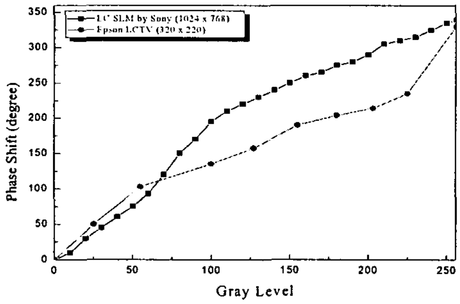


Fig. 15. Experimental results for phase variation of LCD SLM

5. Conclusion

In the present paper we have implemented the Spatial Light Modulator having super high resolution as XGA grade by using a commercial LCD beam projector and analyzed the character of optics modulation with respect to this.

We have also implemented the super high resolution SLM XGA grade by adding, designing, and manufacturing, the electronic circuit possible to compensate, effectively, with respect to the optics module, projection lamp and fans removed from the commercial beam projector, effectively.

We confirmed that the photo intensity of LCD SLM having super high resolution can be implemented and modulated linearly according to the analyzed results through the test and grey levels.

Accordingly, the present paper has proposed that it is possible to be applied into SLM for input of system processing information by light and for spatial filter.

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