High Performance Liquid Crystal on Silicon Spatial Light Modulator (LCOS-SLM) and Flicker Noise Reduction of Multiple Spots

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ABSTRACT

We developed LCOS-SLM as a spatial light modulator for precise pure phase control. Generation of stable multiple spot patterns (MSPs) is important in laser processing, microscopy. We proposed flicker noise reduction method of the MSPs which generated by the LCOS-SLM and confirmed reduction of noise from 2% to 0.5%.

1 INTRODUCTION

We have designed and developed a LCOS-SLM [1], which is a phase only spatial light modulator using nematic liquid crystal for advanced light control. The device is widely used for laser processing [2], microscopy [3, 4], optical tweezers [5], and adaptive optics [6]. For these applications the generation of stable multiple spot patterns (MSPs) is one of important subject [7]. In Ref. [8], We generated the MSPs by the LCOS-SLM and examined time response of MSPs flicker noise.

In this paper, we propose a method for flicker noise reduction and evaluate the efficacy of this method.

2 LCOS-SLM

2.1 Device Structure

The picture of the LCOS-SLM device and controller is shown in Fig. 1. The controller is connected to the computer by DVI interface, and we can control phase distribution of readout light easily. Figure 2 shows cross-section of the LCOS-SLM. A liquid crystal which is modulation material is sandwiched between silicon backplane and transparent electrode. This device can modulate phase distribution of light by applying voltage to each pixelated electrode of silicon backplane. This device uses refractive index change of liquid crystal layer by voltage controlling. Its pixel number is 1272 x 1024, and pixel pitch is 12.5μm. The light entering from glass substrate side is transmitted the liquid crystal layer and is reflected by dielectric mirror. The light efficiency of the device is extremely high by employing dielectric mirror.

Fig1. LCOS-SLM and driver

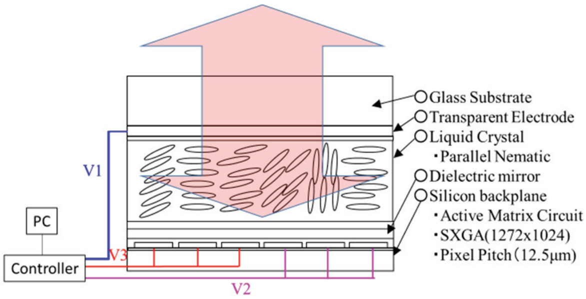

Fig2. Structure and driving method of LCOS-SLM

2.2 Fundamental Characteristic

Table 1 is summary of characteristics of the LCOS-SLM. The diffraction efficiency was examined using a diffracted spot from blazed grating (wavelength: 532nm). The diffraction efficiency is defined as I_1/I_0, where I_1 is intensity of the first order diffraction spot when a grating pattern is displayed, and I0 is the intensity of the zero order light when no pattern is displayed. The LCOS-SLM has high diffraction efficiency over 85% in the condition of 4 lp/mm grating pattern. At the maximum diffraction angle (binary phase grating of 40 lp/mm), it is 30%.

Table 1 Specifications of LCOS-SLM

Pixel	1272 x 1024 (SXGA)
Pixel pitch	12.5 x 12.5 um
Active area	15.9 x 12.8mm
Light utilization efficiency	76 - 97% *
Phase modulation	> 2pi radians
Speed	Rise : 5 - 30 ms * Fall : 20 - 140 ms *
Interface	DVI
* depend on wavelength	

3 FLICKER NOISE REDUCTION OF MULTIPLE SPOT

3.1 Time response of MSPs flicker noise

We generated the MSPs with four spots by the LCOS-SLM and examined temporal of flicker noise of each spot. The picture of the MSPs generated by iterative Fourier transform algorithm (IFTA) method [9] are shown in Fig. 3. The response time from one spot to MSPs is approximately 20ms. Figure 3 shows time response of flicker noise of each spot. The data has been observed by a CMOS camera with the frame rate of 2500Hz. As shown in Fig. 3, the intensity uniformity of four spots are within ±4%, and the temporal flicker noise is within 2%. These results indicate that SLM driving rate of 240Hz(4.1ms) directly causes this flicker noise.

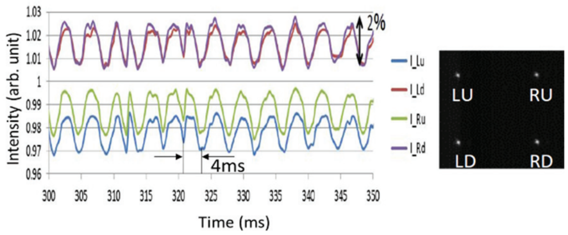

Fig3. Time response of spot flicker noise by conventional driving (homopolarity)

3.1 Noise reduction in MSPs

For flicker noise reduction, we controlled alternative voltage polarity of the LCOS-SLM so that optical phase modulated by different voltage polarities mutually negate in focal plane. Figure 4(a) shows driving area of inverse voltage timing, and light shined corresponding to each timing. Conventional voltage timing chart and our proposal one are shown in fig. 4(b) and 4(c), respectively.

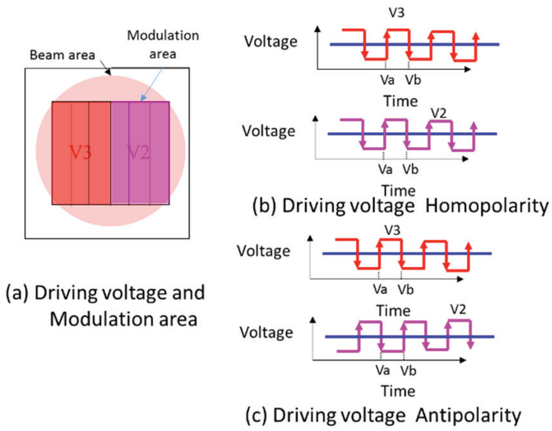

Fig4. Flicker noise reduction Method

3.2 Results

Figure 5 shows result of the proposal method. It shows improvement of flicker noise from 2% to less than 0.5 %.

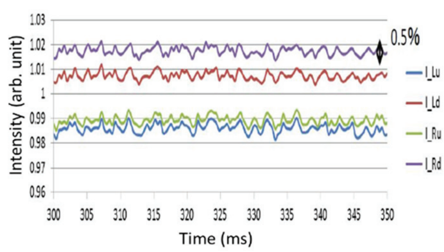

Fig5. Time response of spot flicker noise by proposal driving (antipolarity)

4 CONCLUSIONS

We evaluated the MSPs generation of four spots by using the LCOS-SLM and IFTA method and examined temporal characteristics of flicker noise of each spot. The flicker noise shows synchronization of driving voltage frequency. We do reduction of flicker noise from 2% to 0.5% by changing driving voltage polarity within the beam area. The generation technique of the MSPs with high stability and high precision can be applied for practical applications such as laser process, optical tweezer, atom trapping system, and microscopy.

ACKNOWLDGEMENTS

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