Measurement of characteristics and phase modulation accuracy increase of LC SLM "HoloEye PLUTO VIS"

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Abstract. Phase liquid crystal spatial light modulators (LC SLM) are actively integrated in various optical systems for dynamic diffractive optical elements imaging. To achieve the best performance, high stability and linearity of phase modulation is required. This article presents results of measurement of characteristics and phase modulation accuracy increase of state of the art LC SLM with HD resolution "HoloEye PLUTO VIS".

1. Introduction

Phase liquid crystal spatial light modulators (LC SLM) [1] are actively integrated in various optical systems for dynamic diffractive optical elements imaging. However, majority of scientific applications [2-8] require stable phase modulation which might be hard to achieve with commercially available SLM due to its initial orientation on applications in consumer devices such as projectors.

State of the art LC SLMs implement digital voltage addressing scheme which simplifies controllers and allows to address high quantities of pixels ($\sim 10^7$). This, however, leads to phase temporal fluctuations due to step-wise voltage addressing. As shown in [9-10], voltage addressing frequency depends on quantity of addressable phase levels. Higher number of addressable levels requires lower frequency which in turn leads to higher amplitude of phase fluctuations.

In this paper phase LC SLM "HoloEye PLUTO VIS" was analyzed and tuned for the best performance. This SLM has the following characteristics: operation mode – reflection, quantity of pixels - 1920×1080, pixel size - 8×8 μm^2, frame rate - 60 Hz, quantity of addressable phase levels - 256 (8 bit).

2. Phase modulation measurement and accuracy increase

For SLM phase modulation measurements double-beam interference method was used [10-11]. Experimental setup is shown in Figure 1. The light source is HeNe laser with 633 nm wavelength. Laser beam is filtered and collimated with lenses L1, L2 and pinhole D1. Polarizer P selects horizontal polarization. Diaphragm D2 bounds beam aperture. Diffractive grating splits beam into three parts: zero and two first diffraction orders. Absorbing shield blocks zero diffraction order. Lens L3 forms image of diaphragm D2 in SLM plane. Analyzer A selects horizontal light polarization. Lens L4 in conjunction with lens L3 forms image of diffractive grating in camera photosensor plane. Due to blocked zero diffraction order image of diffractive grating has doubled spatial frequency. Actually this image is a result of interference of two first diffraction orders.
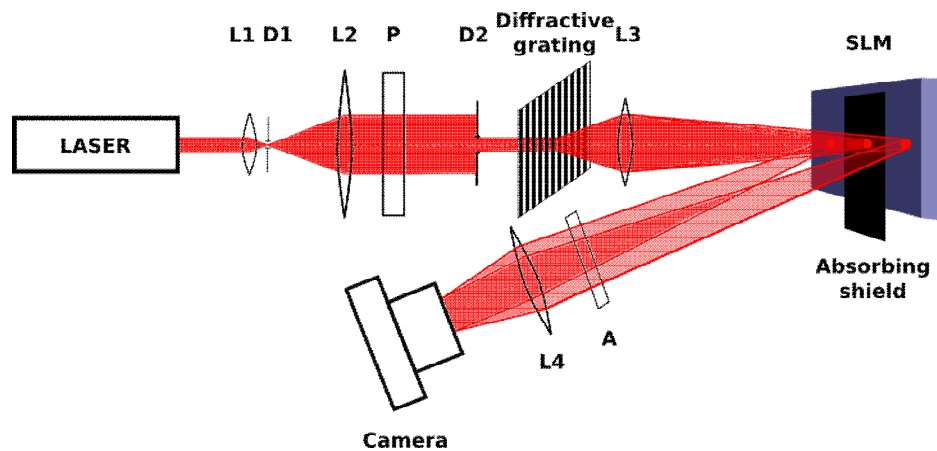
Figure 1. Experimental setup for phase modulation measurements.

Interference patterns were registered with scientific camera Megaplus II ES11000. While addressing the first half of SLM with different signal levels and the second one with zero signal, phase shift value changes accordingly, and thereafter location of interference fringes shifts. Location shift value corresponds to phase shift value. Three voltage addressing sequence configurations supplied with SLM were analyzed [10-11]: "18-6" (default configuration; allows for 1216 addressable phase levels), "5-5" (allows for 192 levels) and "0-6" (allows for 64 levels). Depending on quantity of addressable phase levels voltage addressing frequency changes accordingly. Less phase levels allows for higher voltage addressing frequency. For configuration "18-6" this frequency is equal to 120 Hz and for "0-6" it equals 480 Hz. Also, higher voltage addressing rate leads to lower maximum phase modulation depth.

Main characteristics of SLM for three measured configurations were derived. They are given in Table 1. Maximum momentary phase shift is maximum phase shift detected for all signal values and time delays. Maximum averaged phase shift is maximum phase shift averaged over frame duration for all signal values. Maximum phase fluctuations amplitude is half of maximum difference between the highest and the lowest phase shift for any given signal value. Quantity of distinguishable equidistant phase levels were determined as ratio of maximum phase shift value to doubled maximum phase fluctuations amplitude plus unity (because first and last phase levels have width equal to single amplitude).

Table 1. Characteristics of phase modulation of LC SLM "HoloEye PLUTO VIS".

Sequence configuration	"18-6"	"5-5"	"0-6"
Maximum momentary phase shift, π	3.17	3.01	2.39
Maximum averaged phase shift, π	3.05	2.88	2.29
Maximum phase STD, π	0.24	0.13	0.07
Maximum phase fluctuations amplitude, π	0.48	0.23	0.13
Quantity of distinguishable equidistant phase levels	4	7	10

With phase fluctuations increase, interference fringes visibility decreases. Measured dependencies of phase STD on signal value and interference fringes visibility on signal value for configuration "0-6", which provides lowest fluctuations, are shown in Figure 2.

It is clear that there is definite relation between values of phase STD and visibility. Higher fluctuations cause decrease of interference fringes visibility which is measure of coherence between modulated and unmodulated beams.
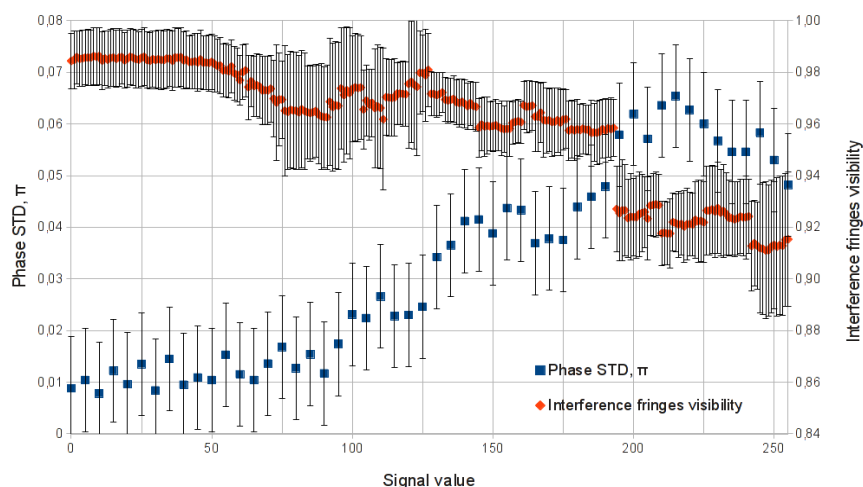
Figure 2. Dependencies of phase STD and interference fringes visibility on signal value for configuration "0-6".

3. Conclusion

Phase modulation characteristics of LC SLM "HoloEye PLUTO VIS" with three different voltage addressing sequence configurations were analyzed. Dependencies of phase shift on addressed signal value and time delay from frame start were obtained. It was determined that with default settings (configuration "18-6") SLM has phase STD equal to 0.24π and only 4 distinguishable equidistant phase levels. Highest characteristics were achieved with configuration "0-6": phase STD equals 0.07π and quantity of distinguishable equidistant phase levels equals 10. Definite relation between phase STD and interference fringes visibility was demonstrated.

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