Retardance measurement by spatially probing the sample with optical vortices

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Abstract. Modern optical systems utilize various degrees of freedom, such as polarization, for shaping and controlling the light. Common representative of such a component is spatial light modulator (SLM), consisting of liquid crystal display, allowing for imposing predetermined retardation with given orientation of optical axis of anisotropy. Therefore, it is widely used for polarization coded phase shifting, polarization splitting of wavefront in digital holography etc. Narrowing tolerance in optical experiments puts higher demands on precise setting of the modulator and the parameters set. Consequently, measuring such devices and their parameters is essential for proper functionality. We present a single shot, common path method for measuring retardance map of the modulator, based on spatial probing the modulator with point images of spatially coherent light source and transforming them to optical vortices.

1 Introduction

Phase of light is important quantity providing optical metrologist with plenty of information about various properties of transparent samples. In phase measurements, different degrees of freedom, such as coherence and polarization of light are used to control the light and to achieve the measurement objectives with higher precision and accuracy. While the coherence of light is often at least partially predetermined by the nature of measurement taken and leaves only limited, nevertheless important space for being adjusted, polarization of light provides the metrologist with control of spatially varying phase difference between independent optical channels in common optical path. Recently, Jones matrix microscopy [1, 2], enabling access not only to the phase of the sample but also its polarization state, emerges in optics. Either for controlling and verifying the polarization manipulations as a measurement tool or for a measurement itself as in the case of Jones matrix microscopy, methods for measuring spatially distributed anisotropy are of increasing demands.

A well-known principle of double helix point spread function (DH PSF) [3] allows for measuring the phase difference between optical vortices. It has been already proved as a valuable tool for measuring topography of reflective as well as diffuse samples either by sampling the surface with point images created by microhole plate [4] or by marking the surface with fluorescent nanobeads [5]. We propose a different approach to spatially probing the sample via diffraction grating, providing us with equidistant point images, and apply it for the retardance measurement of a sample with a priori known orientation of the optical axis of anisotropy, the SLM.

2 Results and discussion

Experimental setup is as follows. Fibre coupled laser light is collimated and set diagonally polarized by means of a polarizer LP and half-wave plate HWP. The light then passes through diffraction grating, whose orders are focused on the SLM. Afterwards, the reflective SLM is reimaged by means of 4-f system with Q-plate [6] in its Fourier plane, preceded by quarter-wave plate QWP oriented by 45 ° relative to the axis of anisotropy . The quarter-wave plate converts the horizontally and vertically polarized light into left- and right-handed polarized light, which is subsequently converted into optical vortices with unit topological charge of opposite sign. Finally, the light is brought to interference by linear polarizer and detected on CMOS camera.

Fig. 1. Experimental setup

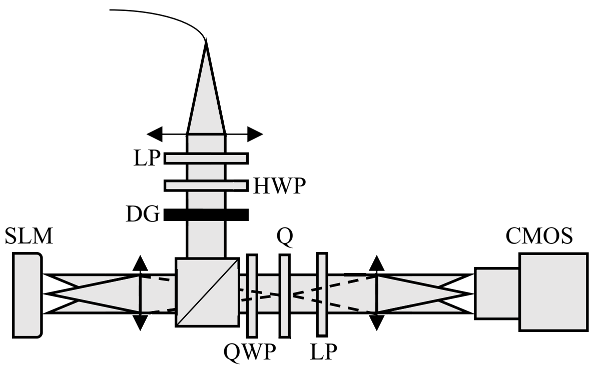

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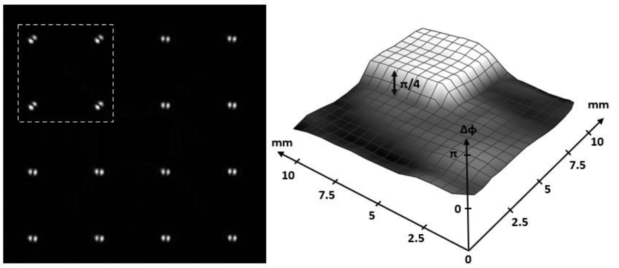
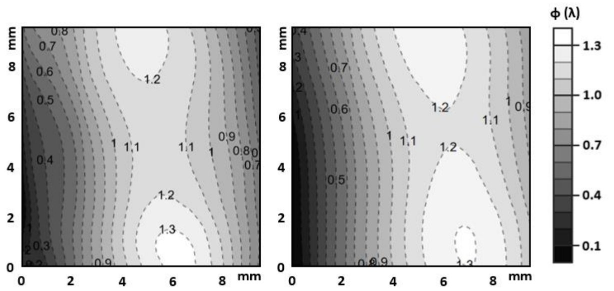
Fig. 2. Central part of the image of the SLM. The SLM is addressed with a phase map containing a phase jump in the top left corner (left figure) and reconstructed retardance jump (right figure)



It is worth notice that the retardance can be, to a decent level, briefly evaluated even visually from the frame, of course for the precise evaluation the numerical processing is required. Diffraction efficiency of individual orders is not of a concern in principle, however, to maximize signal/noise ratio across the frame, it is better if there is same energy in individual PSFs. Advantage of the method is that optical aberrations of the imaging system used should not have impact on the accuracy of the measurement, nevertheless severe aberration can and will affect the precision of the method in various ways.

Fig. 3. Comparison of computer addressed map (left figure) and evaluated retardance (right figure).



3 Conclusion

We presented a novel, single shot, common path method for measuring retardance map of spatial modulator. Albeit the principle of projecting the phase difference to the angular orientation of the double helix PSF is well known, we proposed and verified a new application of the phenomenon. Measuring spatial distribution of polarization properties of the sample is rapidly emerging area in optical microscopy and although our contribution provides only part of the information needed for determination of sample anisotropy and its application is therefore restricted, it proved as simple and utterly robust method.

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