Diattenuation imaging of artificial and biological samples using polarization-structured spot array

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Polarization imaging is a technology which allows us to see invisible information of various samples to understand their properties. Because polarization information relates to the changes of polarization states induced by a sample, illumination is as important as detection. In this study, we aim to develop a polarization imaging method, using a polarization-structured spot array as illumination. To assess the capability, we measured the diattenuation distribution of artificial and biological objects as samples. Experimental results demonstrated that our method is effective to measure diattenuation in a single shot.

Keywords: Polarization Imaging, Computer-generated Hologram, Diattenuation, Single shot

1.Introduction

Polarization imaging provides a unique opportunity for analyzing object's properties such as birefringence and diattenuation. Such information is useful when quantifying different properties of objects including biological samples. Polarization measurement observes the changes of the polarization states before and after light interacts with an object. A major polarization imaging technique requires switching incident polarization lights and precise mechanical drive [1]. This measurement tends to take a high cost of acquisition time and the system implementation. In this paper, we aim to develop a polarization imaging method using a polarization-structured spot array as an incident light. Diattenuation information of objects, including artificial and biological samples, was measured to demonstrate the effectiveness of our method in capturing polarization information in just a single shot.

2. Method of diattenuation imaging

The proposed method for obtaining the distribution (absorption rate and axis angle) of diattenuation using a polarization-structured spot array as an illumination light is explained. In the polarization-structured spot array used, horizontal and vertical linear polarization spots are regularly and densely arranged. In our method, two spots with different polarization directions are simultaneously used for image construction based on spatial division multiplexing. The light transmitted through a sample is imaged with a polarization imaging sensor to obtain information on different polarization components. This approach allows us for single-shot polarization imaging.

We assume two linear diattenuation axes of a sample, referred to as α-axis and β-axis (absorption rate, μ_1, along the α-axis is the maximum, and that along β-axis, μ_2, is the minimum,$(0 \le \mu_1 \le \mu_2 \le 1)$). $I_{d-ang}(\theta, \varphi)$ is defined as light intensity detected when the angle of α-axis is θ and the angle of incidence light polarization is φ. To obtain θ, the intensity distributions for a set of four pairs of input polarization (0° or 90°) and detected polarization (45° or 135°) are required. Using the intensity distribution set, we get diattenuation parameters θ, μ_1, μ_2 as follows:

$$\theta = \frac{1}{2}\tan^{-1}\left(\frac{B}{C}\right), \tag{1}$$

$$\mu_1 = 1 - \frac{A\sin(2\theta)+B}{2I\sin\theta}, \tag{2}$$

$$\mu_2 = 1 - \frac{A\sin(2\theta)-B}{2I\sin\theta}, \tag{3}$$

where

$$A = I_{45}(\theta,0) + I_{45}(\theta,90) + I_{135}(\theta,0) + I_{135}(\theta,90), \tag{4}$$

$$B = I_{45}(\theta,0) + I_{45}(\theta,90) - I_{135}(\theta,0) - I_{135}(\theta,90), \tag{5}$$

$$C = I_{45}(\theta,0) + I_{45}(\theta,90) - I_{135}(\theta,0) - I_{135}(\theta,90). \tag{6}$$

3. Experiment

In the experiment, a polarization-structured spot array was generated by using a computer-generated hologram (CGH) with a polarization converter, which converts linear polarization to azimuthal polarization. We illuminated a sample with the polarization-structured spot array and captured the image with a polarization image sensor (TRI050S1-PC).

In the first experiment, we used an artificial object consisting of two polarization filters with the axis of $90°$ within the upper part and $135°$ within the lower part as a target sample. Figure 1 shows the result. In Fig. 1 (b), line segments express the angle of θ. Although, there are some errors, the direction of diattenuation axis is obtained. In Figs. 1 (c)(d), the map of μ_1 takes values close to zero and is clearly distinguished the area of polarization filters and the gap space. The map of μ_2 takes fairly greater values than that of μ_1. This shows that our method enables us to get diattenuation information in just a single shot.

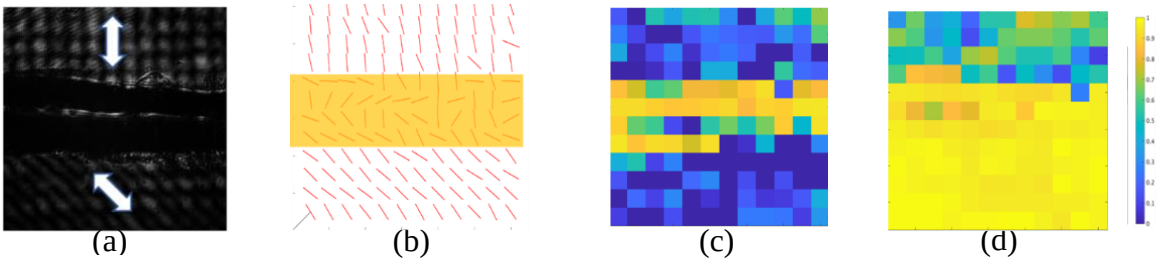

Figure 1. Experimental result on diattenuation imaging of an artificial object. (a)Acquired image, (b) direction of diattenuation axis, (c) the map of absorption rate μ_1, (d) the map of absorption rate μ_2

Next, we applied our method to polarization imaging of potato starch granule to investigate the effectiveness of the method not only for artificial objects but also for biological samples. Figure 2 shows the result of the experiment. The length of the arrows indicates the difference of absorptance rate ($\mu_2 - \mu_1$). We can confirm that the absorption difference inside the starch granule is much smaller than that around the edge of the starch granule. This means that the absorption difference is little inside the starch granule. This tendency matches with previous studies [3, 4].

In contrast, we can find some arrows pointing in specific directions along the edge of starch granule, which means the edge tends to have stronger diattenuation. This is also consistent with previous studies [3, 4]. The results suggest potential capability of our method.

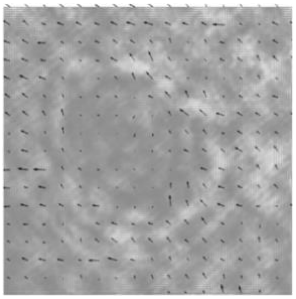

Figure 2. Direction of diattenuation axis (scaled) overlapped to the acquired image obtained in the experiment.

4. Conclusion

We have experimentally demonstrated the utility of our method in capturing polarization information from artificial and biological samples. The results also show the potential for single-shot polarization imaging. The use of a polarization-structured spot array as illumination will contribute to an extension of computational polarization imaging.

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Reference

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