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Invited Paper

Holographic and polarization features analysis for microplastics characterization and water monitoring

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ABSTRACT

The assessment of microplastics (MPs) pollution and water quality monitoring raise a lot of attention in recent years. Discriminative methods are highly needed for quick and accurate in situ MP detections. Digital holography records the wavefront information of the objects and contains the morphology, refractive index, and roughness information. Polarization imaging inspects the optical anisotropy of MPs, which is related to their birefringence and material characteristics. In this work, we explore the capability of holographic and polarization imaging for the identification of MPs. The computed features, such as the angle of polarization (AoP) and degree of linear polarization (DoLP), show distinguishable characteristics of MPs. We inspect the method feasibility on MP classification as well as biological and natural particles. The proposed method shows potential use in real-time, non-contact in situ MPs detection and water pollution monitoring.

Keywords: Polarization holography, machine learning, microplastic identification

1. INTRODUCTION

Polarization states characteristics, including phase retardation, optics axis orientation, angle of polarization (AoP), and degree of linear polarization (DoLP), reveal the anisotropy, birefringence, and structural information of the materials.[1,2] Digital holography[3–5] (DH) recently demonstrates its outstanding performance in microplastic (MP) identification[6–8] and material analysis.[9,10] Compared with the structural and morphological characteristics, i.e., circularity and roughness, polarization and holographic features[11] are closely related to the material molecular structures.[12]

In this work, we propose an intelligent polarization holographic system that can capture informative sample images for their discriminative analysis and identification. The hardware system is integrated with a specially manufactured synthetic polarization mask to improve imaging efficiency. This system is among the first to combine DH, and polarization imaging (PI), and machine learning (ML) for intelligent MP identification and material analysis. In this study, we describe the working principle of this system and demonstrate representative experimental results in Section 2. The conclusion and prospects of this work are discussed at the end.

2. METHODS AND EXPERIMENTS

We design a compact imaging system and show the schematic diagram in Figure 1. A laser diode generates a continuous laser wave with 632.8 nm wavelength. The laser light goes through a convex lens, a linear polarizer, and a quarter-wave plate, sequentially, to collimate and accurately control the polarization states of the laser beam. Then, the laser light goes through a sample plate and records the object information, while the sample particles absorb and scatter partial light. The finally formed patterns are recorded by a polarization camera. Different from the typical PI system, which manually sets light polarization states, we develop an innovative one-step PI camera mounted with a Stokes polarization mask (SPM). SPM integrates 0°, 45°, 90° and 135° polarization states and works for automatic image processing and feature extraction.[13]

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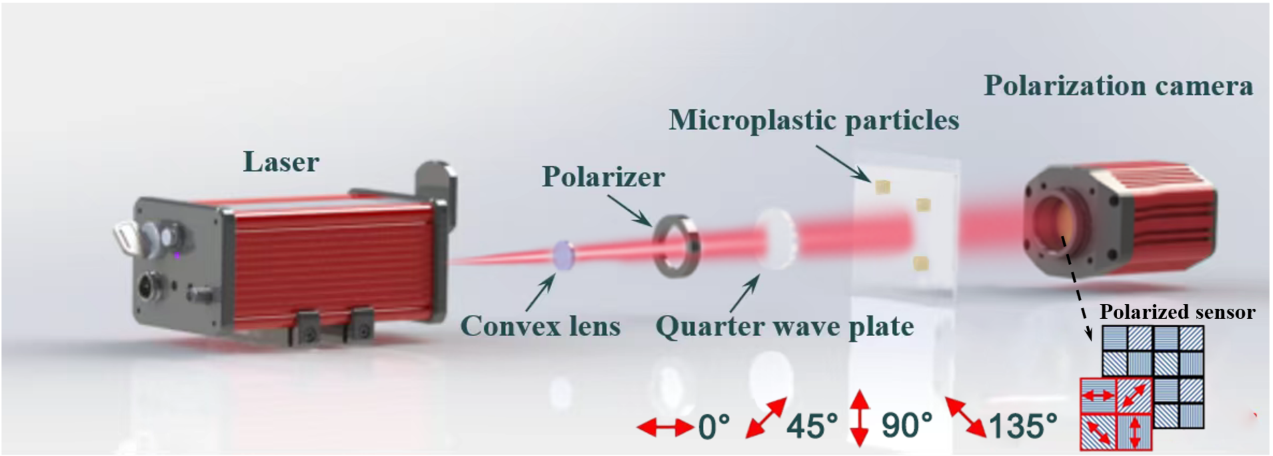

Figure 1. System setup diagram. Laser light comes from a laser diode with a 632.8 nm wavelength and sequentially goes through a convex lens, a linear polarizer, a quarter wave plate, and the sample plates. Images are recorded by a special-made polarization camera with an SPM.

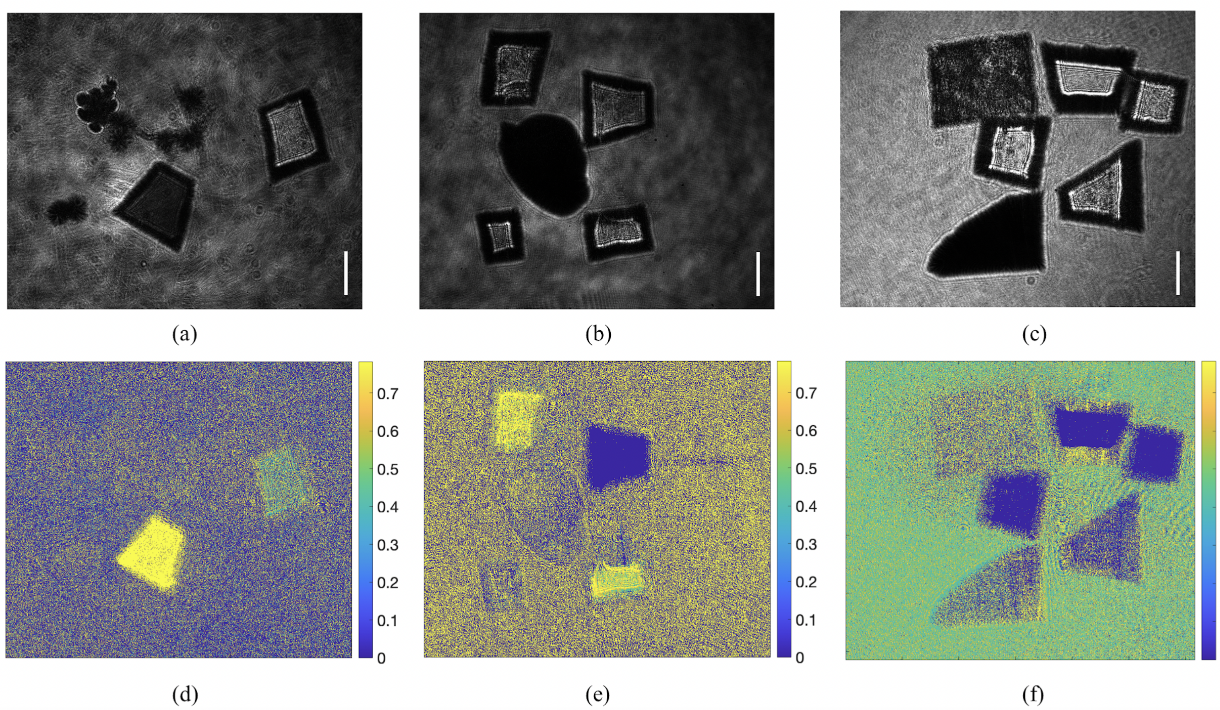

Figure 2. Experimental results inspection for the MPs and natural particles. Intensity images for MPs with (a) chlorella, (b) Daphnia magna, and (c): paper and tin foil. (d), (e), and (f): AoP plots. Scale bar: 0.5 mm.

Experiments are conducted between MPs and different kinds of natural particles and micro-organisms. We present the experimental results in Figure 2. To evaluate the imaging capability, we demonstrate the intensity image and corresponding AoP plots of MPs with (a) and (d): chlorella, (b) and (e): Daphnia magna, and (c) and (f): paper and tin foil. For each group, the AoP plot performs different patterns among specimens. AoP and other physical features, i.e., phase retardation, and DoLP, are used for statistical analysis and ML classifier training. Classification experiments with the extracted physical features perform > 0.8 AUC values, exceeding the classifications with textual features at 0.6 AUC values.

3. CONCLUSION

This study proposes an intelligent imaging system to discriminate and analyze the MPs materials with PI and DH. The recorded images with rich information can be used for molecular structure-related classification. This method can further help in the study of toxicity testing on micro-organisms and the environmental MPs pollution monitoring.[14]

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