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Polarization imaging performances based on different retrieving Mueller matrixes

Fei Shen [a,b], Kaipeng Wang [a,b], Qiangqiang Tao [a,b], Xiong Xu [a], Ruowu Wu [a], Kai Guo [b], Hongping Zhou [b], Zhiping Yin [c,*], Zhongyi Guo [b,*]

[a] *State Key Laboratory of Complex Electromagnetic Environment Effects on Electronics and Information System, Luoyang, 471003, China*
[b] *School of Computer and Information, Hefei University of Technology, Hefei, 230009, China*
[c] *Academy of Opto-Electronic Technology, Hefei University of Technology, Hefei, 230009, China*

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ABSTRACT

With the aids of Monte Carlo simulation, we have presented the performance evaluation for underwater polarization imaging based on the polarization retrieve (PR) algorithm. Under horizontal linearly polarized (HLP) light and right circularly polarized (RCP) light irradiation, the simulation results demonstrate that the corresponding polarization properties can provide additional information for the imaging, and the contrast of the polarization image can be enhanced greatly compared to the single intensity (INT) image underwater. The PR method is used for reducing the scattering impacts on degree of polarization (DoP) of the light, and the contrast of the PR imaging can be enhanced obviously compared to DoP imaging in clear ocean. Meanwhile, the modified PR (MPR) method with different retrieval Mueller matrixes (RMM) deriving from different distances (l) of transmission channel has been investigated, which show that the retrieval accuracy will be enhanced with increasing transmission distances of RMM and the visibility and contrast can be further enhanced.

1. Introduction

Polarization is a fundamental property of the light, which describes the vector nature of an optical field. Compared with intensity images, polarization provides additional information for characterizing optical properties of materials. Based on this feature, a promising polarimetric technique is proposed to improve the imaging quality by imaging the target from the same reflective background. Generally speaking, the polarization properties between the different objects, such as the man-made objects that are less depolarized than naturally occurring objects, are dissimilar due to the different materials or surface features. Therefore, an image encoded by the polarization will allow the distinction between man-made object and the natural background, although they have the same reflectivity [1–3]. Similarly, the polarization properties of the target and the turbid medium are different. So, polarization imaging techniques have been well developed to image an object hidden in a turbid media system, such as in the system of fog [4], cloud [5], underwater [6], and biological tissue [7]. There are some techniques, such as polarization difference detection method [8–10], and optimization polarization difference imaging [11], have been used in turbid media, which can enhance the detecting capabilities. However, these methods working on the polarization imaging is employed to reduce the influence of backscattering [10]. When the objects

* Corresponding authors.
E-mail addresses: zpyin@hfut.edu.cn (Z. Yin), guozhongyi@hfut.edu.cn (Z. Guo).

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are hidden in highly scattering media system, target detection suffers from reduced contrast because of the superposition of the photons scattering caused by both object and scattering media, therefore, these methods are still difficult to detect the objects.

In this paper, we demonstrate that our PR method [12–16] can degrade the influence of scattering effect to some extent. To further enhance the image contrast, we propose a modified polarization retrieve (MPR) method by changing the transmission distance of retrieval Mueller matrixes (RMM) in the medium, and we find that by increasing the transmission distance of RMM appropriately, the imaging contrast can be effectively enhanced.

2. System model and mumerical scheme

The schematic of the system model is shown in Fig. 1, where the monochromatic lights diffuse through a homogeneous underwater system with the transmission distance of L. The direction of incident light is parallel to the water level, and a detector with the area of $1 \times 1\,m^2$ is placed in the same side with the source.

In fact, there are two main influences for light imaging in water: absorption and scattering (Mie scattering). The characteristics of water and particulate matters in underwater environment have been investigated for decades [17–20]. The absorption in water depends on the incident wavelengths, and the suggested wavelength range for light transmission in water is about 500–600 nm [17]. Therefore, as shown in Fig. 1, the wavelength is set as $\lambda = 532$ nm which can meet the requirement of blue-green region, and the relative index of refraction is set as $n = 1.05$ (average value for a large number of marine particles) [18]. Another important parameter in seawater is particle number density which describes the concentrations of scatterer per unit volume, and the relationship between particle number and concrete diameters of particles in our simulation are shown in Fig. 2 (a) originating from Ref. [19].

Here, we will consider three kinds of ocean water, such as clear ocean, coastal ocean and harbor water. Absorption coefficients (a) and scattering coefficients (s) measured in three hydrologic stations [20] are shown in Table 1, where $e = a + s$ and it represents extinction coefficient.

Fig. 2(b) shows the photo of objects in our system, which can be divided into three objects. The Objects 1 is the English letters "HFUT" which is made up of four steel sheets. They have high-reflectivity (100% reflection at the surfaces) and low-depolarization characteristics. The Objects 2 "O" is made up of stone which have similar reflectivity (90% reflection) with Objects 1 and high-depolarization characteristics. Thus, the Objects 1 and Objects 2 will be visually similar under intensity imaging. In addition, the background is wooden, which has a depolarizing property similar to that of the Objects 2, and has

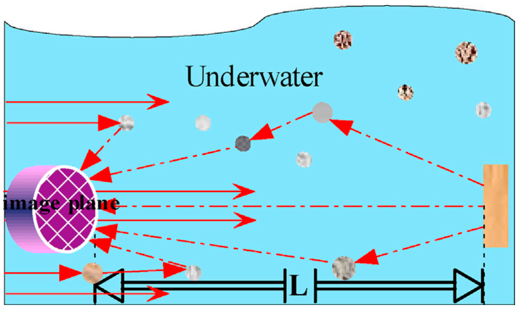

Fig. 1. Schematic of the polarization imaging system.

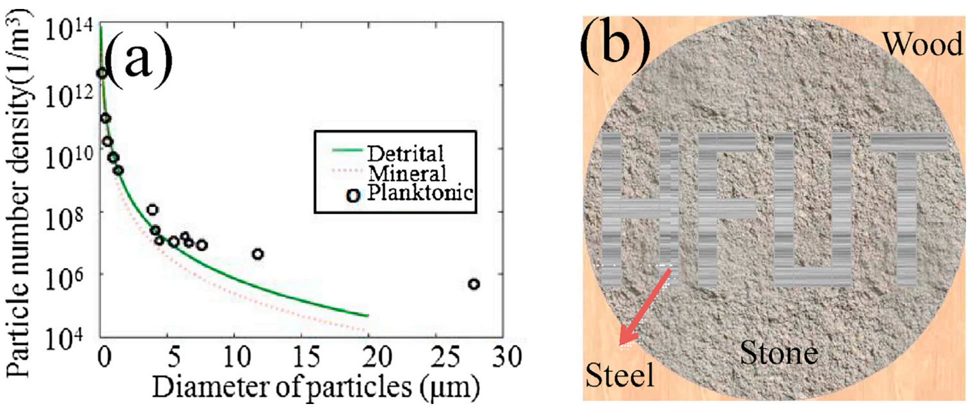

Fig. 2. (a) The characteristics of underwater channel, and (b) Photo of objects.