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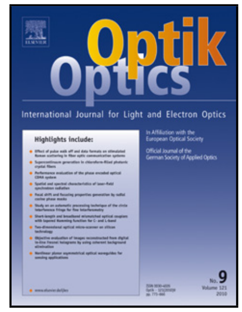

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Novel "quasi-Bayer" micro-polarizer patterns for the division-of-focal-plane polarimeters

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Abstract

In this paper, we present two novel "quasi-Bayer" micro-polarizer (MP) patterns for the polarization imaging based on the division-of-focal-plane polarimeters (DoFP). Compared with the traditional equally-weighted MP pattern with four different micro-polarizers, the "quasi-Bayer" pattern requires less photo-lithography-based selective etching steps, leading to a significant reduction of the MP array's fabrication complexity. In addition, for the mainstream bilinear interpolation algorithm, the proposed "quasi-Bayer" pattern with three micro-polarizers exhibits the lowest mean square error (MSE) of 0.43%. Moreover, the "quasi-Bayer" patterns take advantages not only at the fixed illumination level, but also for different illumination levels. Reported experimental results validate the effectiveness of the "quasi-Bayer" patterns by varying the input light intensity from 13 lux to 213 lux.

Keywords: Polarimetric imaging; division-of-focal-plane polarimeters; micro-polarizer array; "quasi-Bayer" pattern.

1. Introduction

Recent years have witnessed the fast development of the polarization imaging based on the focal plan polarimeters with predetermined pattern, which is also known as the division of focal plane polarimeters (DoFP) [1–19]. By integrating a layer of pixelated micro-polarizers (MP) on top, traditional monochromatic image sensors photo-sensing pixels are enabled to simultaneously extract the incident lights different polarization components. With high similarity to the color filter array (CFA) widely adopted in the color image sensor, the most classic Bayer pattern for color filter array becomes the primary choice for designing the pattern of micro-polarizers in DoFP [7, 11, 13]. As a result, in most literatures, the micro-polarizers are arranged to a 2×2 periodic pattern, with their local major polarization axes oriented differently [7–17]. In the Bayer-patter-CFA-based color imaging, it is well-known that the spatial resolution is traded-off for the simultaneous extraction of different wavelength channels (i.e. R, G and B), and interpolation algorithms are necessary to compensate the spatial resolution loss, namely demosaicing [20]. The same concept of "demosaicing" applies in the DoFP.

The way of DoFPs demosaicing has been paved by Ratliff *et al* in [21]. Several bilinear interpolation strategies were explored to improve the polarization image quality. These bilinear algorithms were extended to higher order bicubic and bicubic-spline interpolation methods by Gao *et al* in [22]. According to the acquired simulation results, the bicubic-based interpolation algorithms outperform the bilinear-based ones, however, it is at the expense of computational complexity and high cost of the hardware implementation. In order to well-balance the interpolation accuracy and the computational complexity, in [23], Gao *et al* adopted another gradient-based interpolation method. Depending on the calculated gradient, the edge in the polarization image is determined. The bicubic convolution interpolation is applied to the edge area while the bilinear interpolation is applied to the non-edge area [23]. As a result, under various illumination environments, the gradient-based interpolation algorithm outperforms bilinear and bicubic interpolation algorithms. Although a number of interpolation algorithms have been explored and validated as above-mentioned, they are all reported for the identical MP pattern, which is presented in Fig. 1(A). This 2×2 pattern include four equally-weighted micro-polarizers with their major polarization axes along 0°, 90°, 45°, 135°, respectively. Nevertheless, this is not the only pattern ever reported for the MPs design/fabrication in the previous literatures. In [7, 11, 13], a "quasi-Bayer" pattern was exploited for the micro-polarizer arrays design and fabrication. As shown in Fig. 1 (B), there are two pixels directly exposed to the incident light without any micro-polarizer applied, which can be used to record the total intensity of the incident light. This "quasi-Bayer" pattern significantly reduces the fabrication complexity of the micro-polarizer array, since there are only two photo-lithography-based selective etching steps are needed. By contrast, for the most widely adopted pattern in Fig. 1 (a), at least four photo-lithography-based selective etching steps are necessary to form the equally-weighted 0°, 90°, 45°, 135° micro-polarizers. However, up to now, none of the previous literatures has reported any demosaicing or interpolation algorithm tailored for the "quasi-Bayer" pattern, which takes great advantages in terms of the fabrication complexity and cost.

In this paper, we first explore the mainstream bilinear interpolation algorithm for the "quasi-Bayer" pattern with two

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