

Comment on the paper “Design and analysis of wide-field-of-view polarization imaging spectrometer”

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Abstract. The corrected approach for increasing the filed-of-view of the polarization imaging spectrometer based on Savart polariscopes is presented. © 2011 Society of Photo-Optical Instrumentation Engineers (SPIE). [DOI: 10.1117/1.3530097]

Subject terms: polarization imaging spectrometer; Savart polariscope; field of view.

Paper 100771CR received Sep. 24, 2010; revised manuscript received Nov. 23, 2010; accepted for publication Nov. 23, 2010; published online Jan. 20, 2011.

In a very recent paper by Zhang et al., several designs of polarization imaging spectrometer (PIS) with increased filed of view (FOV) are presented.¹ The concept of the FOV increasing method is to eliminate the distortion of the interferogram. They thought that the optical path difference (OPD) of a conventional PIS contains two parts in Fig. 1, the inside [Eq. (1)] and the outside^{1,2} [Eq. (2)]. The inside OPD is produced by Savart polariscope. The outside is introduced by the imaging lens. These OPDs can be written as

$$\begin{aligned}\Delta_{iCPS} &= AB - AC \\ &= t \frac{n_o^2 - n_e^2}{n_o^2 + n_e^2} (\cos \omega + \sin \omega) \sin i \\ &\quad + \frac{t}{\sqrt{2}} \frac{n_o}{n_e} \frac{(n_o^2 - n_e^2)}{(n_o^2 + n_e^2)^{3/2}} (\cos^2 \omega - \sin^2 \omega) \sin^2 i, \quad (1)\end{aligned}$$

$$\Delta_{oCPS} = CD = d_{CPS} \sin i = \sqrt{2} t \frac{n_o^2 - n_e^2}{n_o^2 + n_e^2} \sin i, \quad (2)$$

respectively, and the total OPD of the conventional PIS is given by $\Delta_{CSP} = \Delta_{iCPS} - \Delta_{oCPS}$. The distortion is caused by Δ_{iCPS} . So Zhang et al. proposed several designs based on combined Savart polariscopes to cancel the $\sin i$ term in Eq. (1) ($\sin i$ term is the main part of Δ_{iCPS} , which is much bigger than $\sin^2 i$ term).

However, there are two major errors in their paper:

1. The expression ($\Delta_{CSP} = \Delta_{iCPS} - \Delta_{oCPS}$) of the total OPD of a conventional PIS is not correct. The original derivations of Eq. (1) (Françon and Mallick,³ and Hashimoto and Kawata⁴) already explicitly account for the “outside OPD” Δ_{oCPS} (see Appendix B in Ref. 3). More generally, the convention of integrating this “outside OPD” in treatments of birefringent media interferometry has been adopted for a good reason: the OPD is only meaningful in terms of interactions between planar wave fronts. Avendano-Alejo and Rosete-Aguilar⁵ provide a good discussion of this issue. The correct total OPD should be only expressed as

$$\begin{aligned}\Delta_{PIS} &= AB - AC - CD \\ &= t \frac{n_o^2 - n_e^2}{n_o^2 + n_e^2} (\cos \omega + \sin \omega) \sin i \\ &\quad + \frac{t}{\sqrt{2}} \frac{n_o}{n_e} \frac{(n_o^2 - n_e^2)}{(n_o^2 + n_e^2)^{3/2}} (\cos^2 \omega - \sin^2 \omega) \sin^2 i; \quad (3)\end{aligned}$$

2. The distortion of the interferogram is not produced by $\sin i$ term but $\sin^2 i$ term in Δ_{PIS} .⁶ A spectrometer based on Savart polariscope can be looked as a Young’s interferometer.⁴ And the interferogram is determined by the lateral displacement as a function of variable incidence angle of the input beams. And its OPD can be described by

$$\Delta_{\text{Young}} = d \frac{x}{f} = d \sin i, \quad (4)$$

where d is the lateral displacement, x is the position of the interferogram fringe, f is the focal length of the imaging lens,

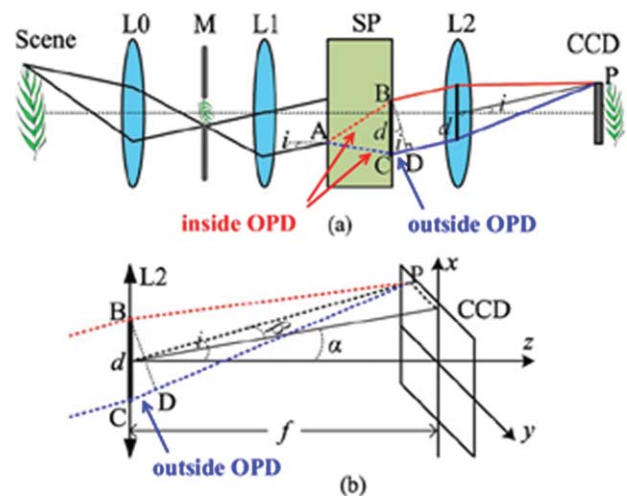


Fig. 1 Inside OPD and outside OPD in (a) layout of a conventional PIS, (b) optical diagram equal to (a), e.g., in Ref. 6 (Color online only).

and i is the incidence angle. Accordingly, the term of $\sin i$ is the key component to produce interferogram, and its coefficient d is the lateral displacement produced by the beam splitter (Savart polariscope). For a small incidence angle, Eq. (4) could describe the interferogram very well, but when the incidence angle is large (for example, more than 10° for PIS), the second term $\sin^2 i$ should be added into the equation above because the $\sin^2 i$ is not small and can not be neglected anymore [i.e., Eq. (4) should be changed into Eq. (3)]. This square term will produce the hyperbolic interferograms (this is the distortion). Thus we could not retrieve the spectrum from the interferogram. This is the reason why the conventional PIS based on Savart polariscope has a very small FOV. To increasing the FOV, the $\sin^2 i$ term should be eliminated. Actually, a previous paper⁷ by some of the same authors of Zhang et al. is consistent with our points than: Ref. 7 includes the “outside OPD” term in their derivation of the total OPD for a modified Savart polariscope. They also refer to the higher order terms of $\sin i$ as the main cause of fringe pattern distortion when comparing the modified versus conventional Savart polariscope.

Acknowledgments

This work was partially supported by the 863 Program. The authors are grateful to the anonymous reviewers for fruitful comments and suggestions.

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