

Stokes CMOS polarimetry limits studied at non-classical polarisation states

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Abstract. We present the study of the two polarisation state analysers. The first consists of a polarisation camera with a removable QWP, and the second consists of a non-polarisation camera with a rotating QWP and a stationary linear polariser. The theoretical analysis and experiment focus on studying the influence of polarimeter optical components accuracy and errors such as retardation errors, misalignments and extinction ratio on Stokes parameters precision. This research is a cornerstone to understanding polarisation state analysers limits. We examined laser beams with non-classical polarisation distribution, namely the Poincaré beam and the beam with radial polarisation.

1 Introduction

In recent years, laser beams with spatially variable polarisation distribution have been widely studied. A wide range of potential applications as various possible generation methods undoubtedly causes an increase in their popularity [1-4].

We aim to analyse the Bessel beam (BB) and the structured laser beam (SLB) with non-classical polarisation distribution. A longitudinal electric field could arise using an eligible input polarisation in focused electromagnetic fields like BB [5]. The knowledge of Stokes parameters (eq. 1) is required to detect the longitudinal component [6]. Therefore, our present research emphasises the influence of the polarimeter optical components accuracy and errors such as retardation errors, misalignments and extinction ratio on Stokes parameters precision.

$$\mathbf{s} = \begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix} = \begin{pmatrix} I_0 + I_{90} \\ I_0 - I_{90} \\ I_{+45} - I_{-45} \\ I_R - I_L \end{pmatrix} \quad (1)$$

$$2\psi = \text{atan} \frac{S_2}{S_1}; \quad 2\chi = \text{atan} \frac{S_3}{\sqrt{S_1^2 + S_2^2}} \quad (2)$$

$$\text{Dolp} = \frac{\sqrt{S_1^2 + S_2^2}}{S_0} \quad (3)$$

Our research focuses on studying two Stokes polarimetry approaches regarding spherical coordinates (eq. 2) and degree of linear polarisation (Dolp) with real optical parameters (eq. 3). We examined laser beams with non-classical polarisation for analytical and experimental analysis, namely the Poincaré beam and radial polarisation.

The most general case of the laser beam with arbitrary spatially variable polarisation is the full-Poincaré beam. The Poincaré sphere describes the polarisation vectors of the beam (see Figure 1) [7]. A particular case of the Poincaré beam is a cylindrical vector beam with spiral polarisation distribution. This polarisation is linear at radial directions and axially symmetric. A particular case of spiral polarisation is azimuthal and radial polarisation [8].

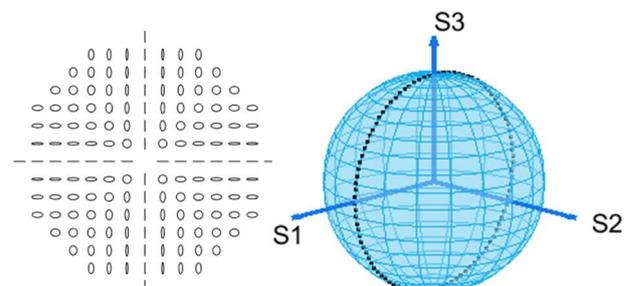


Figure 1: Visualisation of the ideal polarisation vector distribution in the cross-section of the Poincaré beam. The polarisation vectors/ellipses in the cross-section symbolise linear, right-handed and left-handed polarisation. Polarisation handedness is the same for diagonal quadrants. The polarisation vectors of the beam are depicted on the Poincaré sphere.

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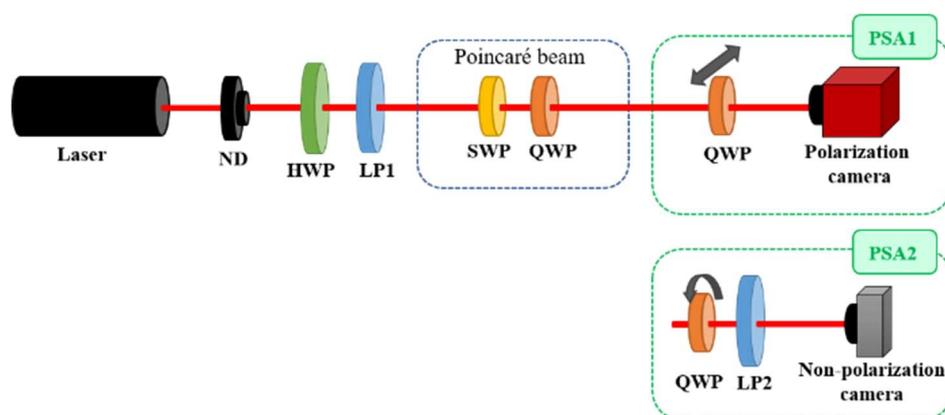


Figure 2: Schematic representation of polarisation distribution measurement in Poincaré beams. The laser beams were analysed with two different polarisation state analysers, PSA1 with a polarisation camera or PSA2 with a non-polarisation camera (Laser: He-Ne 632,8 nm, ND: neutral density filter 2.0, HWP: half-wave plate, LP1: linear polariser, LP2: linear polariser, SWP: structured half-wave plate, QWP: quarter-wave plate)

2 Methodology

The experimental optical setup (see Figure 2) consisted of a neutral density filter and a half-wave plate, which were used to set the input intensity of the laser beam. A linear polariser LP1 indicated a direction of input polarisation. To obtain a vector beam or Poincaré beam, a structured half-wave plate (SWP) (Altechna), SWP and a quarter-wave plate (QWP), respectively, were placed in the beam path.

The laser beams were analysed with two different polarisation state analysers (PSA). PSA1 consists of the polarisation camera (Thorlabs Kiralux®) with a removable QWP for Stokes parameters measurement. PSA2 is a classical approach using a CMOS camera with a rotating QWP and a stationary linear polariser. Stokes parameters evaluation was based on B. Schaefer et al. work [9].

A detailed understanding of the limits of CMOSs and PSAs will enable future imaging of BBs and SLBs with a fixed longitudinal electric field component.

3 Conclusions

The polarisation vector distribution in the cross-section of the real Poincaré beam and its depiction on the Poincaré sphere analysed by PSA1 is shown in Figure 3.

The experiment and the theoretical analysis of measurement uncertainty of PSA1 and PSA2 suggested that although the wire grid polariser of the polarisation camera has a relatively low extinction ratio (100:1) compared to LP2 used in PSA2 (10^5 :1), it could provide better polarimetry approach for the beam with non-classical polarisation. The main benefit of PSA1 lies in the smaller number of required beam cross-section images. If we do not require knowledge of the handedness of the polarisation ellipse, only one image is needed, whereas PSA2 requires eight images.

Detailed information about the theoretical analysis of the real optical component influence (retardation errors, misalignments, and extinction ratio) to spherical

coordinates evaluation and Dolp as the experiment specifics and results will be presented at the conference.

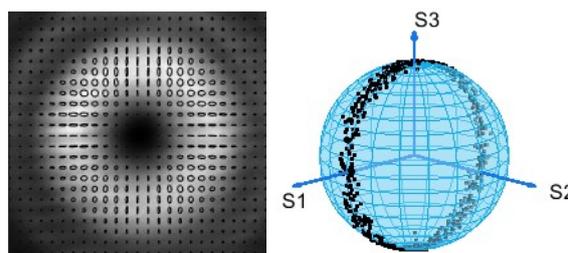


Figure 3: Polarisation vector distribution in the cross-section of the real Poincaré beam analysed by PSA1. The polarisation vectors/ellipses in the cross-section symbolise linear, right-handed and left-handed polarisation. Polarisation handedness is the same for diagonal quadrants. The polarisation vectors of the beam are depicted on the Poincaré sphere

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