Crossed test for the polarimetric characterization of prism 3 of the modulator

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Introduction:

Any birefringent element acts as the basis transformation for an incoming Stokes vector. The matrix associated with this element is the transformation matrix that converts the incoming Stokes vector into the outgoing one. By illuminating the tested optical component with the linear polarization of various angles and measuring the intensities with an analyzer oriented along the direction of vibration of the incoming ray and in the orthogonal direction, we can assess the depolarization, the diattenuation and the rotation effect of the studied element. This is the principle of the fit method used here to characterize the first prism of the modulator. Overall, it needs only two sets of measurements. The general set-up employed to obtain the data is presented in Fig.1. In this optical scheme, presenting two steps (A) and B)) in Fig.1, the light from a polychromatic source (PS) passes through a collimator a spectral filter, and then through a linear polarizer (LP), with the transmission axis oriented along the x-axis (see the dashed line in Fig.1). The linear polarization obtained with LP is then converted into a circular polarization with the help of a QWP, with the fast axis oriented at 45º in the x y plane. The purpose of the first linear polarizer and of the QWP is to minimize the effect of possible partial polarization of the source. Placing then a linear polarizer of variable orientation ($LP_1(\alpha)$), a constant linear polarization could be obtained for any orientation of the transmission axis. LP_1 is followed along the stream of light by the birefringent element we want to characterize, then by a rotating analyzer ($LP_2(\beta)$) and a detector. In Fig.1, the modulator was drawn between the two rotating polarizers. However, any optical component can be placed instead of the modulator.

Considering that the orientations of LP_1 and LP_2 are established via a Malus law, we start the first series of measurements by aligning LP_1 and LP_2 with the transmission axes parallel (Fig.1, A)). Then, we turn them synchronously, with a step of 1º. We took one intensity measurement for each α between 0° and 360°. The detected intensity for each α will correspond to the first term of the outgoing Stokes vector, $\overrightarrow{S_{out}}(\alpha)$:

$$\overrightarrow{S_{out}}(\alpha) = M_{LP_2}(\beta = \alpha) \cdot M \cdot \overrightarrow{S_{in}}(\alpha),$$

where $M_{LP_2}(\beta = \alpha)$ is the Mueller matrix of the polarizer LP_2, $\overrightarrow{S_{in}}(\alpha)$ is the incoming Stokes vector, whereas M is the Mueller matrix of the birefringent element that we want to study.

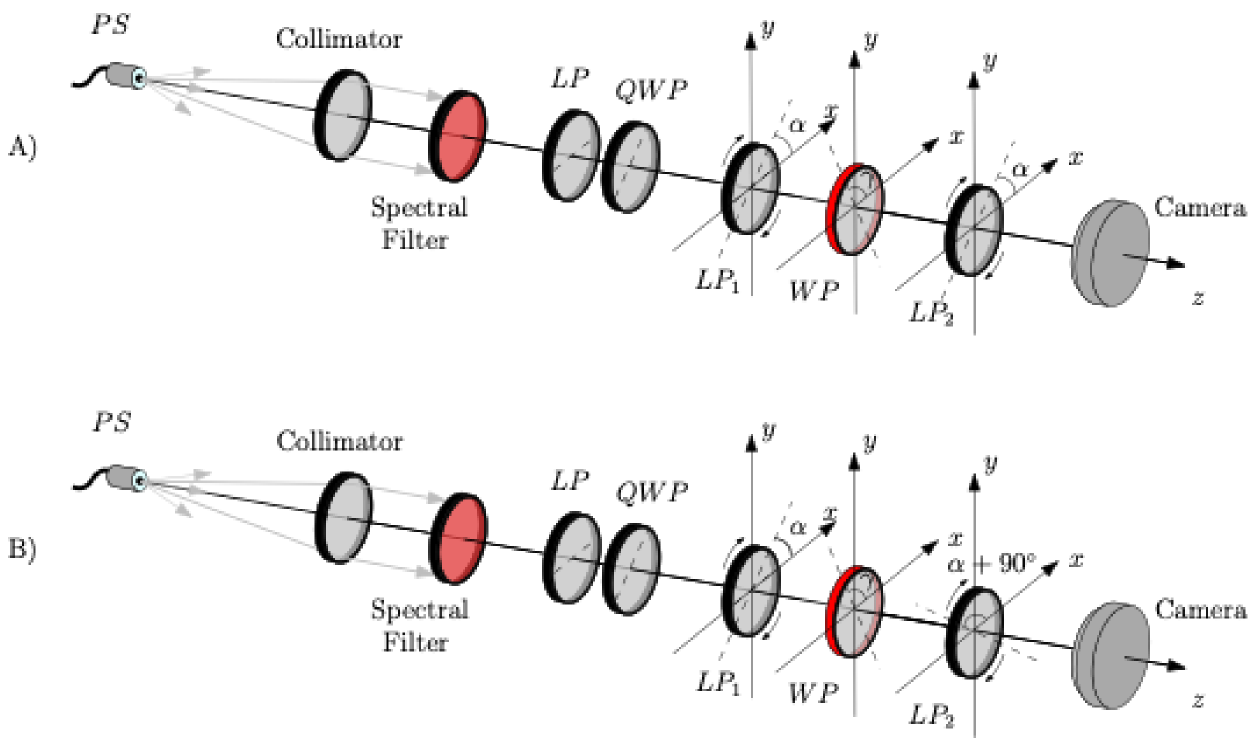

Figure 1: Optical setup conceived for the polarimetric characterization of the modulator and of its components.

For the second set of measurements, at first, the linear polarizers LP_1 and LP_2 are positioned into a crossed configuration: $\beta = \alpha + 90^o$ (Fig. 1, B)). Then, like before, the two linear polarizers are again rotated synchronously, with the angle α taking the same values. The detected intensity for each value of α is represented in this case by the first term of the Stokes vector $\overrightarrow{S_\perp}(\alpha)$:

$$\overrightarrow{S_{out}}(\alpha) = M_{LP_2}(\beta = \alpha + 90^o) \cdot M \cdot \overrightarrow{S_{in}}(\alpha)$$

Supposing that the Mueller matrix of the birefringent component could be assimilated to a waveplate with a fast axis oriented at an angle θ to the x-axis, in x y-plane and characterized by a phase difference ϕ, then, in the ideal scenario where no polarizance and no diattenuation is present, the ratio of intensities is:

$$R(\alpha) = \frac{I_{\perp}(\alpha)}{I_{\parallel}(\alpha)} = \frac{(\cos(\phi) - 1)(\cos\big(4(\alpha - \theta)\big) - 1)}{3 + \cos(\phi) - (\cos(\phi) - 1)\cos\,(4(\alpha - \theta))}$$

Fitting the theoretical expression for $R(\alpha)$ to the experimental data ensures the determination of the main parameters of the birefringent element that is characterized: the phase (ϕ), and the fast axis orientation (θ).

About the dataset:

This data set comprises the images corresponding to the characterization of prism 3 of the modulator used by the spectropolarimeter described in the PhD thesis "Development of a high-performing spectropolarimeter for space usage." The images present values of the intensity the camera detects for incoming light with a central wavelength of 514 nm. A narrow spectral filter with full width at half maximum (FWHM) of 3 nm was used.

The angle α varies here between 0 and 120^{o}, with a step of 1^{o}. For each value of the angle α, five images corresponding to the aligned positioning ($\beta = \alpha$), and four to the crossed positioning ($\beta = \alpha + 90^{0}$) were recorded. The intensity value corresponds to the mean value of each set of four images.

A folder containing Dark images is also included here. It comprises dark images for the two configurations of the linear polarizers when α =0º. A single value of α is used for the dark because of the very small differences induced by the variation of this angle.

The prism was rotated with 90^{0} around the optical axis in order to ensure its fixation in the optical mount. Because of this, the images' horizontal direction corresponds to the prism's vertical.

Structure of the names:

Each folder of the dataset corresponds to a value of the angle α:

P1_value_M3flipped_P20α

In each folder, the files .png are the recorded images for the angle α. The index

I_Aligned_index.png

I_Crossed_index.png

gives the index of the image: i:0:4.

In addition, each folder contains the metadata associated with each set of images.

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