Polarimetry with non uniformly polarized beams

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Summary

In this work, nonuniformly polarized beams are used in polarimetry. These beams act as a parallel polarization state generator because they present many different polarization states at once across its tranverse section. By measuring the polarization state of the input and output beam at 4 different positions, a polarimetric characterization of the sample can be obtained.

Introduction

Polarimetry is a noninvasive testing technique that gives relevant information about the behavior of the sample under test. Partially polarized light can be described by a 4×1 Stokes vector. The sample behavior can be described by its 4×4 real Mueller matrix [1, 2]. Usually the sample is tested sequentially by at least four different polarization states. Here, we propose to use a nonuniformly polarized beam and measure the ouput polarization state at four different positions to obtain a complete characterization of the sample.

Theory

When polarized light is reflected by or transmitted through a sample, the output polarization state, $\mathbf{S}^{out}$, is related to the input one, $\mathbf{S}^{in}$, by means of the Mueller matrix of the sample, $\widehat{M}$, as [1, 2]

$$\mathbf{S}^{out} = \widehat{M}\mathbf{S}^{in} \,. \tag{1}$$

Usually it is assumed that the polarization state is uniform across the whole transverse section of the beam. However, if nonuniformly polarized ligth is used, by calibrating the polarization state of the input beam at four different positions, $\mathbf{S}^{in}(\mathbf{r}_i)$, with $i = 1, 2, 3, 4$, and by measuring the polarization state of the output beam at the same positions, $\mathbf{S}^{out}(\mathbf{r}_i)$, a system of 16 linear equations can be formed in such a way that the Mueller matrix of the sample can be retrieved. The sample is assumed to be homogeneous, at least within the area illuminated by the input beam.

Spirally polarized beams have been used for this purpose [3, 4]. However, this kind of beams presents only linearly polarized states of polarization in their transverse section, so only three states of polarization with linearly independent Stokes vectors can be found. Recently, a simple and cheap way to generate full Poincaré beams, i. e., beams presenting all possible states of polarization [5], has been demonstrated [6]. By using this type of beam and a commercial light polarimeter with a small aperture at its entrance, the polarimetric system can developed.

Experiment and results

The setup schematically shown in Fig. 1 has been developed and as a sample to test the proposed method, we have used a quarter wave phase plate (QWP) with its fast axis oriented along vertical direction. The light polarimeter was mounted on an $X-Y$-micropositioner to carefully select the four positions where the Stokes vector of the input and output beams are measured. After measuring the Stokes vectors, we solve the 16 linear equations obtained by repeteadly applying Eq. (1) to obtain the Mueller matrix of the sample. For our QWP we obtained

$$\widehat{M}_{QWP} = \begin{pmatrix} 0.9753 & -0.0220 & 0.0355 & 0.0047 \\ -0.0081 & 0.9596 & 0.0173 & 0.0238 \\ -0.0090 & 0.0037 & 0.0483 & 0.9980 \\ 0.0103 & 0.0041 & -0.9501 & 0.0190 \end{pmatrix}, \qquad (2)$$

that is quite close to the Mueller matrix of an ideal QWP [1, 2].

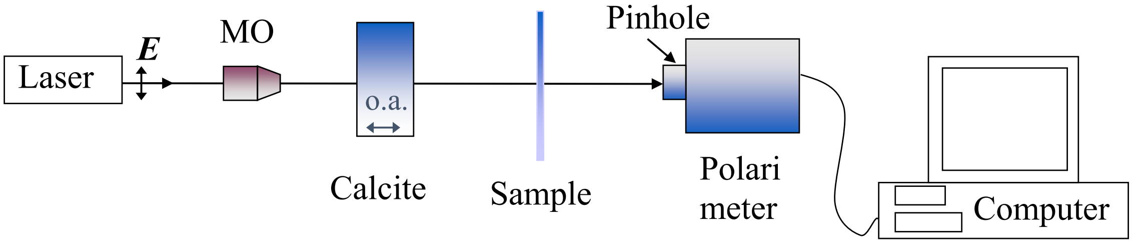

Fig 1. Experimental setup

Conclusions

Here we present a simple Mueller matrix polarimetric method based on the use of a full Poincaré beam to simultaneously generate all possible totally polarized states of polarization. The beam is generated by simply focusing a beam on a uniaxial crystal. At the exit of such a crystal, a full Poincaré beam is obtained [6]. A commercial light polarimeter with a pinhole at its entrance is used to measure the Stokes vector of the input and output beam at four different positions. From the measured Stokes vector, the Mueller matrix of the sample can be obtained.

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References

[1] D.H. Goldstein, Polarized Light, (Marcel Dekker, Inc., 2003).

[2] R.A. Chipman, Polarimetry, in Handbook of Optics, ed, M. Bass, (McGraw-Hill Companies, 2010).

[3] J.C.G. de Sande, M. Santarsiero, and G. Piquero, Optics and Lasers in Engineering, **91**, 97, 2017.

[4] J.C.G. de Sande, G. Piquero, and M. Santarsiero, Optics Communication, **410**, 961, 2018.

[5] A. M. Beckley, T. G. Brown, and M. A. Alonso, Full Poincaré beams, Optics Express **18**, 10777, 2010.

[6] G. Piquero, L. Monroy, M. Santarsiero, M. Alonzo, and J.C.G. de Sande, Journal of Optics, **20**, 2018.