Simultaneous determination of Jones and Mueller matrices for polarimetric characterization of a homogeneous medium

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Polarimetry is a versatile tool to study the microstructural optical properties of a medium. Jones matrix imaging and Mueller matrix imaging are most commonly used techniques for the polarimetric characterization of a medium. Meanwhile, Jones matrix imaging is preferred when the medium is homogeneous in nature whereas Mueller matrix imaging is useful for anisotropic medium. In practice, none of the medium has perfectly homogeneous structure. Therefore, both these techniques are necessary to be implemented for complete polarimetric characterization of a sample. The determination of Jones matrix and Mueller matrix of a medium in a single frame is still a challenging task. In this paper, we demonstrate an analytic inversion method [1] to transform the Jones matrix of a homogenous medium i.e. spatial light modulator (SLM) into corresponding Mueller matrix.

Let J be the Jones matrix of a medium. Then corresponding Mueller matrix can be calculated as

$$M = U * (J \otimes J) * U^{-1} \tag{1}$$

Where, U is unitary transformation matrix[1] and $\otimes$ represents corresponding Kronecker product. This method is first validated for a known optical component i.e. half wave plate (HWP) (table 1) and then Mueller matrices of a reflective type SLM (Holoeye, LC-R720) at its different gray values (GV) have been retrieved from its Jones matrices using this method. The Jones matrix components of this SLM have been adapted from [2]. One of the obtained Mueller image is shown in fig. 1.

Optical component	Jones matrix (J)	Mueller matrix (standard)	Mueller matrix (calculated)
Half wave plate (HWP)	$\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$	$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix}$	$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix}$

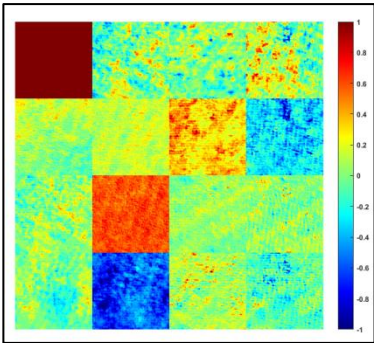Table 1 Calculated Mueller matrix of standard HWP from its Jones matrix.

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Fig. 1 Calculated Mueller matrix image of SLM at GV level 180.

The obtained Mueller matrix elements for SLM suggest that the SLM is not perfectly homogenous in structure i.e. it shows minor depolarization. It might be due to its manufacturing microstructural deformation. It is expected that the analytic method (discussed above) can be used for direct transformation of Jones matrix into corresponding Mueller matrix of any homogeneous medium. Therefore, one can simultaneously determine the Jones and Mueller matrix of a medium in single frame.

References:
[1] C. Hunte, "The Jones-Mueller transformation", Fizika A, **17**, 51-58, 2008.
[2] **Vipin Tiwari**, Surya Kumar Gautam, Dinesh N. Naik, Rakesh Kumar Singh Nandan S. Bisht, "Characterization of spatial light modulator using polarization sensitive digital holography", applied optics, **59 (7),** 2024-2030, 2020.