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Optical polarization studies of Indian Medicinal plant Konda Gogu

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***Abstract*— Polarimetric imaging system operating in the reflection mode is designed to understand the characteristic polarization effects taking place in wood sample prepared from the bark of Cochlospermum religiosum, an Indian medicinal plant known as Konda Gogu in the telugu. The intensity images recorded by this polarimeter are processed using polar decomposition technique to obtain polarimetric parameters. The degrees of polarization images and the corresponding mean intensity values are obtained using Image processing algorithms that were developed in MatLab platform.**

***Keywords*: Complete Polarimeter, Mueller Matrix Imaging, Polar decomposition, Degree of polarization, Cochlospermum religiosum.**

I. INTRODUCTION

Imaging Polarimetry technique is extensively employed to understand the optical polarization effects simultaneously occurring in an optically active sample of interest. The characteristic optical polarization properties that alter the incident polarizations parameters when the coherent beam meets an anisotropic sample is of interest, many researchers have used different optically active samples and various imaging techniques [1-10].

In this technique of Mueller Matrix Imaging Polarimetry, seven independent polarization states i.e, open, horizontal, vertical, +45, -45, right circular and left circular states that are predefined in the state generator that is shining the sample and the state analyzer that is recording the intensity information were used to capture the 49 intensity images. Considering pixel by pixel intensity information, these images are processed to get 16 elemental Mueller Matrix images further using polar decomposition technique the characteristic optical polarization parameters for the sample are obtained [11-14].

The characteristic polarization changes in the sample are understood in terms of the matrix values and images obtained and are attributed to the structural and chemical properties of the sample.

The basic constraint on a complete Mueller polarimeter is that it should map the incident Stokes vector to the resultant Stokes vector through the Mueller Matrix, this imposes a necessary condition that the Degree of Polarization is less than or equal to one [15-17].

II. THEORY

A Polarized light beam with predefined states characterized by Stoke's parameters, when incident on a tissue sample,

undergoes a transformation in the intensities, that is represented by a 4 × 4 matrix called the Mueller matrix and the transformed Stoke's vector is written as

$$S_{out} = M\,S_{in} \qquad (1)$$

Where, S_{out} is the Stoke's vector of transmitted light, S_{in} is the stokes vector of incident light and M is the Mueller matrix.

All Mueller matrices obtained may not be physically realizable. The basics constraint for a Mueller matrix to be physically realizable is mathematically expressed as

$$\sum_{i,j=1}^{4} m_{ij}^2 \leq 4m_{11}^2 \qquad (2)$$

The Mueller matrix M can be decomposed into three elementary matrices using polar decomposition technique represented as

$$M = M_{\Delta}\,M_R\,M_D \qquad (3)$$

Where, M_{Δ} is the Depolarizing matrix which indicates the depolarizing effects of the sample. M_R represents the effects of linear birefringence and optical activity and is called as Retardance matrix and finally M_D describes the effects of linear and circular dichorism called as Diattenuation Matrix

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Diattenuation, $D = \frac{1}{m_{11}}[m_{11}^2 + m_{12}^2 + m_{13}^2]$ (4)

Retardance $R = \cos^{-1}\left\{\frac{t_r M_R}{2} - 1\right\}$ (5)

and Depolarization value $\Delta = 1 - \frac{|t_\sigma (M\Delta) - 1|}{3}$ (6)

where, $0 \leq \Delta \leq 1$ for a physically realizable Mueller matrix.

All these values can be directly obtained from the Mueller matrix and the mean values of Diattenuation, Retardance and Depolarization are obtained from the recorded Mueller Matrix intensity images by using algorithms in MatLab platform. [7-8]

III. EXPERIMENTAL SETUP AND PROCEDURE

The wood sample is from the bark of the tree Konda Gogu, selected from Telangana forest regions of India. The sample was dried by natural process for evaporating the moisture content. A portion of the sample weighing approximately 0.5kg is reserved for chemical composition estimation and the remaining part of the sample was made ready to have a uniform thickness. The sample is shown in Figure 1.

Fig. 1. Konda gogu sample.

A collimated beam of light through a rotatable polarizer and retarder, forming a state generator with predefined polarization state shines the wood sample [15-17]. The collection optics consisting of a rotatable analyzer and retarder representing state analyzer is kept in the reflection mode at 45^0 from the input beam direction throughout the experiment. Initial calibrations are done for the setup, a schematic representation of the experimental setup is shown in Figure 2.

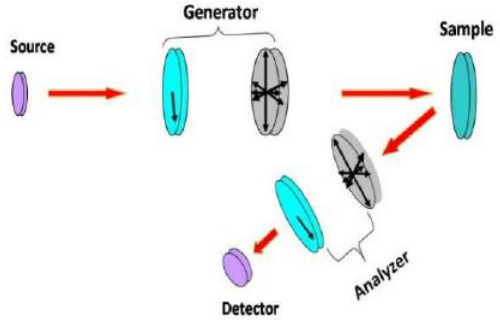

Fig. 2. Schematic of experimetnal setup.

The detector is designed to capture the intensity images with various orientations of elements in generator and the analyzer state. Seven independent variable states are used to record the 49 intensity images from the setup for a sample. These images are cropped using cropping algorithms in MatLab platform that are processed to acquire the 16 images corresponding to the 16 elements of Mueller matrix from the captured images. The 16 elemental Mueller Matrix images acquired for the sample are shown in Figure 3.

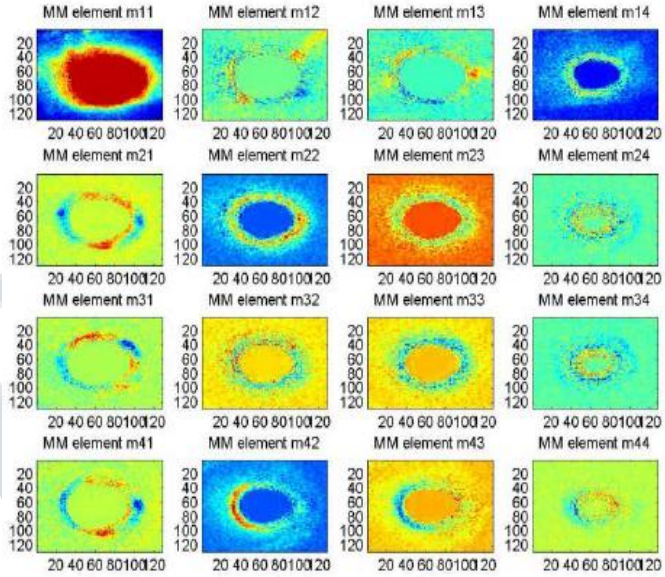

Fig. 3. 16 elemental mueller matrix images.

To ascertain the reproducibility, the 49 intensity images are acquired many times and the standard deviation results showed that the percent error in the Mueller matrix is 2.47%

which is admissible this can be attributed to the manual adjustments of the recordings and background lighting conditions, the measured Mueller matrix values are shown in Table 1 and the % chemical composition is shown in Table 2.

TABLE 1. MUELLER MATIRX OBTAINED

1	-0.09195	-0.29885	0.011494
0.21264	0.1092	-0.09195	-0.04598
0.017241	-0.01724	-0.10345	0.022989
-0.05747	0.086207	-0.08046	-0.00575

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TABLE 2. ELEMENTAL COMPOSITION

Sample Name	H_2O %	C %	O %	H %	N %	Traces %
Konda gogu	68.58	14.8	11.93	1.71	0.91	2.07

IV. RESULTS AND DISCUSSIONS

The mean Mueller Matrix obtained is normalized to the first element of the matrix to isolate the intensity dependent effects in the image and also this simplifies the analysis. The acquired Mueller Matrix images are further processed using scripts in MatLaB platform to acquire intensity component from which, the polarization parameters are obtained. From the measured Mueller Matrix the Depolarization, Diattenuation and Retardance images are acquired and are shown in Figure 4, Figure 5 & Figure 6 respectively. The mean values of Diattenuation, Depolarization and Retardance for the sample are obtained and indicated in Table 3.

TABLE 3. MEAN POLARIZATION VALUES OBTAINED

Polarization parameter	Mean values
Diattenuation	0.1815
Depolarization	0.7589
Retardance	2.3492

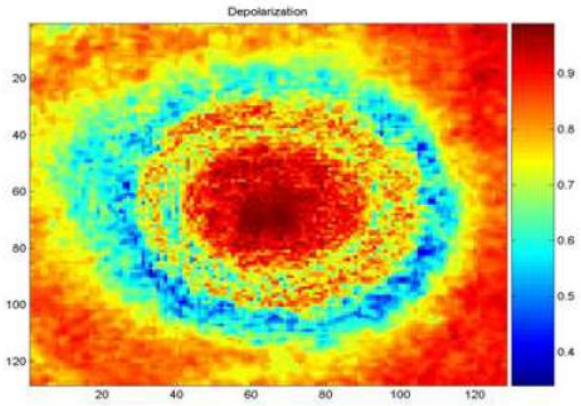

Fig. 4. Depolarization image of Konda Gogu.

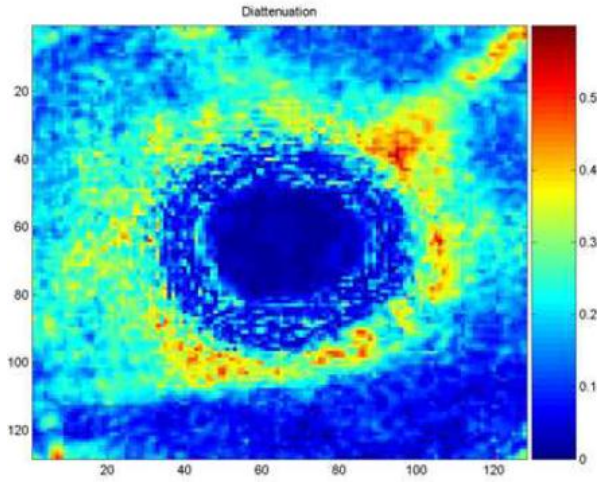

Fig. 5. Diattenuation image of Konda Gogu.

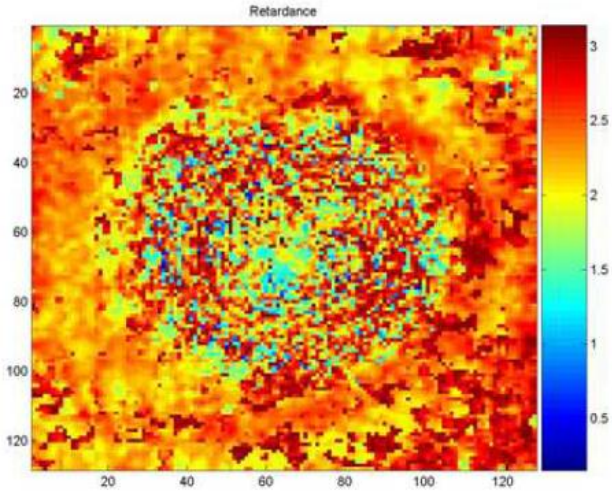

Fig. 6. Retardance image of Konda Gogu.

The 16 Mueller intensity images are also processed using image processing algorithms to acquire the Degree of Linear polarization (DoLP), Degree of Circular polarization (DoCP) and Degree of total Polarization (DoP), these images are shown in Figure 7, Figure 8 & Figure 9 respectively and the mean values of intensity are given in Table 4 respectively.

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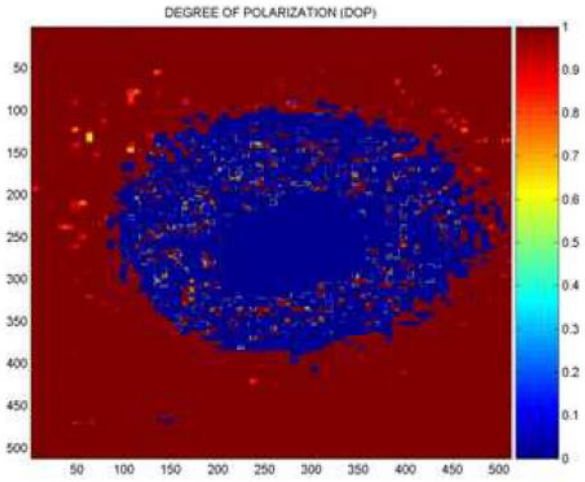

Fig. 7. DoP image of Konda Gogu.

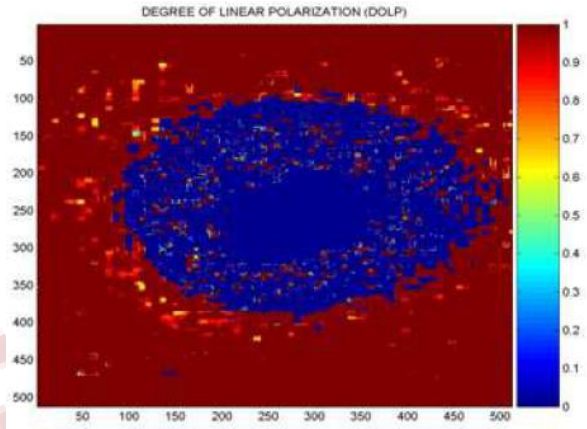

Fig. 8. DoLP image of Konda Gogu.

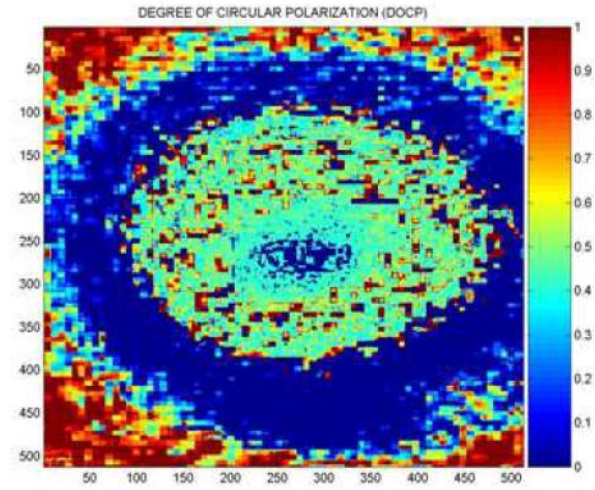

Fig. 9. DoCP image of Konda Gogu.

TABLE 4. MEAN VALUES OBTAINED FOR SAMPLE

Sample	Mean values
DoP	0.7856
DoLP	0.7589
DoCP	0.2033

The polarization response of sample was observed and compiled with the theory to fulfill the constraints as given in equation (2). The depolarization value is attributed to the different scatterings of incident light by sample. The Retardance value is due to discontinuity present this value also reflects the variation of composition and moisture present in the sample. The degree of linear polarization is observed to have minimal variation from unity and even the same is true for DoP. This variation indicates that the linear polarization state is maintained in the sample and the large variation in the DoCP value from unity indicates that the sample showed large speckle intensity distributions and high moisture content as indicated in Table 2 showing the percent composition of H2O present in the sample.

CONCLUSION

Polarization studies of the wood sample Cochlospermum religiosum commonly known as Konda Gogu, in the form of a Mueller matrix are obtained and as expected the Cochlospermum religiosum sample exhibited polarization anisotropic character which is evident from the results tabulated. The experimental results identified various optical polarization changes in terms of Diattenuation, Depolarization, Retardance and scattered intensity distributions in the form of DoP, DoLP and DoCP for the sample are also presented. The high amount of H_2O present in the sample is understood in terms of the variations in the degree of polarization effects. From the polarization images and parameters the compositional influence on the scattering of polarized light is understood.

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