Single-Shot Jones Matrix Microscopy

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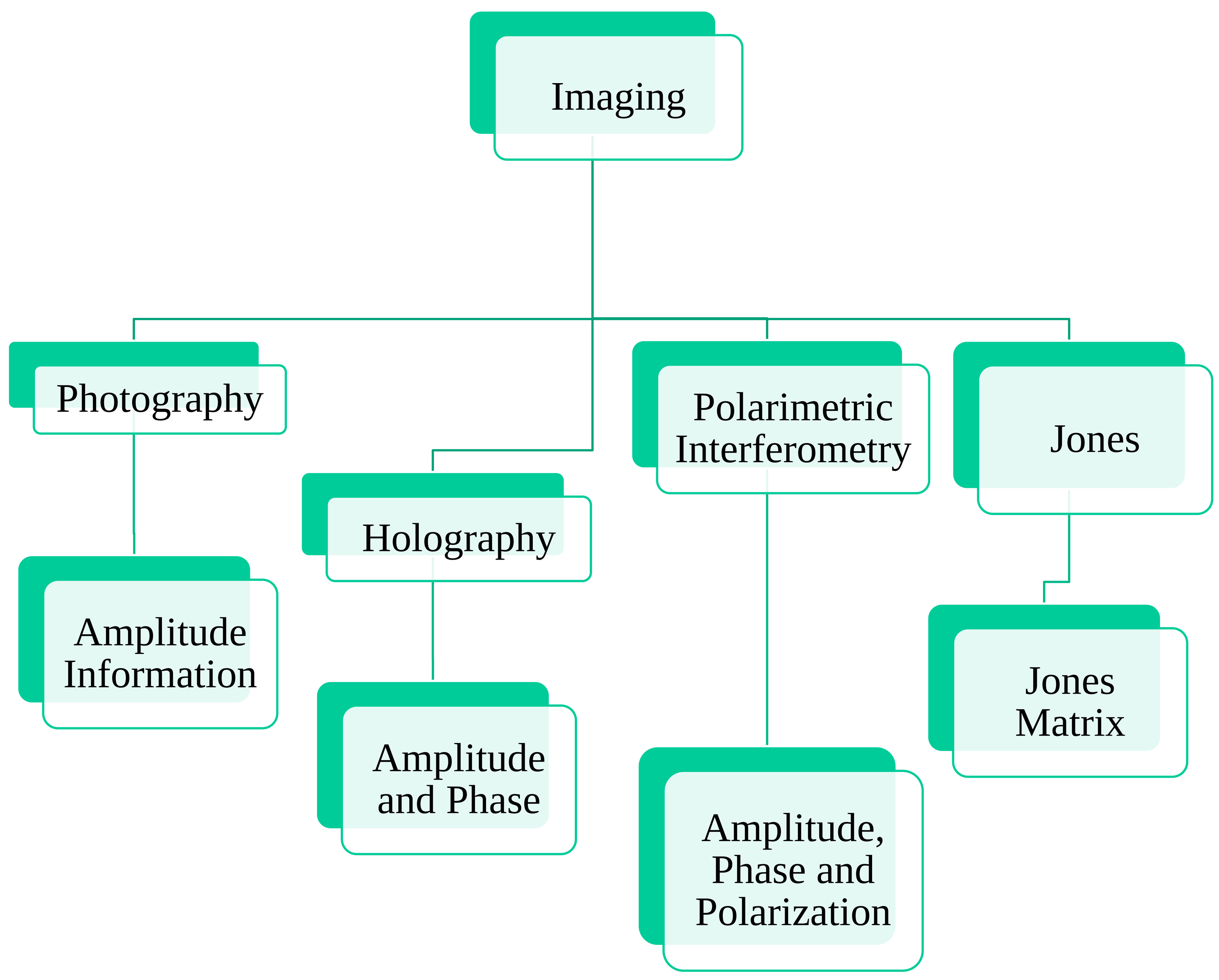
Abstract Field based polarization measurement is essential to understand and quantify the optical response of any target sample. The method discussed here is digital holography microscopy that enables us to quantify spatially the Jones Matrix of a transparent anisotropic sample. Our method provides precise information about the polarization properties in a single shot, therefore, well suited for a dynamic biological specimen.

Introduction



Principle

The Jones Matrix formalism says that an input light field with E_{ix} and E_{iy} and the output field upon emerging from an object are related as

$$\begin{bmatrix} E_{ox} \\ E_{oy} \end{bmatrix} = \begin{bmatrix} J_{xx} & J_{xy} \\ J_{yx} & J_{yy} \end{bmatrix} \begin{bmatrix} E_{ix} \\ E_{iy} \end{bmatrix}$$

Where $J_{ij} = |J_{ij}| e^{\phi_{ij}}$ is the Jones matrix element and Φ is a phase with $i, j = x, y$.

For +45^0 degree polarized input light output field can be written as

$$\begin{bmatrix} E_{+45x} \\ E_{+45y} \end{bmatrix} = \begin{bmatrix} J_{xx} & J_{xy} \\ J_{yx} & J_{yy} \end{bmatrix} \begin{bmatrix} 1 \\ 1 \end{bmatrix} = JE_{+45} \qquad (1)$$

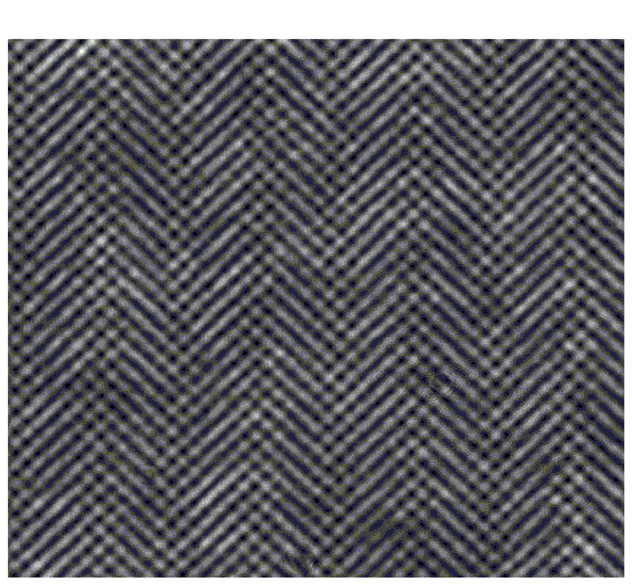
Similarly for -45^0 degree polarized input light output field can be written as

$$\begin{bmatrix} E_{-45x} \\ E_{-45y} \end{bmatrix} = \begin{bmatrix} J_{xx} & J_{xy} \\ J_{yx} & J_{yy} \end{bmatrix} \begin{bmatrix} 1 \\ -1 \end{bmatrix} = JE_{-45} \qquad (2)$$

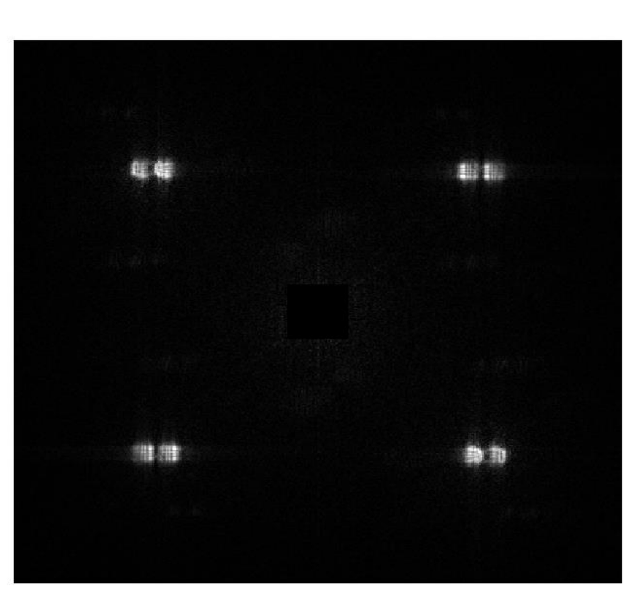
These two output fields are then interfered with the two reference beams having different carrier frequency *Rx* and *Ry*. Then the recorded multiplexed interference pattern can be written mathematically as

$$I = \left| JE_{45} + JE_{-45} + R_x + R_y \right|^2$$

The recorded interferogram is then analyzed using Fourier fringe analysis to achieve the complete Jones matrix information. Multiplex interference pattern and its Fourier transform are shown in Fig.1 (a) and (b) respectively.



(a) Recorded multiplex interference pattern



(b) Fourier transform

Fig.1

Experimental Setup

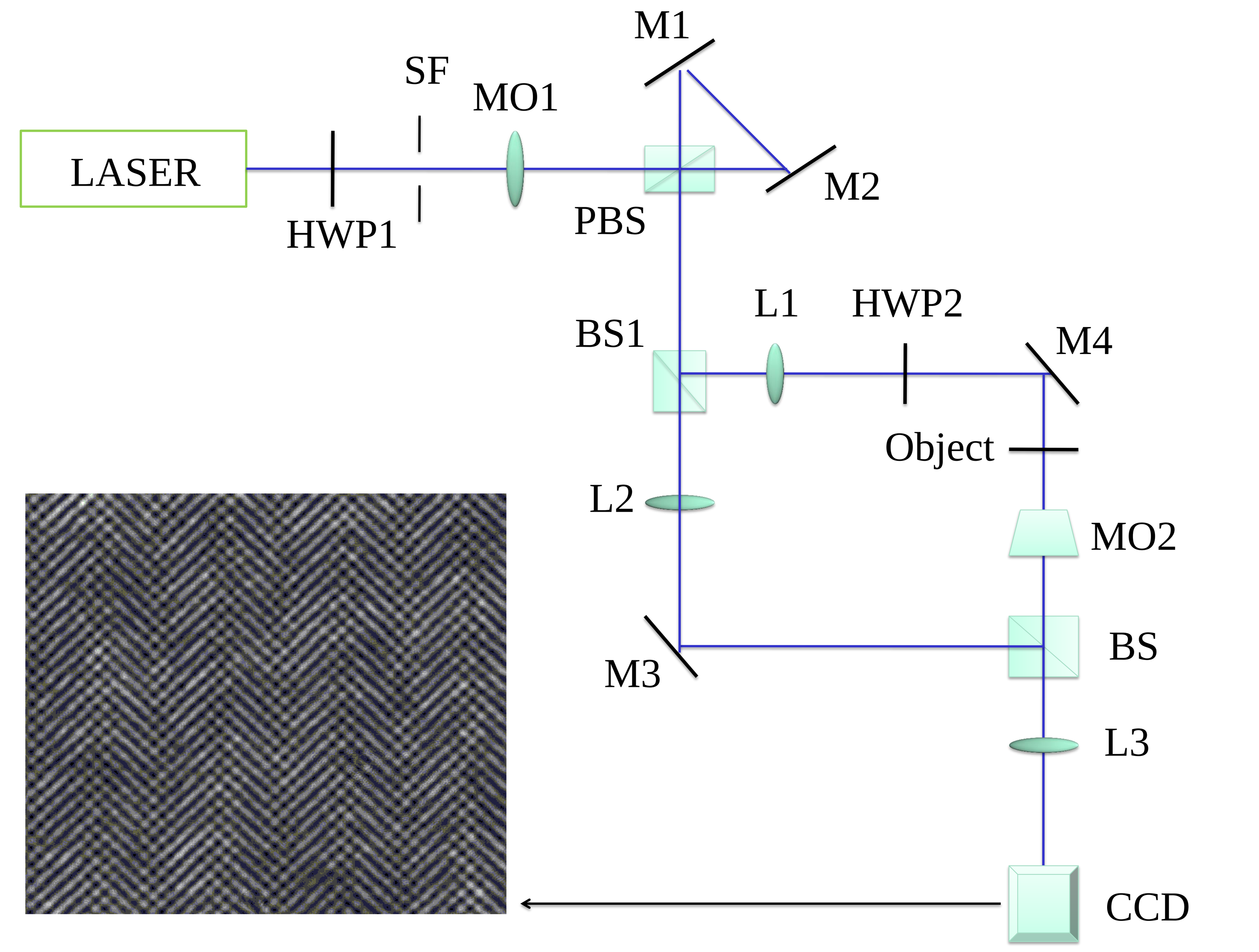
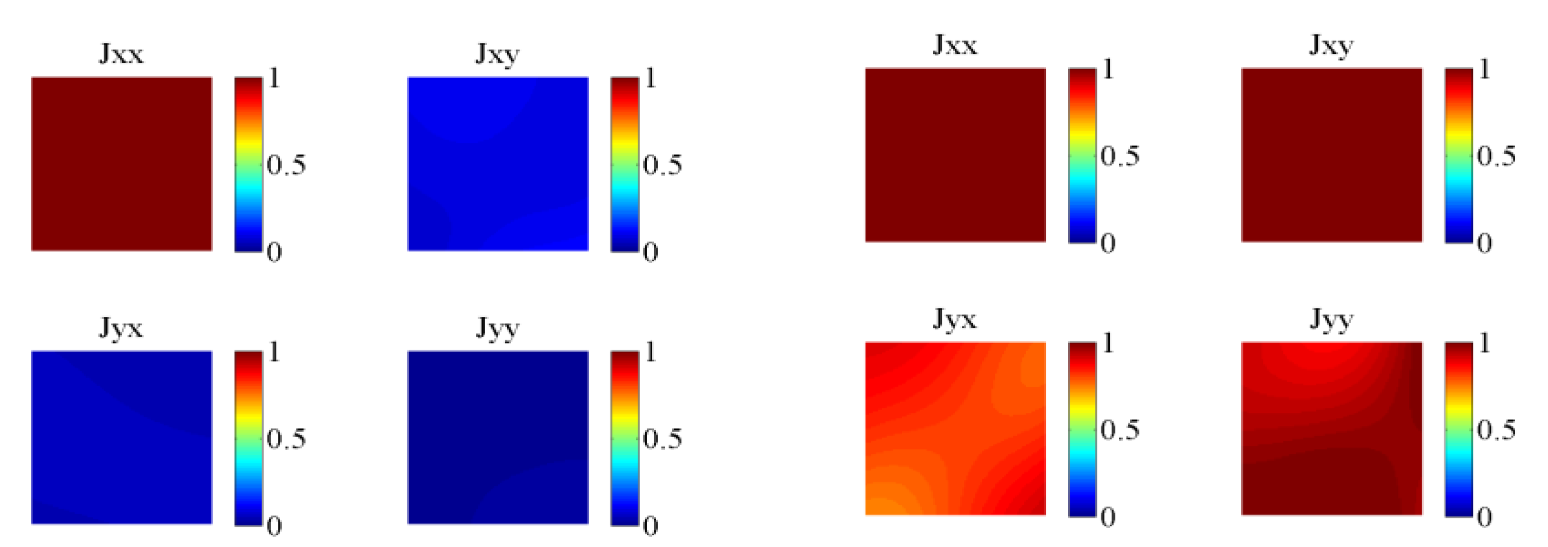


Fig.2. Experimental Setup : Single Shot Jones Matrix Microscopy
Microscope Objective MO1 and MO2, Mirror M1, M2, M3 and M4, Lens L, L1, L2 and L3, Beam Splitter BS1 and BS, Spatial Filter SF, Polarizing Beam Splitter PBS, Half Wave Plate HWP1 and HWP2.

A polarizer oriented at 0^0 and 45^0 degree is used as a sample .

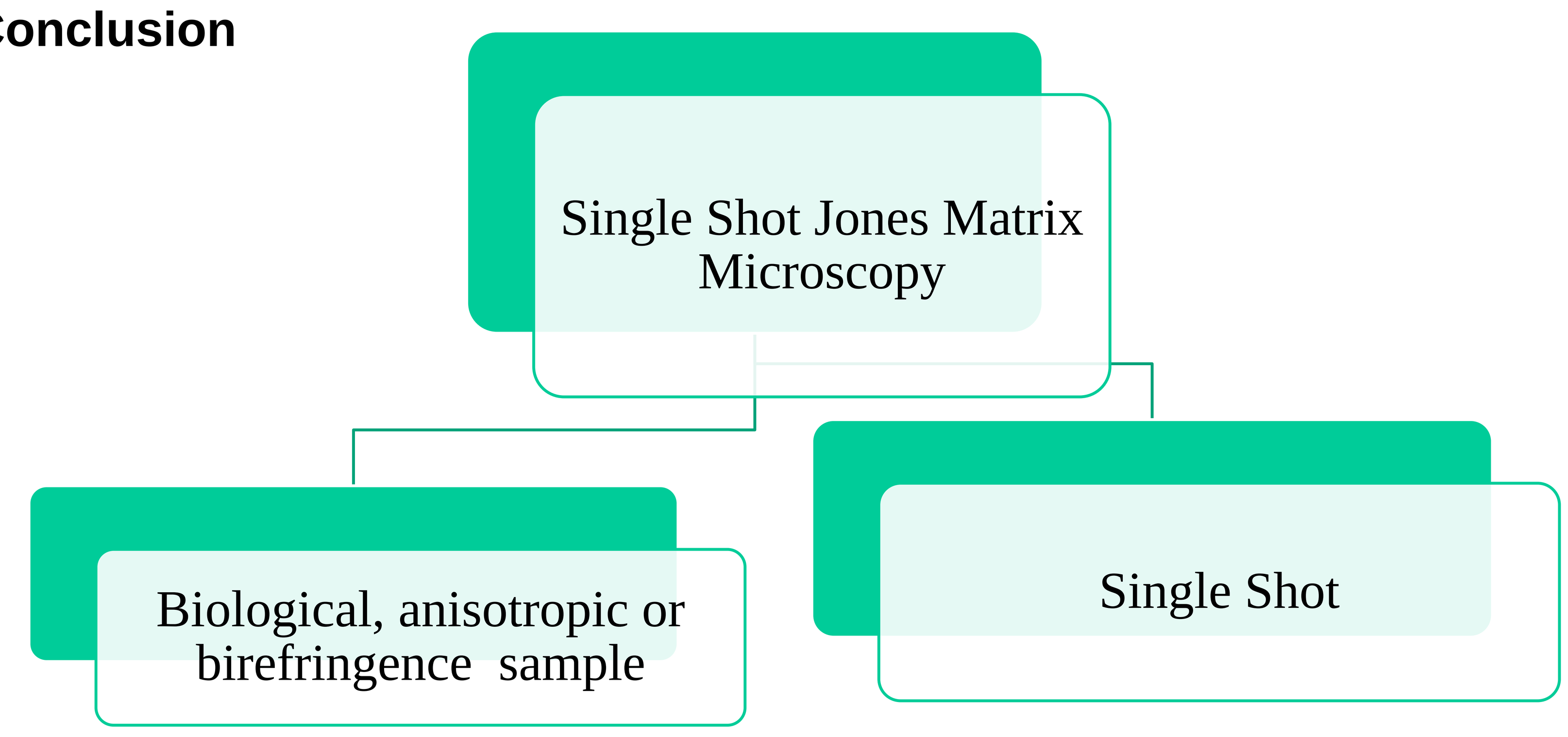
Experimental Results



(a) Recovered Jones Matrix for 0^0 (b) Recovered Jones Matrix for 45^0

Fig.3 (a) and (b) show the Jones Matrix of a Polarizer oriented at 0^0 and 45^0 respectively

Conclusion



References

[1] Yang T.D.,Park K.J., Kang Y.G.,"Single-shot digital holographic microscopy for quantifying a spatially-resolved Jones matrix of biological specimens" OPTICS EXPRESS 24,25 (2016).
[2] Hecht,Eugene,5th Ed.,Pearson Education Limited (2017)
[3] Sánchez-Ortiga E.,Doblas A, Saavedra G., Martínez-Corral M.,Garcia-Sucerquia J.,"Off-axis digital holographic microscopy:practical design parameters for operating at diffraction limit"Appl. Opt. 53,2058(2014)
[4] Wang, Z., Millet, L. J., Gillette, M. U., and Popescu, G.,"Jones phase microscopy of transparent and anisotropic sample" Opt. Lett. 33, 1270 (2008).
[5] Soni N.K.,Somkuwar A.S.,Singh R.K.,"Jones Matrix Imaging for Transparent and Anisotropic Sample"Proc. of SPIE 9654, 965420(2015).
[6] Sreelal M. M., Vinu R. V. , Singh R.K.,"Jones matrix microscopy from a single-shot intensity measurement" Opt. Lett. 42,5194(2017) .
[7] Mitsuo Takeda, "Fourier fringe analysis and its application to metrology of extreme physical phenomena: a review [Invited]," Appl. Opt. 52, 20-29 (2013)