Polarized Light Field Microscopy Using Deep Learning

3D birefringence measurements of transparent microscopic volumes

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Polarized Light Microscopy

Birefringence, diattenuation & fluorescence polarization for live cell imaging.

Quantitative (magnitude + orientation) measurement of birefringent structures in living cells such as microtubules, actin, etc.,

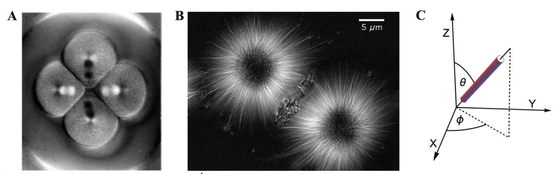
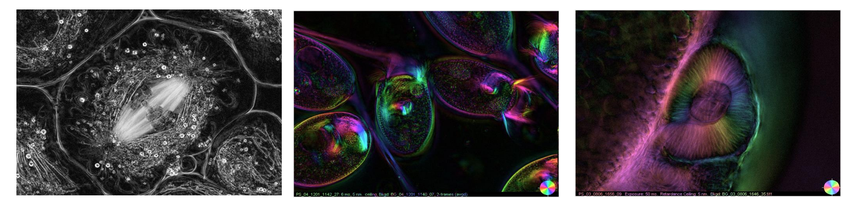


Figure 1. (A) Micromere-forming 4th mitosis in sand dollar egg, imaged with traditional polarized light microscope by Shinya Inoué. **(B)** Retardance image of a mitotic spindle isolated from a fertilized sea urchin egg and recorded with the LC-PolScope. **(C)** Schematic illustrating the orientation of a polymer bundle represented by a cylinder in object space. The orientation is given by two angles, the azimuth ϕ in the focus plane X-Y and the tilt θ away from the microscope axis Z.

Vari-LC polarization state controller utilizing liquid crystal variable retarders.

Devices and software available from ***OpenPolScope.org***

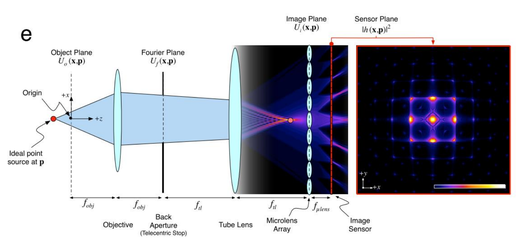


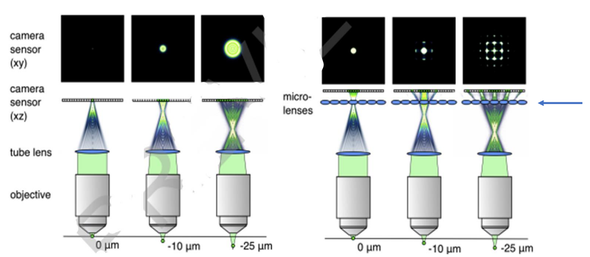
Architectural Dynamics of Living Cells Laboratory established by Dr. Shinya Inoue. Dr. Oldenbourg invented the LC-PolScope in 1999. The focus is on the development of instrumentation in collaboration with biological investigators

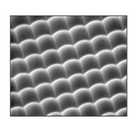
Light Field Microscopy

4D light field acquisition using plenoptic camara

Calibration process to rectify geometry and intensity variations before iterative deconvolution for resolution recovery and aberration correction of 3D reconstruction.







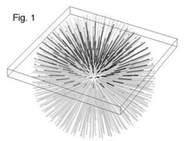
microlens array

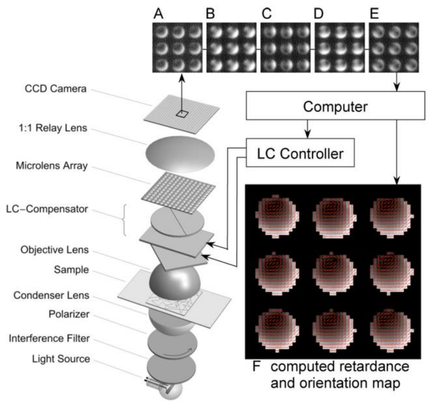
[Recording and controlling the 4D light field in a microscope using microlens arrays.](#)
Levoy M, Zhang Z, McDowall I.J Microsc. 2009
Richardson-Lucy deconvolution

We are developing a napari plug-in for Light Field Microscopy Imaging for LFM Reconstruction with iterative and deep learning approaches.

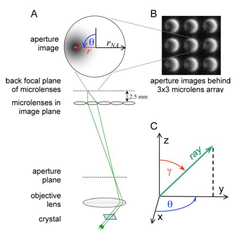
Polarized Light Field Microscopy

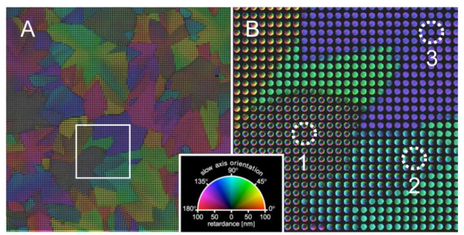
Measuring optical anisotropy of uniaxial, non-attenuating samples in 3 dimensions.



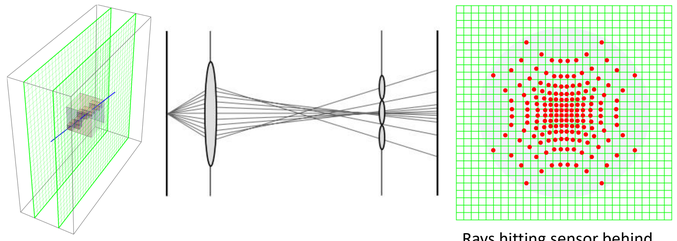


Acquisition of multiple polarizations (channels), using liquid crystal universal compensator





Forward Model: Optical Ray Tracing with Jones Calculus



Object Volume

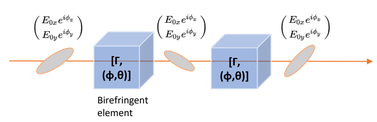
Optical System

Rays hitting sensor behind single lenslet

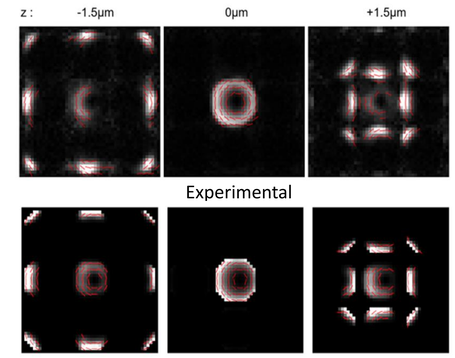
We use geometric ray-tracing with optical elements as a series of birefringent voxels, with intersection lengths calculated with the Siddon algorithm.

The process is **noncommutative**.

Jones vector/ matrix interaction

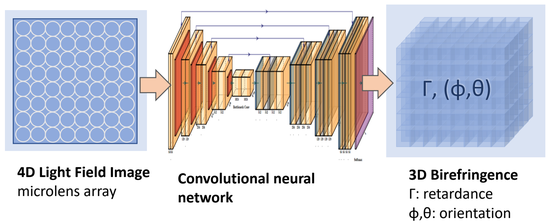


Simulation confirmed with experiment



Limited-Angle Tomographic Reconstruction of Birefringence: Learning the Inverse Transform

Physics-informed,
train with synthetic data
using forward model



4D Light Field Image
microlens array

Convolutional neural network

3D Birefringence
Γ: retardance
ϕ,θ: orientation

Exploiting Inherent Bias

Deep Priors
Generative adverserial
Variational autoencoders

Network Architecture: Incorporating Physics and Symmetries

Exploring how to incorporate known symmetries, group transforms into networks

Convolutional, 2D, 2.5D, 3D, …
Quaternion, Hyper/Complex-valued
Group Equivariant, Spherical, Steerable
Geometric Deep Learning
Graph Convolutional

Polarization Representations
Stokes, Mueller, Jones;
Geometric, Poincare sphere
Group SO(3)/SU(2),
Pauli Algebra,
Quaternion
(See Geneva Schlafly's poster.)