ROTOPOL

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A technology is presented that extends the range of application of any existing optical microscope to measure quantitatively and simultaneously Birefringence, Extinction, and Transmission images. It consists of two parts:

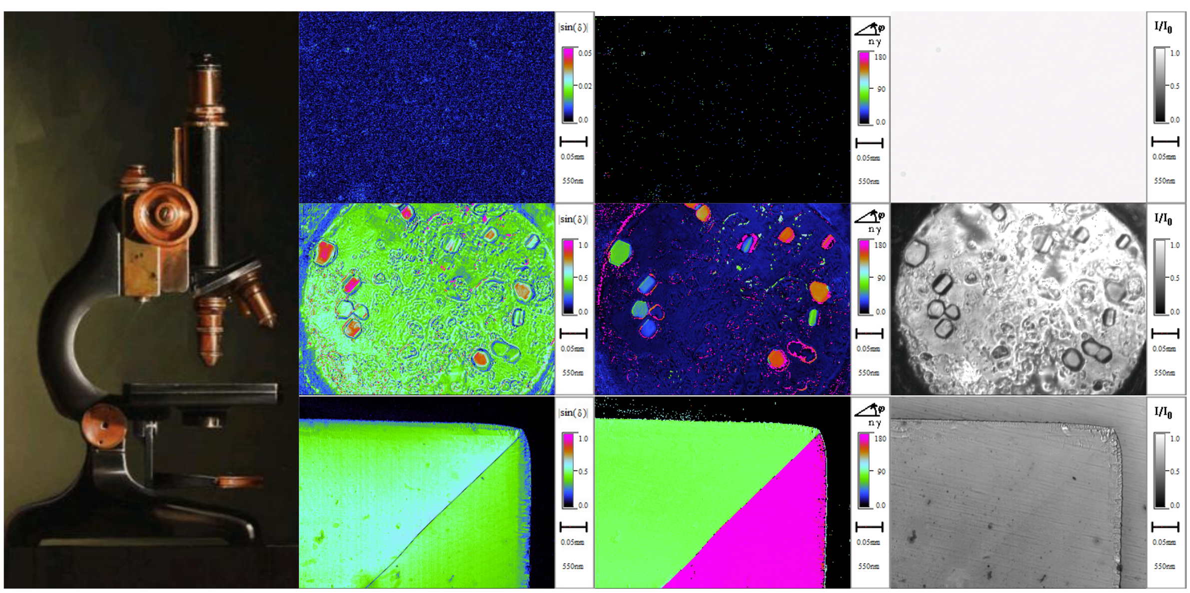
a) the camera-rotating polarizer unit
b) a circular polarizer

Description of unit a), rotating polarizer

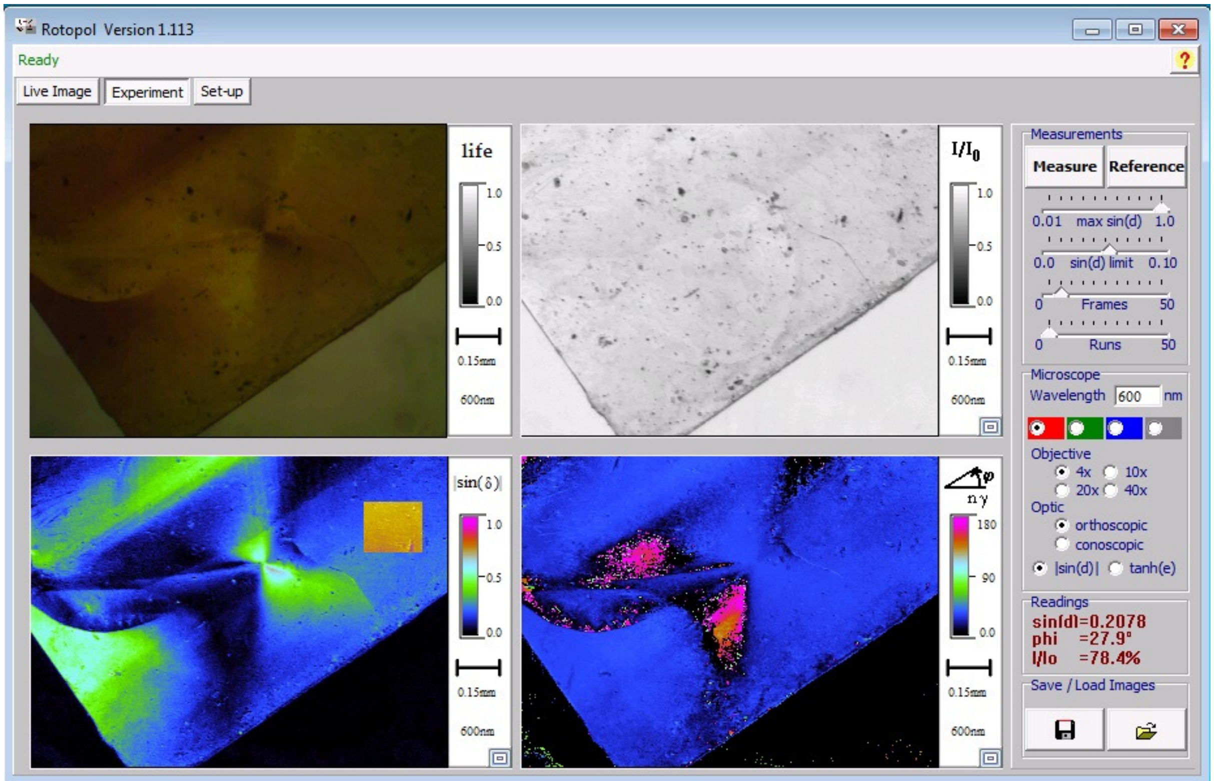
A rotating polarizer is placed in front of a camera with integrated optical components. The unit can be placed on any microscope replacing a standard ocular or on a C-mount that allows insertion of an ocular (some newer microscopes require removal of a depolarizer for this to work). The polarizer is computer-controlled through the USB connection and the images of the digital camera are received also via a standard USB port on a Microsoft Windows operating computer.

Below are examples of measurements performed with a *1915* vintage Bausch & Lomb optical microscope. The ROTOPOL device replaced the brass ocular piece on the top. A simple green-filter polarizer plus two quarter wave compensators (one with its slow axis aligned with the polarizer, the other at 45 degrees, which allows calibration to exact quarter wavelength retardation) was fastened underneath the sample table.

The first row of images next to the microscope shows the background where the technology has removed all dust and other imperfections. The second row shows a ‘well’ from a crystallization plate with crystals. The third row exhibits the birefringence of a thin heterogeneously birefringent crystal plate.



Old microscope used for ROTOPOL measurements (see text).



Screenshot with crystal as sample. The image on the top-left represents a live image of the microscope. Dragging the mouse over the image (orange highlight in the bottom left image) gives sin(d), phi and I/Io readings.

Description of unit b), circular polarizer

There are different options. A very low-cost option combines a simple color filter foil with a calibrated combination of polarizer and quarter-wave plates to produce quarter-wave retardation within a 1% error margin. In addition, achromatic quarter wave plates can be used in combination with a polarizer at 45 degrees. In the easiest implementation, the foil option is placed on the sample table, but underneath the sample.

SPECS:

Image resolution is that of the camera, typically 2048 x 1536 or as small as 320 x 240. Preferred camera: AmScope MA300 (with Direct Show drivers).

Noise level: For a single measurement with proper background calibration |sin(d)| <> 0.01. With integration, this can be lowered to 0.001 (microscope independent). The extinction angle resolution is better than estimated 0.5 degrees.

Maximum retardation: For simple foil-color filters, dispersion limits the applicable range to d = 4π, for 50nm half-width interference color filters this value is considerable higher, but the signal is a modulus of π/2 if no further measures are taken. However, utilizing measurements of two wavelengths allows to separate out this ambiguity, which is currently in the process of being implemented into the software.

Signal linearity: For a properly calibrated camera, sin(d) readings linearity is better than 5% (this depends on the quality of the circular polarizer). Similarly, extinction is determined with approx. 2 degree accuracy (improvements possible via calibration, not yet implemented).

Sampling time: This method requires mechanical rotation of a polarizer with sequential reading of images. For better signal to noise readings one can also integrate measurements, thus the range of sampling time is ca. 3 seconds to 10 minutes.

Calibration: The camera needs to be set to linear intensity response and proper dark-current reading (zero signal for zero intensity).The motor zero-position needs to be set once only to place the polarizer "horizontally" for properly referencing the extinction angle reading.

Do-It-Yourself

The software plus detailed blueprints and construction advice can be obtained at a very competitive rate. A shopping list is provided. To enable further development of this project, regular software improvements, and updates (according to the wishes and input of users), a reasonable license fee is kindly requested.

Software license plus blueprints	$ 3,000
Optional extended help, for getting it built	$ 3,000

Additional costs to be expected by the user:

Material costs (incl. achromatic quarter-wave plate)	$ 1,500
Mechanical workshop cost estimate	$ 500

Interested parties can obtain further information from the developer of this technology, Research Associate Professor Werner Kaminsky:
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The Software license is arranged through the Center for Commercialization, c4c, University of Washington, contact: Laura Dorsey,
ldorsey@u.washington.edu

Further Reading

1. A. M. Glazer, J. G. Lewis & W. Kaminsky: A new optical imaging system for birefringent media. J.Royal Soc.London A452 (1996) 2751-2765.
2. M. A. Geday, W. Kaminsky, J. G. Lewis, A.M.Glazer: Images of absolute retardance L×Dn, using the rotating polariser method. J. of Microscopy 198 (2000) 1-9.
3. W. Kaminsky, E. Gunn, R. Sours, B. Kahr: Simultaneous false-color imaging of birefringence, extinction, and transmittance at camera speed. J Microscopy. 228 (2007) 153-164.
4. W. Kaminsky: Real-time linear-birefringence-detecting polarization microscope. April 21st 2009, **US Patent 7522278**.