

**Park Systems GmbH - Accurion**  
Stresemannstr. 30 37079 Göttingen, Germany  
+49-551-999600 (Germany)  
parksystems.com inquiry@parksystems.com

## Microscopic Characterization of 2D Materials by Spectroscopic Imaging Ellipsometry

### Imaging Ellipsometry

**Imaging ellipsometry**, combines the power of **ellipsometry** with **optical microscopy**. It achieves the highest lateral resolution in the field of ellipsometry and offers a very sensitive imaging technology for thin films. Typical samples range from tiny samples like flakes of 2D materials to inhomogeneous surfaces like some CWD samples of 2D materials or terraces at Epitaxial Graphene surfaces.

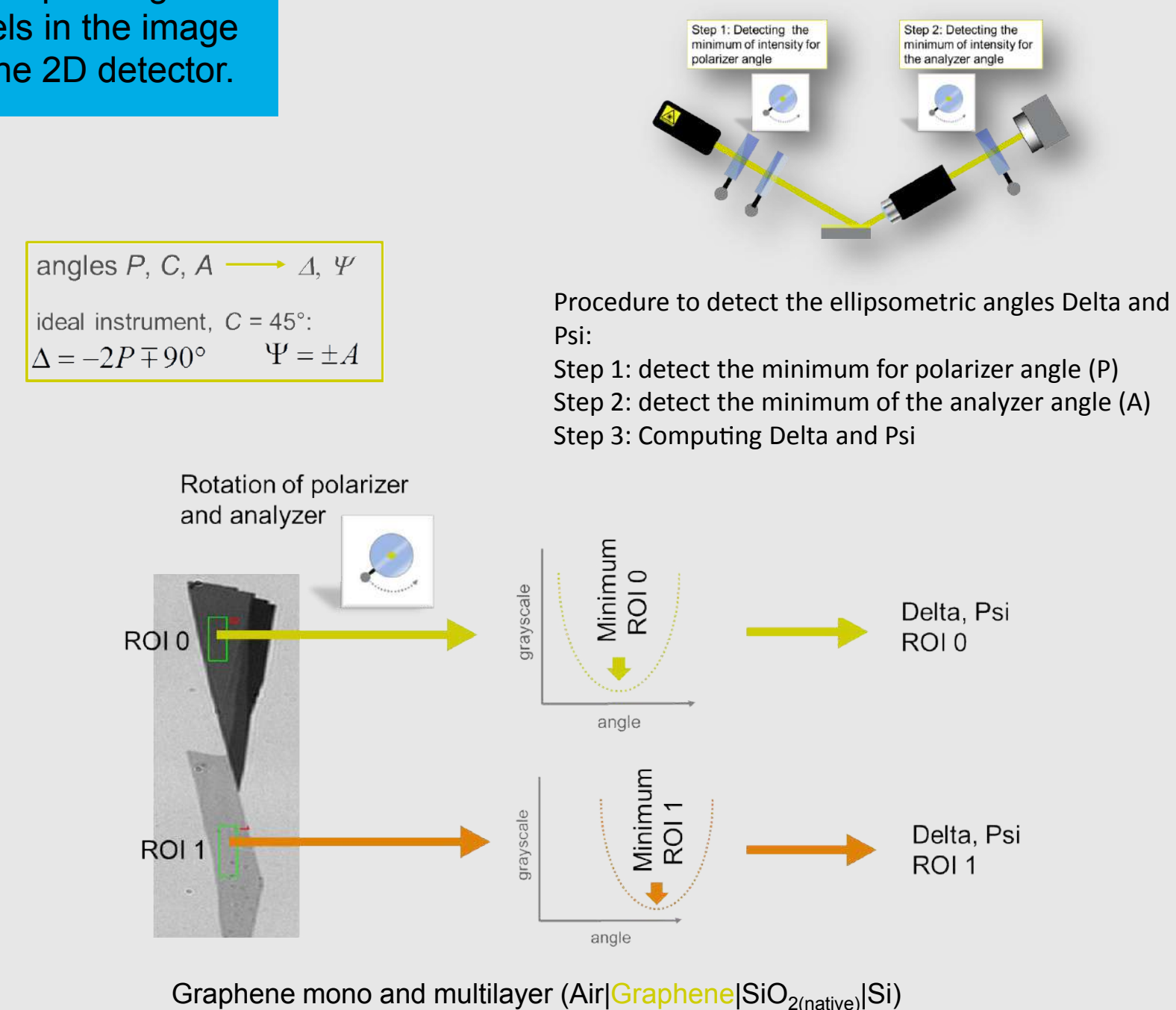
The ep4 is the latest microscopic imaging spectroscopic ellipsometer with unique measurement capabilities. It can provide real-time ellipsometric enhanced contrast images, and maps of the ellipsometric angles Psi and Delta. These data can be transferred into Thickness and the complex refractive indices by computerized optical modeling.



### Regions of Interest

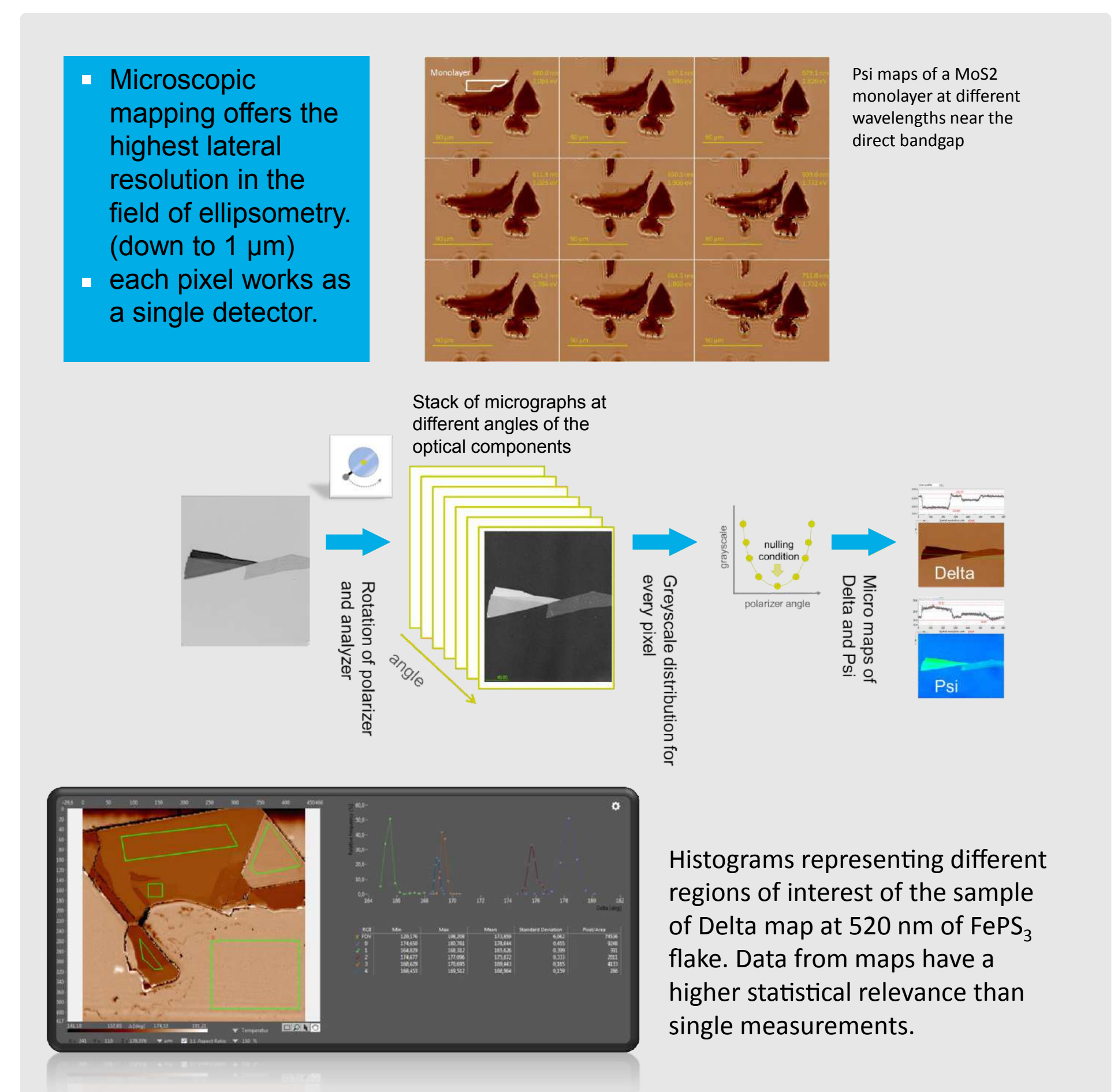
- Imaging ellipsometry offers the option to study portions of the sample by selecting corresponding pixels in the image of the 2D detector.

The intensity changes are recorded only for the pixels, that represent the Region of Interest (ROI). With this method, a much higher lateral resolution is available and similar areas can be measured in parallel.



### Microscopic Mapping

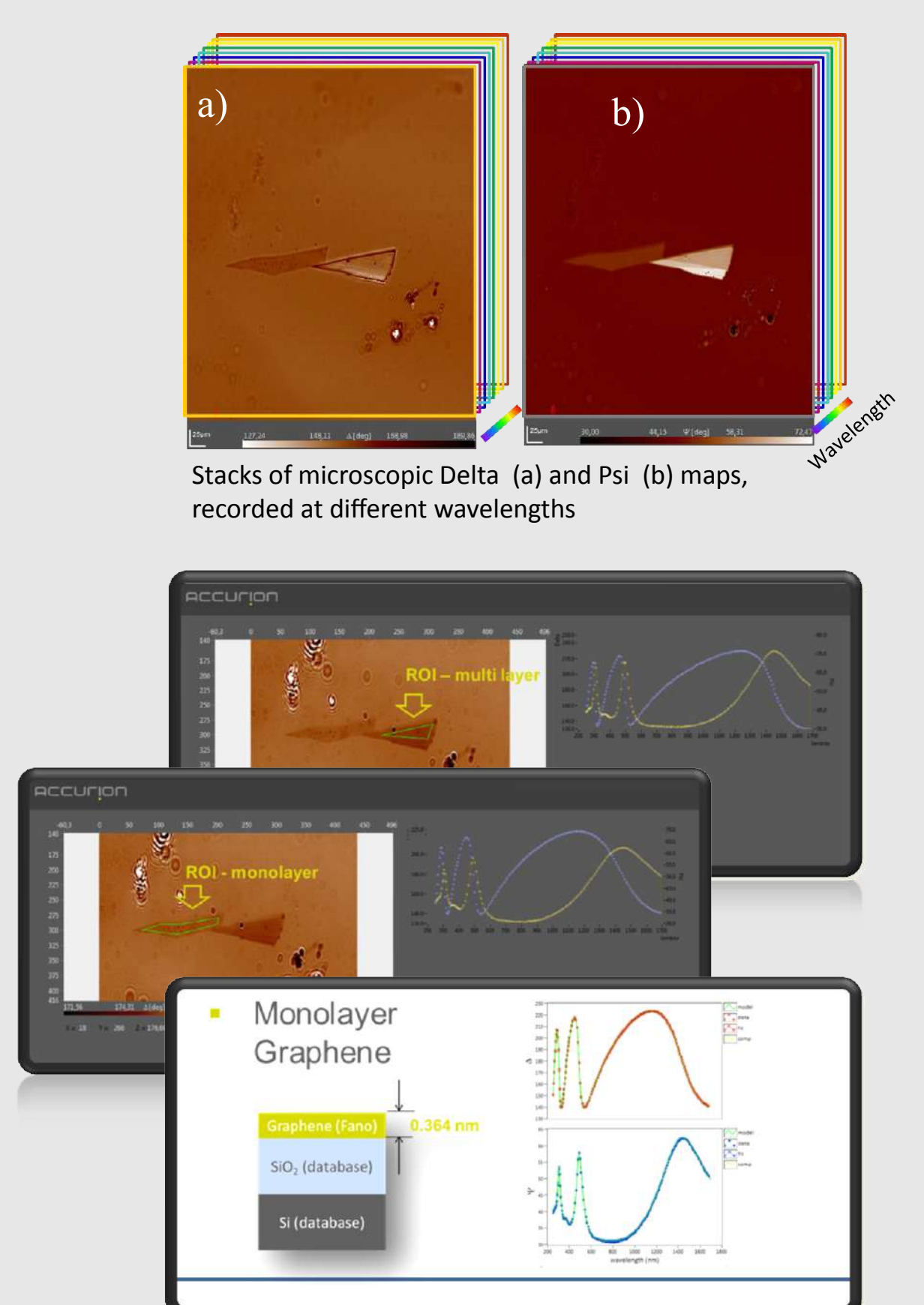
- Microscopic mapping offers the highest lateral resolution in the field of ellipsometry. (down to 1  $\mu\text{m}$ )
- each pixel works as a single detector.



### Extracting Wavelength Spectra

- The extraction of spectra from a stack of microscopic maps is a tool to measure the complete spectra of the smallest regions of interest.

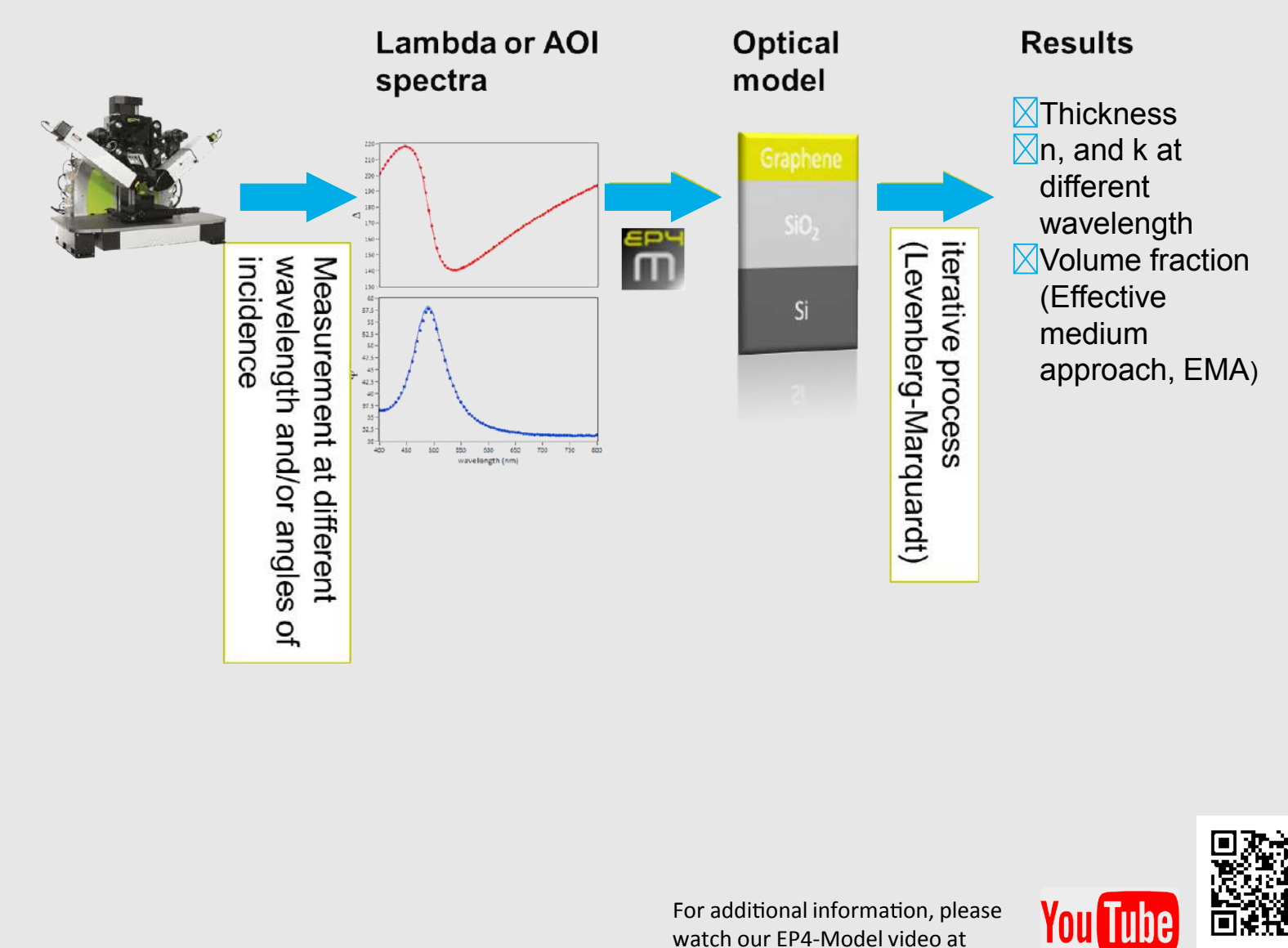
- Record Delta and Psi maps at different wavelengths
- Select a region of interest in one representative map
- Software calculates the delta and Psi values for the ROI
- Send spectra to the model and calculate the parameter of interest



### Optical Modeling

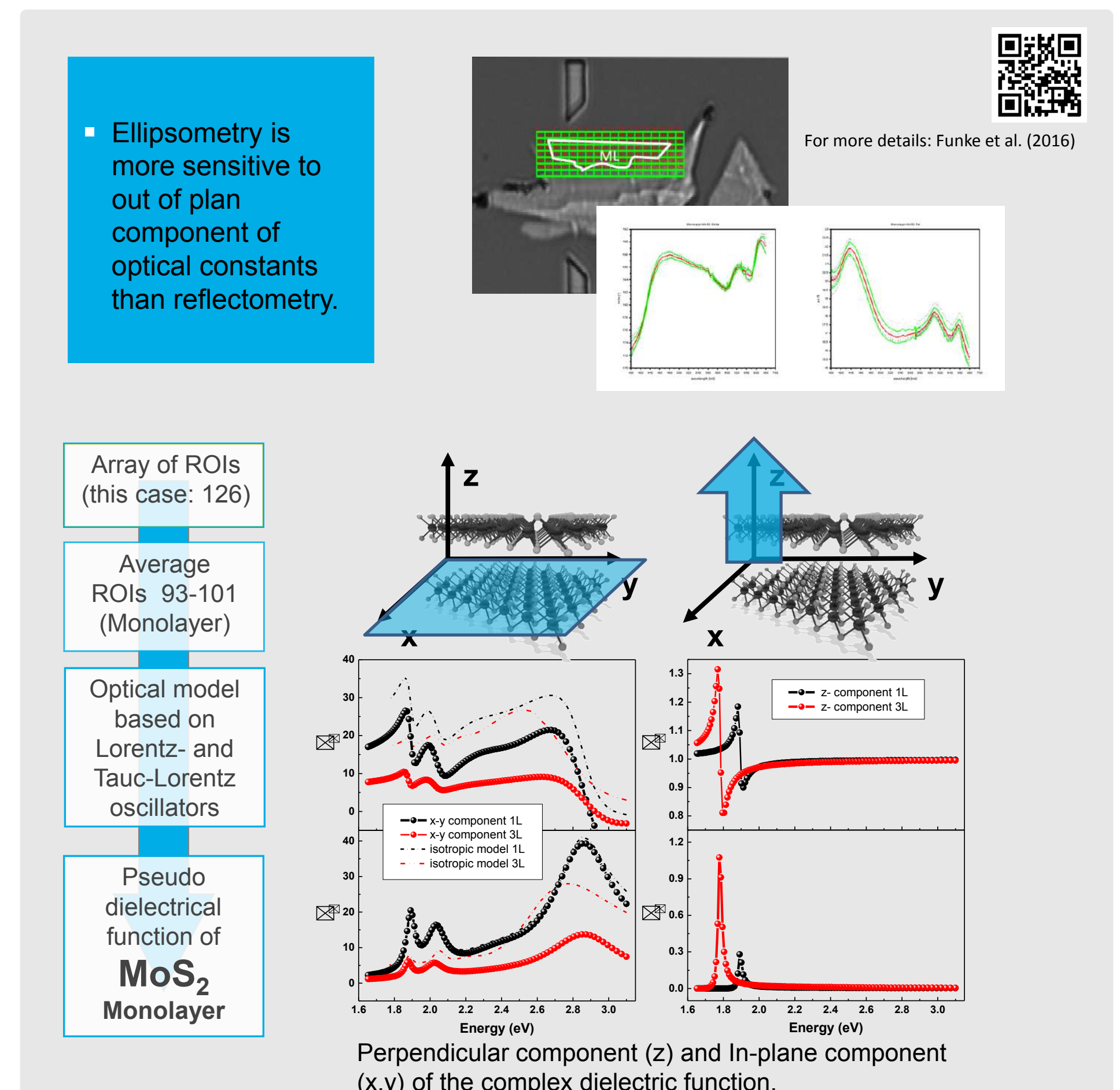
- Calculation of optical- and metrological parameters for ultrathin films
- Effective medium approach (EMA) also offers information about chemical composition

The Drude equation connects the ellipsometric angles Delta and Psi with the Total reflection coefficient of the Fresnel equation and on this track with physical parameters like the complex refractive index and the layer thickness. By using different wavelengths the dispersion function of the layers and/or of the substrate is available. The number of fit parameters is related to the number of measured parameters. To increase the number of parameters, angle of incidence, and wavelength spectra can be measured.



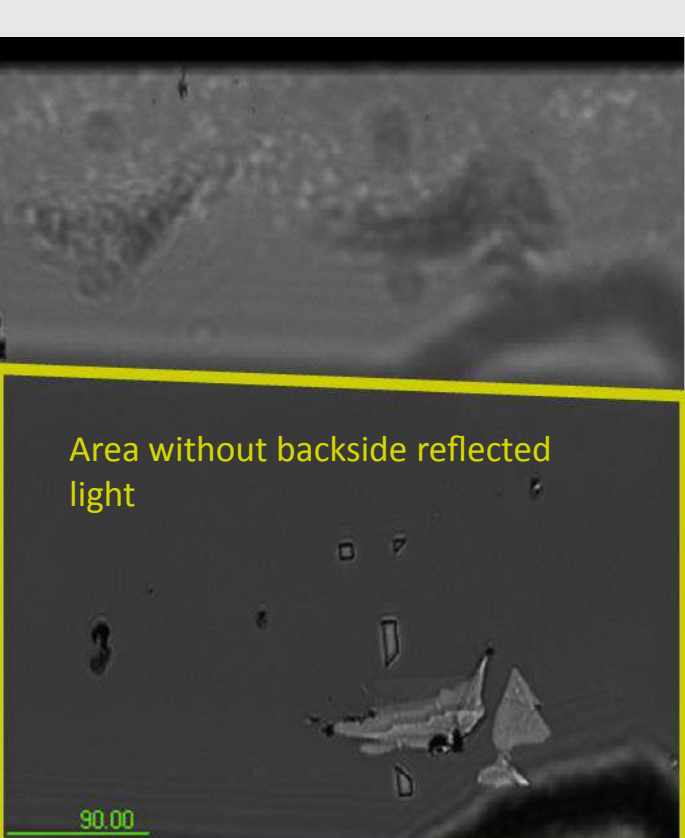
### Optical Properties

- Ellipsometry is more sensitive to out of plan component of optical constants than reflectometry.

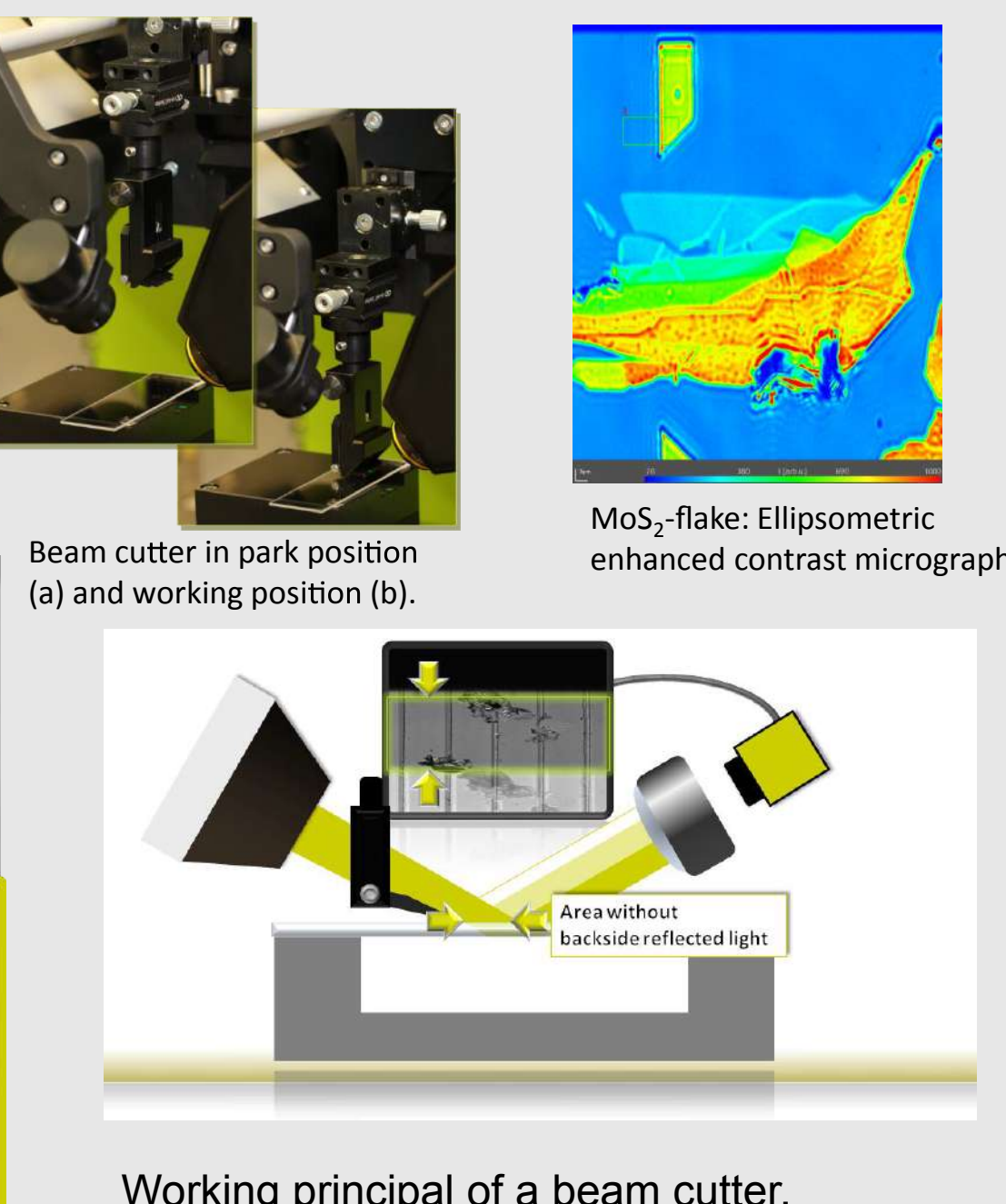


### Knife Edge Illumination

- No contribution by backside reflected light
- Non destructive, no treatment of the backside.



Ellipsometric enhanced contrast micrograph of a MoS<sub>2</sub> flake on sapphire.



For additional information, please watch our beamcutter video at

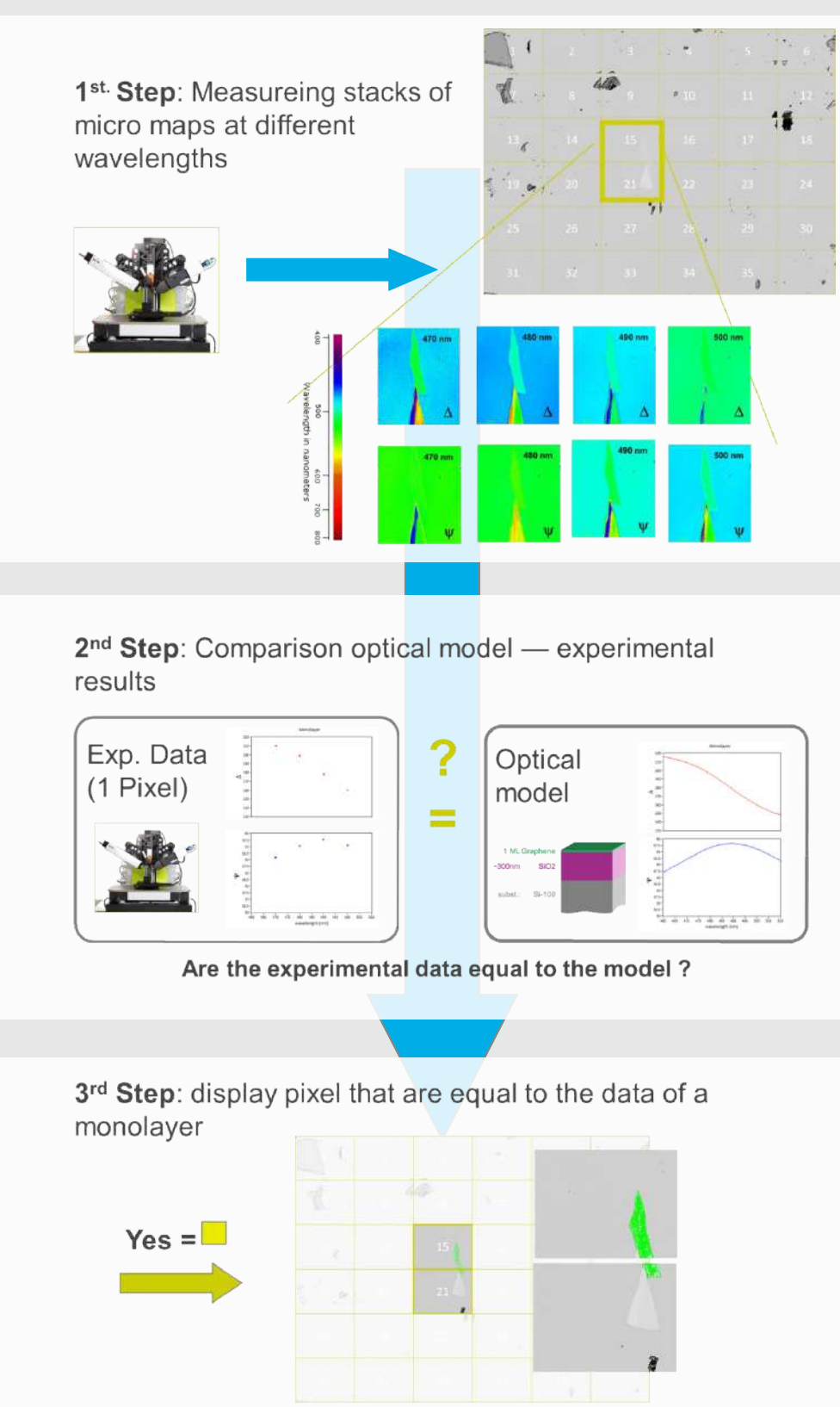


Sample provided by: Ursula Wurstbauer et al. TU München

### Automatic Flake Search

- Calculation of optical- and metrological parameters for ultrathin films
- Effective medium approach offers chemical composition

- Localization of sample areas with required properties
- For example, monolayers were identified by comparing the measured Delta and Psi values with the data from the optical model.
- This approach is useful to identify monolayers but other properties could also be probed.
- After identifying an interesting sample, the tool can be used to search for the same experimental data elsewhere on the sample.
- This concept has been proven with hex-BN.



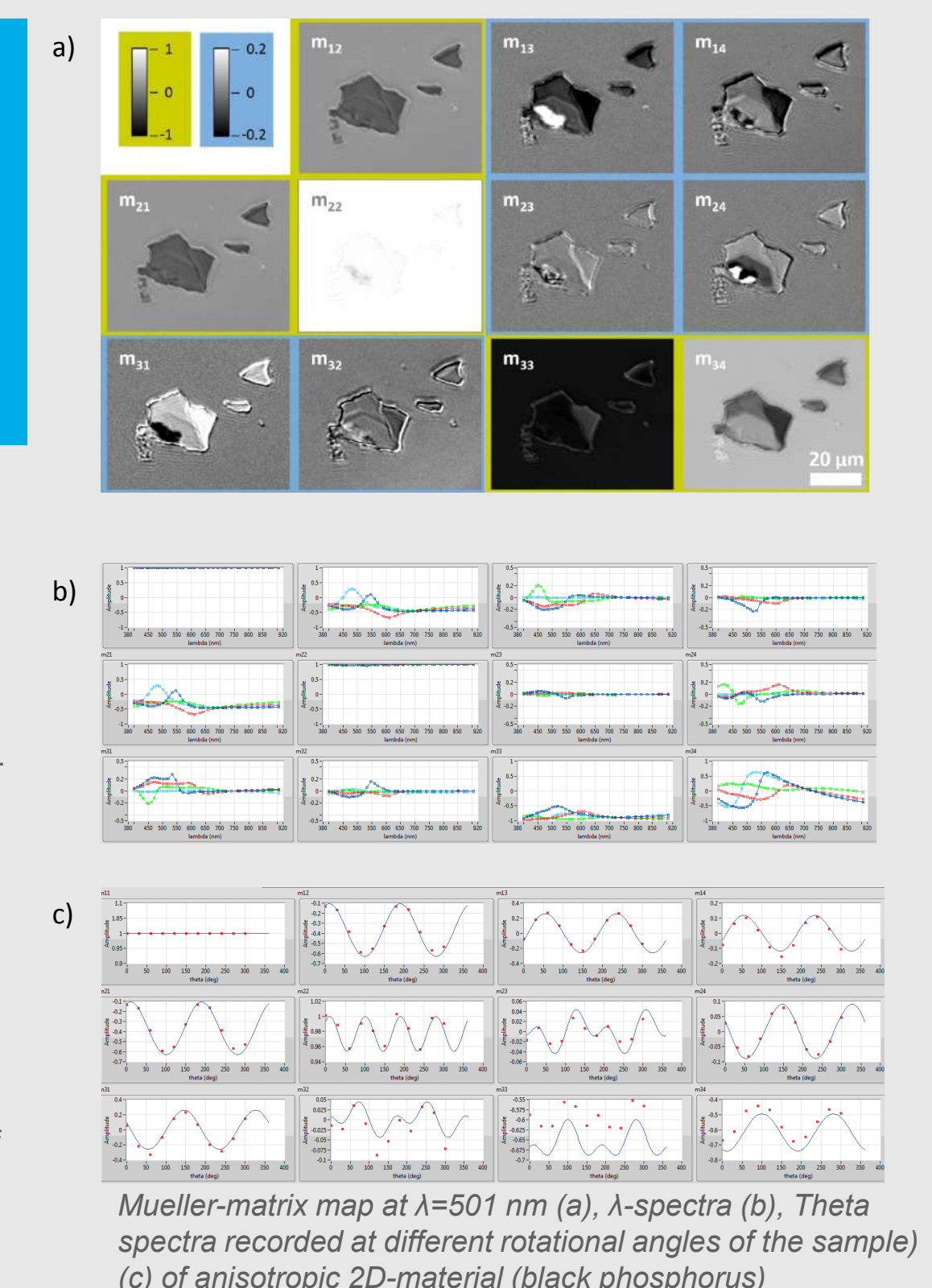
For additional information, please watch our 2D-materials video at



### Microscopic Müller Matrix

- Müller Matrix Ellipsometry is the method of choice for anisotropic samples.
- First microscopic Müller Matrix Ellipsometry

- Example: micro-structured flakes of black phosphorus (anisotropic) on silicon substrate.
- Application type: anisotropic thin-film layer.
- Overall focused Mueller-matrix images with microscopic lateral resolution.
- Identification of isotropic and anisotropic regions.
- Determination of anisotropic refractive indices and orientation of optical axis.



Sample provided by: Aday J. Molina-Mendoza (University of Madrid, Spain) & Andres Castellanos-Gomez (IMEDEA Nanoscience, Madrid, Spain)