Óbuda UNIVERSITY

Doctoral School on Materials Sciences and Technologies

Institute of Technical Physics and Materials Science
Centre for Energy Research

7th Semester Report On

‘ Optical Calibration of the Multi-Color Ellipsometric Mapping Tool from Cheap Parts ’

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Presentation Outline

1 Introduction

- 1.1 Aim of the Research
- 1.2 Research Methods
- 1.3 Characterization methods

2 Discussion

3 Results

4 Conclusion

1. Introduction

Spectroscopic Ellipsometry (SE)

- Non-destructive, non-invasive and non-intrusive optical technique.
- Measures the relative change in polarization state of the measurement beam.
- The two SE measurable values: Amplitude ratio tan(**ψ)** and phase difference (**Δ)** between the **p**- and **s**-polarizations.
- **ψ** and **Δ** are related to the wavelength of the light beam '**λ**' and the angle of incidence of the beam '**θ**' at the sample surface, respectively.
- Major Steps: Measurement, Data interpretation, Modelling, Fitting, Evaluation and Results.

1.1. Aim of the Research

- Making an optical mapping tool *prototype* from cheap parts like:

  Tablets, monitors and big screen LCD,LED TV

- Programming the data collection and data processing software .

- Making measurements on selected samples and determining the precision of the prototype.

1.2. Research Methods

Original Concept of Prototype building using different parts

1. Light-source (LED-panel)
2. Diffuser sheet
3. Film-polarizer
4. Analyzer

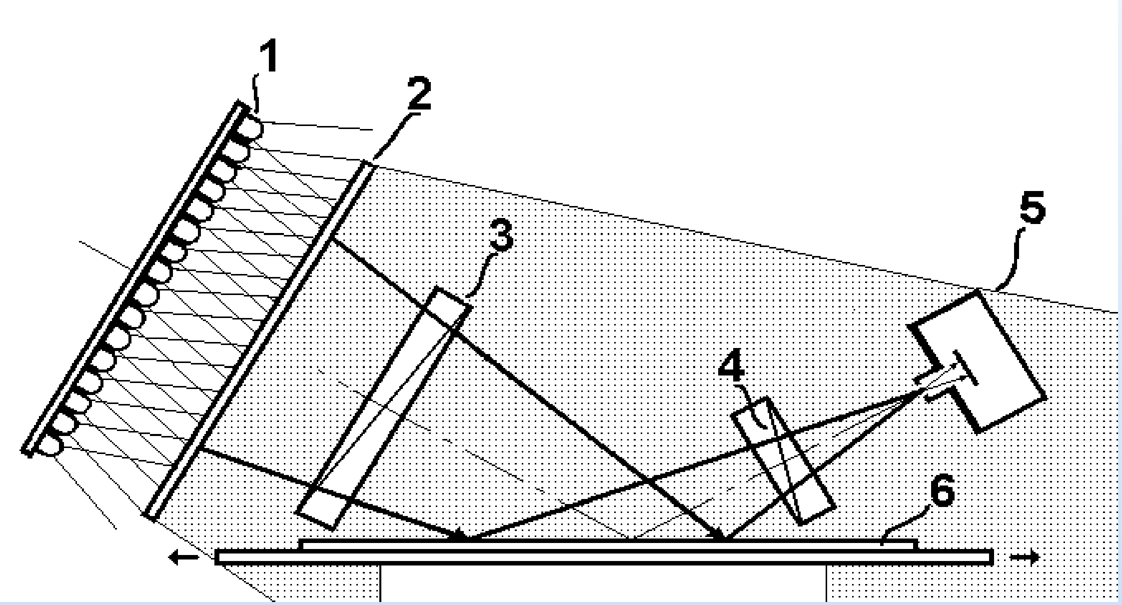


Fig. 1: Original concept of the non-collimated beam ellipsometer

5. Detector (pin-hole + CCD-detector) and
6. Sample

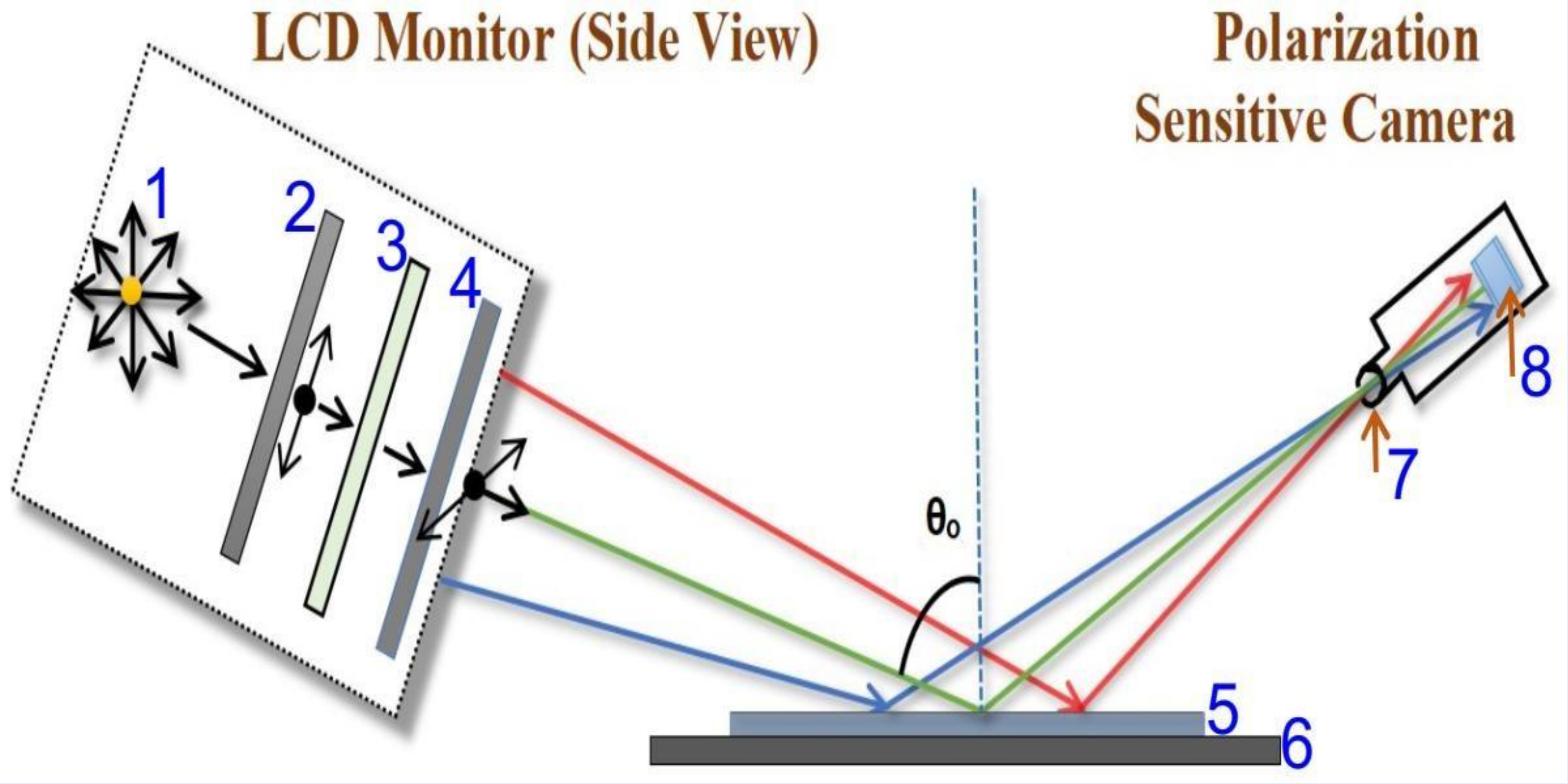


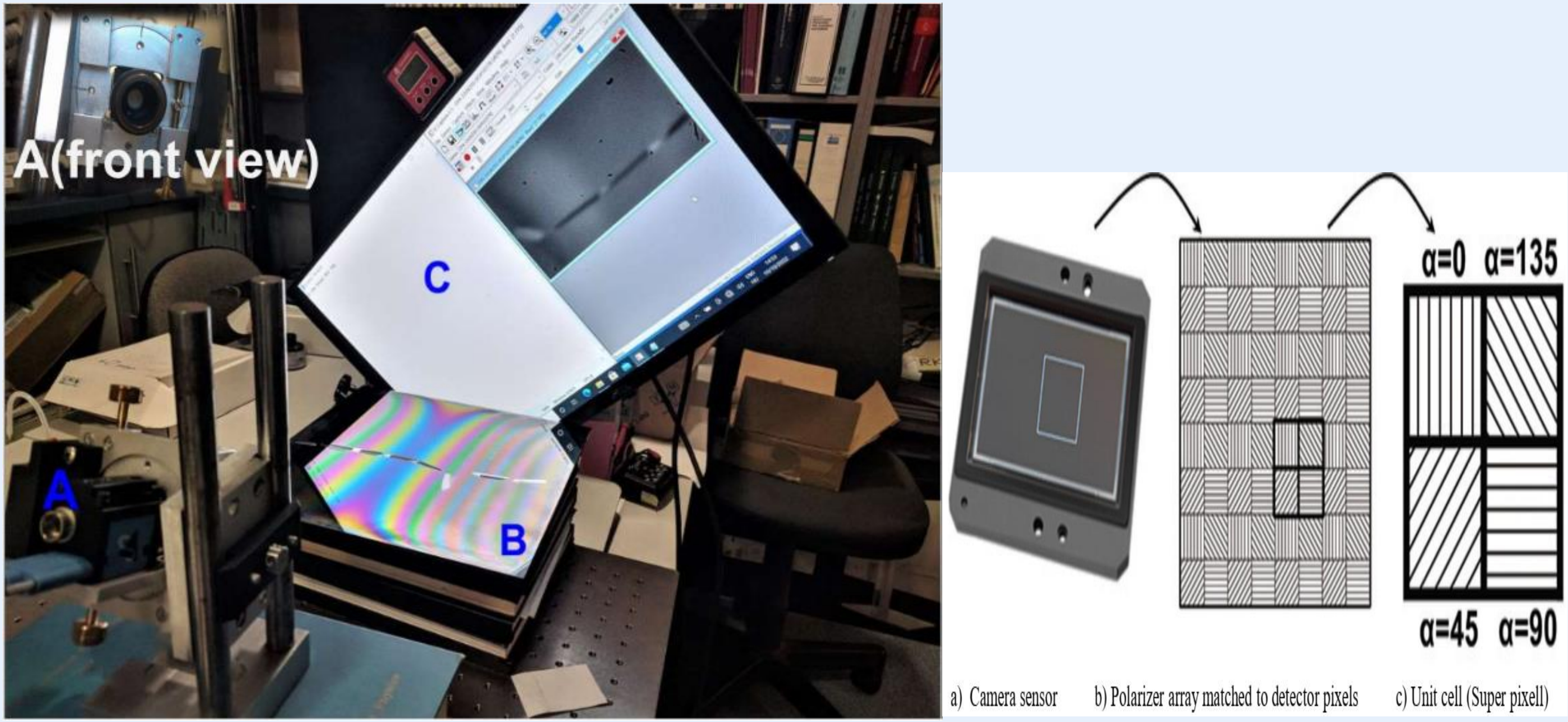
Fig. 2: New concept of the non-collimated beam ellipsometer prototype from cheap parts

1) Light source **2)** Vertical polarizer **3)** Liquid crystal cell

4) Horizontal polarizer **5)** Sample **6)** Sample holder

7) Pin hole (sub-mm size) and **8)** Camera sensor

The new concept is without the rotating polarizers



a) b)

Fig. 3: **a) Experimental set up**

A) Polarization sensitive camera **B)** Sample + holder **C)** LCD monitor

b) Schematic structure (CMOS Pregius Polarsens sensor),

NB. CMOS sensor is Integrated 4-Directional Wire Grid Polarizer

1.3. Characterization methods

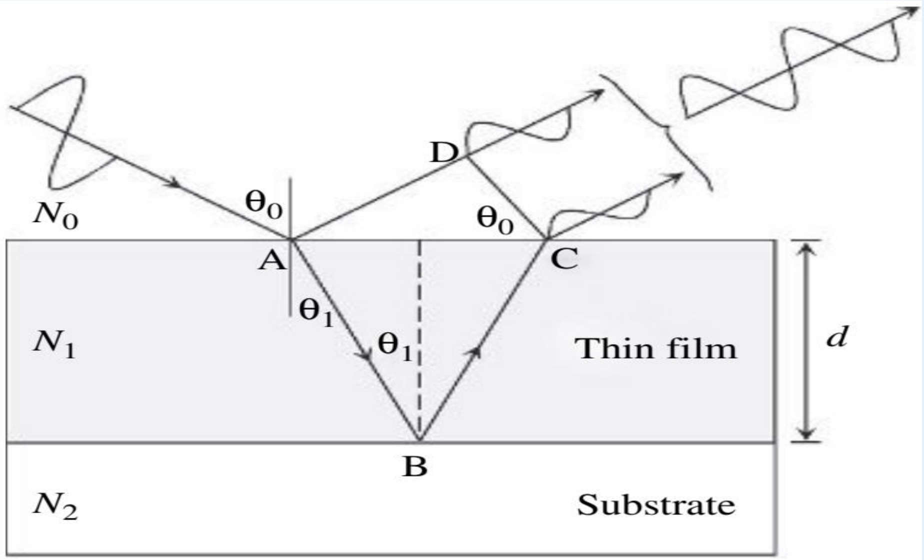


Fig. 4: Schematic diagram of the optical interference in an ambient/thin- film/substrate optical model

$$\rho = \tan(\Psi)\exp(i\Delta) = \frac{r_p}{r_s} \qquad (1)$$

$$r_{jk,p} = \frac{N_k cos\theta_j - N_j cos\theta_k}{N_k cos\theta_j + N_j cos\theta_k} \quad r_{jk,s} = \frac{N_j cos\theta_j - N_k cos\theta_k}{N_j cos\theta_j + N_k cos\theta_k} \qquad (2)$$

$$t_{jk,p} = \frac{2N_j cos\theta_j}{N_k cos\theta_j + N_j cos\theta_k} \quad t_{jk,s} = \frac{2N_j cos\theta_j}{N_j cos\theta_j + N_k cos\theta_k} \qquad (3)$$

Monitor correction ,

$$Q_{opt} = Q_{meas} * Q_{monitor} \qquad (4)$$

1.3.1. Rotating Compensator Spectroscopic Ellipsometer (M2000DI)

- Provides fast and very accurate thin film characterization over a wide spectroscopic range.
- Measures film thickness and optical constants on single or multilayer stack.
- Extreme sensitivity for very
- thin over layers

  even below 1 nm thickness.

Fig. 5: Rotating Compensator Spectroscopic Ellipsometer (M2000DI)

2. Results (Motive for calibration)

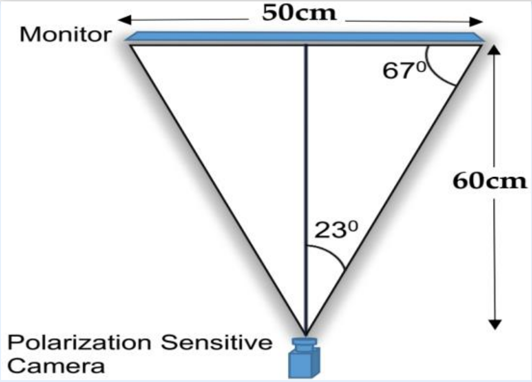


Fig. 6: Direct ellipsometric measurement of monitor.

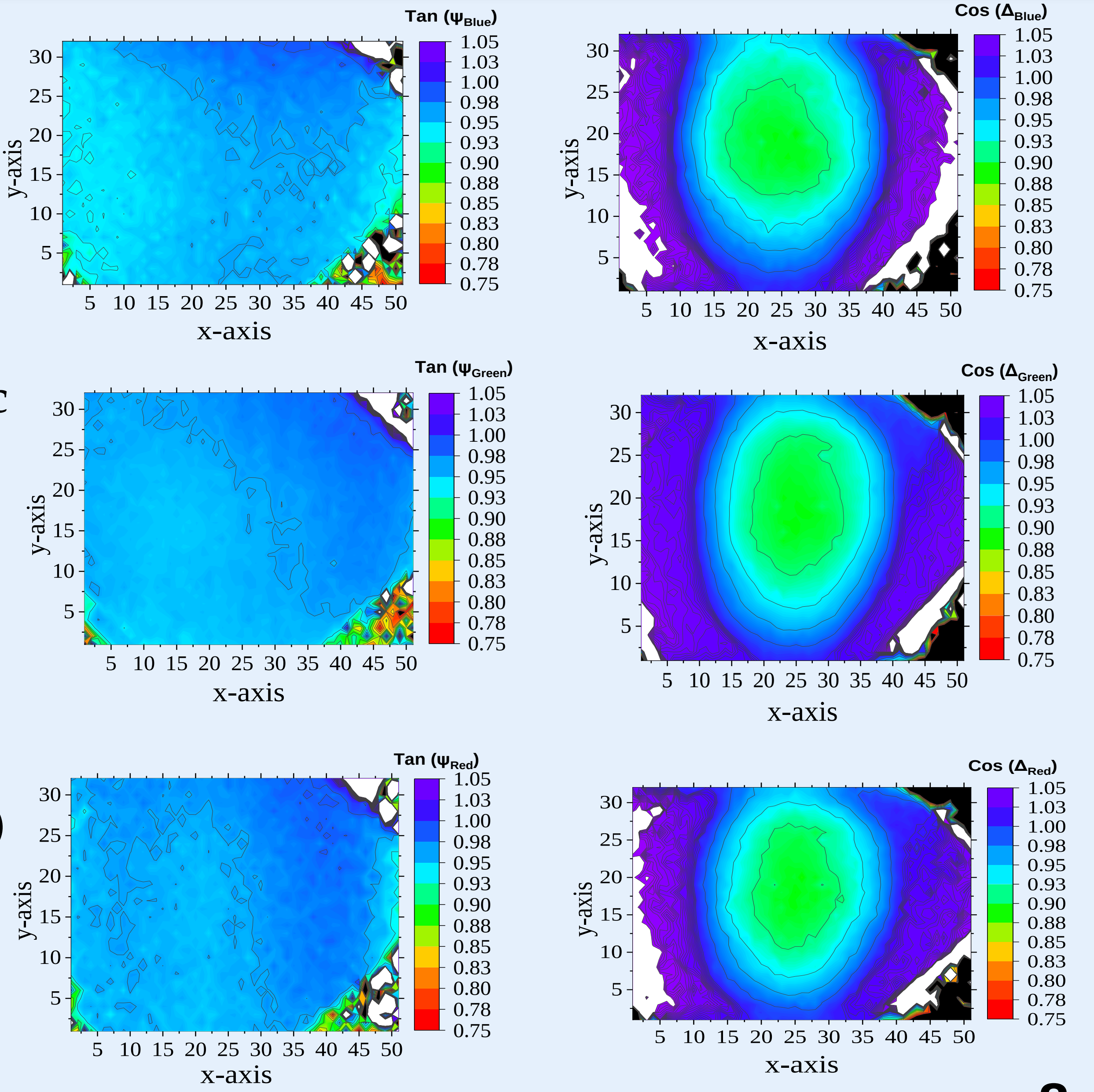


Fig. 7: A 60nm SiO_2/Si sample tan(Ψ) and cos(Δ) measurements for RGB spectrum

3. Results

- Each 20 cm diameter oxide sample was placed at six different. positions on the 30x30 cm^2 holder, 51x32 pixel groups of data points.
- Three SiO_2/Si samples with a nominal thickness of 40, 60, and 100 nm are used for the calibration process ,the MSE results are shown below.

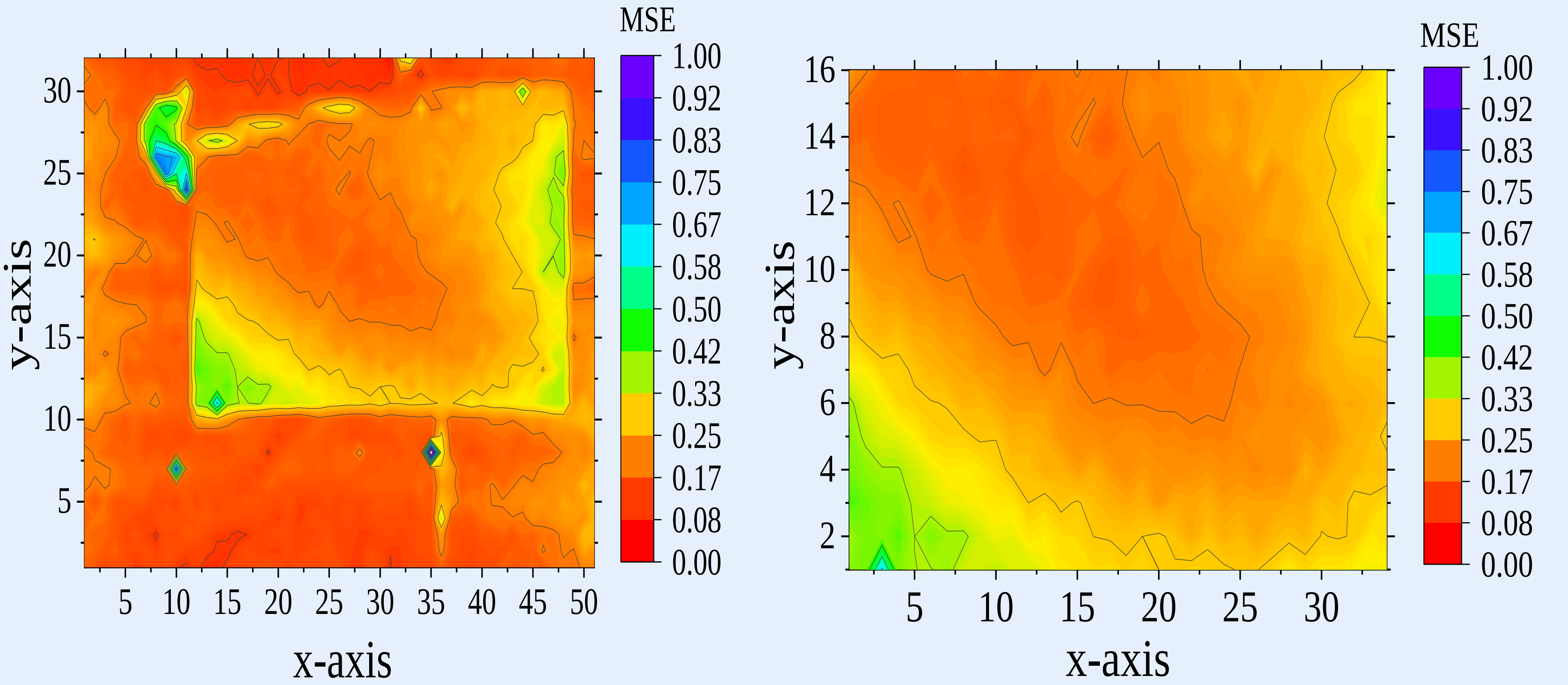


Fig. 8: **Left**: Merged MSE full map , **Right**: Low-MSE pixel map.

3. Results

- The oxide samples on three different positions, hence a better calibration was done. Below are the common angle of incidence calibration maps.

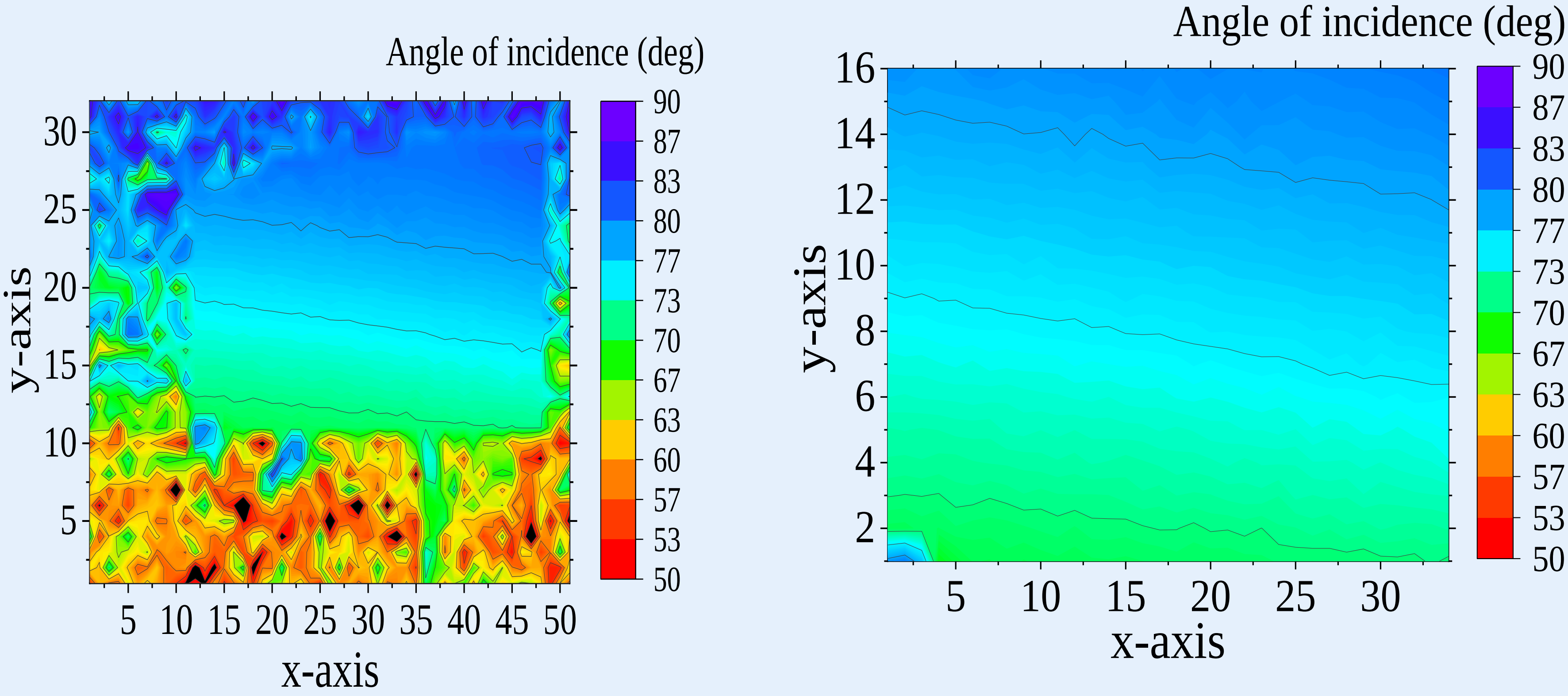


Fig. 9: **Left**: Full angle-of-incidence map

Right: Angle of incidence with low-MSE pixels

3. Results

The same calibration process resulted in the thickness maps of our calibration oxide samples, merged in a single frame map.

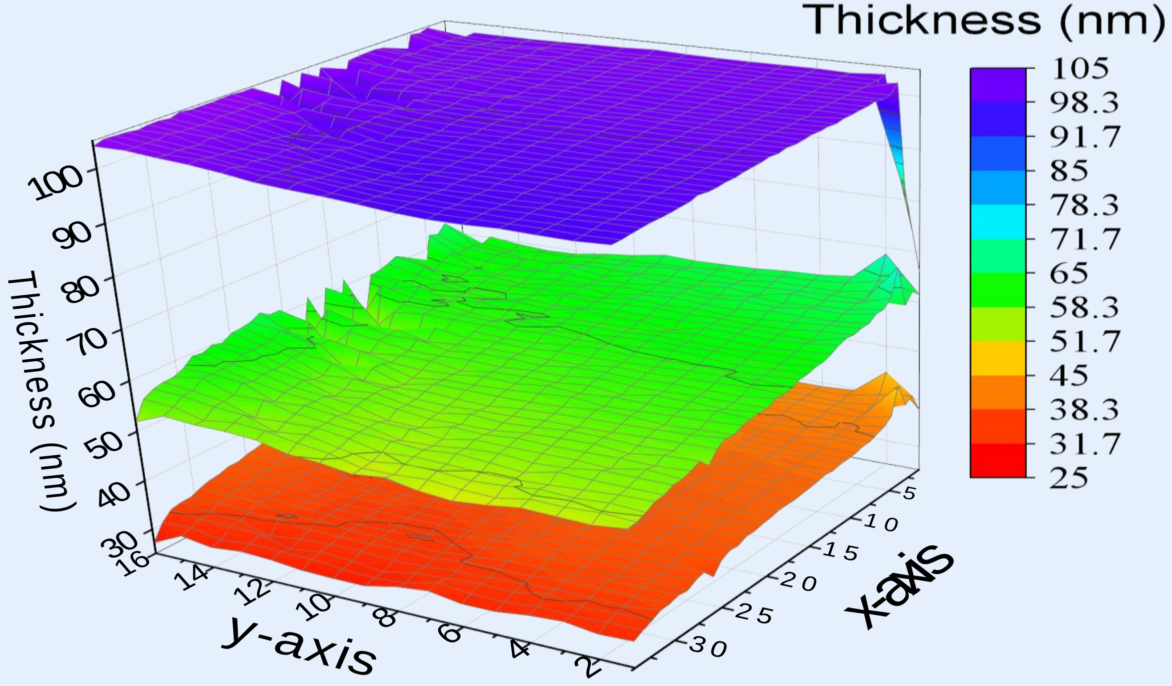


Fig. 10: Thickness maps of SiO_2/Si samples with nominal thickness of 40 nm, 60 nm, and 100 nm (low-MSE areas)

3. Results

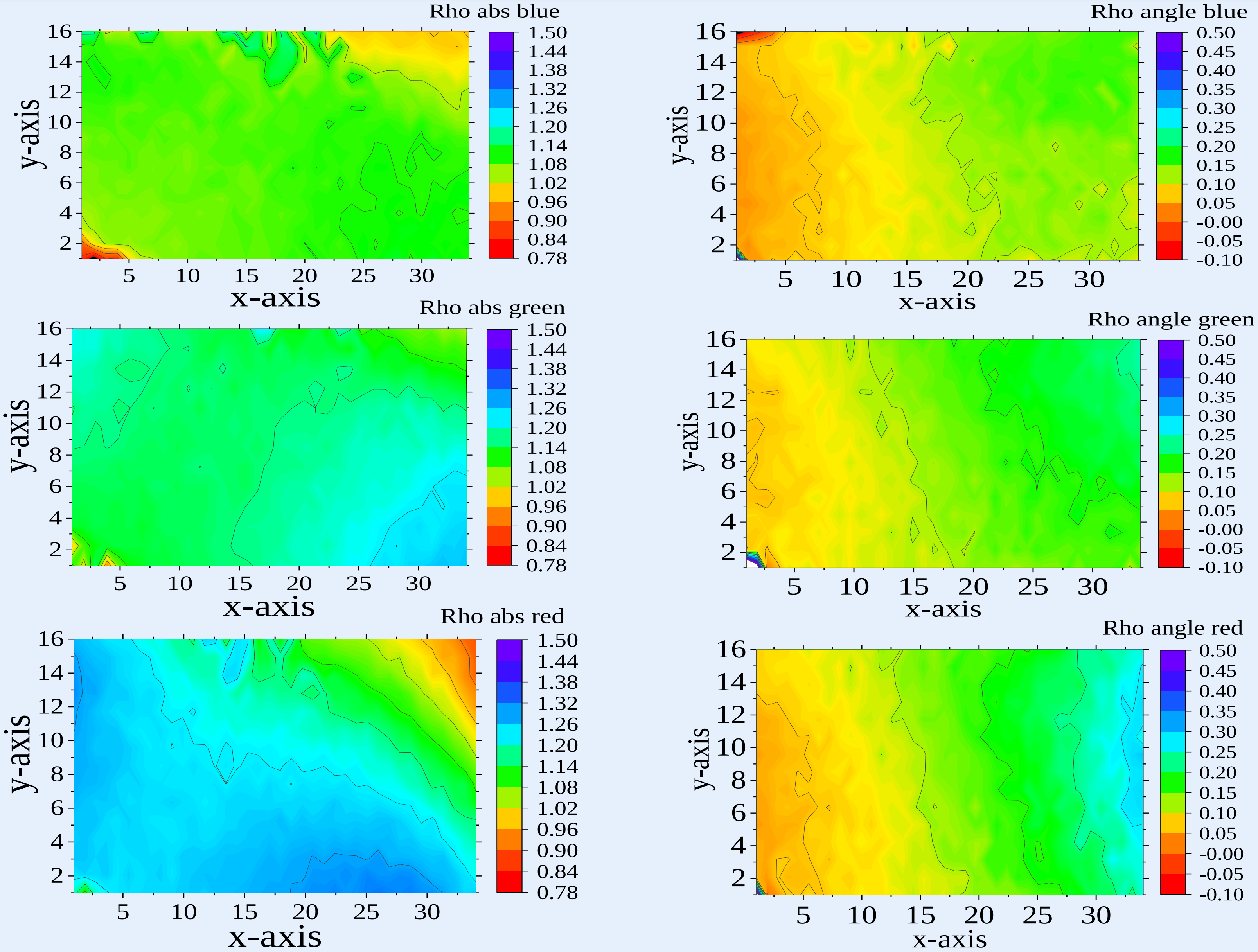


Fig. 11: **Left column:** real $\varrho_{monitor}$, **Right column:** phase shift correction in red.

3. Results

The conventional Wollam M2000 ellipsometer and our non-collimated ellipsometer after correction and is within 1 nm, which is a good agreement.

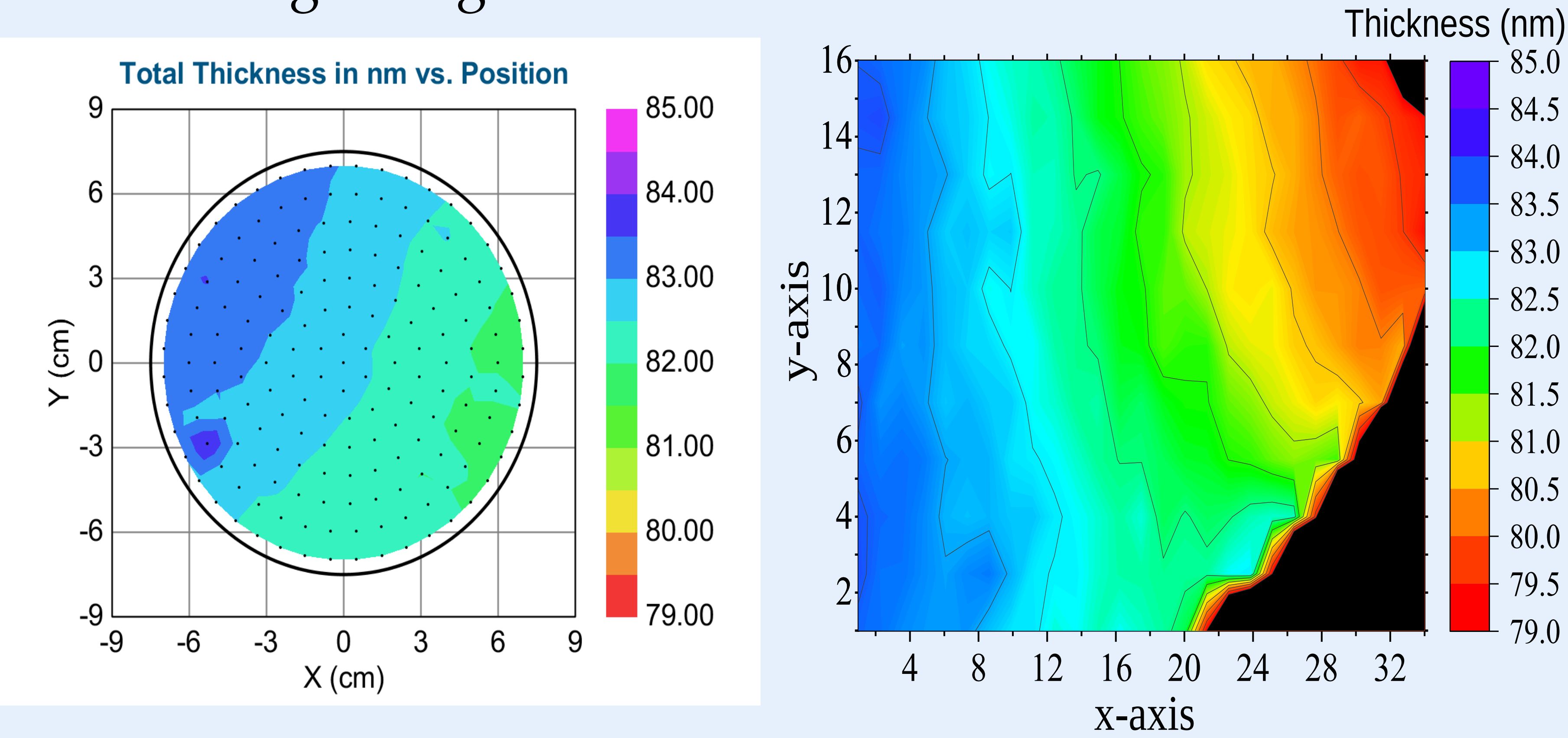


Fig. 12: **Left:** 80nm SiO_2 map thickness from Wollam M2000

Right: non-collimated, calibrated mapping tool

4. Conclusion

Advantages

- The new prototype is fast imaging and made up of cheap parts
- Ellipsometric data of large areas can be collected around 10 times faster compared to the “traditional” scanning methods.
- Wide mapping area, up to 150cm is possible .
- No moving parts.

Limitations

- Only three wide wavelength bands (RGB) are in action ,which narrows the range of the light band source.
- ‘0.1 degree’ angle uncertainty from the digital angle gauge used in rotation angle of the LCD, which affects incident polarization state of the light.

Semester Activities, Conferences

- The 9th **International Conference on Spectroscopic Ellipsometry** (ICSE) held in Beijing, China from May 22-28th, 2022. Online Presentation.
- “Carla Camp Graz- the **Photonics Career** Hub” (Photonics Austria), from 21-23 September 2022, held in the university of Graz, Austria**.**
- Symposium on Materials Science held on October 5-7, 2022
- “**XXXVII Kando Conference** 2022”, Óbuda University, which was held from 3-4 November 2022
- **SPIE Photonics West**, held 28 January – 2 February 2023 in San Francisco, California, United States, ***published the paper***;
- 12th Workshop on Spectroscopic Ellipsometry (WSE), September 19-21, 2023 in Prague, in the Czech Republic.
- Budapest School on Modern X-ray Science 2023 (October 3-6, 2023)
- **26th Spring Wind Conference**, held in Miskolc, Hungary, from 5-7 May 2023.
- XL. Kando Conference. **KSC2024, November 7-8, 2024.**

❑ Participated in many online Seminars (Eg. Advanced Photonics Webinar: on Vectorial Metrics in Optics”, on 14th Dec 2022, Surface Science Discussions 2024 – Programme, January 9-10, 2024, and many others)

Semester Activities, Publications

Publications

- Multi-color ellipsometric mapping tool from cheap parts
https://doi.org/10.1117/12.2649926

- Multi-color ellipsometric mapping tool from cheap parts
ISBN: 9789634493204
https://m2.mtmt.hu/api/publication/33751620

- Optical Calibration of a Multi-Color Ellipsometric Mapping Tool Fabricated Using Cheap Parts.
Photonics 2024, 11(11), 1036
https://doi.org/10.3390/photonics11111036

köszönöm szépen !