BIPM Capacity Building & Knowledge Transfer Programme

2023 BIPM - TÜBİTAK UME Project Placement

REPORT

Project Name	Measurement capabilities of the Agilent Cary 7000 universal measurement spectrophotometer (UMS) along with temperature probe.
Description	The Agilent Cary 7000 is universal measurement spectrophotometer (UMA) which can satisfy all solid sampling needs. It can collect hundreds of UV-Vis-NIR spectra overnight or characterize optical components and thin films in minutes to hours rather than hours to days. The Cary 7000 UMS is a turn-key solution for research, development, thin films/coatings, solar and glass. This instrument has multiangle specular transmittance capabilities which allow to design experiments never before possible. It can also be used along with temperature control probe. The many measurement possibilities and the precision of this spectrophotometer mean that its operation is not easy. This is a relatively new measuring equipment which is available to very few research centers dealing with the measurement of transmitted light. Central Office of Measures just like Tubitak dispose such an equipment. The opportunity to train and work on the Cary 7000 spectrophotometer in Tubitak is feasible for me to get results and to collaborate with other professionals in the industry. I am convinced that by participating in the internship I will be able to broaden my horizons and gain valuable experience that will be useful in my current and future professional work
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Date	04.09.2023 – 29.09.2023 r.

Motivation & Introduction

The Agilent Cary 7000 is universal measurement spectrophotometer (UMA) which can satisfy all solid sampling needs. It can collect hundreds of UV-Vis-NIR spectra overnight or characterize optical components and thin films in minutes to hours rather than hours to days. This instrument has multiangle specular transmittance capabilities which allow to design experiments never before possible. It can also be used along with temperature control probe.

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Research

A spectrophotometer measures either the amount of light absorbed or reflected from a sample object. Spectrophotometry is the quantity based study of electromagnetic spectra.

The Agilent Cary 7000 is universal measurement spectrophotometer which can satisfy all solid sampling needs. The Cary Universal Measurement Accessory (UMA) provides the ability to automatically measure absolute specular reflectance, transmission and scattering at a wide range of angles and different polarizations, unattended. This accessory is unique to the materials market providing solutions to research and QA/QC in the areas of thin films and coatings, optics, glass and solar.

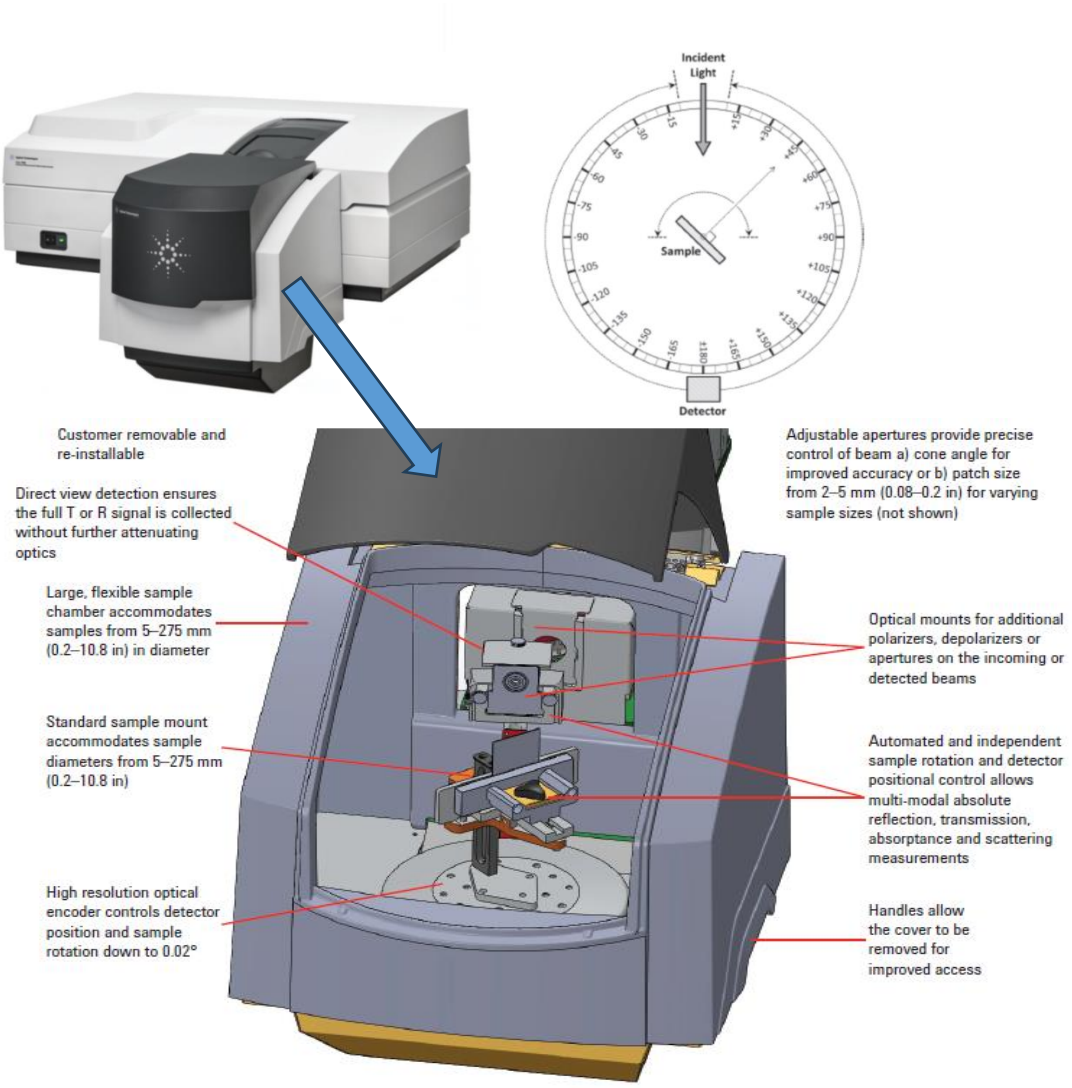


Figure 1. Scheme of The Agilent Cary 7000

The UMA defines two separate angular co-ordinates to describe the position of the sample and detector with respect to the incident light beam. The angle of incidence, or sample angle, is defined as the angle formed between the normal to the surface of the sample and the incident beam when the sample is mounted in the sample holder. The sample can be driven fully through 360° however the range of sample angles provided by the UMA is typically from -90° <= Sample Angle <= +90°. The angular resolution for setting the sample angle is 0.02°. Figure 1 shows both the sample and detector angular coordinates. The detector angle is defined as the angle subtended at the center of the sample chamber by the incident beam and a line to the radial position of the detector. The detector angular range is from 10 – 180° on either side of the incident beam (similarly defined as ±angles). The resolution for setting the detector angle is also 0.02°.

The many measurement possibilities and the precision of this spectrophotometer mean that its operation is not easy. This is a relatively new measuring equipment which is available to very few research center dealing with the measurement of transmitted light. Central Office of Measures just like Tubitak UME dispose such an equipment.

During my internship we have prepared instruction on how to use spectrophotometer with UMA and temperature probe. We have described all steps of preparation to measurement and measurement itself in the instruction. During 2023 BIPM - TÜBİTAK UME Project Placement I have done a lot's of different measurements. I've done measurements as Collect Sequence and Single Angle mode both transmittance and reflectance. I've performed measurements as Scan, where wavelength range can be chosen, and as Read where we can do measurement only in one wavelength.

I've measured samples of different transmittance value at different angles, wavelengths in different polarization.

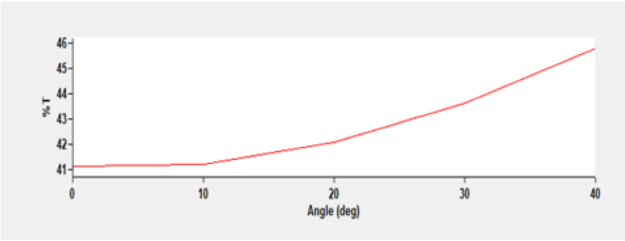


Fig.2. Sample T ≈ 40 %, λ = 600 nm, Angles: sample (0 - 40); detector: 180.

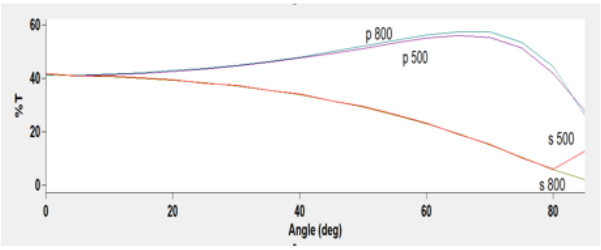


Fig.4. Sample T ≈ 40 %, λ = (500, 800) nm, Angles: sample (0 - 85); detector: 180 with p and s polarizer

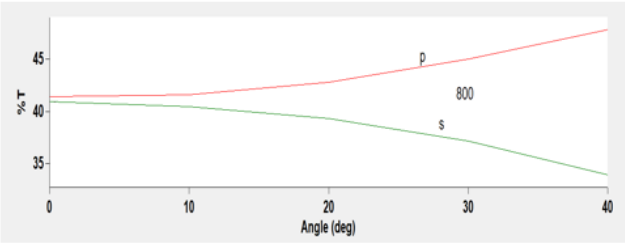


Fig.3. Sample T ≈ 40 %, λ = 800 nm, Angles: sample (0 - 40); detector: 180 with p and s polarizer

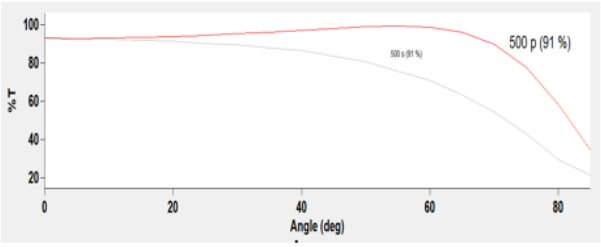


Fig.5. Sample T ≈ 91 %, λ = 500 nm, Angles: sample (0 - 85); detector: 180 with p and s polarizer

I've compered different measurement methods: Scan and Read.

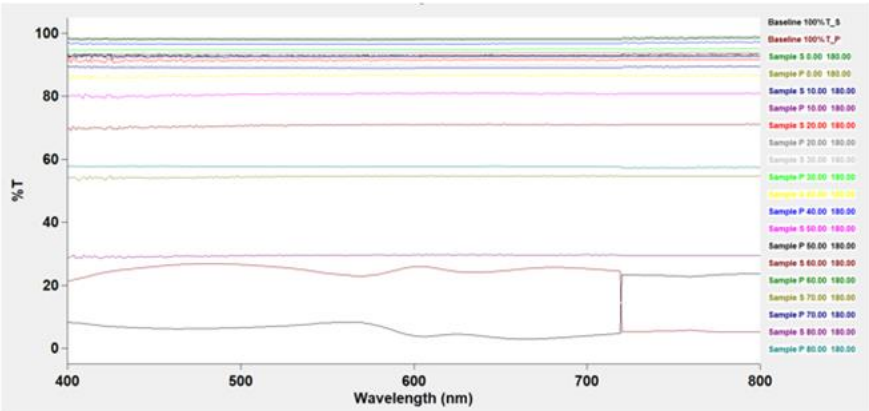


Fig.6. Sample T ≈ 90 %, λ = (400 – 800) nm, Angles: sample (0 - 80); detector: 180 with p and s polarizer.

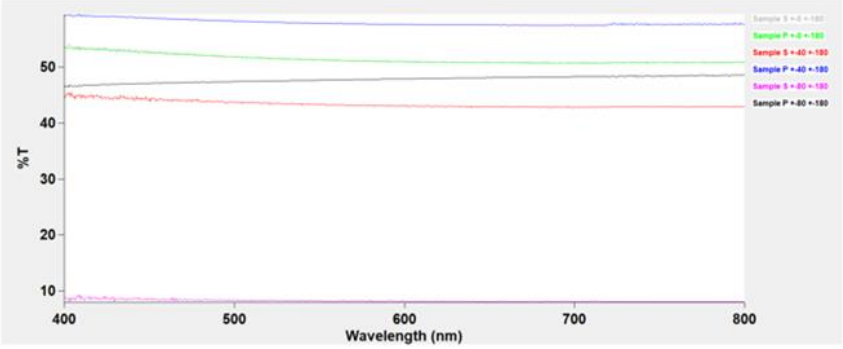


Fig.7. Sample T ≈ 50 %, λ = (400 – 800) nm, Angles: sample average from positive and negative (0 - 80); detector: 180 with p and s polarizer.

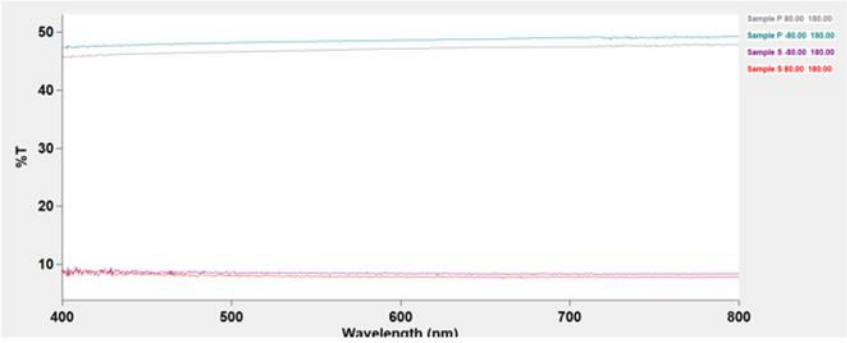


Fig.8. Sample T ≈ 90 %, λ = (400 – 800) nm, Angles: sample positive and negative 80, detector: 180 with p and s polarizer.

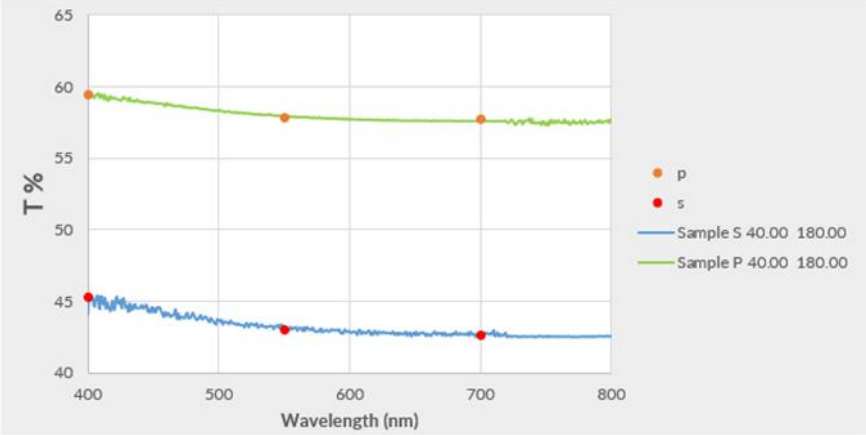


Fig.9. Comparison between measurement metods scan and read. Sample T ≈ 50 %, λ = (400 – 800) nm, Angles: sample 40, detector: 180 with p and s polarizer.

I've been learned how to do reflectance measurement and then calculate specular gloss of primary standard according to the formula

The specular gloss of the primary standard $G_s(\theta_0)$ is given by

$$G_s(\theta_0) = G_0(\theta_0) \times \frac{\rho_s}{\rho_0(\theta_0, \lambda_D)}$$

where:
$G_0(\theta_0)$ is the specular gloss of the theoretical standard = 100 for each angle of illumination,
$\rho_0(\theta_0, \lambda_D)$ is the specular reflectance of the theoretical standard at a wavelength
λ_D = 589.3 nm,
ρ_s is the specular reflectance of the primary standard.

Tab. 1. Specular reflectance $\rho_0(\theta_0, \lambda_D)$ of the theoretical gloss standard for each standard illumination angle at wavelength λ_D = 589.3 nm

Illumination angle	$\rho_0(\theta, \lambda_D)$
20°	0.049078
60°	0.100056
85°	0.619148

$G_s(\theta_0) = 90{,}7$

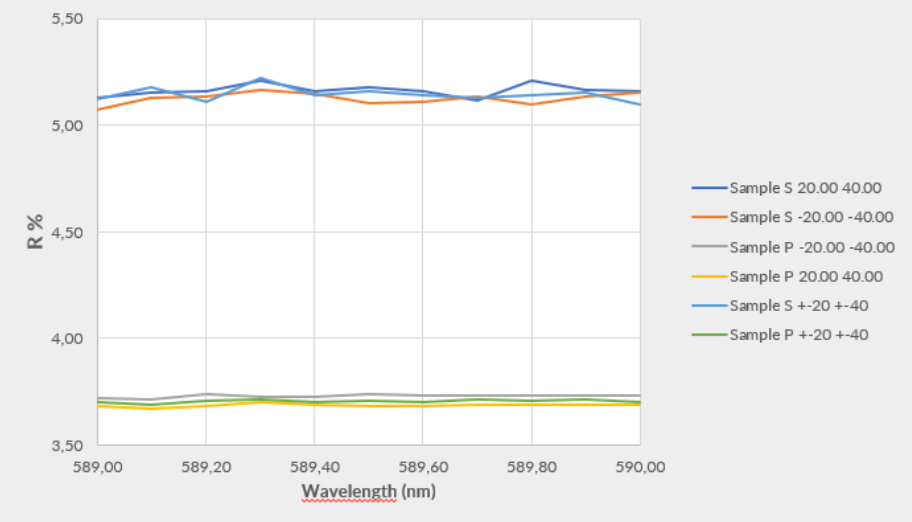
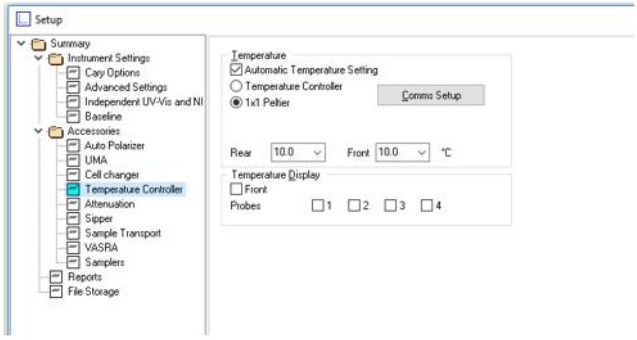


Fig.10. Reflectance, λ = (589 – 590) nm, Angles positive and negative: sample 20, detector: 40 with p and s polarizer.

During the internship I was thaught how to use dual cell peltier accessory which allowes to set and control temperature of the sample.



Conclusions and Future Work

I appreciate the opportunity to undergo training during the internship, and I'm grateful for the chance to enhance my skills and knowledge. The opportunity to train and work on the Cary 7000 spectrophotometer in Tubitak UME was a fantastic, valuable experience. I've learned a lot about how to work with The Cary Universal Measurement Accessory (UMA). The opportunity of participating in the internship, to train and work on the multiangle spectrophotometer will highly increase my knowledge and skills in the field of spectrophotometry in light transmittance and reflected. In the future, the result of my internship may be the construction of a new measuring stand and the launch of a new service in GUM.

Acknowledgements

I am very grateful to BIPM and TÜBİTAK UME for the opportunity to participate in this project. It was a pleasure to work in UME! Particularly, I would like to thank my supervisor Assoc. Prof. Dr. Özcan BAZKIR (Head of Optics Laboratory) and Dr. Seval MERİÇ (Deputy Head of TÜBİTAK UME Optics Laboratory), for their kindness and unselfish share of knowledge and experience with me. Also, I would like to thank with all my heart to whole Optic Group for fantastic atmosphere during the internship.