

BIPM Capacity Building & Knowledge Transfer Programme

2020 BIPM - TÜBİTAK UME Project Placement

REPORT

Project Name	Realization and maintenance of national measurement standard for optical radiation
Description	The project provided training to the candidate in the field of Photometry and Spectrophotometry. The training will improve the candidate's theoretical knowledge and technical skills in the calibration of spectral properties of solid materials, calibration of illuminance and luminance meters, luminous intensity and flux measurements, and color temperature measurements of a source.
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Motivation & Introduction

The project at the BIPM-TUBITAK UME project placement 2020 involves the review of measurement capabilities and maintenance of the luminance and illuminance responsivity, realization of the candela, and the spectral properties of solid materials (transmittance, absorption, and reflectance). The National Metrology Institute of South Africa (NMISA) maintains the traceability route to industry for units relating to optical radiation. This project will provide training on the calibration of parameters relating to photometry and spectrophotometry, to enhance candidate's knowledge and technical skills in this subject. This will ensure continuous support to the local and regional industries that rely on accurate and traceable measurements for photometric and spectrophotometric applications.

The main objectives of this project are to

- Improve the Photometry and Spectrophotometry calibrations and measurement capabilities.
- Investigate and reduce measurement uncertainties.
- Provide support and traceability to the local and regional industries regarding parameters in Photometry and Spectrophotometry.

Research

In the project, measurements were performed with the mentors and observations when mentors were performing calibrations. The candidate was supplied with notes which provided an inside detail in the subject studied. The project plan was to perform illuminance and luminance responsivity, lamp color temperature, luminous intensity, and luminous flux measurements. Due to COVID-19 interruptions, we only performed spectral transmittance measurements of neutral density (ND) filters, illuminance meter calibration, and lamp color temperature calibration.

The measurements of spectral transmittance of ND filters were performed on a compact double beam, double dispersion spectrophotometer. The spectrophotometer was stabilized for 60 minutes before measurements can commence. The wavelength interval was set from 780 nm to 380 nm with cycle count of 6, cycle time of zero and a data interval of 5 nm. The bandwidth was set to 3 nm, it was selected so that the light beam does not strike the edges of the sample compartment. Baseline correction was performed before measurements. The measurements were traceable to the national standard of spectral absorbance and are plotted in Figure 1.

Illuminance is the ratio of luminous flux to the unit surface area,

$$E_v = \frac{d\Phi_v}{dA}$$

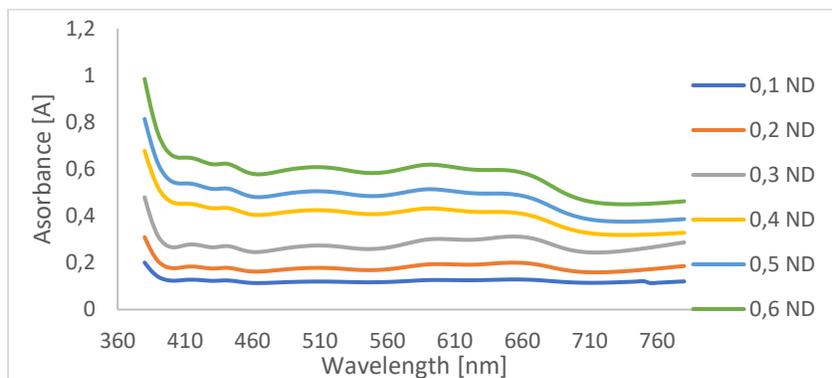


Figure 1: Spectral absorbance values of neutral density filters traceable to the national standard for absorbance measured at 5 nm interval for a set bandwidth of 3 nm.

E_v is illuminance measured in $\text{lm}\cdot\text{m}^{-2}$ or lux (lx)

$d\Phi_v$ unit of luminous flux in lumens (lm)

dA unit of surface area A measured in m^{-2}

Illuminance measurements are performed on a four-meter optical bench, with baffles between the light source and the meter. The light source is mounted and aligned inside a lamp housing cabinet. Illuminance meter calibration was performed using a substitution method where the meter being calibrated was compared to the transfer photometer heads with known luminous responsivity ($\text{nA}\cdot\text{lx}^{-1}$). The tungsten filament light sources operated at 2 856 K color temperature are used as reference light sources. The lamp voltage and current values are determined for 2 856 K color temperature after aging for 50 hours. A stable current source system is used to control the current applied to the light source. The current of the light source is calculated by reading the measured voltage signals from the digital voltmeter connected to the calibrated shunt resistance connected in series to the light source. This current control process was carried out with a computer software system.

The order of measurements were (i) measure the lamp light output with the transfer photometer head at different distances and calculate illuminance level using Equation

$$E_v = \frac{y}{s_v}$$

y is the photocurrent obtained from transfer photometer head [nA]

s_v luminous responsivity of the transfer photometer head [$\text{nA}\cdot\text{lx}^{-1}$]

(ii) Perform measurements with the meter being calibrated at the same distances as the transfer standard photometer. (iii) Measurements were performed again with the photometer head for verification. Measurements were corrected for background reflections by subtracting the dark readings to the light readings.

Luminous responsivity of the transfer photometer head is realized using the reference photometer head in the comparison method and calculated using Equation

$$S_v = S_{vref} \frac{y}{y_{ref}} \left(\frac{T}{T_{ref}} \right)^m$$

S_{vref} is the luminous responsivity of the reference photometer head

y_{ref} photocurrents obtained from the reference photometer head [nA]

T, T_{ref} color temperatures measured with the transfer and reference photometer head respectively

m is the mismatch index of the photometer head

The luminous responsivity of the transfer standard photometer head was calculated to be 1,535 nA.lx⁻¹. The results are summarized in Table 1.

Table 1: Measured illuminance values of the meter being calibrated along with the applicable correction factors.

Illuminance level	E_{ref}	E_{test}	Correction factors	Uncertainties
[lux]	[lux]	[lux]		[%]
50	52	47	1,106	0,8
500	524	473	1,108	0,8
800	826	747	1,106	0,8
2 000	2 074	1 875	1,106	0,8

We also calibrated a luminous intensity lamp for color temperature. The lamp was calibrated against a photometer calibrated for color temperature. The transfer photometer was mounted on one end of the optical bench with the lamp on the other side with baffles in-between. The transfer photometer measurements were verified with a spectroradiometer before and after measurements with the photometer. The spectroradiometer was mounted in a 0°/45° geometry setup. The spectroradiometer was mounted at 45° receiving geometry, with a calibrated diffuse reflectance tablet at 0° receiving geometry.

The color temperature of the lamp depends on a value of the lamp current, hence the lamp current was adjusted until the correct color temperature (2 856 K) of the lamp was found. The results are summarized in Table 2.

Table 2: Measured lamp voltage and current with a controlled current system run with a computer software.

Lamp voltage	Uncertainty	Lamp current	Uncertainty	Luminous intensity	Uncertainty	Correlated color temperature	Uncertainty
[V]	[μV/V]	[A]	[mA/A]	[cd]	[%]	[K]	[K]
67,552	37	7,275	0,12	710,66	0,40	2 856	14

Conclusions and Future Work

Due to the COVID-19 situation, not all planned measurements were performed. From the experience and knowledge gained, I will use it to improve current measurement capabilities and improve future measurement capabilities at my NMI. I will investigate and improve some of uncertainty contributions at my NMI to continue providing traceability to industry, health sector and research institutions.

Acknowledgements

I would like to express my sincere gratitude to the BIPM and TUBITAK UME for the opportunity to improve my knowledge and technical skills. I would also like to thank entire staff (Head of department Dr Özcan Bazkır, mentors; Dr Şenel Yaran, Dr Seval Meriç, Dr Zühal Alpaslan Kösemen, Dr Çağrı Kaan Akkan, Mr Gökhan Yakin) of the Optics laboratory for taking their time to share their knowledge.