Schweizerische Eidgenossenschaft
Confédération suisse
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Federal Institute of Metrology METAS

BxDiff – WP1

Advanced metrological issues related to BRDF

Objectives

The scientific objectives for WP1 are:

1. To address advanced metrological issues related to BRDF measurements in order to reduce by a factor 2 the measurement uncertainty, and reach an agreement of 0.1 % (k = 2) between NMIs, in favourable spectral and geometrical measurement configurations.

2. To establish a full metrological traceability of the BRDF from small objects (micrometre-scale) to regular objects (centimetre-scale)

Tasks

Task 1.1: Improvement of primary goniospectrophotometers

Task 1.2: Specific metrological issues related to speckle

Task 1.3: Comparison of measurement facilities at in and out-of-plane angles of BRDF measurements

Task 1.4: Specific metrological issues related to small size areas

Task 1.5: Multi-scale traceability

Task 1.1: Improvement of primary goniospectrophotometers

Activity number	Activity description	Partners (Lead in bold)
A1.1.1 05.2019 10.2019	**CSIC will describe and report the variables** (e.g. polarisation of light source, detector polarisation bias and polarisation biased optics) **that should be taken into account in the BRDF measurement in polarisation-sensitive instruments**. This will be used in A1.1.2.	**CSIC**
A1.1.2 05.2019 04.2020	Using input from A1.1.1, **CSIC, CNAM and CMI will modify their goniospectrophotometers** to enable **the control of polarisation and account for polarization-related effects**, therefore making it possible to improve the uncertainty on the measurement of BRDF. Samples from A5.2.3 will be used. These modified goniospectrophotometers will be used in A1.3.2, A1.5.1 and A1.5.3.	**CSIC**, CNAM, CMI
A1.1.3 05.2019 04.2020	**CI will upgrade their goniospectrophotometer to improve uncertainties related to sample position and alignment**, leading to reduced uncertainty in angle setting. The current angle uncertainty for θ_i is 0.05° at low incidence angles but grows to 0.2° at about 45°, and grows larger quickly at higher angles. The objective is to achieve angle uncertainty of 0.1° up to at least the incident angle of 60°.The upgraded goniospectrophotometer will be used in A1.3.2.	**CI**

Task 1.2: Specific metrological issues related to speckle

Activity number	Activity description	Partners (Lead in bold)
A1.2.1 05.2019 06.2020	**CNAM will modify its goniospectrophotometer to enable making speckle effects visible** using incoherent light as illumination source, by reducing the spectral bandwidth and enhancing the angular collimation. At least 2 samples from A5.2.2 will be used.	**CNAM**
A1.2.2 03.2020 08.2020	CNAM and UJM will carry out BRDF measurements on at least 2 samples from A5.2.2 and **provide different practical solutions to reduce the speckle pattern on BRDF measurements** by averaging the collected radiance over different points on the surface.	**CNAM**, UJM
A1.2.3 06.2020 12.2020	CNAM will perform measurements on at least 4 samples from in A5.2.2 with at least 4 levels of visibility of speckle, from invisible to fully visible. **CNAM will then compare the BRDF measurements based on coherent- and incoherent light sources**. The results from this activity will provide input to A1.2.5 and A1.3.2.	**CNAM**
A1.2.4 01.2021 04.2021	**CSIC** will perform spatial measurements on at least 4 samples from A5.2.2 with at least 4 levels of visibility of speckle, from invisible to fully visible. CSIC will use a matrix detector (CCD) to assess the speckle at the collection plane, and a camera to assess the speckle at the measurement area. **Measurements will be performed for monochromatic and broadband illumination and at least for 3 levels of illumination solid angles**.	**CSIC**
A1.2.5 05.2021 08.2021	UJM will describe theoretically the effect of speckle on BRDF measurements and will **simulate speckle patterns in BRDF configurations corresponding to the measurements** from A1.2.3 and using the topographical data from A5.3.2.	**UJM**
A1.2.6 09.2021 12.2021	With input from A1.2.1 to A1.2.5, CNAM, UJM and CSIC will write a paper on **recommendations for avoiding or accounting the impact of speckle on the BRDF measurement**. The paper will be submitted to a peer-reviewed journal as part of A6.1.3 and will be used in A5.4.1.	**CNAM**, UJM, CSIC

Task 1.3: Comparison of measurement facilities at in- and out-of-plane angles of BRDF measurements

Activity number	Activity description	Partners (Lead in bold)
A1.3.1 05.2019 10.2019	**METAS, PTB, CNAM, CI, CSIC and CMI will select at least 4 measurement geometries (in- and out-of-plane)** at which the comparison in A1.3.2.will be done. The choice of the geometries will take into account geometries used in previous comparisons, recommended in standards as ASTM E2539 and outputs of 16NRM08 BiRD	**METAS**, PTB, CNAM, CI, CSIC, CMI
A1.3.2 01.2020 06.2021	PTB, CNAM, CSIC, METAS, CI, and CMI will independently **measure, and compare** among them, **the BRDF of at least 2 samples** from A5.2.7 **at the geometries selected** in A1.3.1 at **550 nm**. CSIC, CNAM, CMI and CI will use the goniospectrophotometers improved in A1.1.2 and A1.1.3, and the outcomes from A1.2.3. The intercomparison has **a target uncertainty of 0.1 % (k=2) for in-plane angles and less than 4 % for out-of-plane angles** (in the visible wavelength range).	**PTB**, CNAM, CSIC, METAS, CI, CMI
A1.3.3 07.2021 12.2021	PTB in collaboration with CNAM, CSIC, METAS, CMI and CI will **write a paper on the intercomparison** carried out in A1.3.2 and send it to the coordinator. Once the paper has been agreed within the consortium, the coordinator on behalf of PTB, CNAM, METAS, CI, CSIC and CMI, will submit it to EURAMET as D1: 'Paper on the intercomparison of measurement facilities and BRDF measurements at in- and out-of-plane angles submitted to a peer-reviewed journal. The target uncertainty is 0.1 % for in-plane angles and less than 4 % for out-plane angles in the visible wavelength range'. The paper will be submitted to a peer-reviewed journal as part of A6.1.3 and will be used in A5.4.1.	**PTB**, CNAM, METAS, CI, CSIC, CMI

Task 1.3: Comparison of measurement facilities at in- and out-of-plane angles of BRDF measurements

samples: Spectralon (99%), Spectralon (50%), satin-white (g.u.=20)

wavelength: 550 nm

		targeted measurement uncertainty (k=2)
in-plane	45° : 0°	0.1%
	0° : 45°	
	45° : -60°	
out-of-plane	45° : 45°,90°	< 4%
	45° : 50.1°, 33.4°	

CSIC	01.2020 – 03.2020
CNAM	04.2020 – 06.2020
METAS	07.2020 – 09.2020
CMI	10.2020 – 12.2020
PTB	01.2021 – 03.2021
CI	04.2021 – 06.2021

Deliverable D1

Paper on the intercomparison of measurement facilities and BRDF measurements at in and out-of-plane angles submitted to a peer-reviewed journal. The target uncertainty is 0.1% for in-plane angles and less than 4% for out-of-plane angles in the visible wavelength range.

12.2021

Task 1.4: Specific metrological issues related to small size areas

Activity number	Activity description	Partners (Lead in bold)
A1.4.1 05.2019 10.2019	**METAS will carry out a bibliographic study on BRDF measurements of small size areas to identify known specific metrological issues.** This will be used for carrying out the measurements in A1.4.2	**METAS**
A1.4.2 09.2020 06.2021	**METAS, CSIC, and DFM will each carry out 45º:0º and 0º:45º BRDF measurements on at least 3 small size samples** (microscopic surfaces) from A5.2.1, using input from A1.4.1.	**METAS**, CSIC, DFM
A1.4.3 08.2021 10.2021	Using input from A1.4.2, METAS in collaboration with CSIC and DFM will write a paper on the topic of 'Recommendations for BRDF measurements of small size samples' The paper will be submitted to a peer-reviewed journal as part of A6.1.3	**METAS**, CSIC, DFM

Task 1.5: Multi-scale traceability

Activity number	Activity description	Partners (Lead in bold)
A1.5.1 09.2020 06.2021	**METAS, CSIC, and CNAM will carry out BRDF measurements on at least 3 samples** from A5.2.1 at **different area sizes, ranging from micrometre to millimetre scales** at **different bidirectional geometries.** The goniospectrophotometers improved in A1.1.2 will be used for the measurements. The results of this activity will be used in A4.2.2 and A4.2.3.	**METAS**, CSIC, CNAM
A1.5.2 08.2021 12.2021	**DFM,** with the support of METAS, CSIC, and CNAM, will use the measurements from A1.5.1 and modelling work from A4.2.1 to **establish a link between measurements of different samples at different experimental conditions.**	**DFM,** METAS, CSIC, CNAM
A1.5.3 04.2021 10.2021	**METAS, CSIC, CNAM, and DFM will carry out an intercomparison** of BRDF measurements on samples used in A1.5.1 using **camera-based and conventional measurements.** CSIC and CNAM will use the goniospectrophotometers from A1.1.2.	**METAS**, CSIC, CNAM, DFM
A1.5.4 12.2021 01.2022	Using input from A1.5.1 to A1.5.3, **METAS**, with support of CSIC, CNAM, and DFM will **write a report on the establishment of a full metrological traceability for BRDF measurements** from 100 micrometres to 2 centimetres size on flat and isotropic samples and send it to the coordinator. Once the report has been agreed within the consortium, the coordinator on behalf of METAS, CSIC, DFM and CNAM will submit the report to EURAMET as deliverable D2 ‘Report on the establishment of a full metrological traceability for BRDF measurements on flat and isotropic samples with sizes ranging from 100 micrometres to 2 centimetres‘.	**METAS,** CSIC, CNAM, DFM

Deliverable D2

Report on the establishment of a full metrological traceability for BRDF measurements on flat and isotropic samples with sizes ranging from 100 micrometers to 2 centimeters.

01.2022

Thank you for your attention