Multiscale and small size BRDF measurements at CSIC

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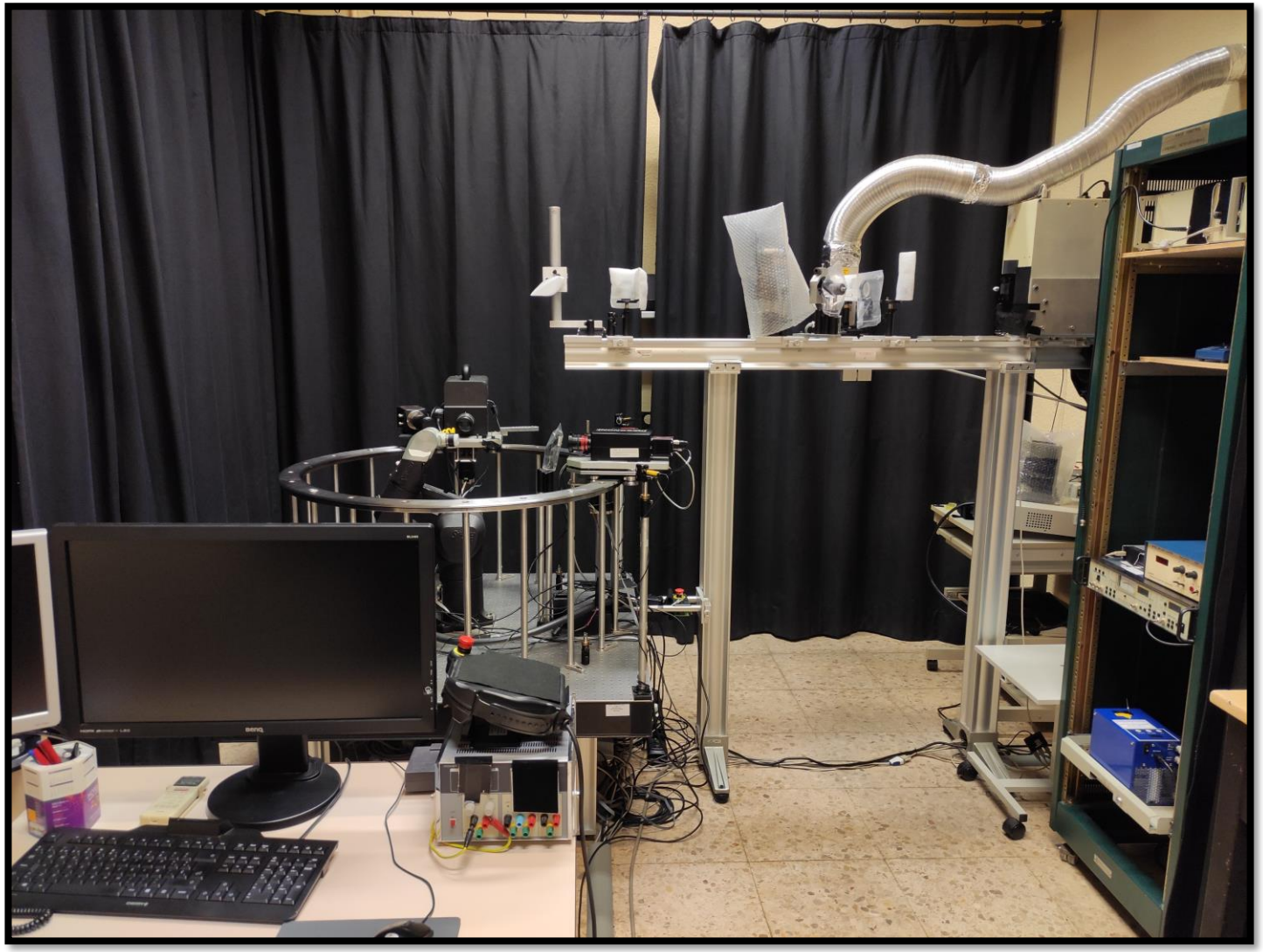
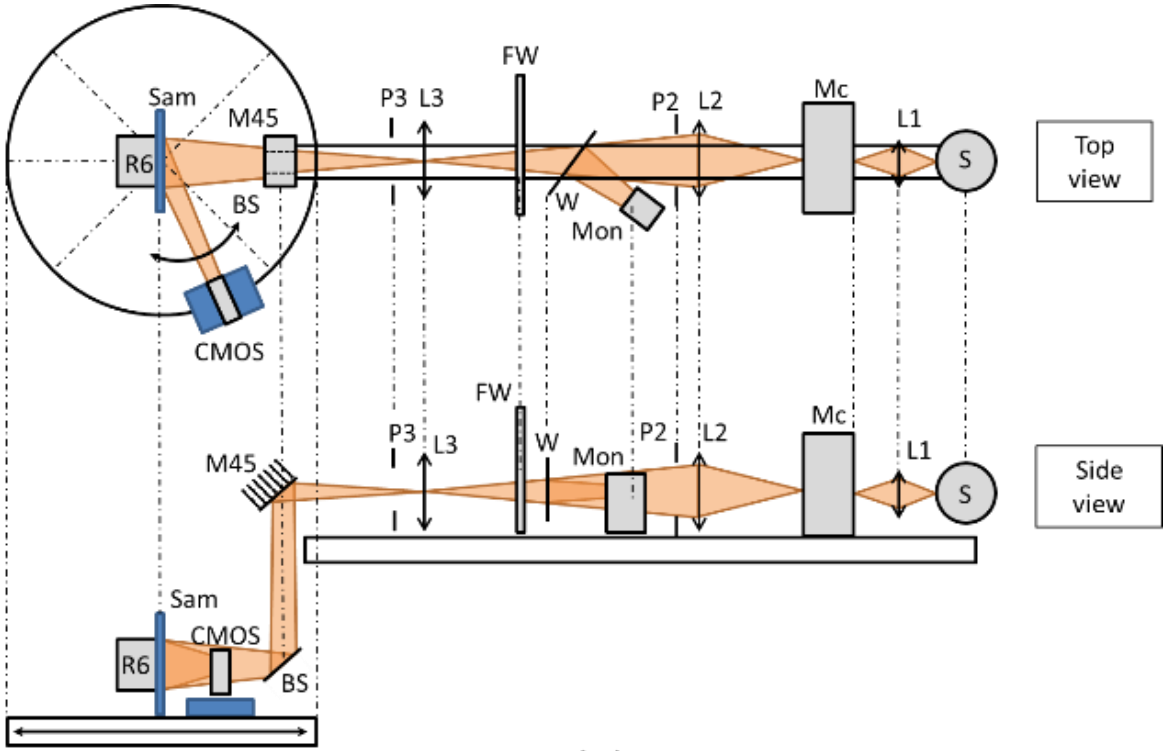
Protocol

Activity number	Activity description	Partner
A1.4.2 M27	METAS, CSIC, and DFM will each carry out 45°:0° and 0°:45° BRDF measurements on at least 3 small size samples (microscopic surfaces) from A5.2.1, using input from A1.4.1.	**METAS**, CSIC, DFM
A1.5.1 M27	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




Sam
M45
R6
BS
CMOS
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L1
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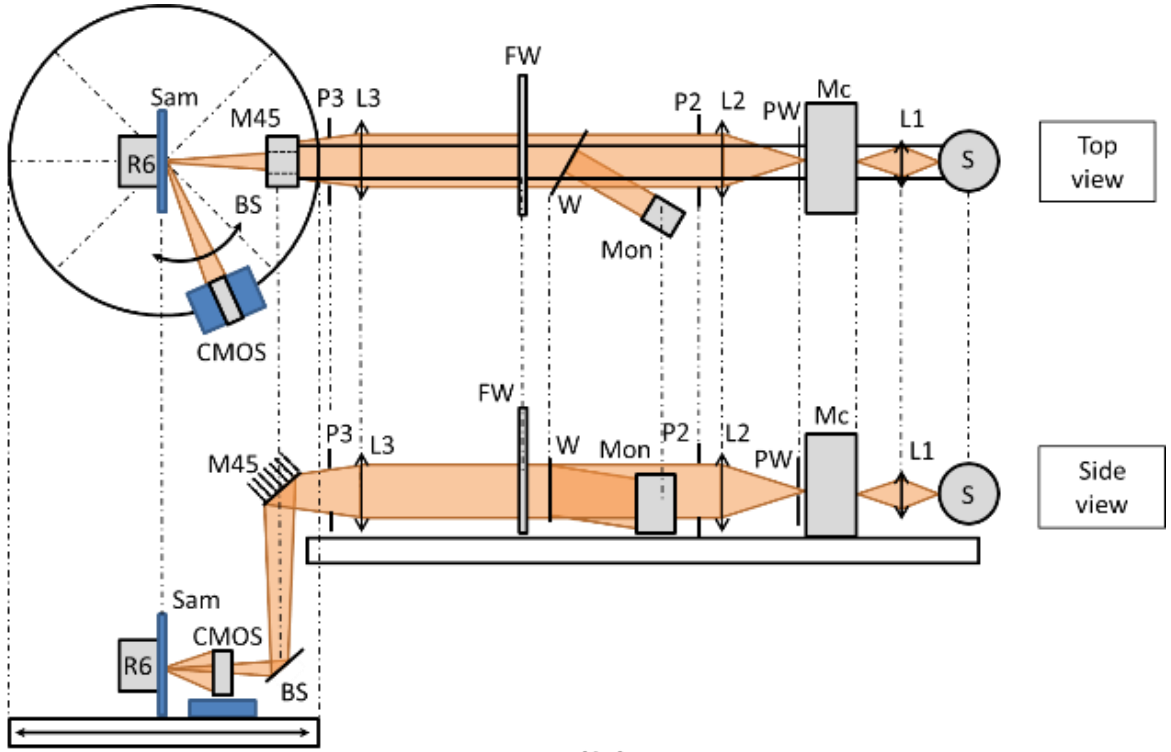
Top view
Side view

(a) A1.4.2


Sam
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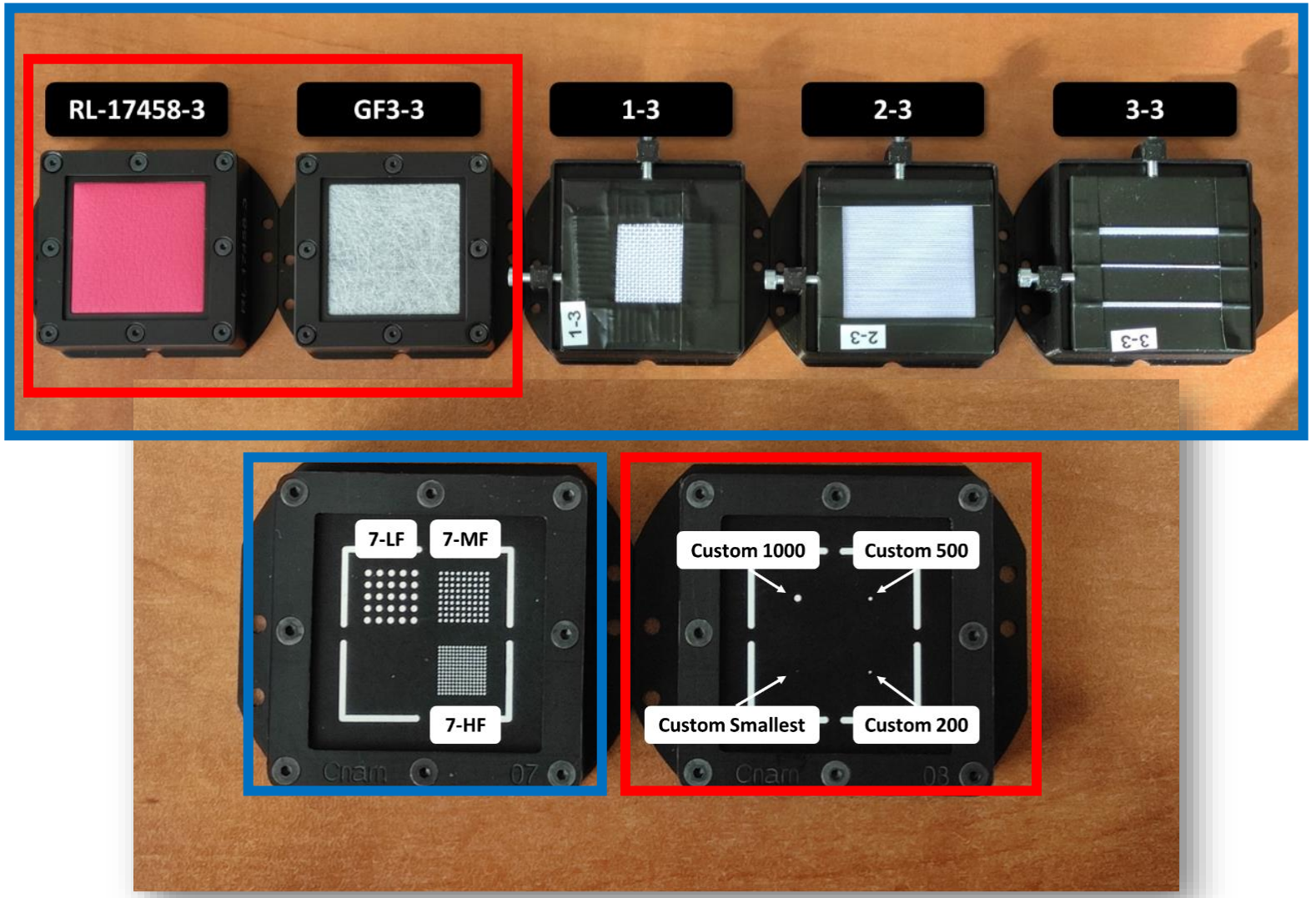
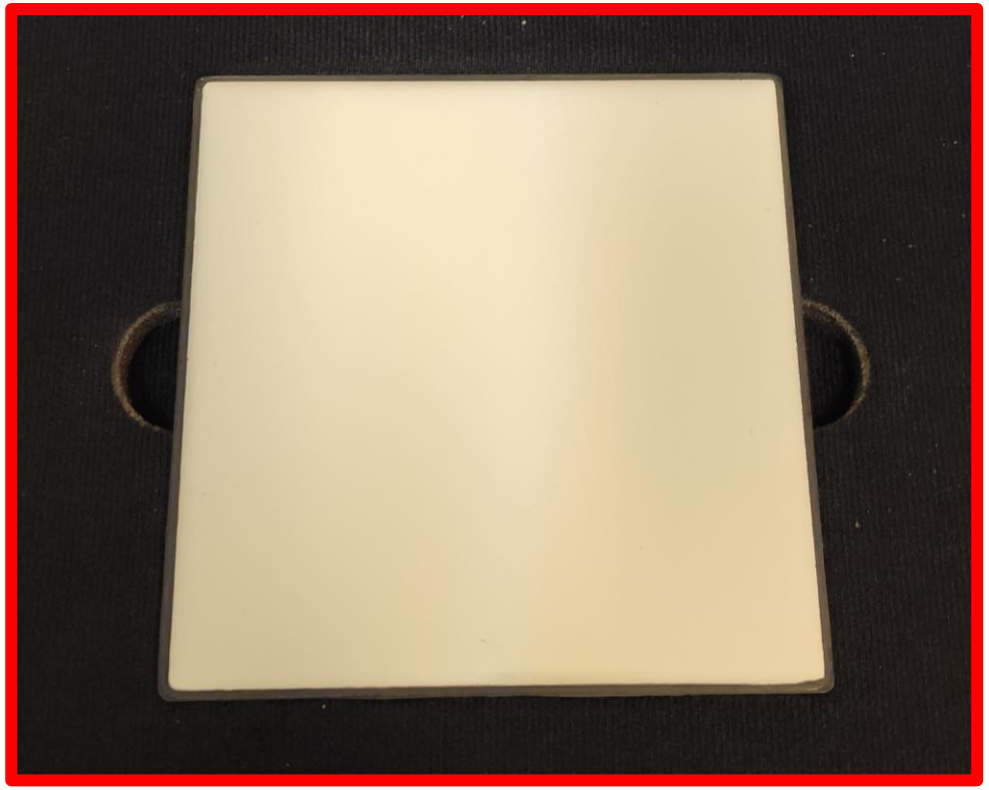
(b) A1.5.1

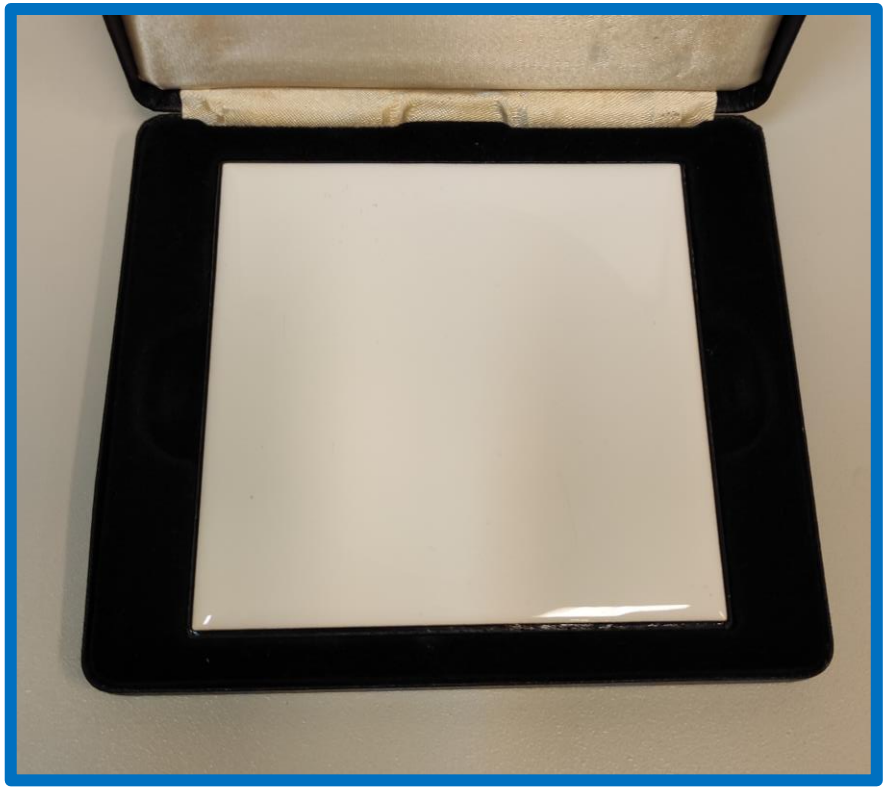

RL-17458-3
GF3-3
1-3
2-3
3-3
7-LF
7-MF
7-HF
Custom 1000
Custom 500
Custom Smallest
Custom 200

A1.4.2

A1.5.1

0°:45° Bidirectional Reflectance Standards



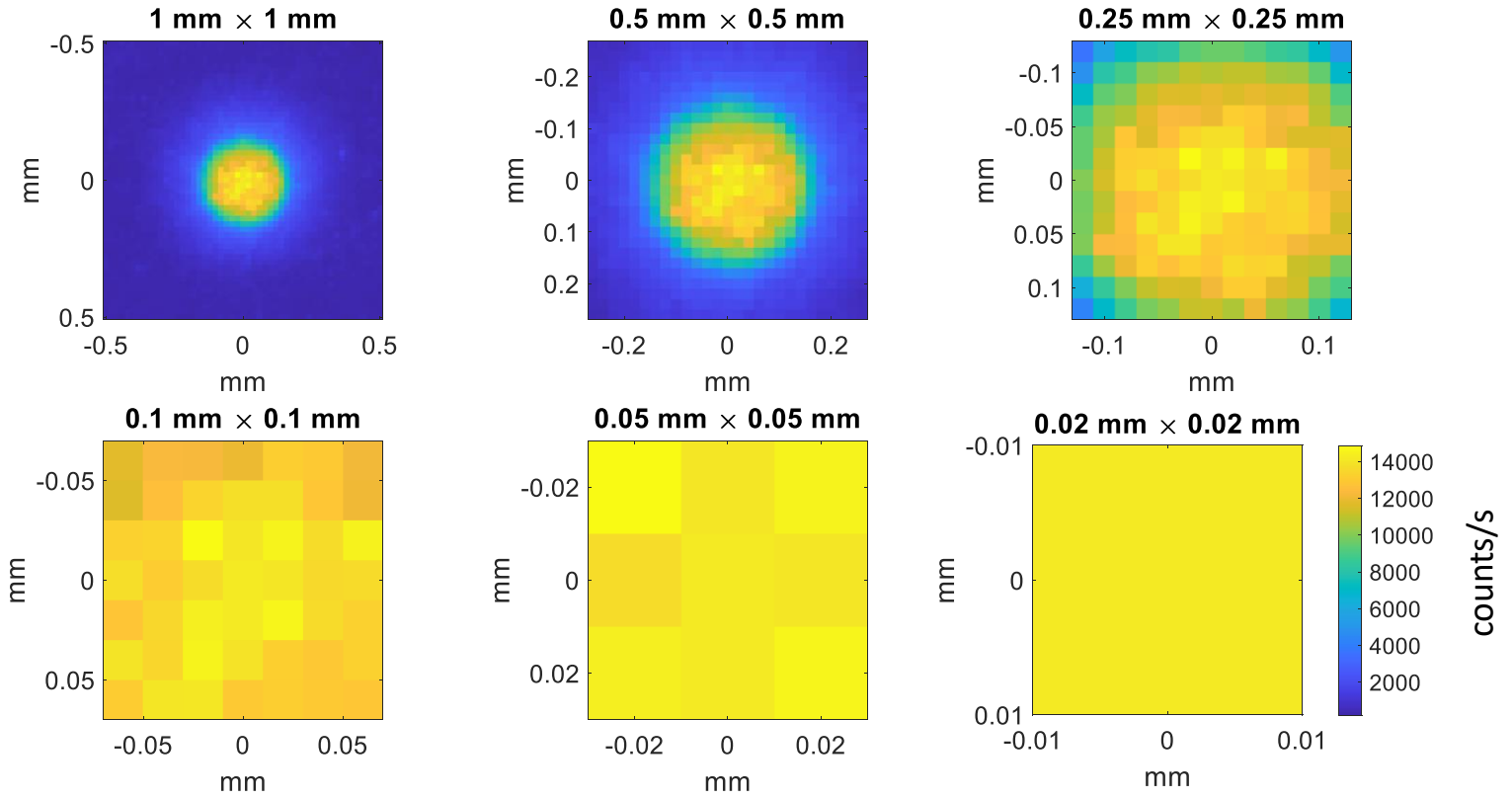


Activity 1.4.2.

Measurement conditions	
Measurement geometries	• 45°:0° • 0°:45°
Measurement areas	• 1 mm × 1 mm • 0.5 mm × 0.5 mm • 0.25 mm × 0.25 mm • 0.1 mm × 0.1 mm • 50 µm × 50 µm • 20 µm × 20 µm
Irradiation area	1 mm of beam diameter
Irradiation wavelength	660 nm
Room temperature	23 °C ± 1 °C
Collection solid angle	$(5.048 \pm 0.012) \times 10^{-3}$ sr*

*different from the one presented in the report

Activity 1.4.2.



HDR image

Representation of an example of the 6 measurement areas that we have evaluated for calculate the BRDF in Activity 1.4.2. This example corresponds to “Custom 200” sample at the measurement geometry 45°:0°.

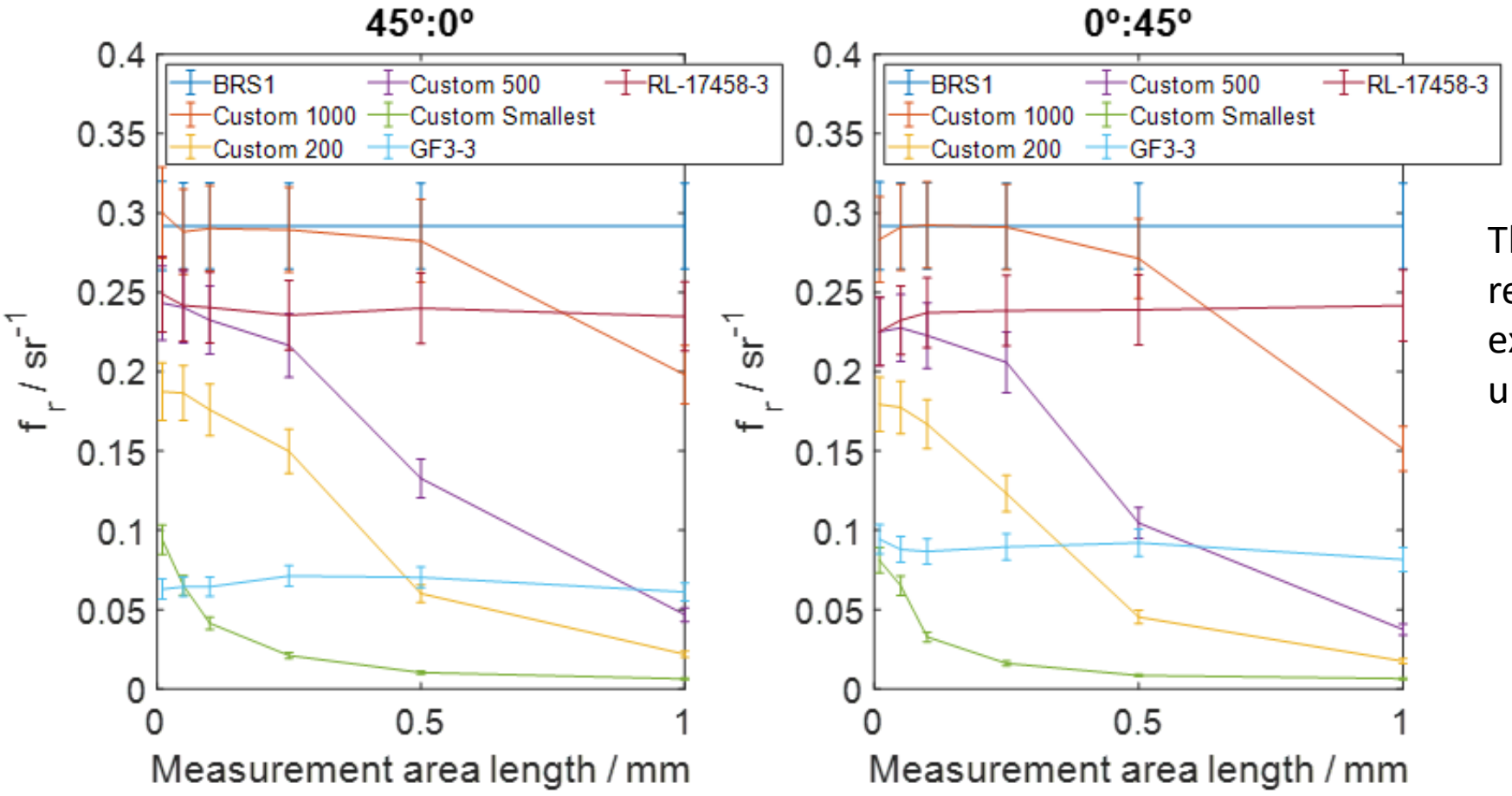
Activity 1.4.2.

BRDF measurement equation:

$$f_{\mathrm{r}} = f_{\mathrm{r,BRS1}}(0°{:}\,45°)\,\frac{\sum_{j\in A_{\mathrm{r}}} N_j}{\sum_{j\in A_{\mathrm{r}}} N_{j,\mathrm{BRS1}}}$$

- $f_{\mathrm{r,BRS1}}(0°{:}\,45°) \equiv$ BRDF value of the 0º:45º bidirectional reflectance standard BRS1 (0.292 sr^{-1}).
- $\sum_{j\in A_{\mathrm{r}}} N_j \equiv$ summation of the response of the pixels in the sample image inside the measurement area, A_{r}.
- $\sum_{j\in A_{\mathrm{r}}} N_{j,\mathrm{BRS1}} \equiv$ summation of the response of the pixels in the BRS1 image inside the measurement area, A_{r}.

Activity 1.4.2.



The errorbars represent the expanded uncertainty (k=2)

Activity 1.4.2.

BRDF values and expanded uncertainties at each measurement geometry and compatibility index of each sample with the biggest measurement area lower than the sample size.

Sample	$f_r(0°:45°) \pm U(k=2)$ / sr^{-1}	$f_r(45°:0°) \pm U(k=2)$ / sr^{-1}	Compatibility index, C
Custom 1000	0.291 ± 0.002	0.289 ± 0.002	0.28
Custom 500	0.2227 ± 0.0016	0.2325 ± 0.0017	-2.1
Custom 200	0.1774 ± 0.0013	0.1865 ± 0.0014	-2.4
Custom Smallest	0.0810 ± 0.0008	0.0940 ± 0.0010	-4.8
GF3-3	0.0816 ± 0.0006	0.0611 ± 0.0004	14
RL-17458-3	0.2416 ± 0.0017	0.2347 ± 0.0017	1.4

Activity 1.4.2.

Relative uncertainties (k=1) of each parameter for measures with the biggest measurement area lower than the sample size.

Sample	$u_r\left(\sum_{j \in A_r \text{ smallest}} N_j\right)$		$u_r\left(f_{r,BRS1}(0°:45°)\right)$	$u_r(\text{non} - \text{linearity})$
	$0°:45°$	$45°:0°$		
Custom 1000	0.03%	0.03%	0.38%	0.60%
Custom 500	0.06%	0.07%		
Custom 200	0.15%	0.17%		
Custom Smallest	0.67%	0.74%		
GF3-3	0.014%	0.019%		
RL-17458-3	0.008%	0.009%		

Activity 1.5.1.

Measurement conditions	
Measurement geometries	• 15°:0° • 30°:0° • 45°:0° • 60°:0°
Targeted irradiation beam diameters	• 20 mm • 10 mm • 1 mm • 0.5 mm • <0.5 mm
Irradiation wavelength	660 nm
Room temperature	23 °C ± 1 °C
Collection solid angle	$(5.048 \pm 0.012) \times 10^{-3}$ sr*

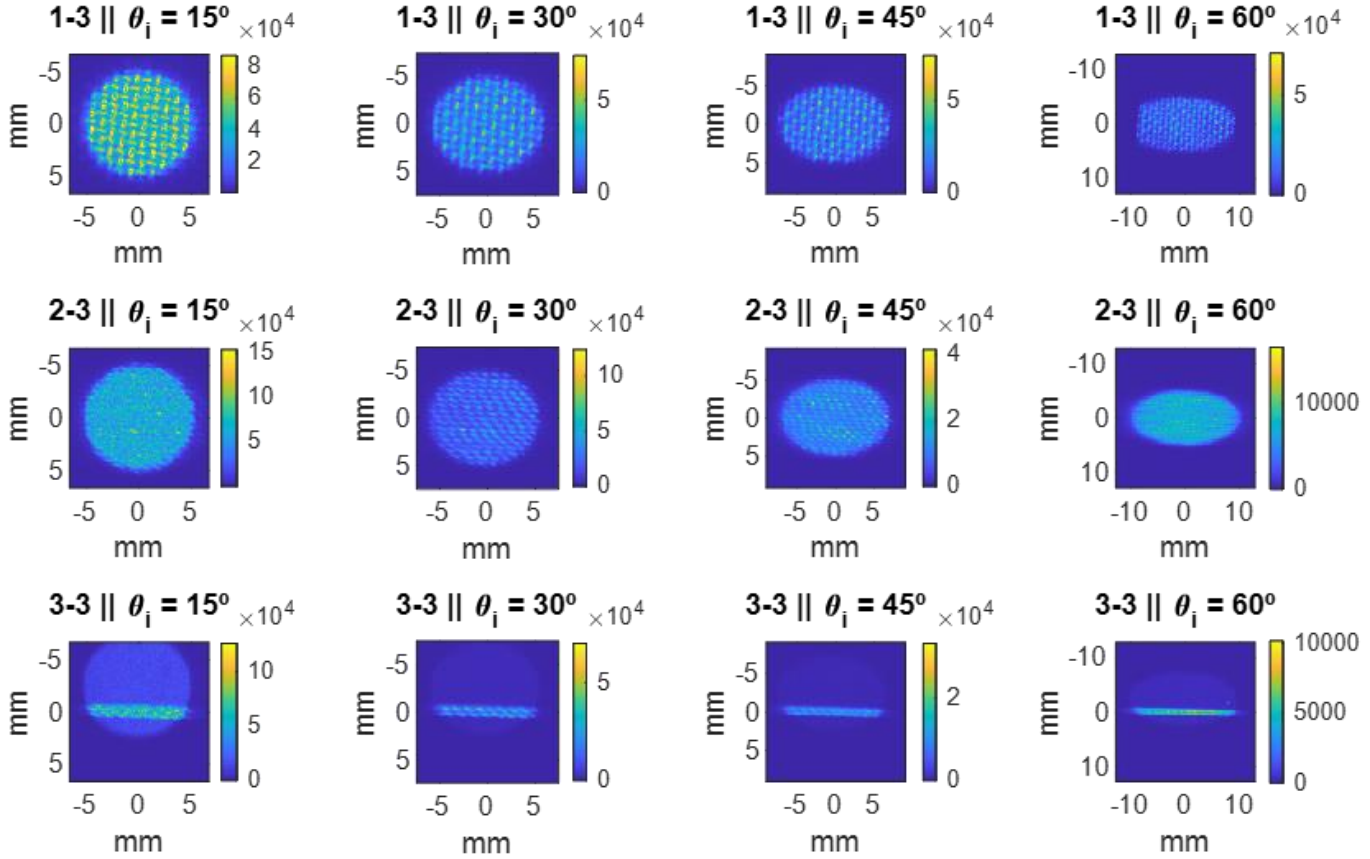
*different from the one presented in the report

Activity 1.5.1.

Specific irradiation beam diameters used for irradiate each group of samples.

Targeted irradiation beam diameter	Actual irradiation beam diameter for samples of first package	Actual irradiation beam diameter for samples of second package
<0.5 mm	0.330 mm	0.195 mm
0.5 mm	0.470 mm	0.285 mm
1 mm	0.550 mm	0.745 mm
10 mm	9.780 mm	7.780 mm
20 mm	20.0 mm	---

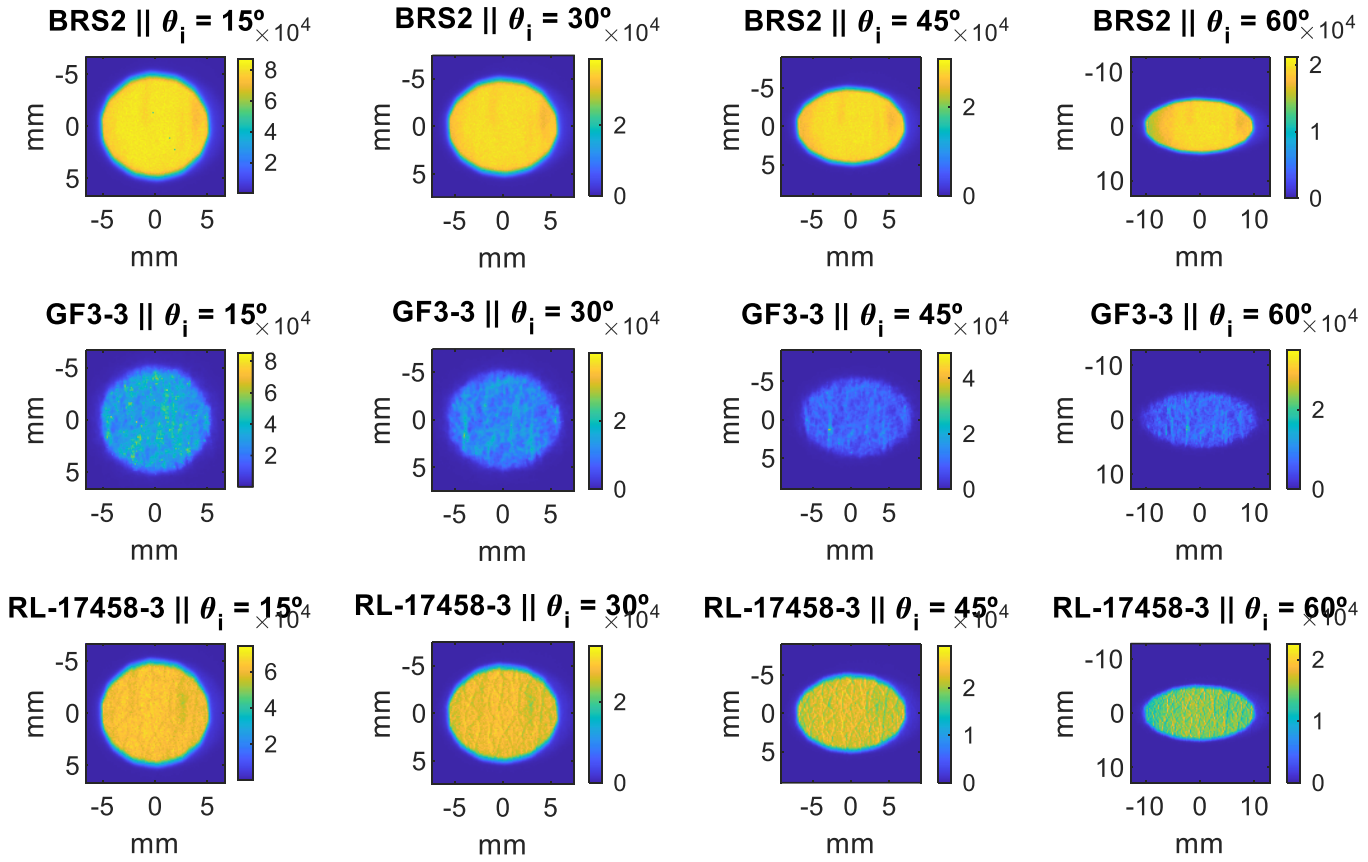
Activity 1.5.1.



*The colormap of the images represents the dark-subtracted response of the pixels in units of counts/s.

HDR images of the first package samples with the 10 mm targeted beam diameter.

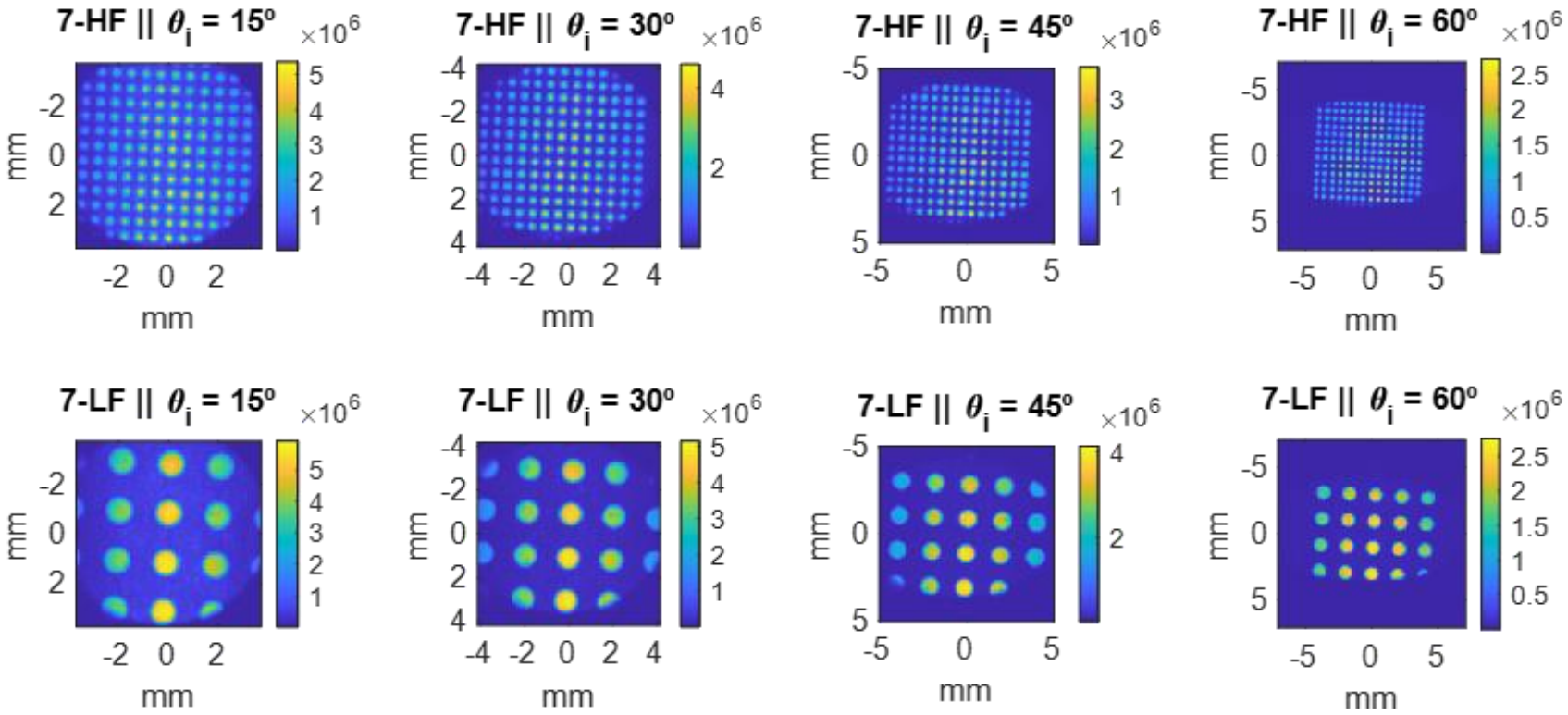
Activity 1.5.1.



*The colormap of the images represents the dark-subtracted response of the pixels in units of counts/s.

HDR images of the first package samples with the 10 mm targeted beam diameter.

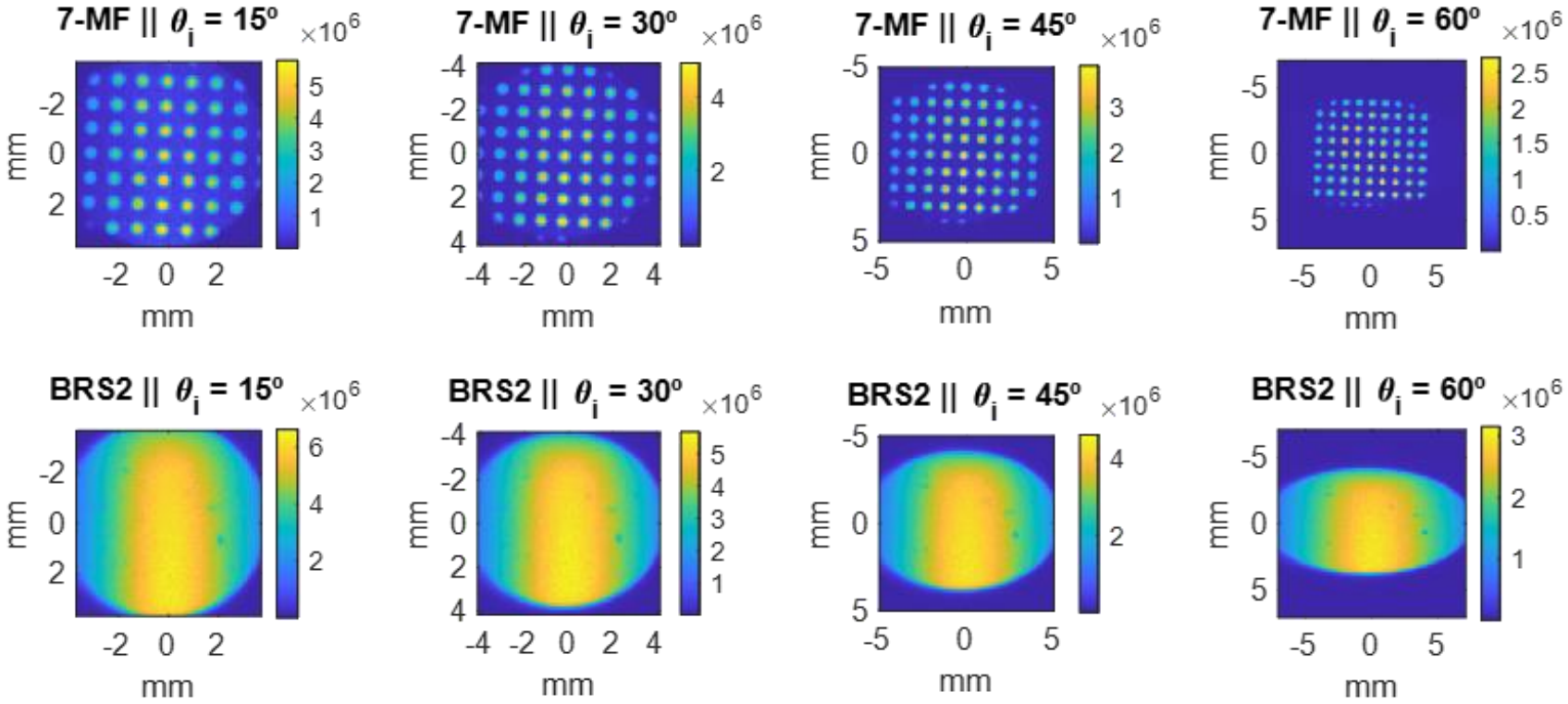
Activity 1.5.1.



*The colormap of the images represents the dark-subtracted response of the pixels in units of counts/s.

HDR images of the second package samples with the 10 mm targeted beam diameter.

Activity 1.5.1.



*The colormap of the images represents the dark-subtracted response of the pixels in units of counts/s.

HDR images of the second package samples with the 10 mm targeted beam diameter.

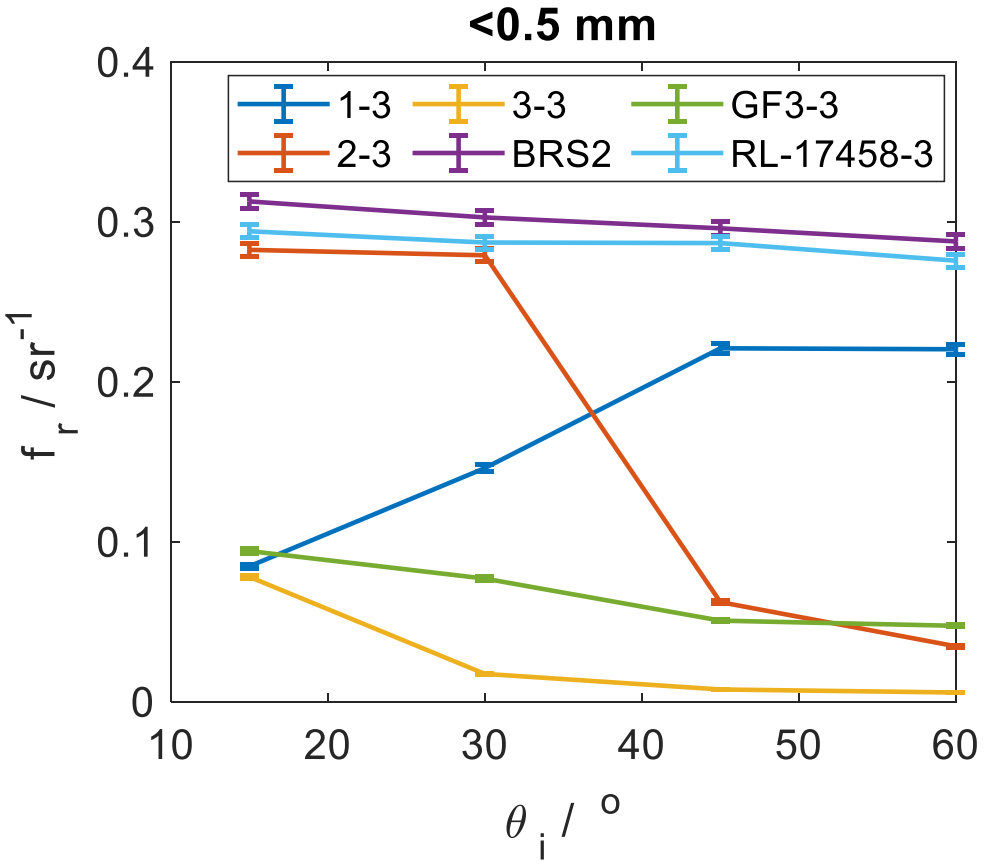
Activity 1.5.1.

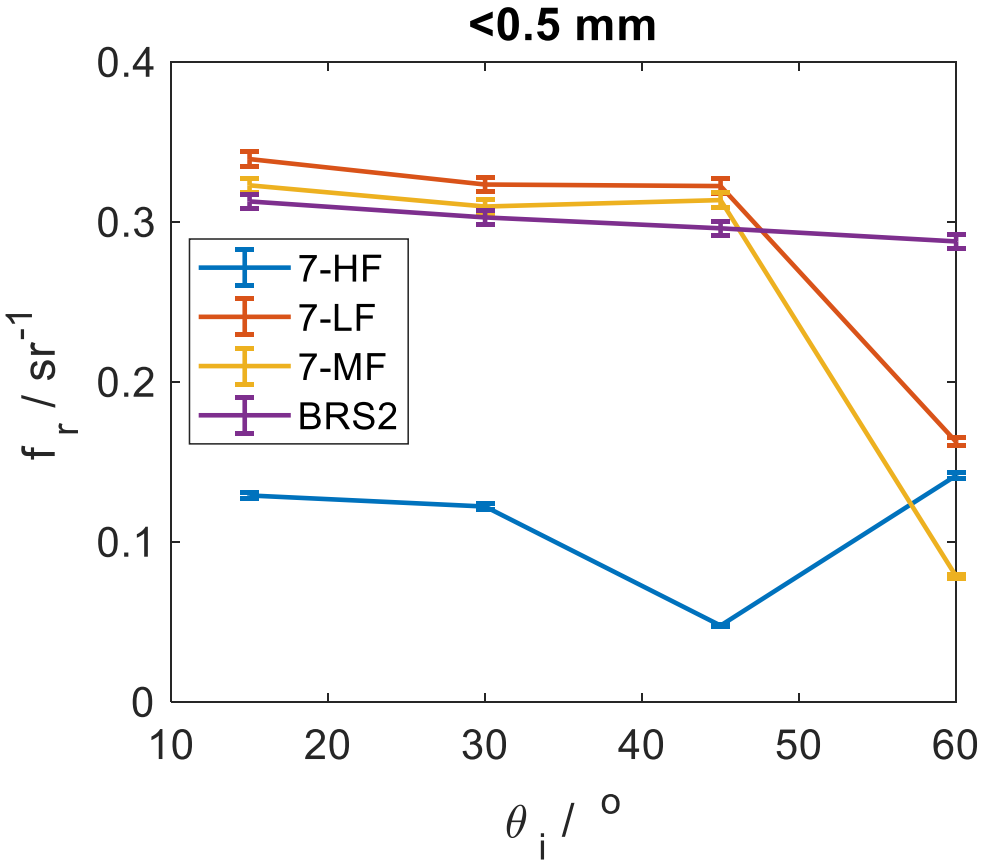
BRDF measurement equation:

$$f_{\mathrm{r}} = \alpha(\theta_{\mathrm{i}}) \frac{\sum_{j \in A_{\mathrm{r}}} N_j}{\sum_{j \in A_{\mathrm{r}}} N_{j,\mathrm{BRS2}}}$$

- $\alpha(\theta_{\mathrm{i}}) \equiv$ angular correction factor of the BRDF of the BRS2 [https://doi.org/10.1364/AO.51.008535].
- $\sum_{j \in A_{\mathrm{r}}} N_j \equiv$ summation of the response of the pixels in the sample image inside the measurement area, A_{r}.
- $\sum_{j \in A_{\mathrm{r}}} N_{j,\mathrm{BRS2}} \equiv$ summation of the response of the pixels in the BRS2 image inside the measurement area, A_{r}.

Activity 1.5.1.





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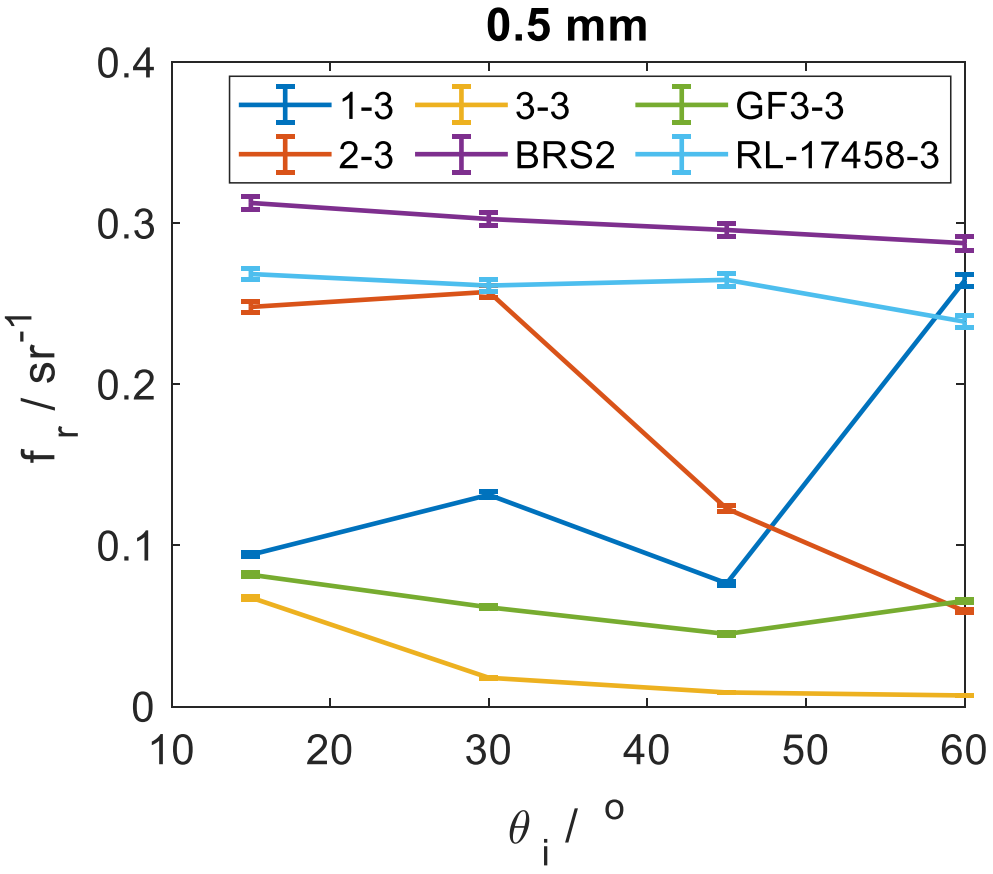

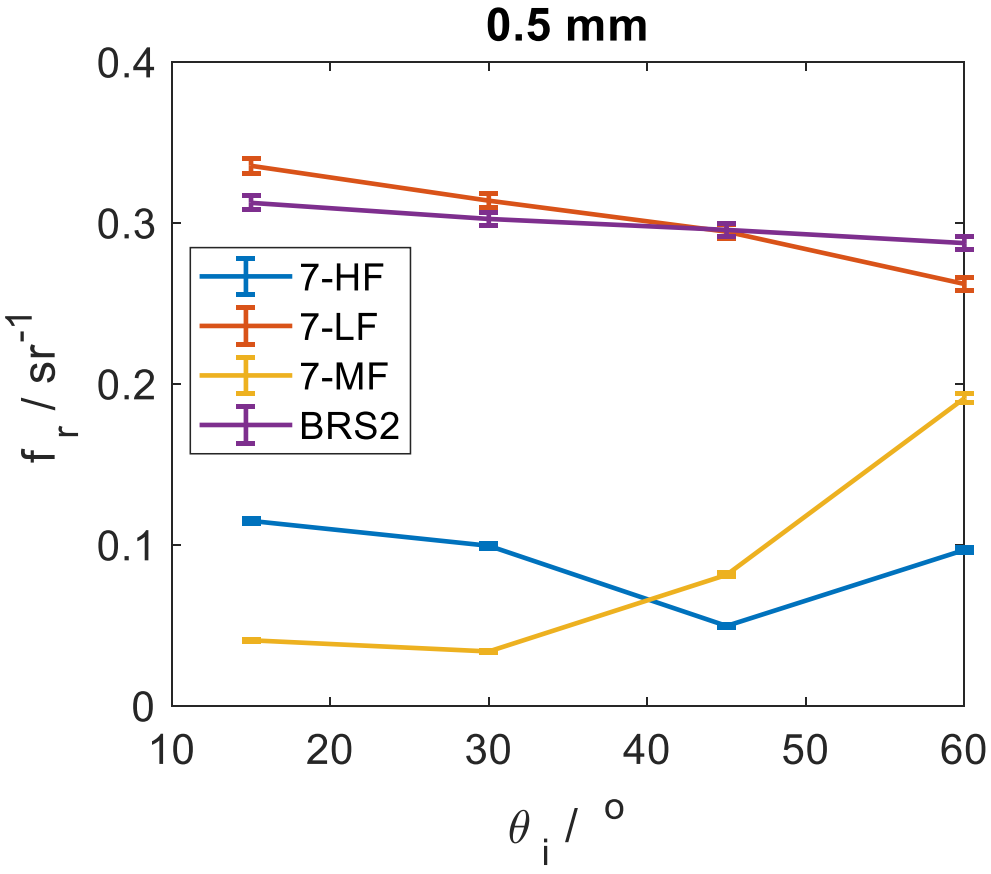

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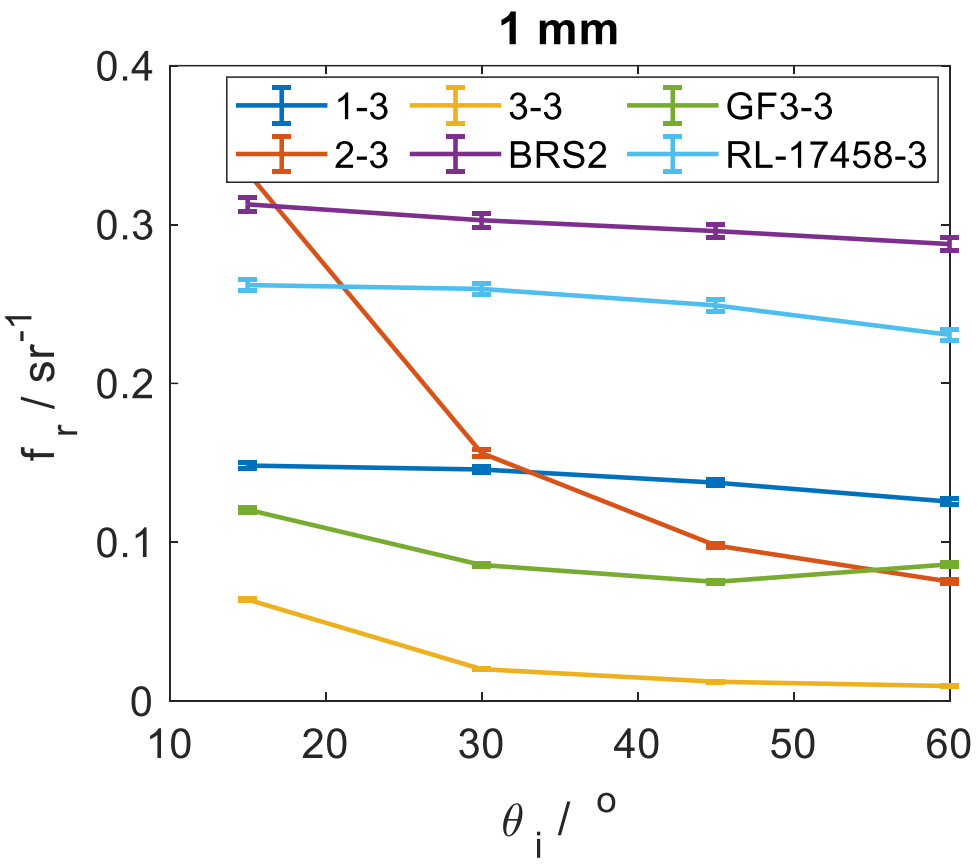

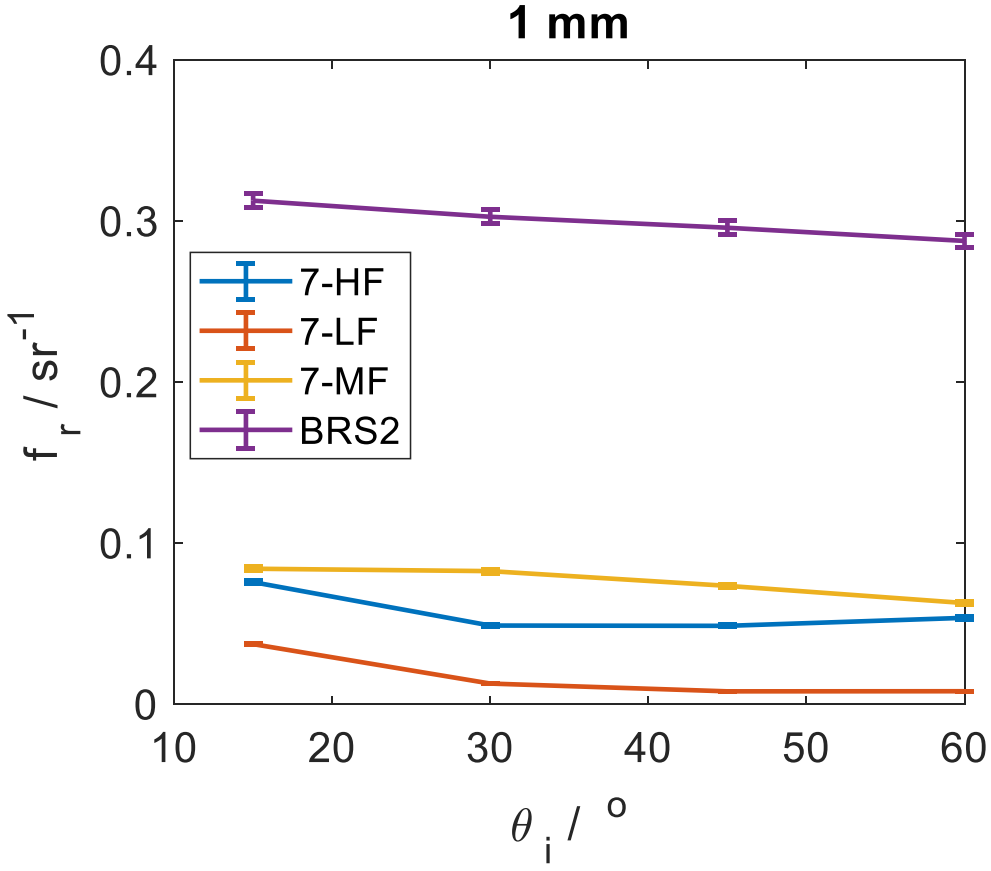

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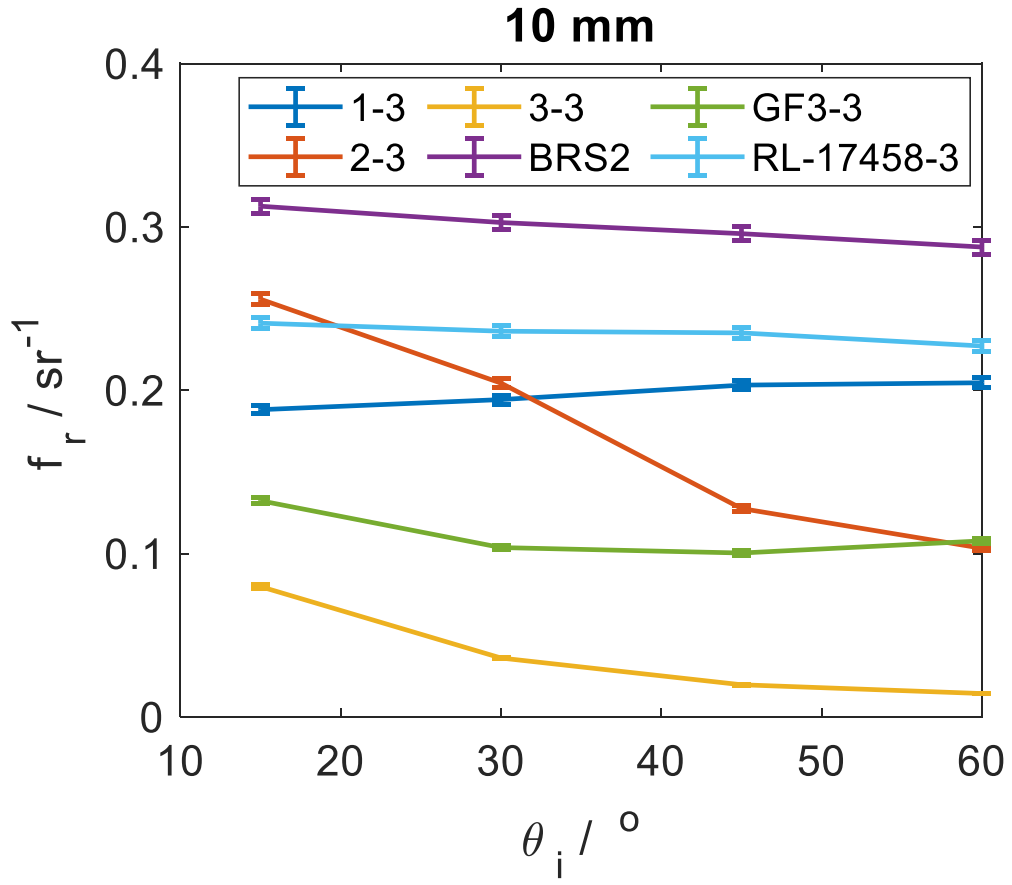
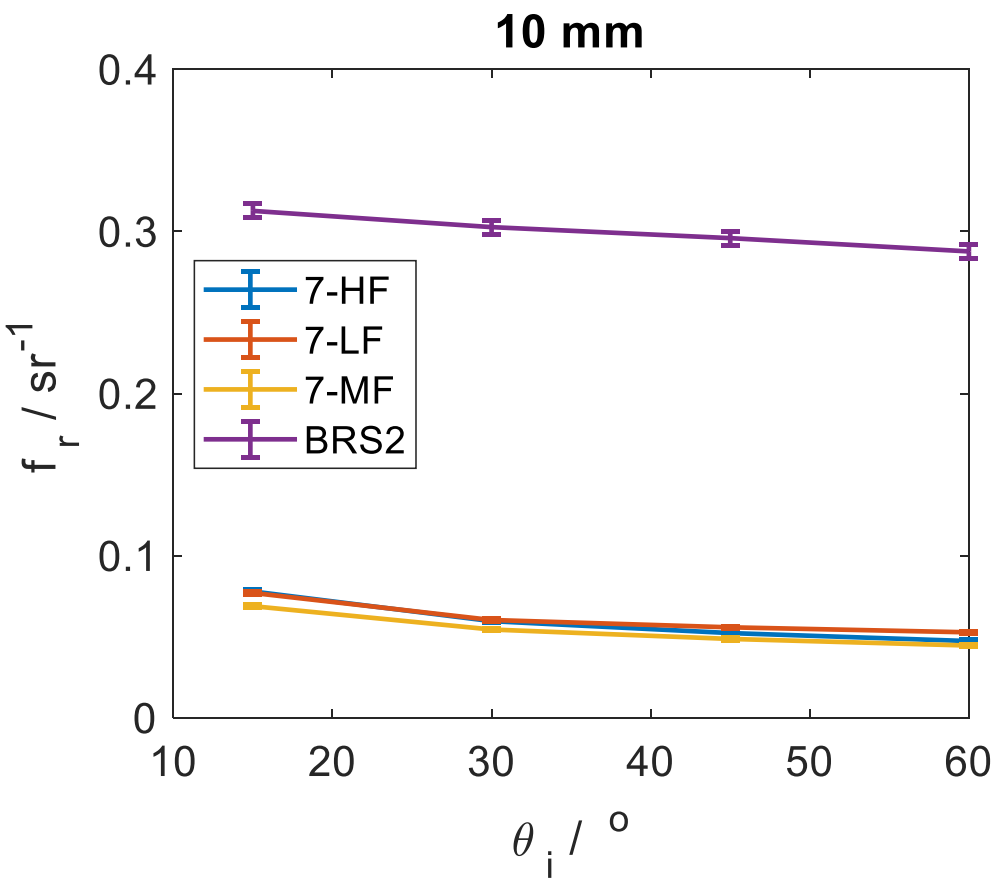
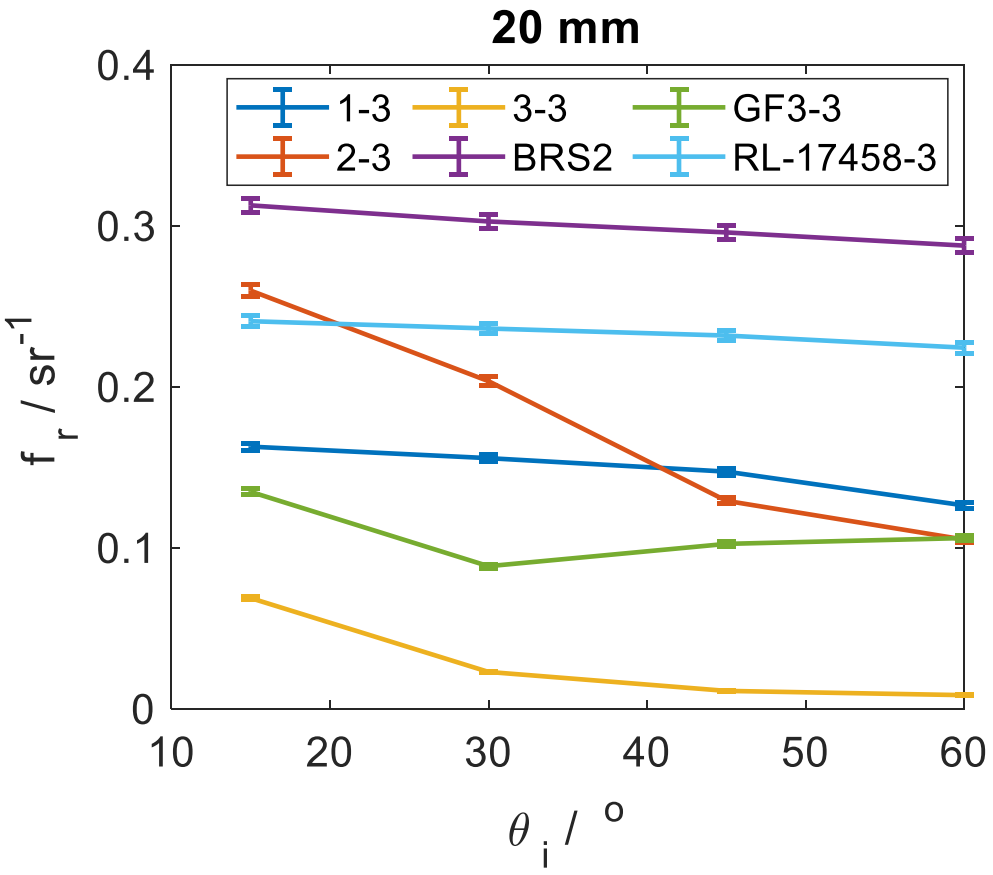


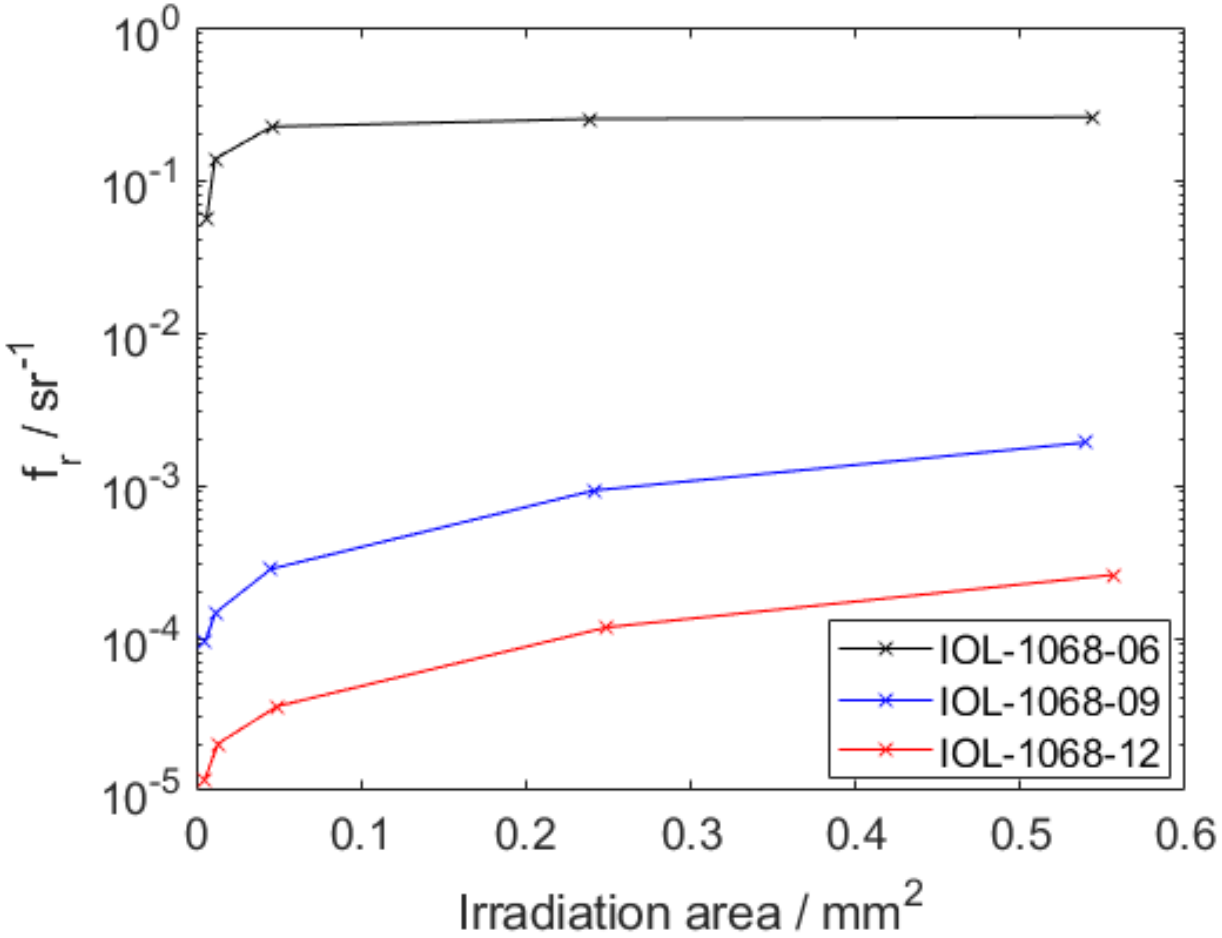


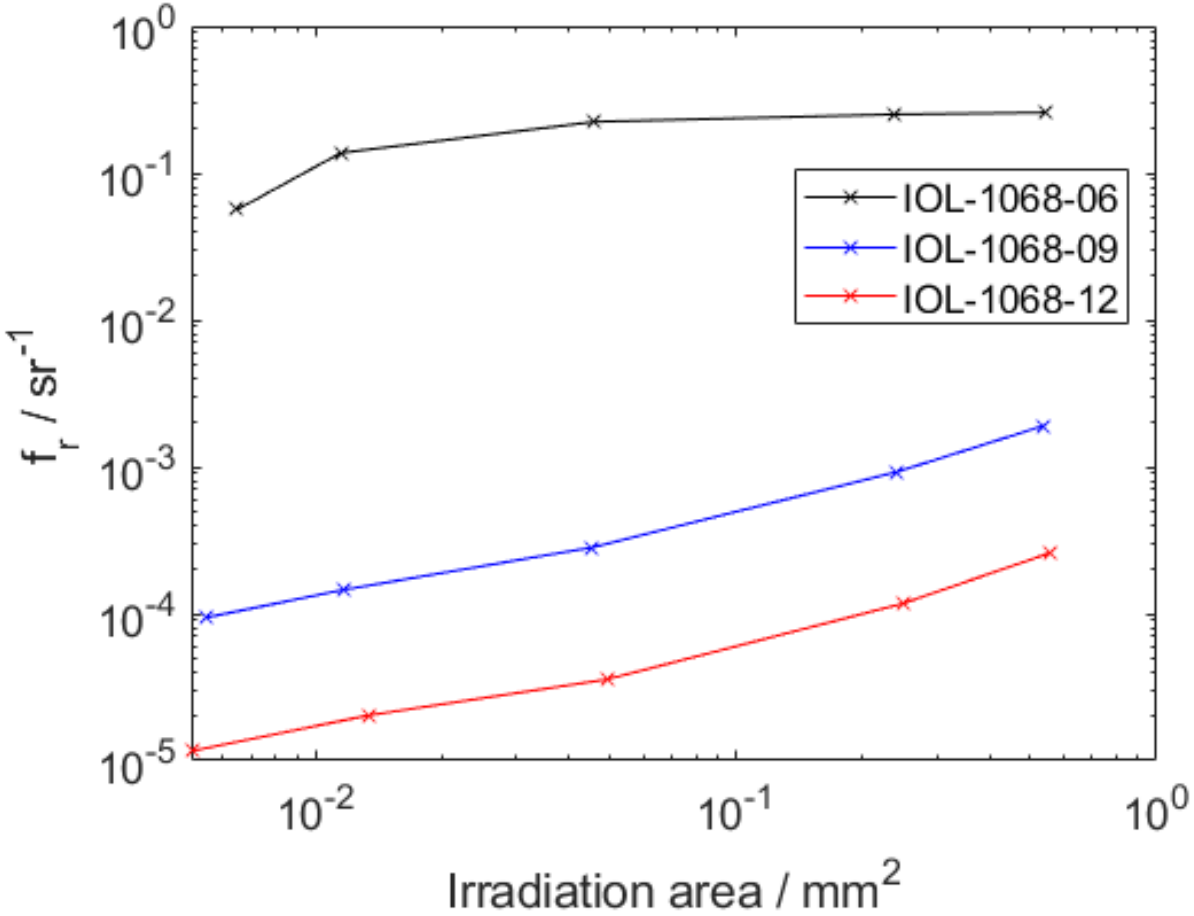
Activity 1.5.1.



BRDF of Covestro Samples

BRDF of Covestro Samples

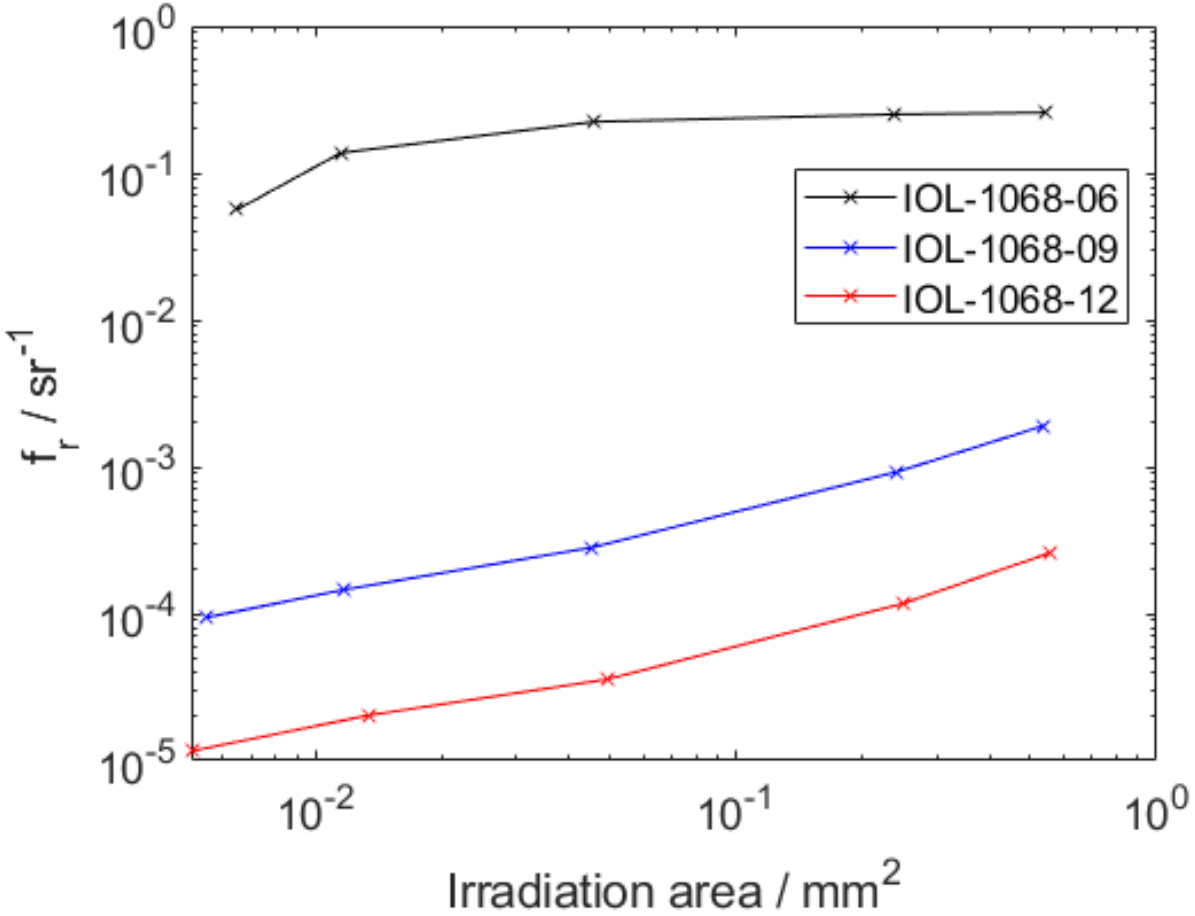




BRDF of Covestro Samples

$$f_{\mathrm{ss}}(\mathbf{r}_\mathrm{i};\mathbf{r}_\mathrm{r}) = \frac{\mathrm{d}f_\mathrm{r}^*(\mathbf{r}_\mathrm{i};\mathbf{r}_\mathrm{r};A_\mathrm{i})}{\mathrm{d}A_\mathrm{i}}$$

$f_{ss}(\mathbf{r}_\mathrm{i};\mathbf{r}_\mathrm{r}) \equiv$ Bidirectional Bipositional Subsurface Scattering (BBSS) function



Conclusions

- ✓ In activity 1.4.2 the results show that, apart from the expected decrease for larger measurement areas, the BRDF depends on the sample size, being higher for larger samples of the same material.

- ✓ In activity 1.5.1., the obtained results don't show a clear trend of the BRDF regarding the irradiation beam diameter for the samples of the first package, but they do for the samples of the second package, although the observed variation was already expected since it is due to the sample/background proportion of the white dots meshes for each irradiation beam diameter.

- ✓ The BRDF of translucent samples really depends on the irradiation area.

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Thanks for your attention