Reflectance measurements

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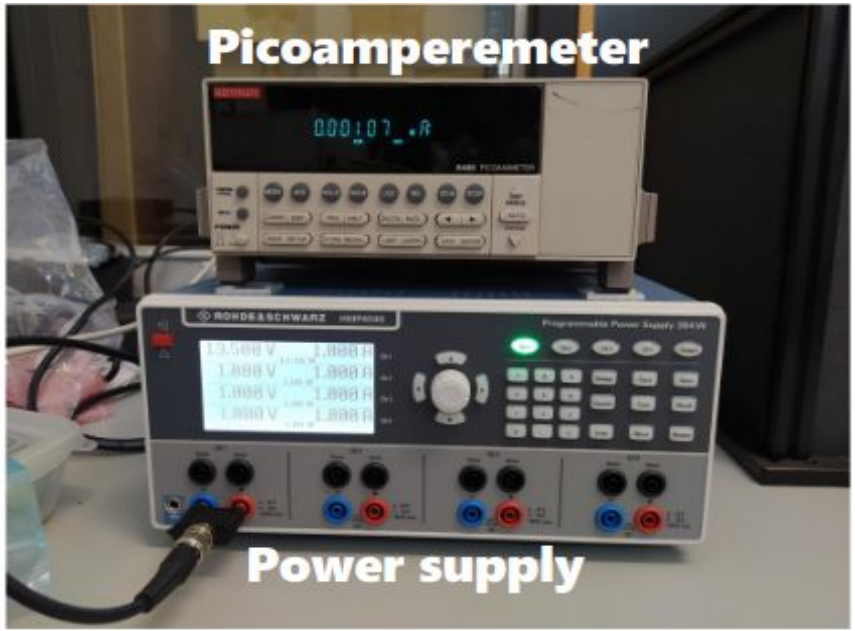
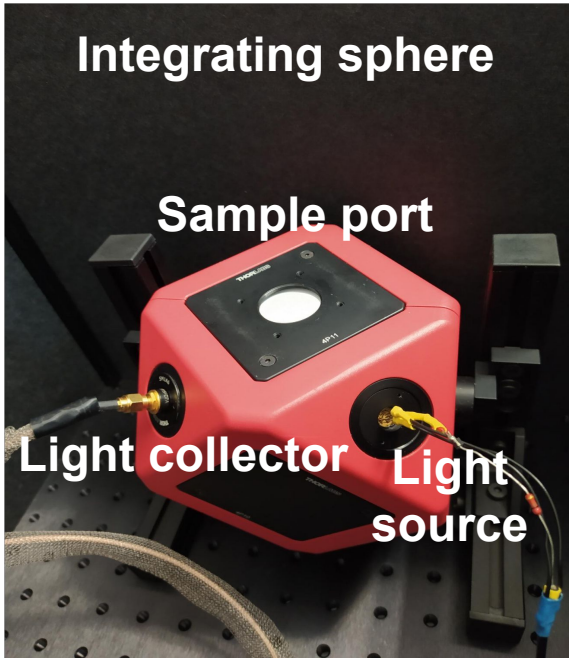
Photon Detection Consortium Meeting

19/07/2022

Goals and setup

- Study of the reflectance of all material elements inside the FD2-VD.
- Impact on light yield maps obtained with simulations.

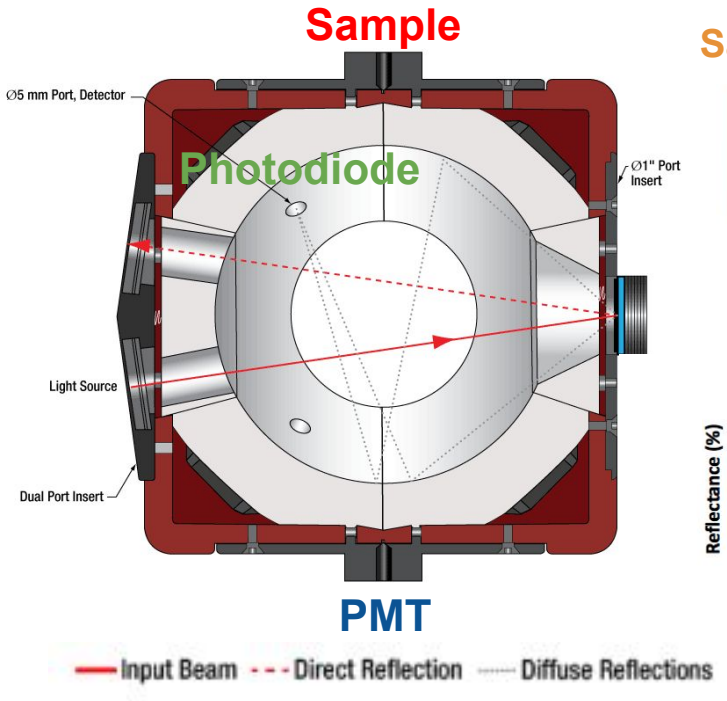




Light source
- LED.
- Tungsten lamp.

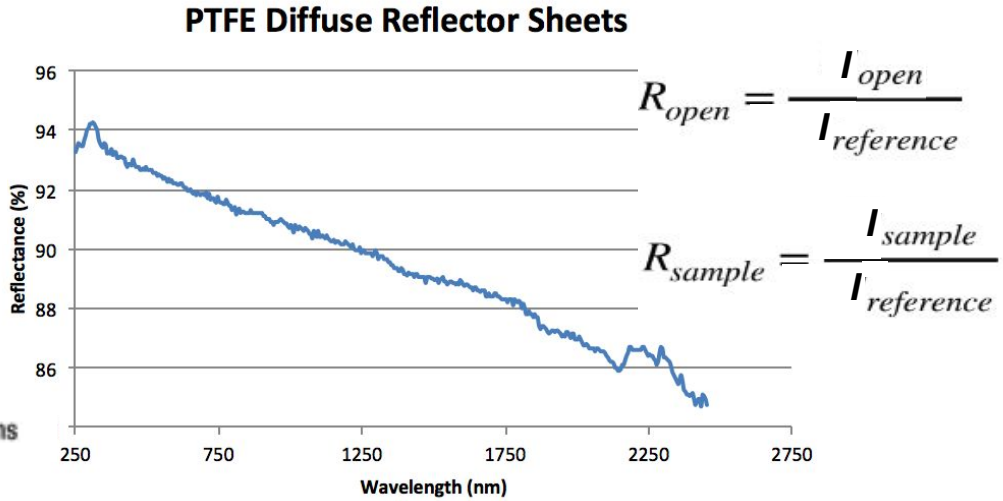
Light collector
- Photodiode.
- PMT.

Integrating sphere working principle



Sample reflectance as a function of the reference reflectance

$$\rho_{sample} = \left(\frac{R_{sample} - R_{open}}{1 - R_{open}} \right) \times \frac{1}{R_{sample}} \times \rho_{reference}$$

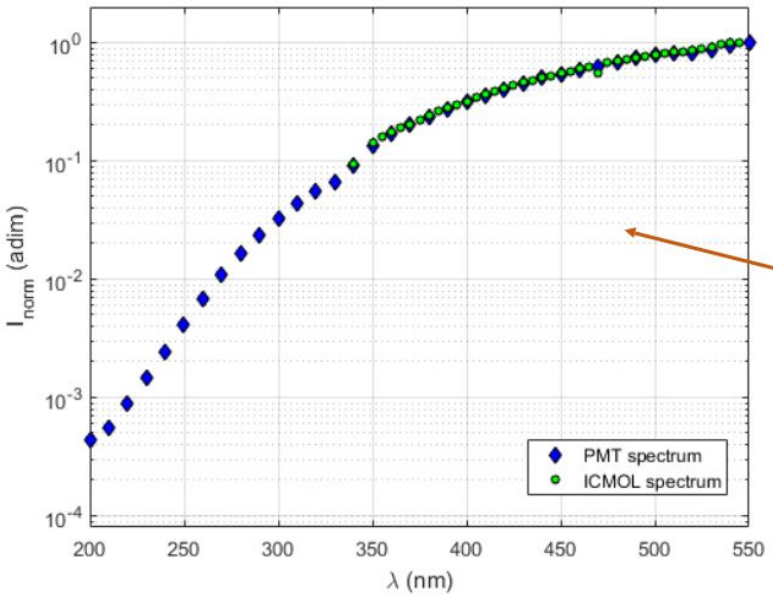


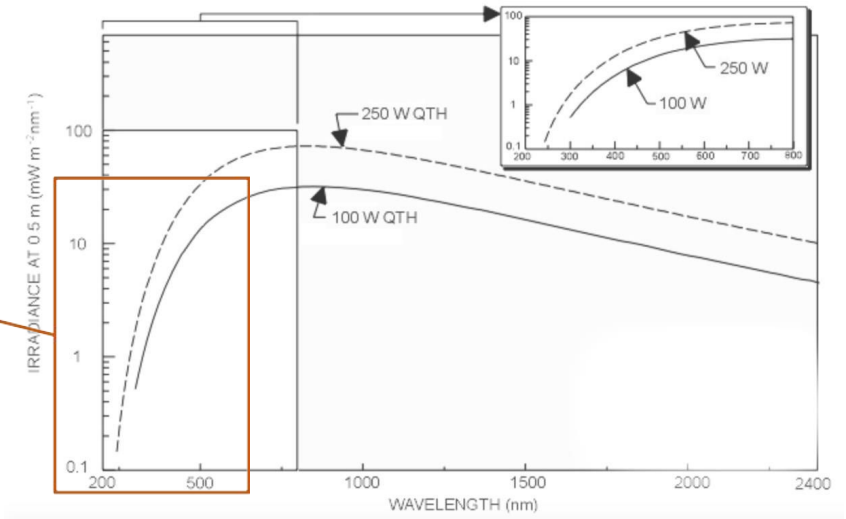
$$R_{open} = \frac{I_{open}}{I_{reference}}$$

$$R_{sample} = \frac{I_{sample}}{I_{reference}}$$

Lambertian reflectance surface and geometrical sphere shape.

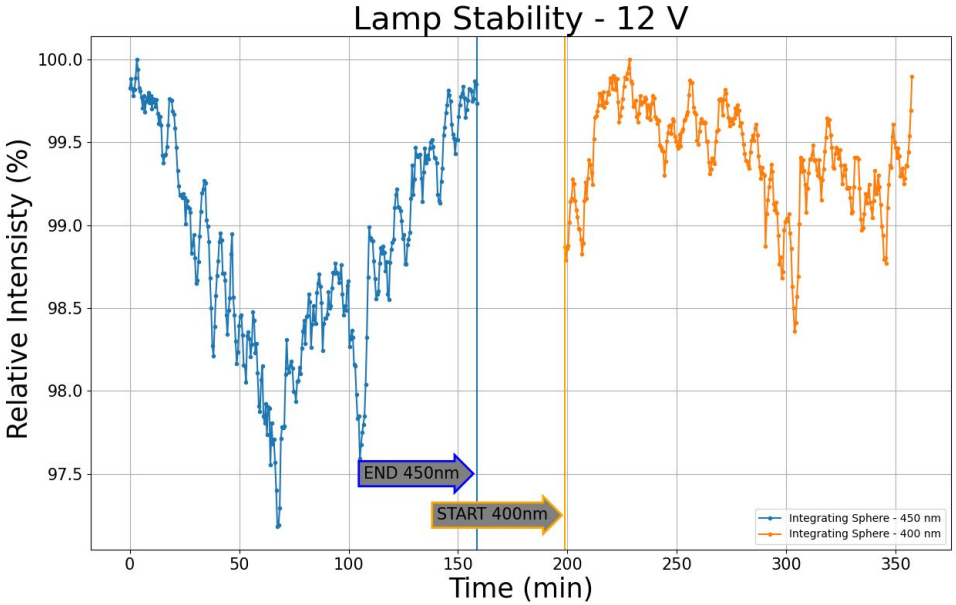
Setup: tungsten lamp spectrum





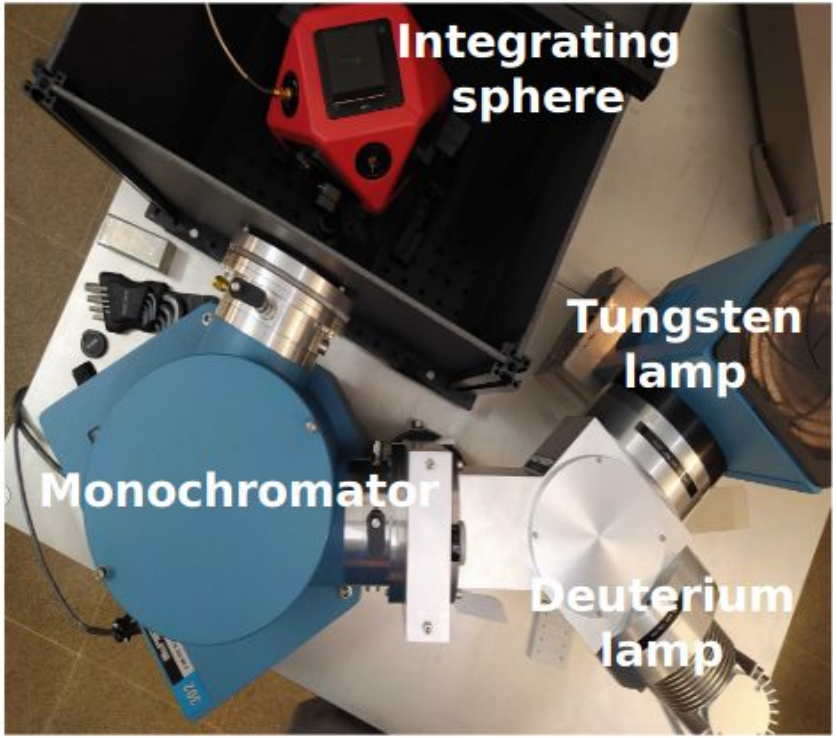
- Measurements in air with a tungsten-halogen lamp McPherson Model 621 of 100 W: spectral range from 300 nm onwards.

Setup: tungsten lamp stability



- Lamp intensity varies with time up to 3 %.
- Data taken, for a given wavelength, in a couple of minutes for reflectance measurements.
- Upper limit for this relative systematic error on the output intensity: **0.5 %**.
- Impact on the reflectance uncertainty must be considered.

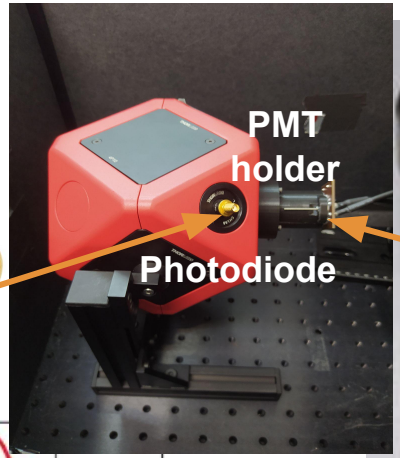
Setup: monochromator

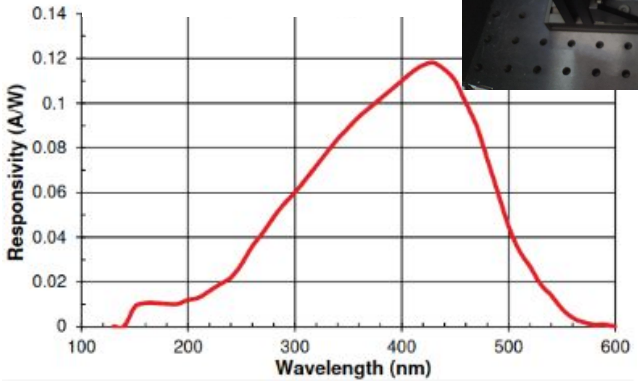


- Monochromator provides a wavelength range from 30 to 550 nm.
- Wavelength resolution: 6 nm with both slits wide open (3 mm).
- We have used a photodiode and a PMT as light readout devices.

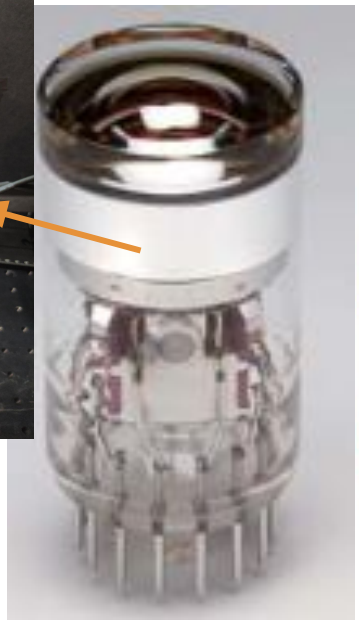
Setup: light collectors

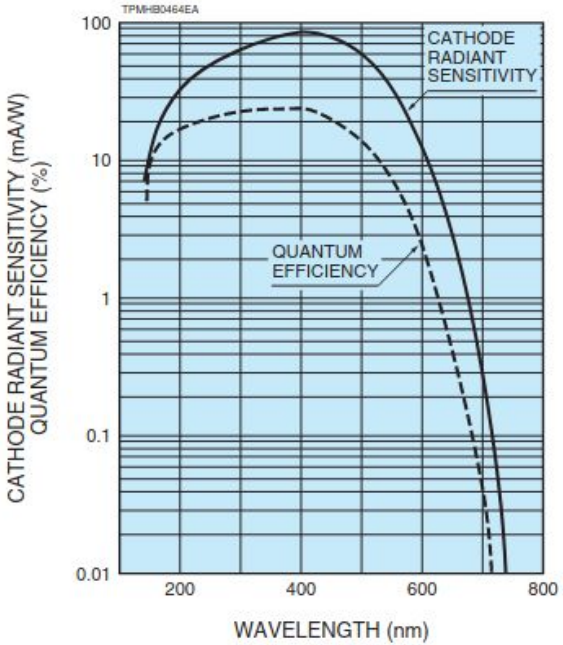
Photodiode SM05PD7A from Thorlabs





PMT R7378A from HAMAMATSU

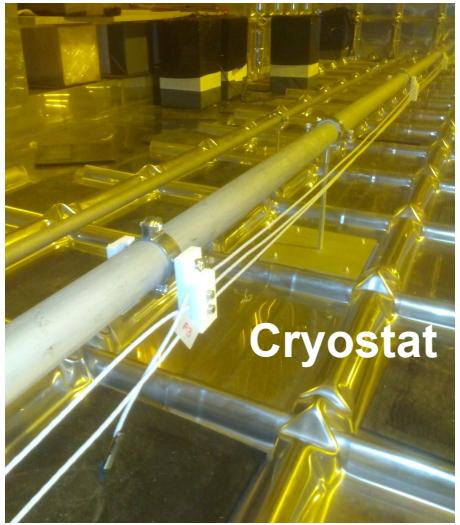


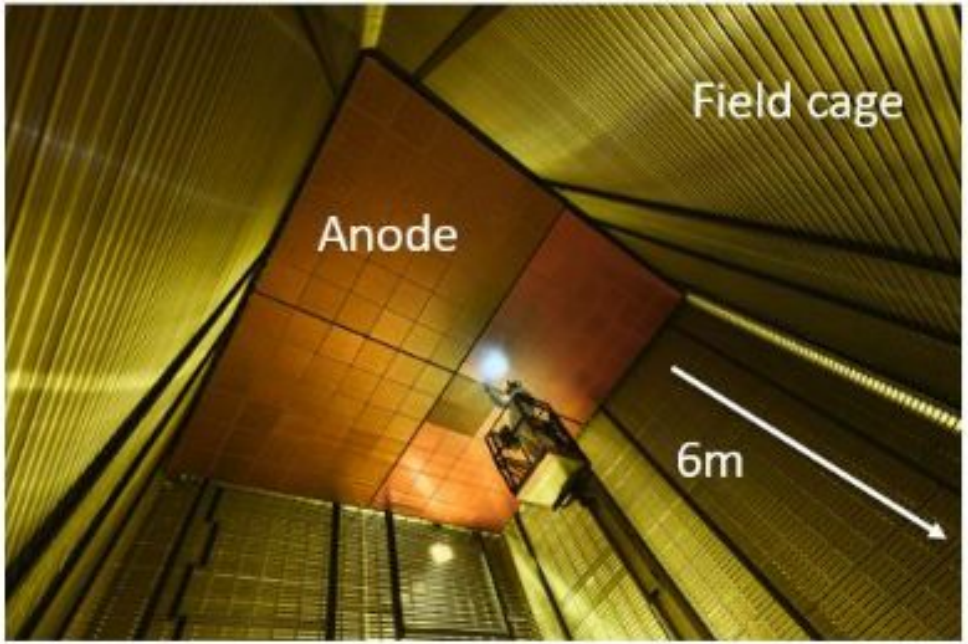


Photodiode spectral response range: 150-550 nm. PMT spectral response range: 160-650 nm.

Main components to be measured

- Anode shielding: **copper and aluminium samples**.
- Field cage profiles: **aluminium**.
- Cryostat wall: **stainless steel**.

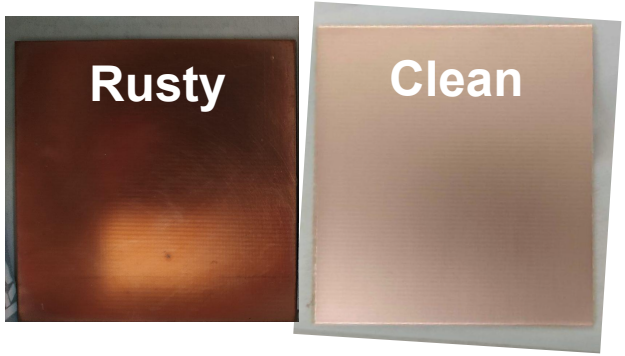




Setup: samples

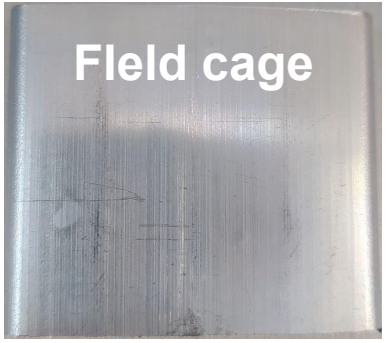
PTFE

Cu



Stainless Steel

Al



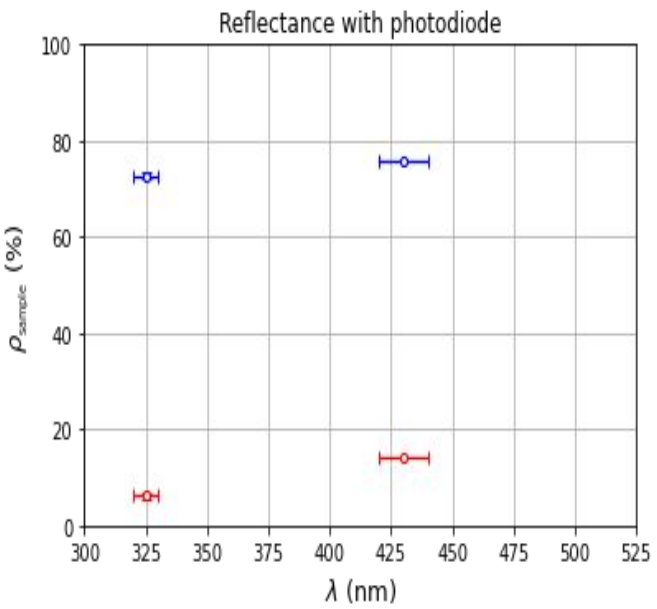
Results

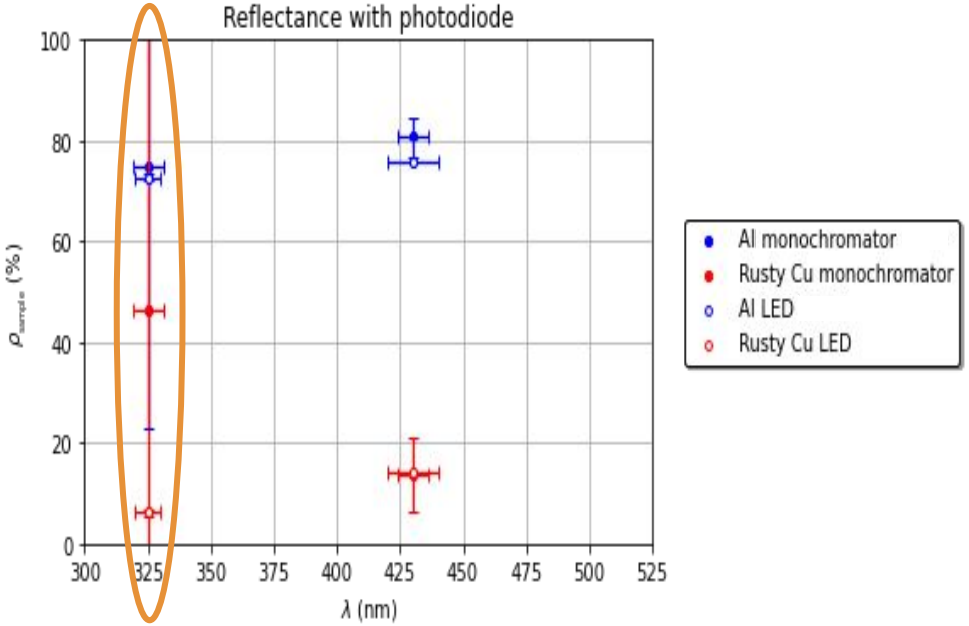
Reflectance with different light sources

LED only (previous measurements)

Photodiode as light collector

LED & Monochromator





Uncertainty with LEDs < 1 %.

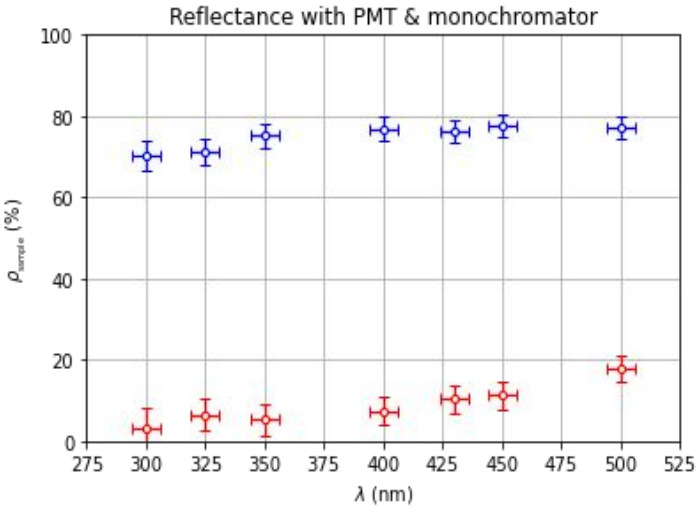
Wavelength resolution of 6 nm with MC.

The low intensity of the lamp affects the accuracy at 325 nm with the photodiode.

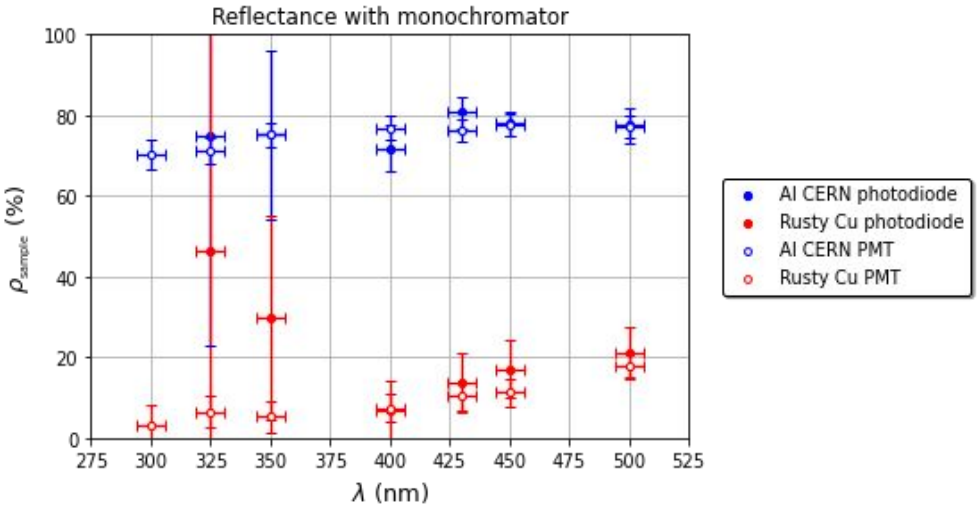
Reflectance with different light collectors

Tungsten lamp as light source

PMT only



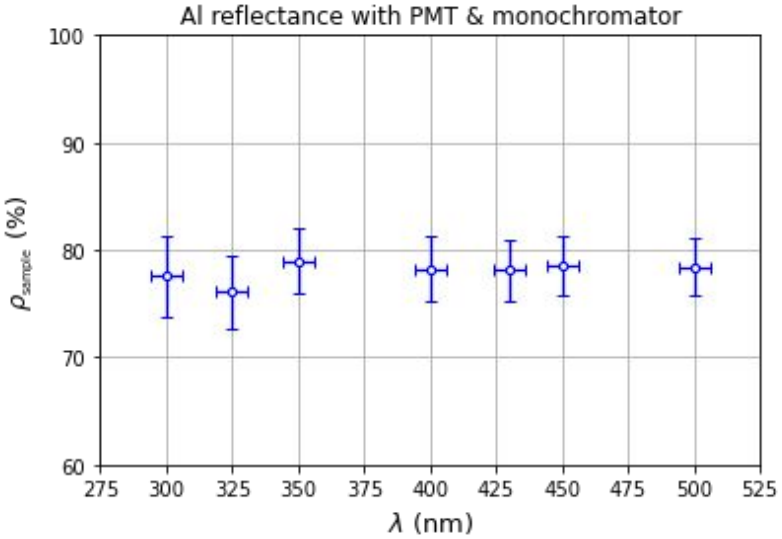
PMT & Photomultiplier

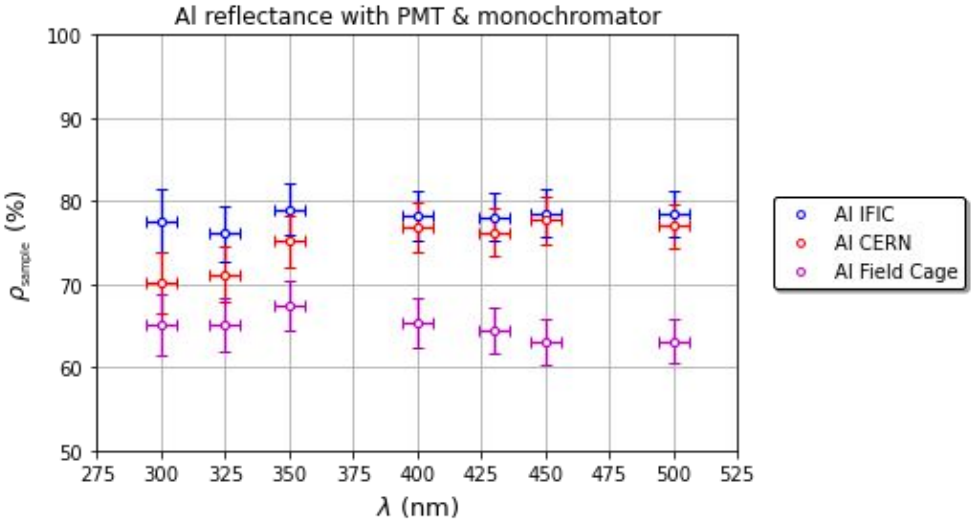


Maximum discrepancy: ~ 5 % for Al.
~ 6 % for Cu.

The low intensity of the lamp affects the accuracy at 325 and 350 nm with the photodiode.

Al reflectances

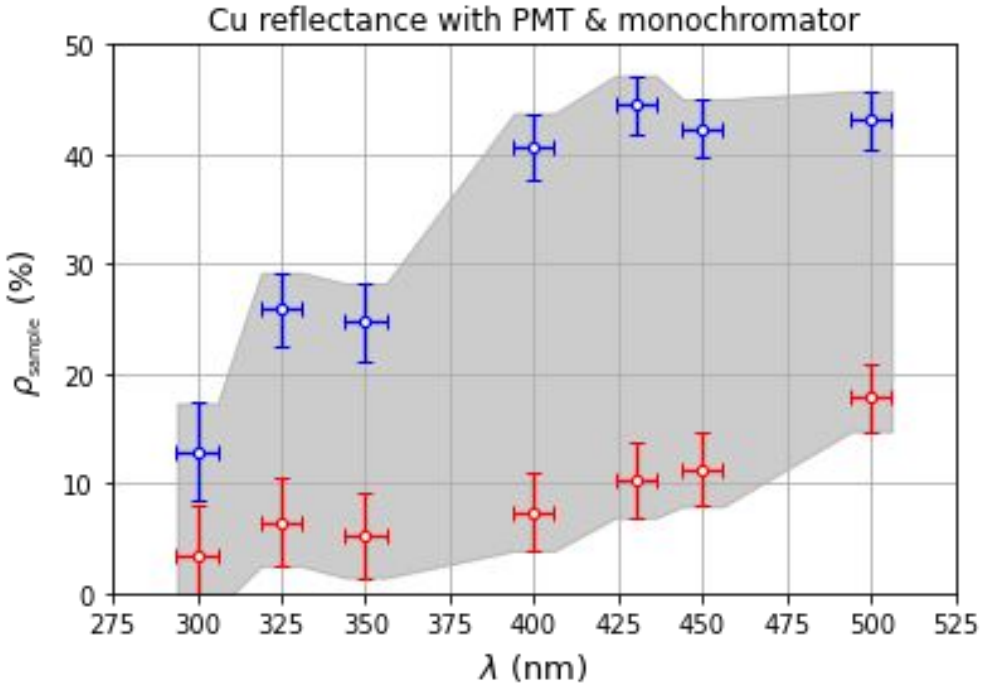




Reflectance between 70-80 % for an aluminium foil on a PCB.

Al from the field cage profile is an old sample manufactured probably with a different production mechanism.

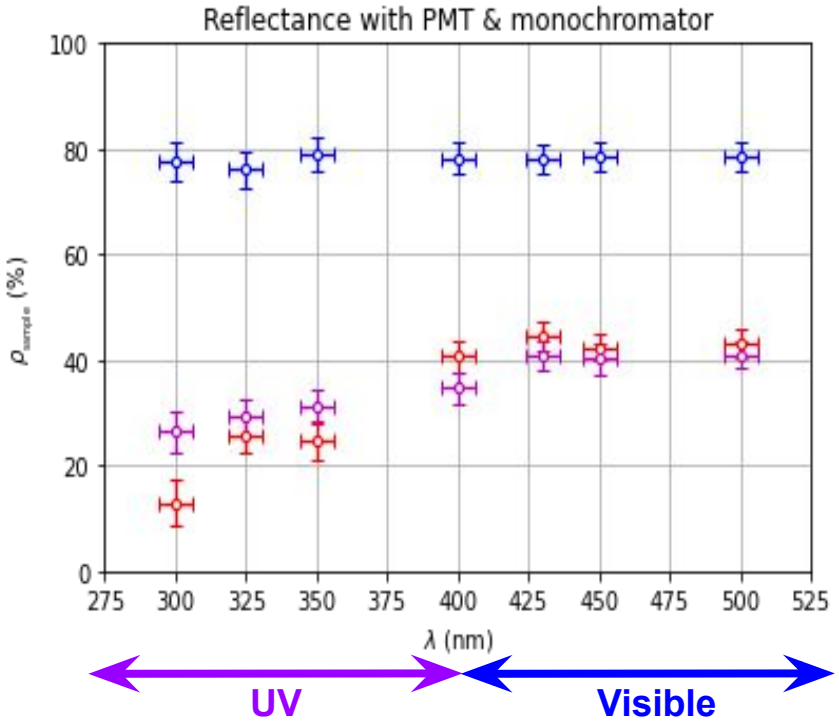
Cu reflectances



- Results compatible with previous measurements presented for the consortium last year.
- Al presents better reflective performance.

Cu oxidation (Cu_2O) is critical for its reflectance.

Reflectance summary for different materials



- Highest uncertainty for all samples at 300 nm.
- 4-5 % uncertainty on the reflectance.

Summary

- Reflectance measurements for the main materials inside the FD LAr volume (stainless steel from the cryostat, copper and aluminum for the anode PCBs and aluminium field cage profiles), in the wavelength range between 300 and 500 nm.

- From these results, aluminium displays the better reflectance, reaching values ~70-80 %.

- Uncertainties from the light readout device and light source translates into a 4-5 % uncertainty on the reflectance at 300 nm.

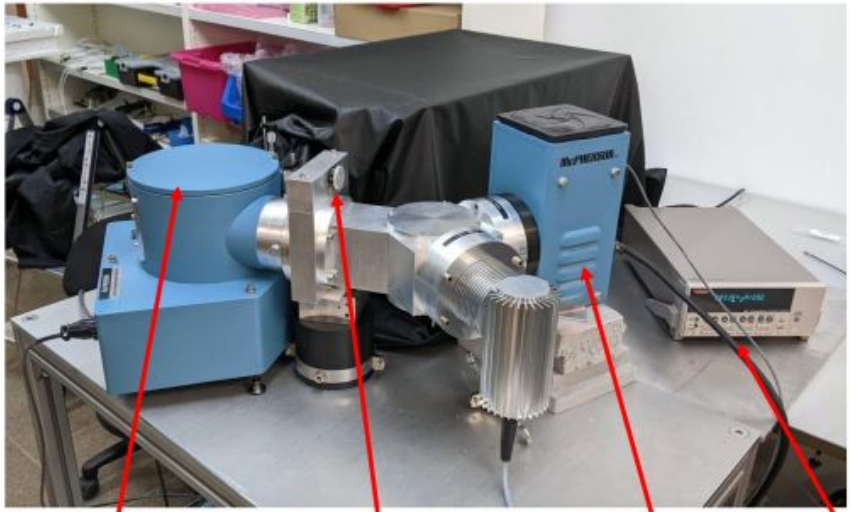
Future prospects: setup upgrade

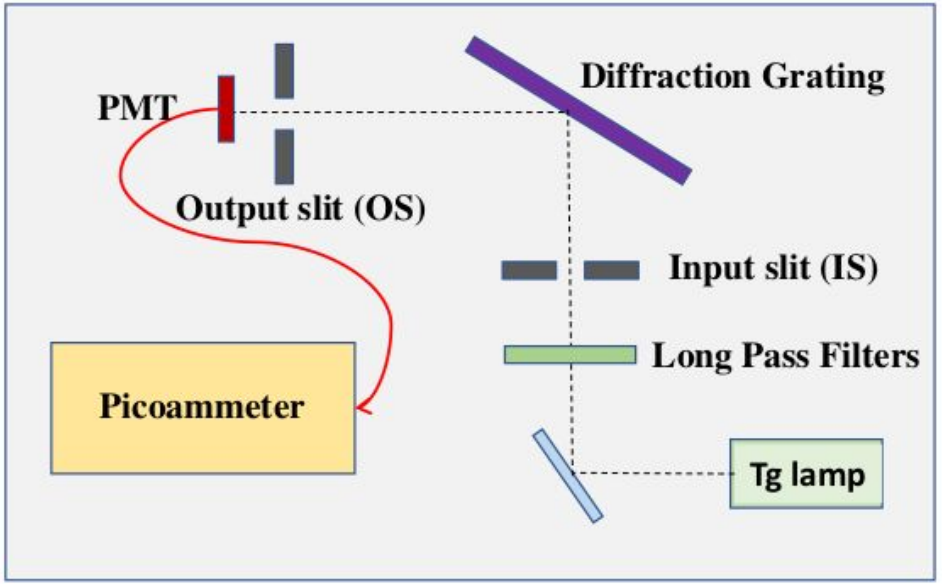
- Measurements below 300 nm up to 100 nm with the deuterium lamp.
- Setup inside a methacrylate box with a gas N_2 atmosphere (the box has arrived and we have started preparing the setup).
- Use of a PMT/MPPC(SiPM) sensitive to both LAr and LXe wavelengths.
- The reflectance of Teflon drops at lower wavelengths, ~70% at 175 nm [*Silva, C., et al (2010). A model of the reflection distribution in the vacuum ultraviolet region*].
  The impact of this behavior will be studied to understand if the method currently used is viable for measurements at 128 nm.

MPPC is short for Multi-Pixel Photon Counter.

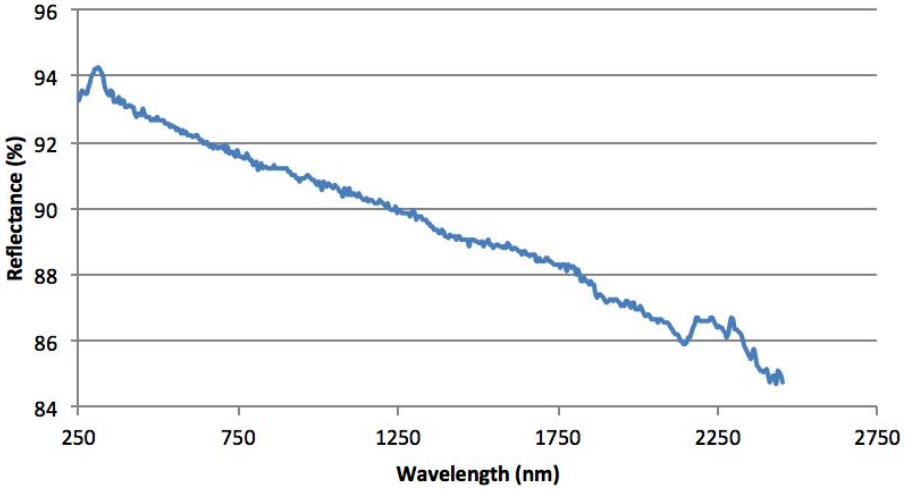
Backup

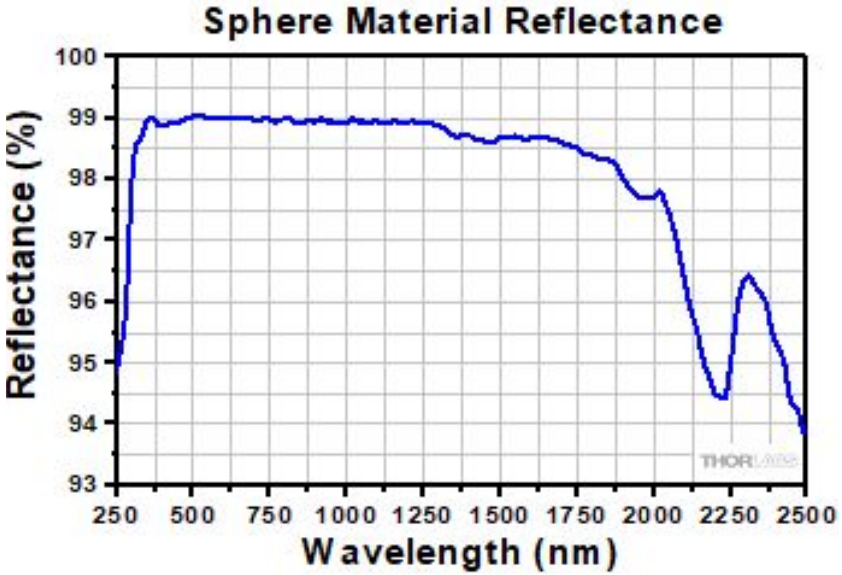
Backup


Diffraction Grating
Long Pass Filters
Tg lamp
Picoammeter


PMT
Diffraction Grating
Output slit (OS)
Input slit (IS)
Long Pass Filters
Picoammeter
Tg lamp

Backup


PTFE Diffuse Reflector Sheets
96
94
92
90
88
86
84
Reflectance (%)
250
750
1250
1750
2250
2750
Wavelength (nm)


Sphere Material Reflectance
100
99
98
97
96
95
94
93
Reflectance (%)
250
500
750
1000
1250
1500
1750
2000
2250
2500
Wavelength (nm)

Backup

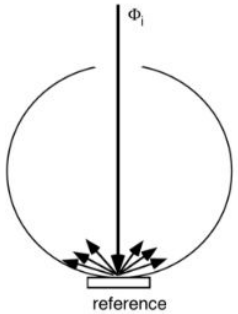
$$M_{open} = \frac{\rho_0}{1 - \rho_W \times (1 - F_L - f)}$$

$$M_{reference} = \frac{\rho_0}{1 - \rho_W \times (1 - F_L - f) - \rho_{Reference} f}$$

$$M_{sample} = \frac{\rho_0}{1 - \rho_W \times (1 - F_L - f) - \rho_{Sample} f}$$

$$F_L = A_L / A_{sphere} = \frac{2x(2.5mm)^2}{100mm^2}$$

$$f = A_{sample} / A_{sphere} = \frac{(2.54/2)^2}{10^2} = 0.016129$$

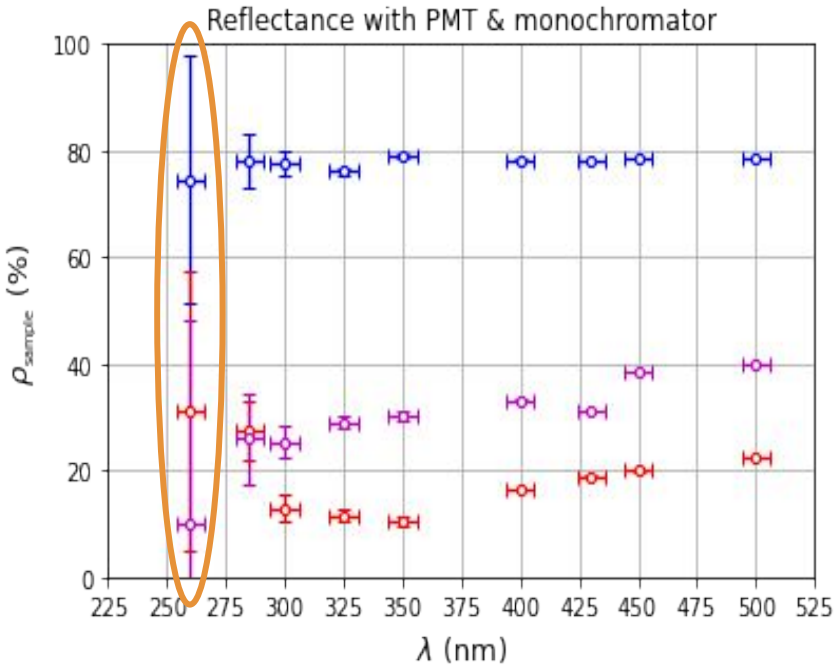


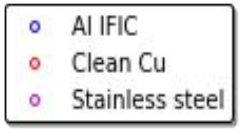
$$L_{Sphere} = \frac{\phi_i}{\pi A_{Sphere}} \times \frac{\rho}{1 - \rho(1 - F)}$$

M, the sphere multiplier

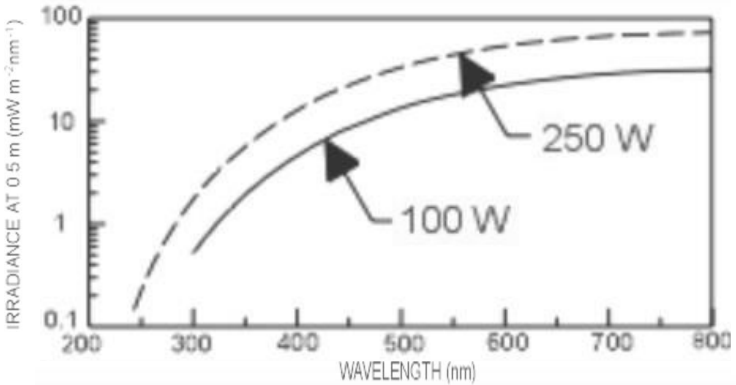
$$F = \sum A_{openings} / A_{sphere}$$

Backup

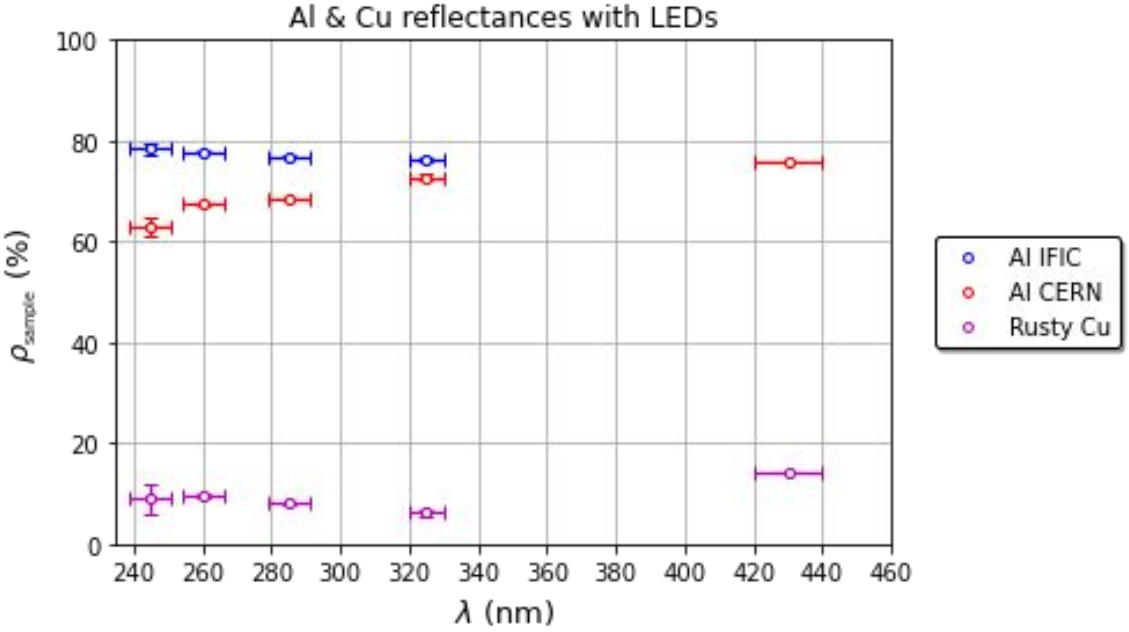




Long vertical error bars because of the tungsten-halogen lamp spectrum.



Backup

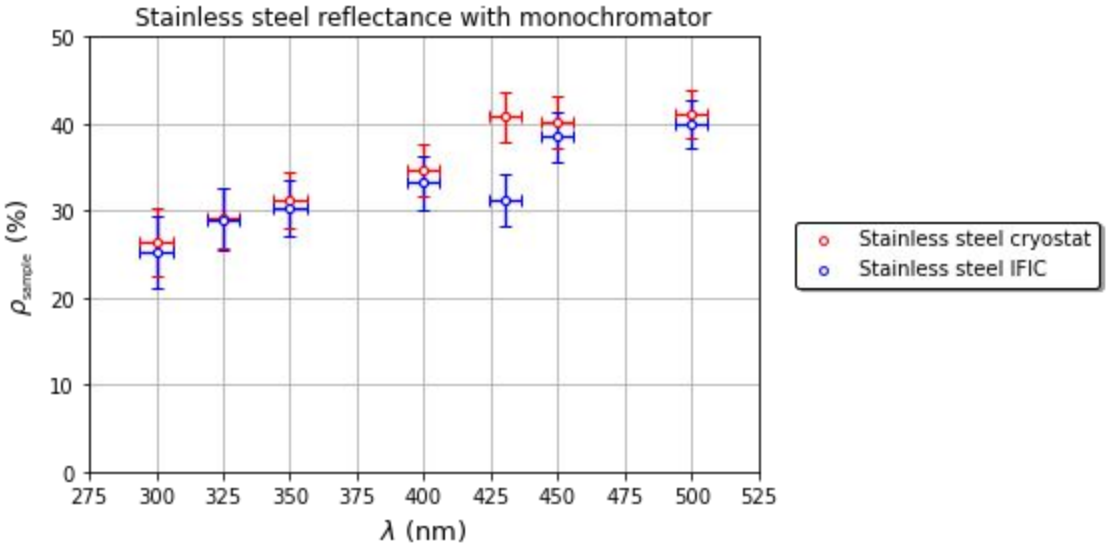

Al & Cu reflectances with LEDs
100
80
60
40
20
0
ρ_{sample} (%)
240
260
280
300
320
340
360
380
400
420
440
460
λ (nm)
Al IFIC
Al CERN
Rusty Cu

Backup

Stainless Steel

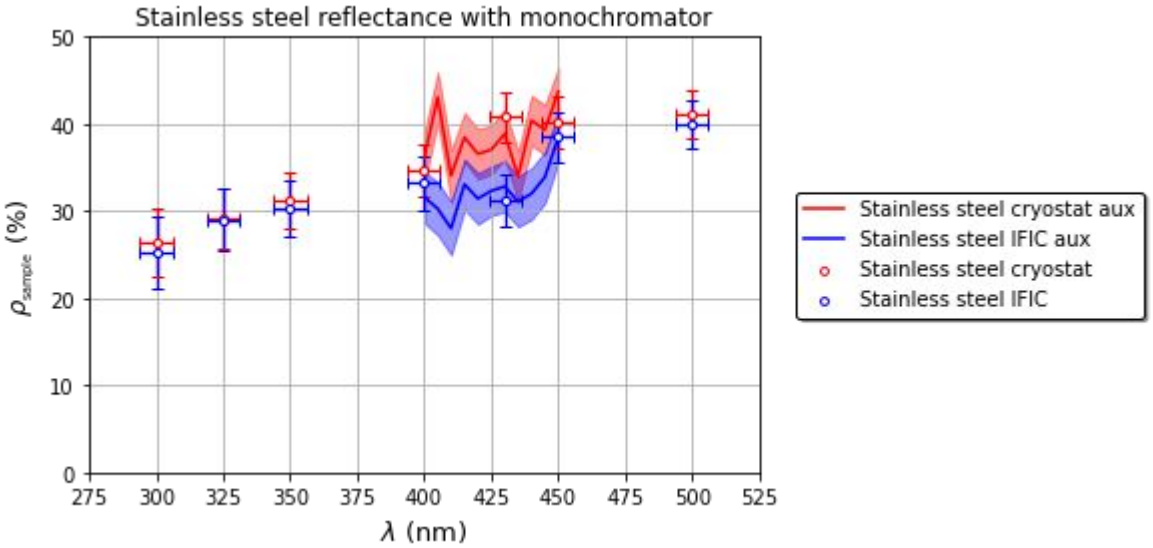
Backup

Stainless Steel

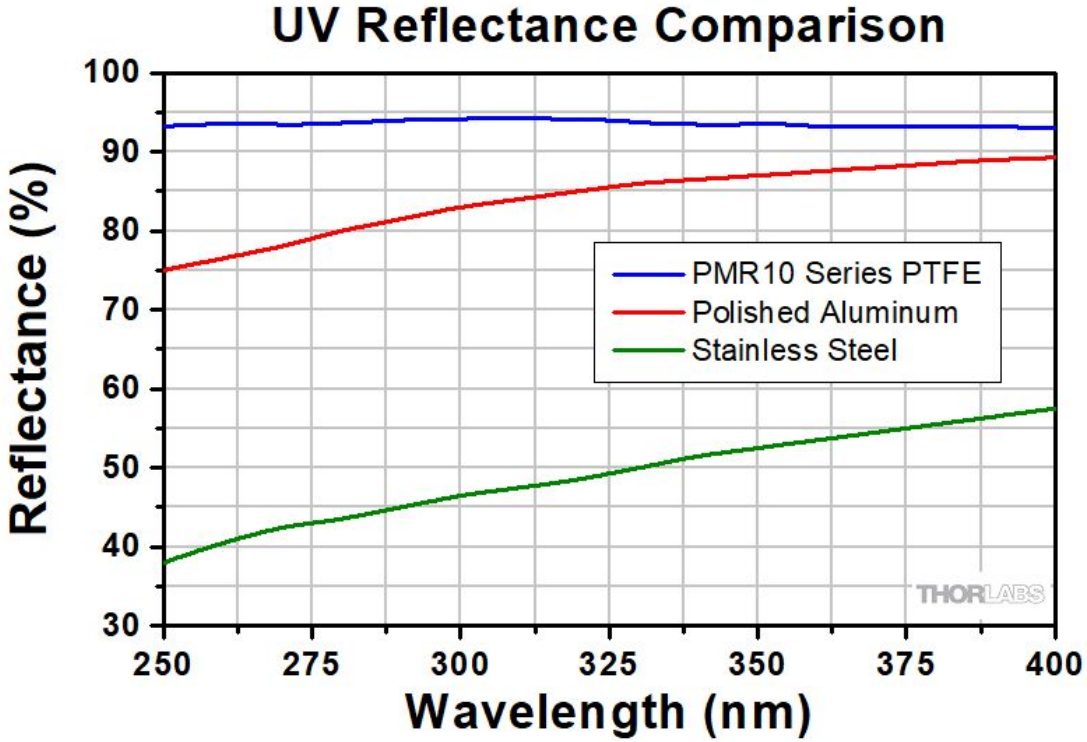


Backup

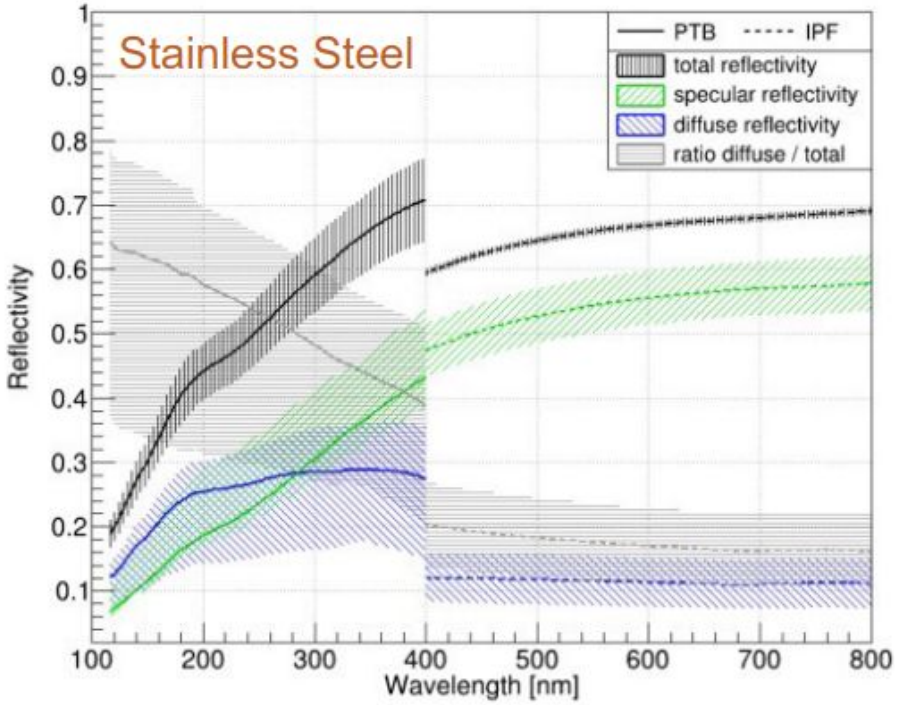
Stainless Steel



Backup


UV Reflectance Comparison
Reflectance (%)
100
90
80
70
60
50
40
30
250
275
300
325
350
375
400
Wavelength (nm)
PMR10 Series PTFE
Polished Aluminum
Stainless Steel
THORLABS

Backup


Stainless Steel
PTB
IPF
total reflectivity
specular reflectivity
diffuse reflectivity
ratio diffuse / total
Reflectivity
Wavelength [nm]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
100
200
300
400
500
600
700
800