

Reflectance measurements

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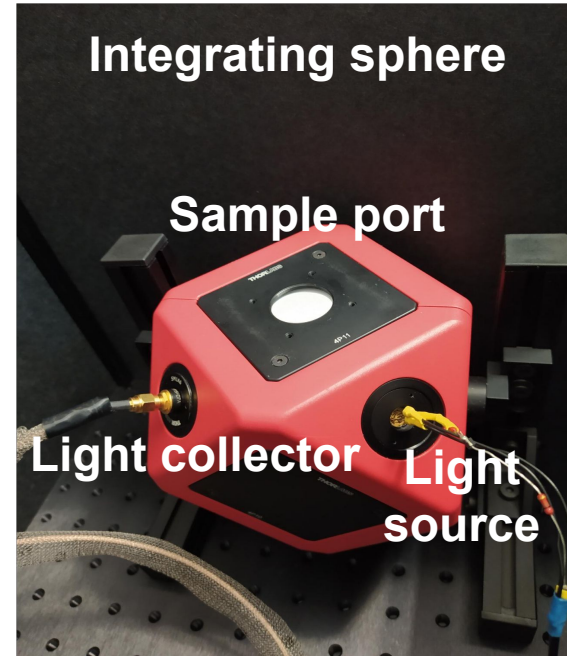
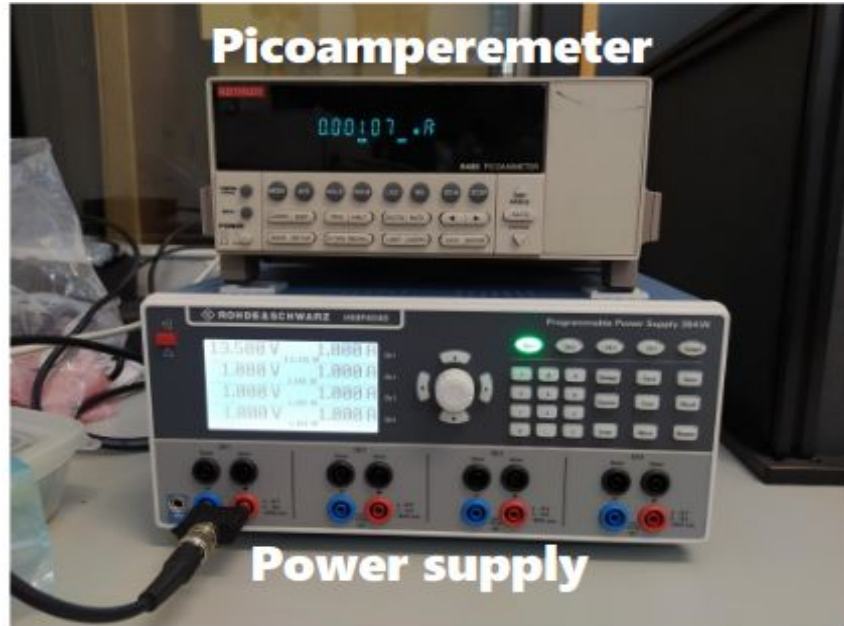
IFIC Group Meeting

23/06/2022



Goals and setup

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



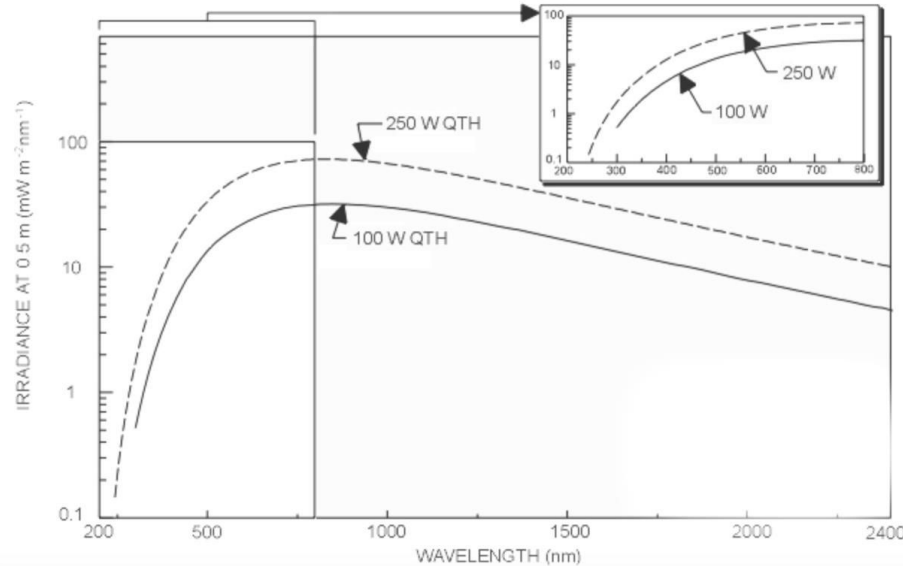
Light source:

- LED.
- Tungsten lamp.

Light collector:

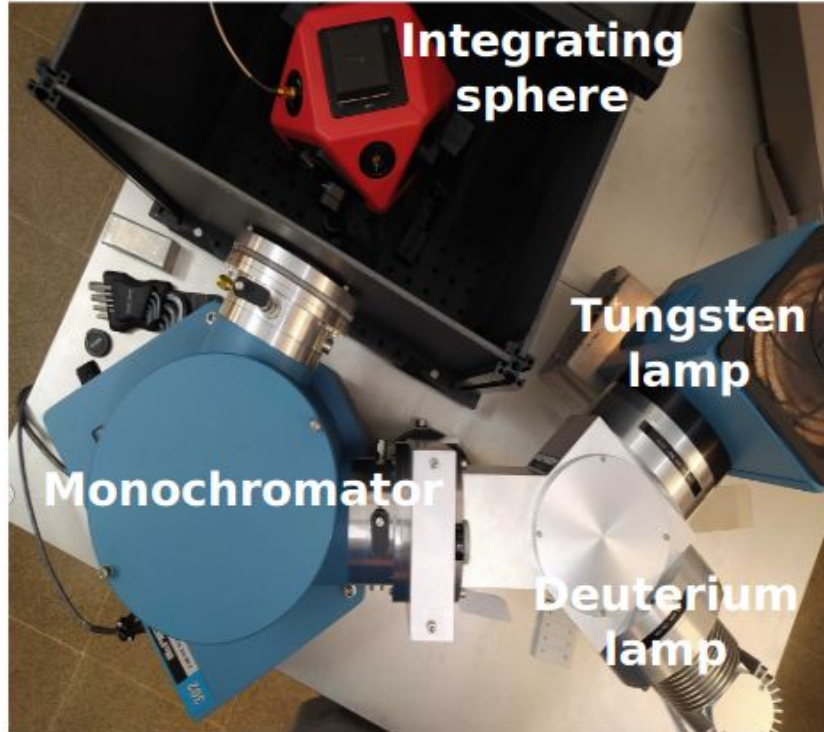
- Photodiode.
- PMT.

Setup: tungsten lamp spectrum



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

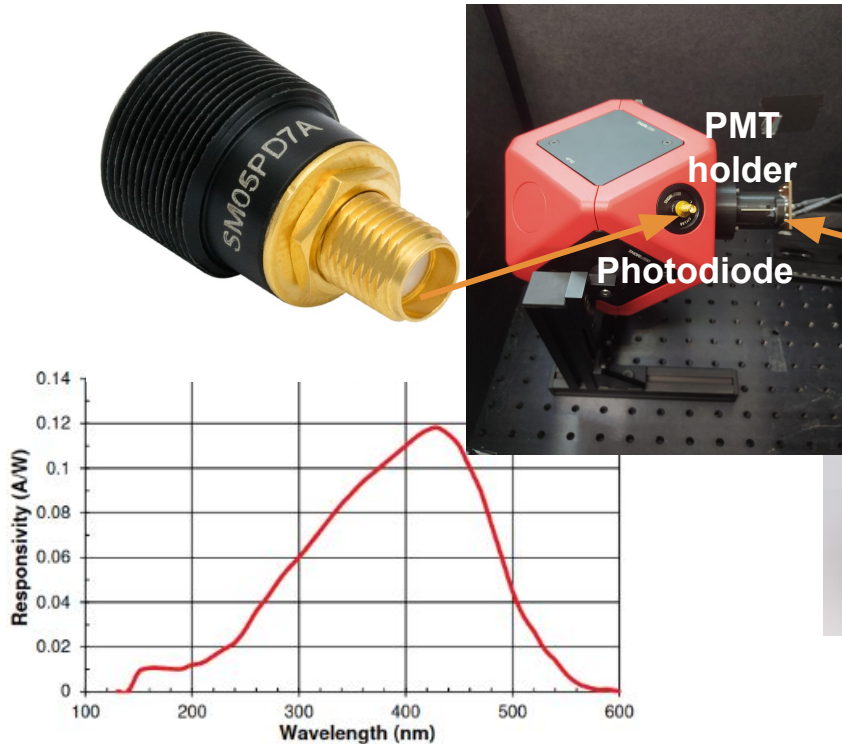
Setup: monochromator



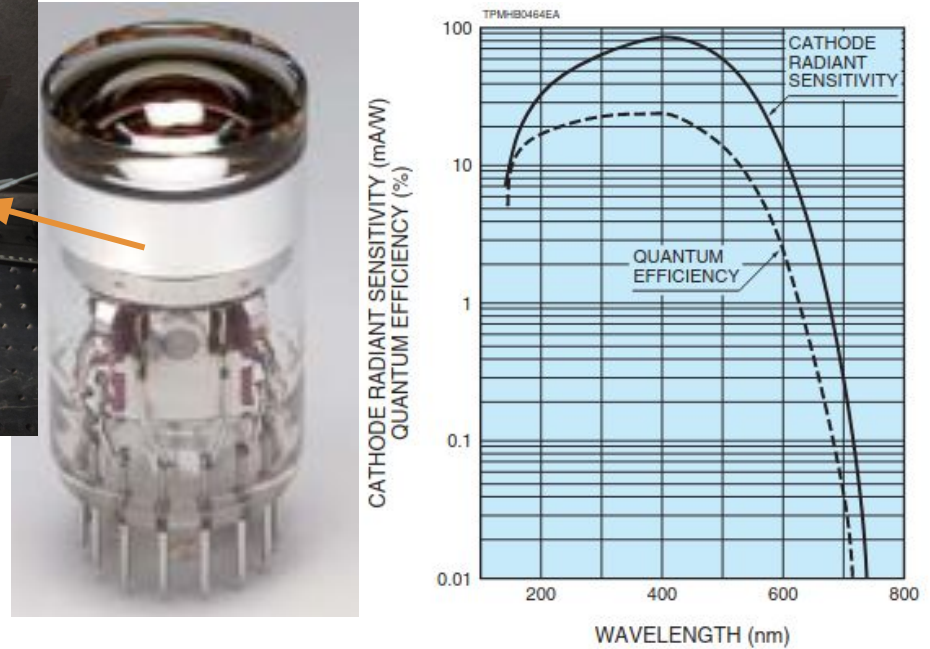
- Measurements in air with a tungsten-halogen lamp McPherson Model 621 of 100 W: spectral range from 300 nm onwards.
- Monochromator provides a wavelength range from 30 to 550 nm.
- Using both a photodiode and a PMT as a light readout device.

Setup: light collectors

Photodiode SM05PD7A from Thorlabs



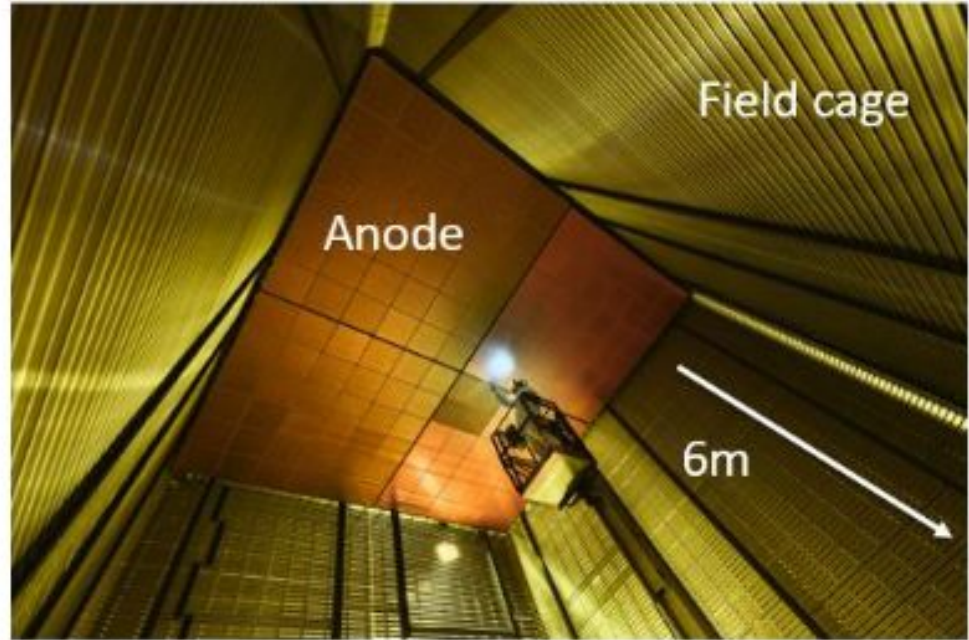
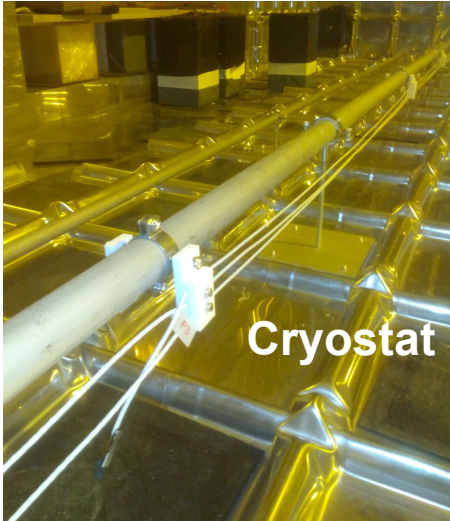
PMT R7378A from HAMAMATSU



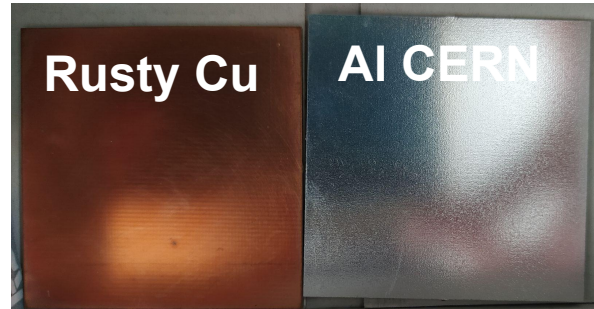
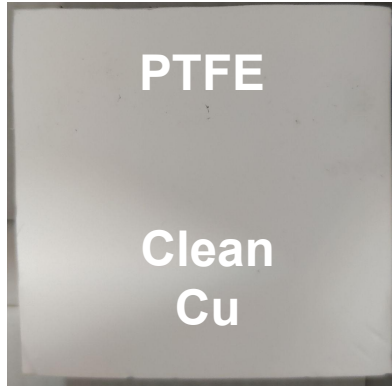
Photodiode spectral response range: 150-550 nm. PMT spectral response range: 160-650 nm.

Main components to be measured

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

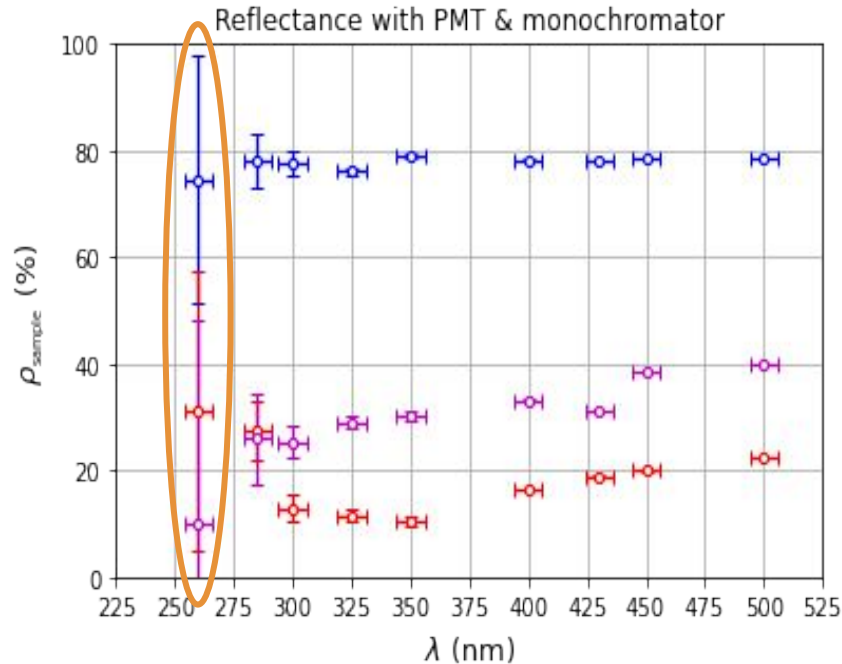


Setup: samples

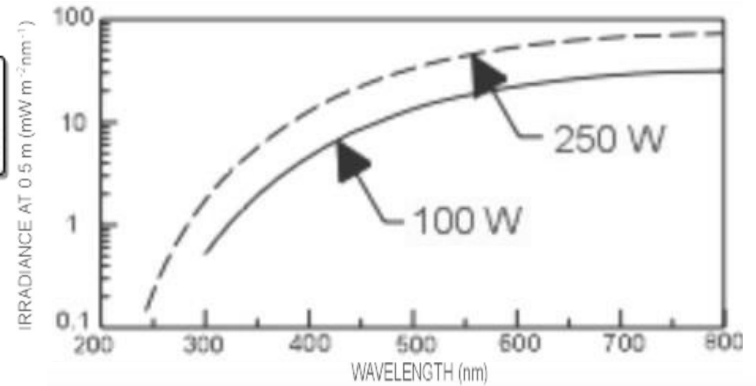


Results

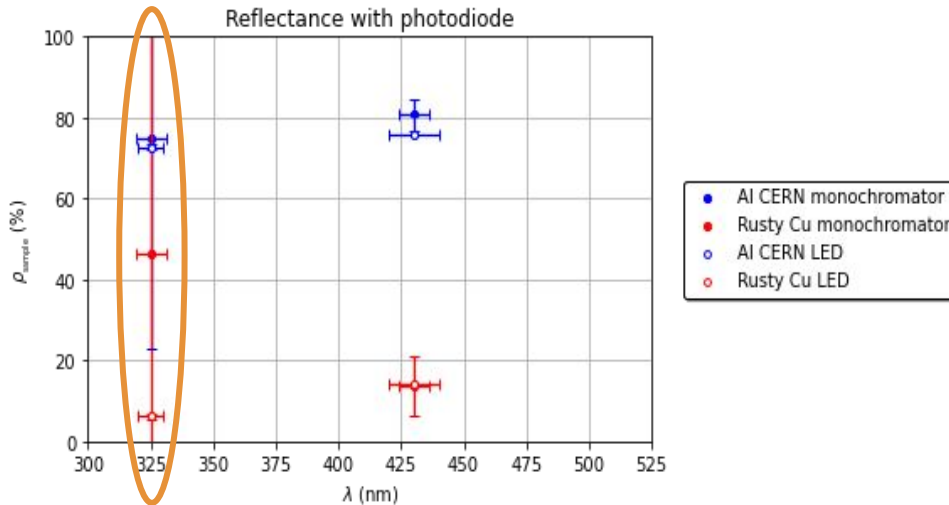
Sample reflectances with PMT



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

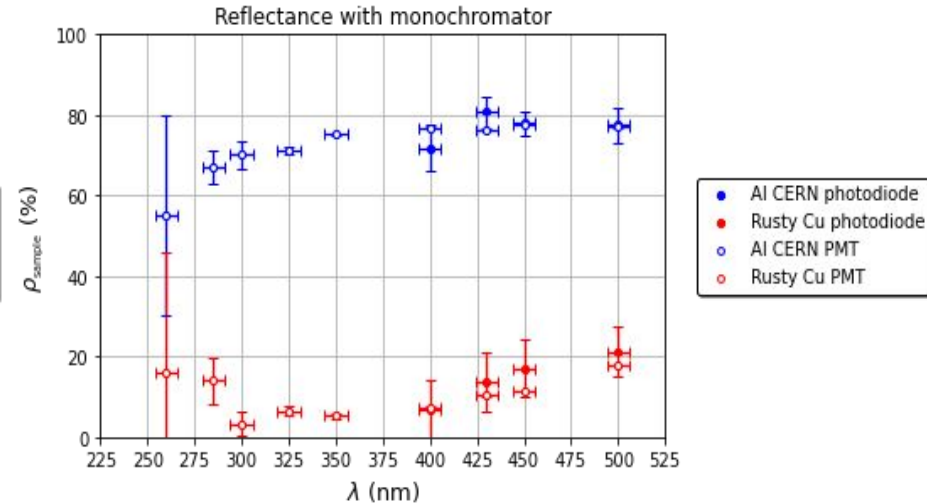


Light sources

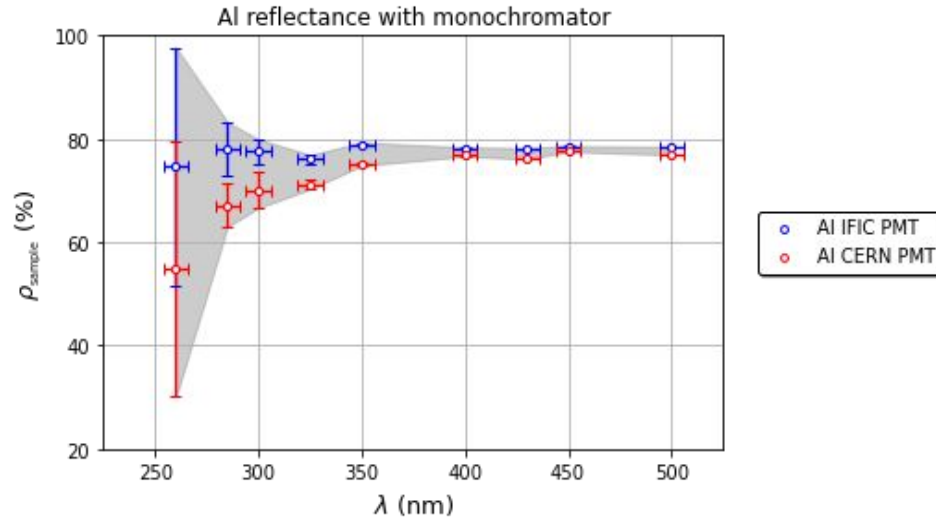


The low intensity of the lamp affects the accuracy at 325 nm with the photodiode.

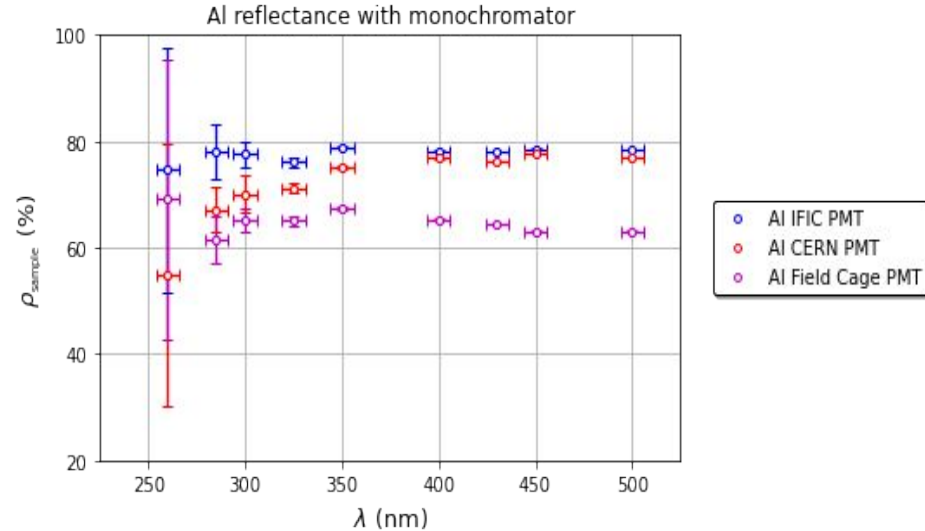
Light collectors



Al reflectances with PMT

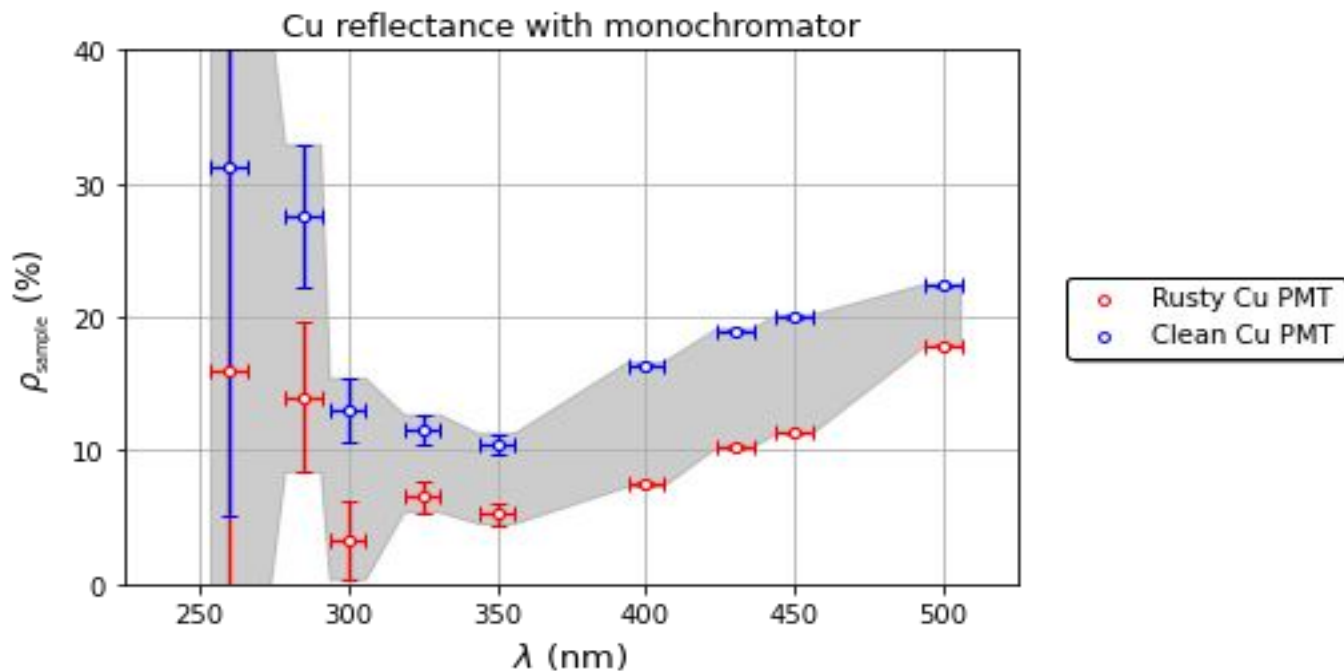


Reflectance above 60 % for an aluminium foil on a PCB.



The Al field cage profile is an old sample originated probably with a different production mechanism.

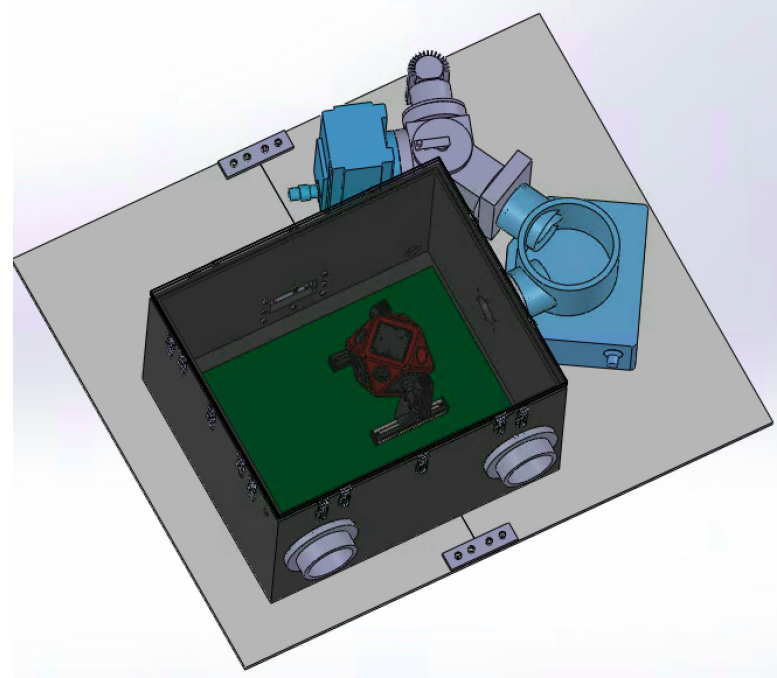
Cu reflectances with PMT



Future prospects

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 (to be delivered in the coming weeks).
- To find a PMT/MPPC(SiPM) sensitive to both LAr and LXe wavelengths.
- To be tested: the behaviour of the sphere (Teflon) at very low λ .
An alternative setup to measure reflectance is under study.



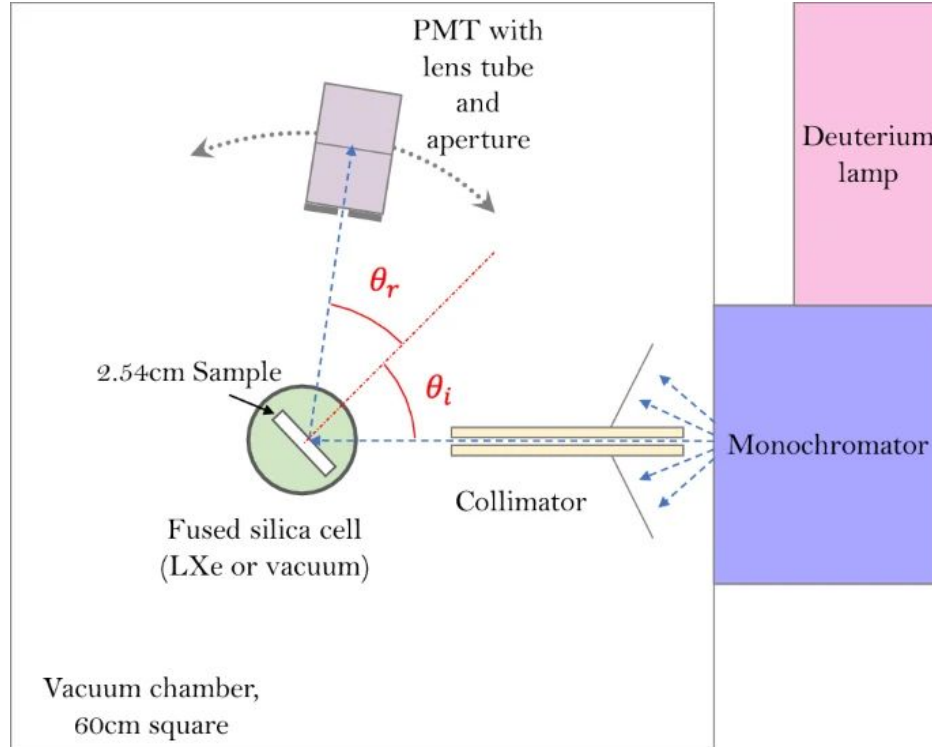
Conclusions

Conclusions

- With the new setups we may be able to provide the reflectance at 128 (Ar light) and 175 (Xe light) nm, both in vacuum and in LAr.
- To guarantee accurate reflectance values at the VUV for the different components of the FD2, we should measure samples from ProtoDUNE at CERN.

Backup

Future prospects: alternative setup



Kravitz, S., et al. (2020).
Measurements of angle-resolved reflectivity of PTFE in liquid xenon with IBEX. *The European Physical Journal C*, 80(3), 1-20.

- Specular reflection measurements for a full angle range.
- In case we can measure the total reflectance with the sphere, we could obtain the diffuse part:

$$R_{\text{tot}} = R_{\text{spec}} + R_{\text{diff.}}$$

Future prospects: alternative setup

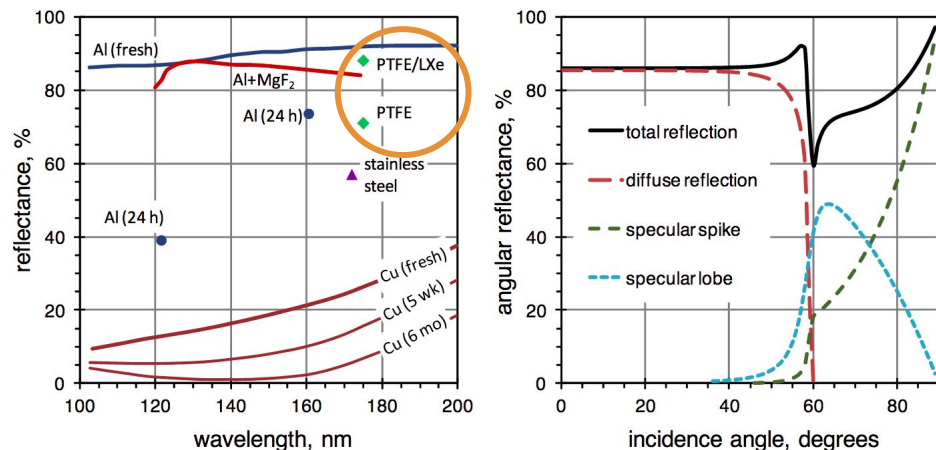
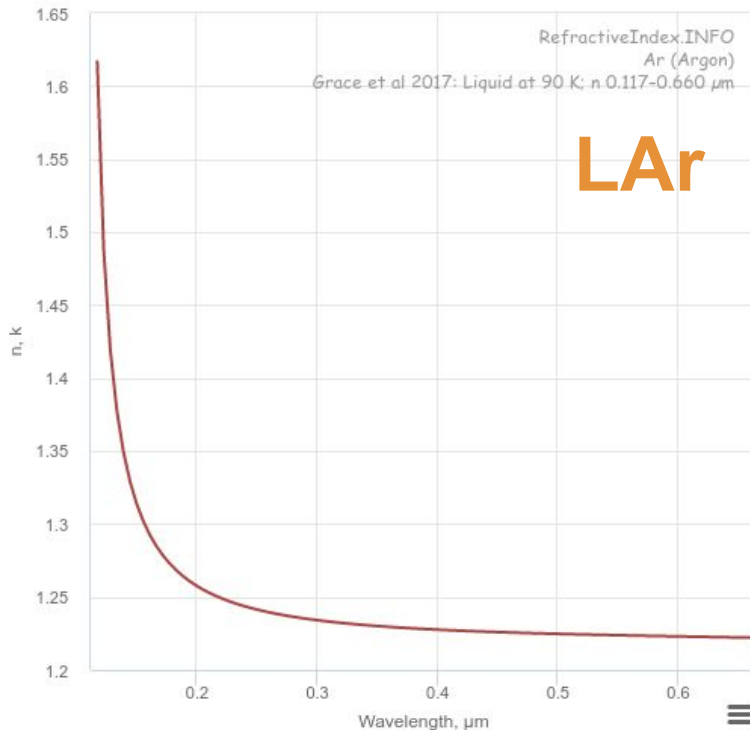


Figure 16. The VUV reflectance of some materials employed internally in noble liquid chambers is shown left. Data for Al [160] and Cu [161] are for freshly evaporated films and the ensuing degradation from build-up of the native oxides; a logarithmic decrease of reflectivity up to 3 years after Al evaporation was reported in [162]. Data for Al passivated with MgF₂ (both deposited by evaporation) is from [163]; a similar coating on a chemically-etched surface was used in the 80 kg LXe detector in [164]. Data for stainless steel is from [165]. Measurements with pressed, polished PTFE illuminated with Xe scintillation light in vacuum were reported in [166]; an angle-averaged value is indicated here. A model extrapolation for the angular reflectance of a PTFE/LXe interface is shown on the right ([167], courtesy C. Silva). The increase in specular reflection relative to the interface with vacuum increases the angle-averaged reflectance to approximately 90%. Some experimental measurements suggest even higher reflectivity for the PTFE/LXe interface [168, 169, 170].

Chepel, V., & Araújo, H. (2013). Liquid noble gas detectors for low energy particle physics. *Journal of Instrumentation*, 8(04), R04001.

- In LXe, PTFE reflectance increases.
- The reflectance mechanism is different in LXe than in vacuum.
 $n(\text{LXe}) > n(\text{PTFE}) \Rightarrow$ total internal reflection.
- Refractive index for LAr at 128 and 175 nm?

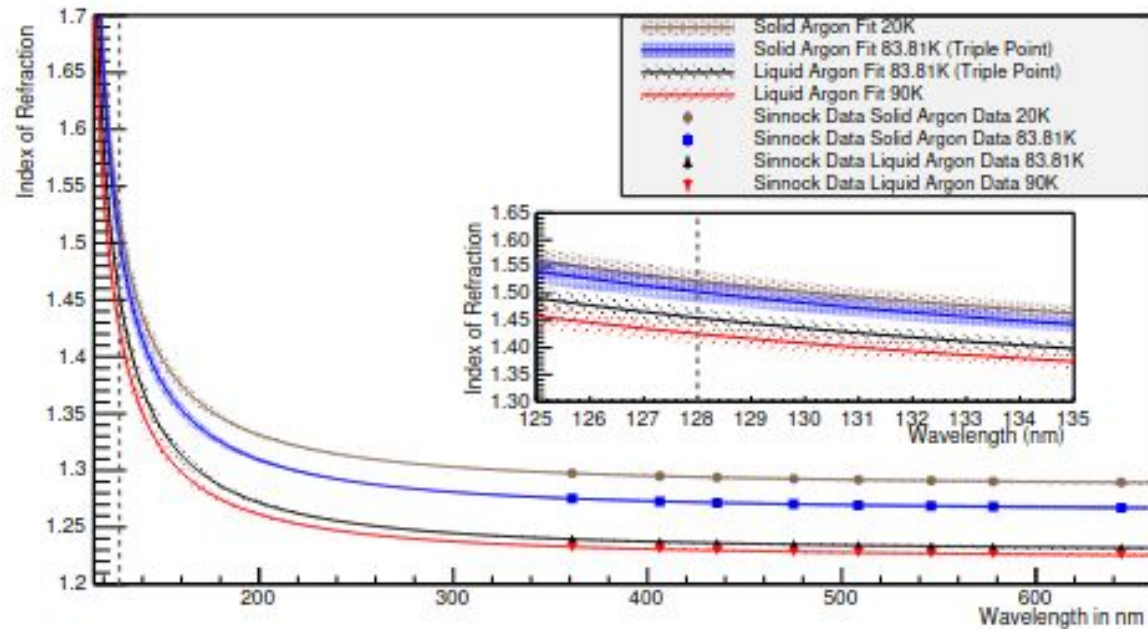
Future prospects: alternative setup with LAr



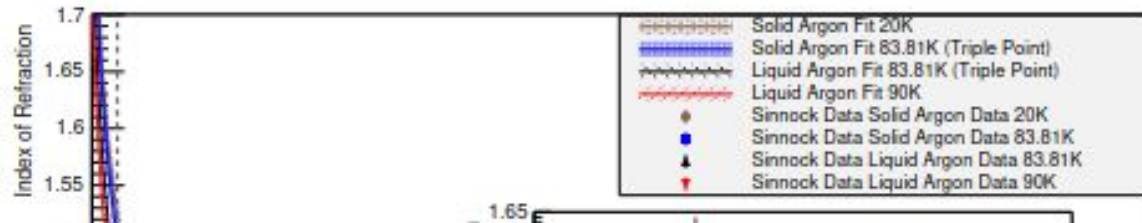
Grace, E., et al (2017). Index of refraction, Rayleigh scattering length, and Sellmeier coefficients in solid and liquid argon and xenon. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, 867, 204-208.

- Ar light: $n(128 \text{ nm}) = 1.4179$.
- Xe light: $n(175 \text{ nm}) = 1.2750$.

Backup

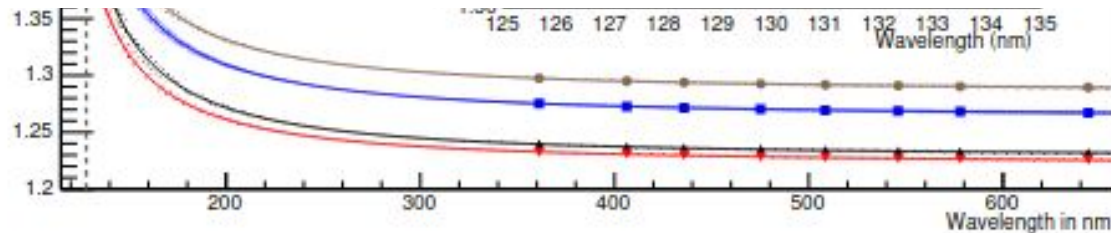


Backup

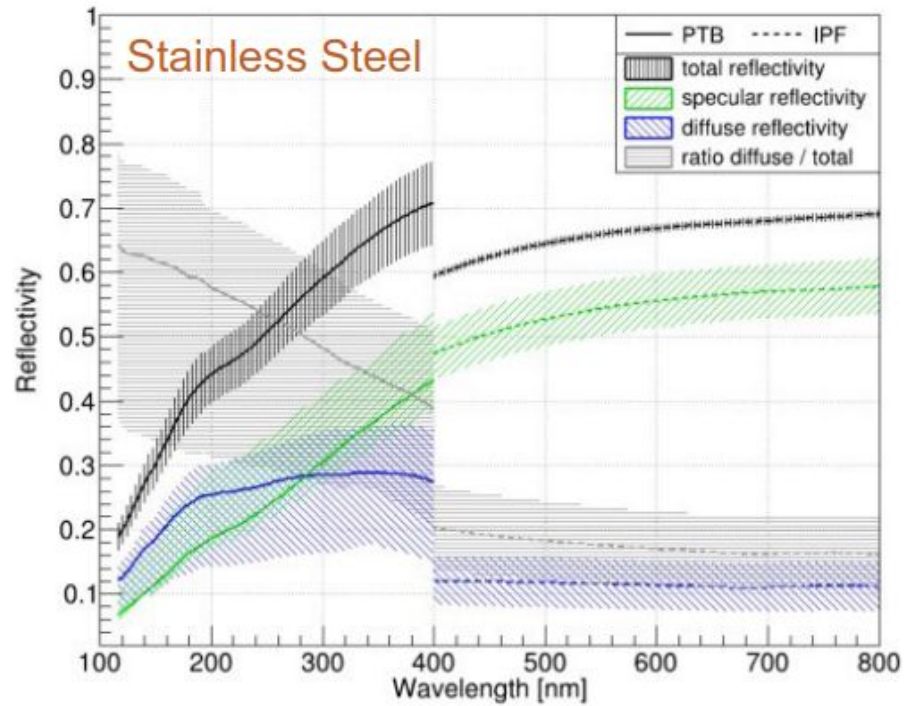


Dispersion formula

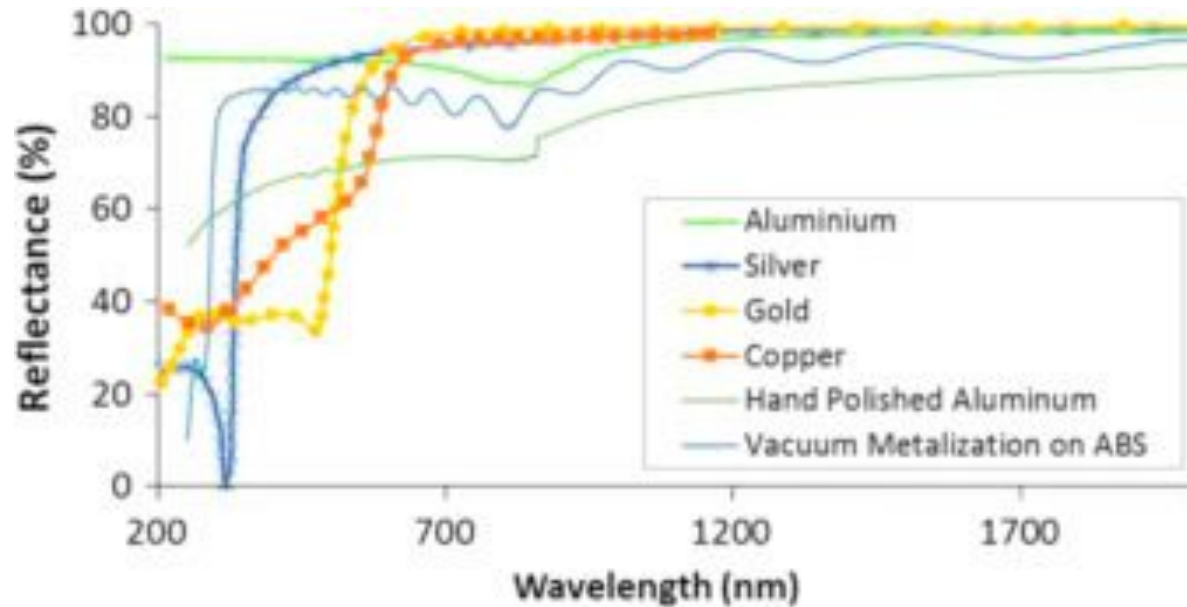
$$n^2 - 1 = 0.26 + \frac{0.23\lambda^2}{\lambda^2 - 0.1066^2} + \frac{0.0023\lambda^2}{\lambda^2 - 0.9083^2}$$



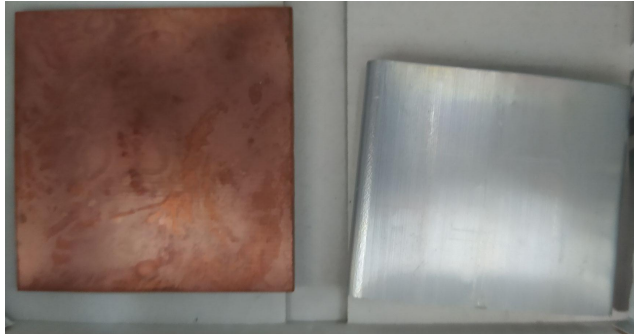
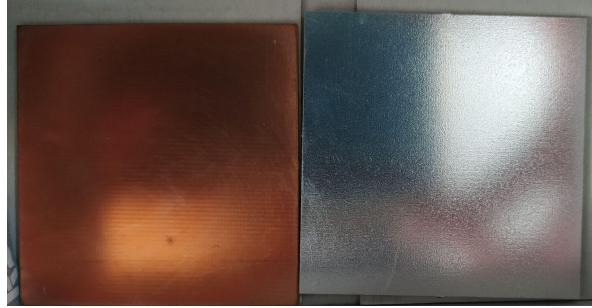
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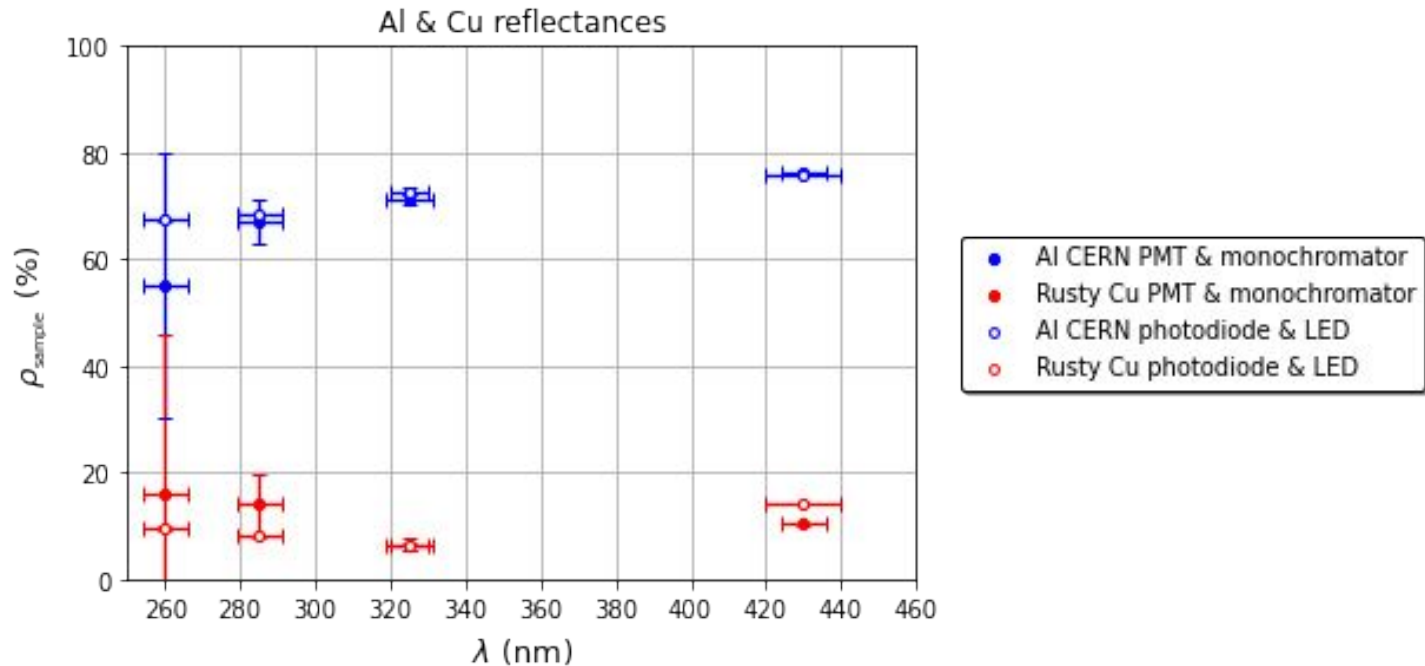
Backup



Backup



Reflectance measurements with different devices



Backup

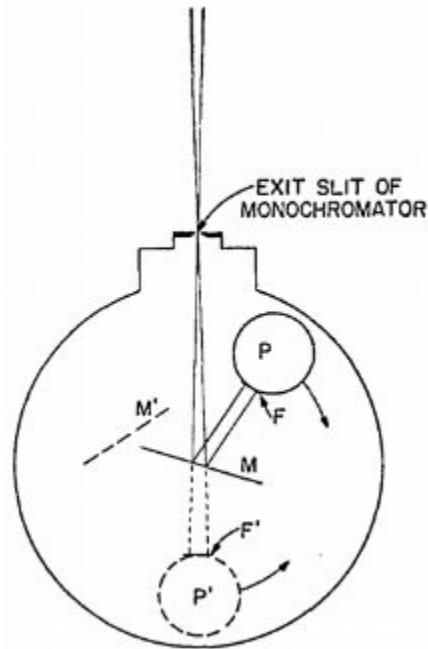


FIG. 2. The attachment to monochromator for reflectance measurements in the vacuum ultraviolet.

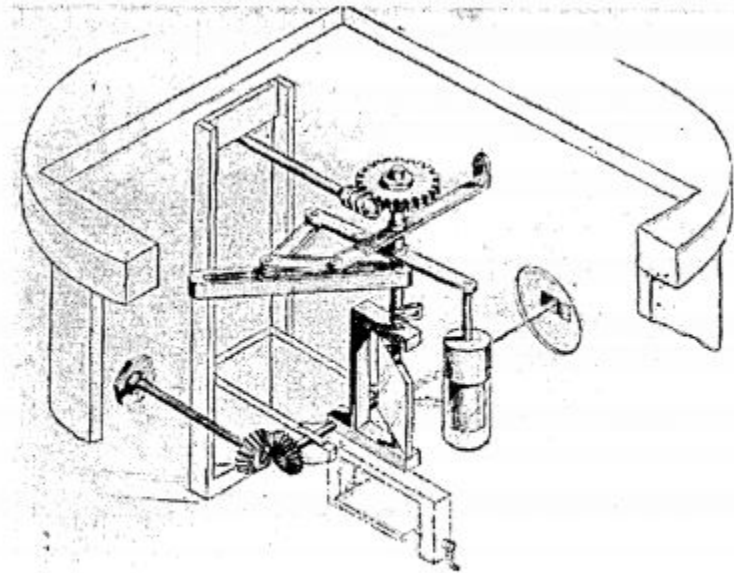


FIG. 3. Illustration of the operational principle of the mechanism which manipulates the sample substrate and provides the angle-doubling motion for the detector.

Pending tasks

Setup discussion

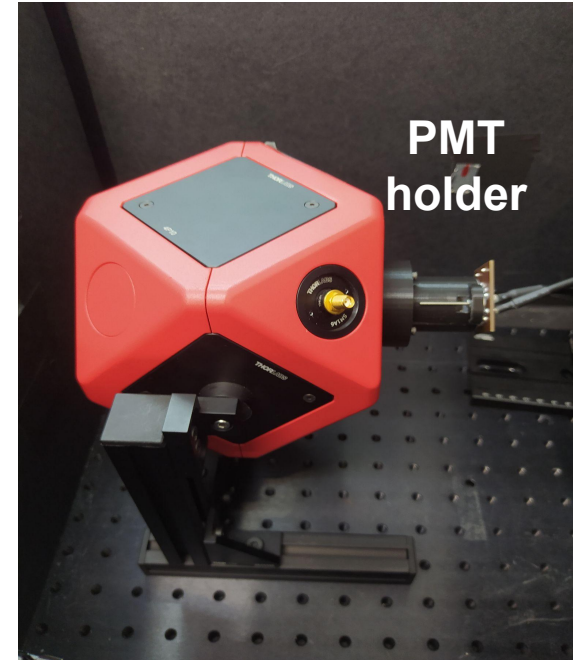
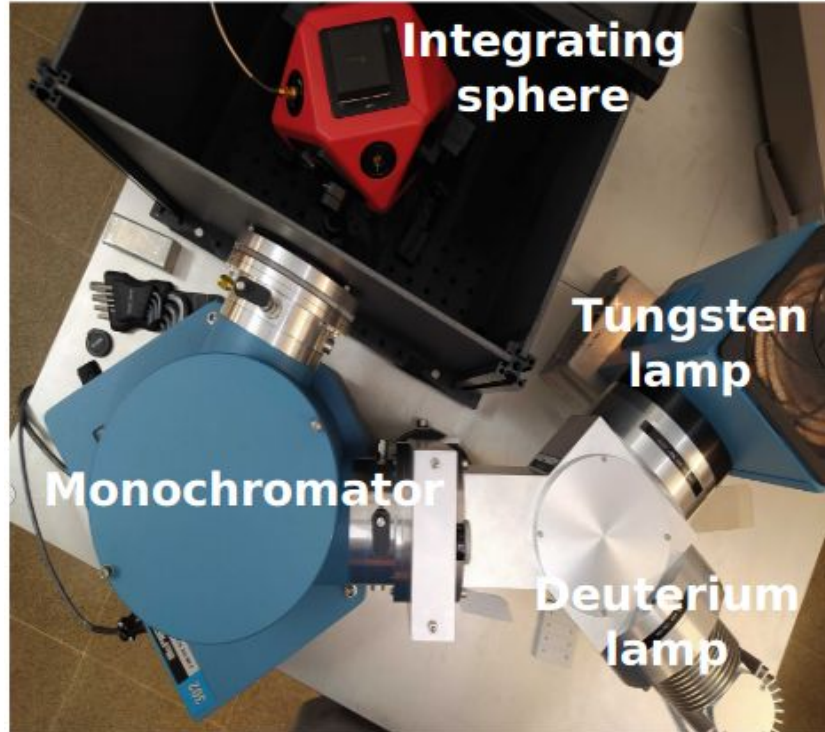
- Add here our design to perform (specular) reflectance measurements with the PMT, monochromator and the vacuum chamber.
- We could use one stepping motor to turn both the sample and the PMT by means of gears and belts. They will permit us to rotate the PMT around the sample at double speed.
- In addition, in case we can measure the total reflectance by using the integrating sphere, we could subtract the specular component to obtain the diffuse one. That is, quantify the two sorts of reflectances of a given sample.

We assume $R_{\text{tot}} = R_{\text{spec}} + R_{\text{diff}}$.

Pending tasks

- Ask Jorge for a new Cu sample. 
- Ask maintenance service for a stainless steel sample. 
- Measure specular reflections at 45° for all samples at the visible region.
Compare with tabulated data if possible.
- Figure out how to measure at 8° with the integrating sphere.
Problem: PMT position. We don't have any holder for it on the double port side.
Possible solution: just hold the PMT outside with the holder used for dichroic filter measurements and introduce a bit the PMT window in the sphere.
Reminder: pressure on the PMT must be made uniformly.

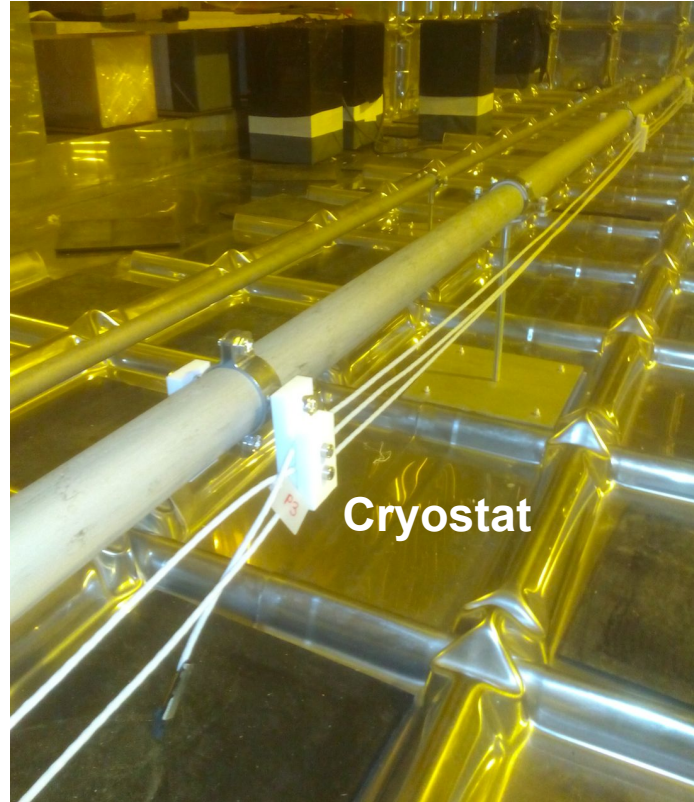
Setup



PMT coupled on the bottom port of the integrating sphere.

Setup: samples

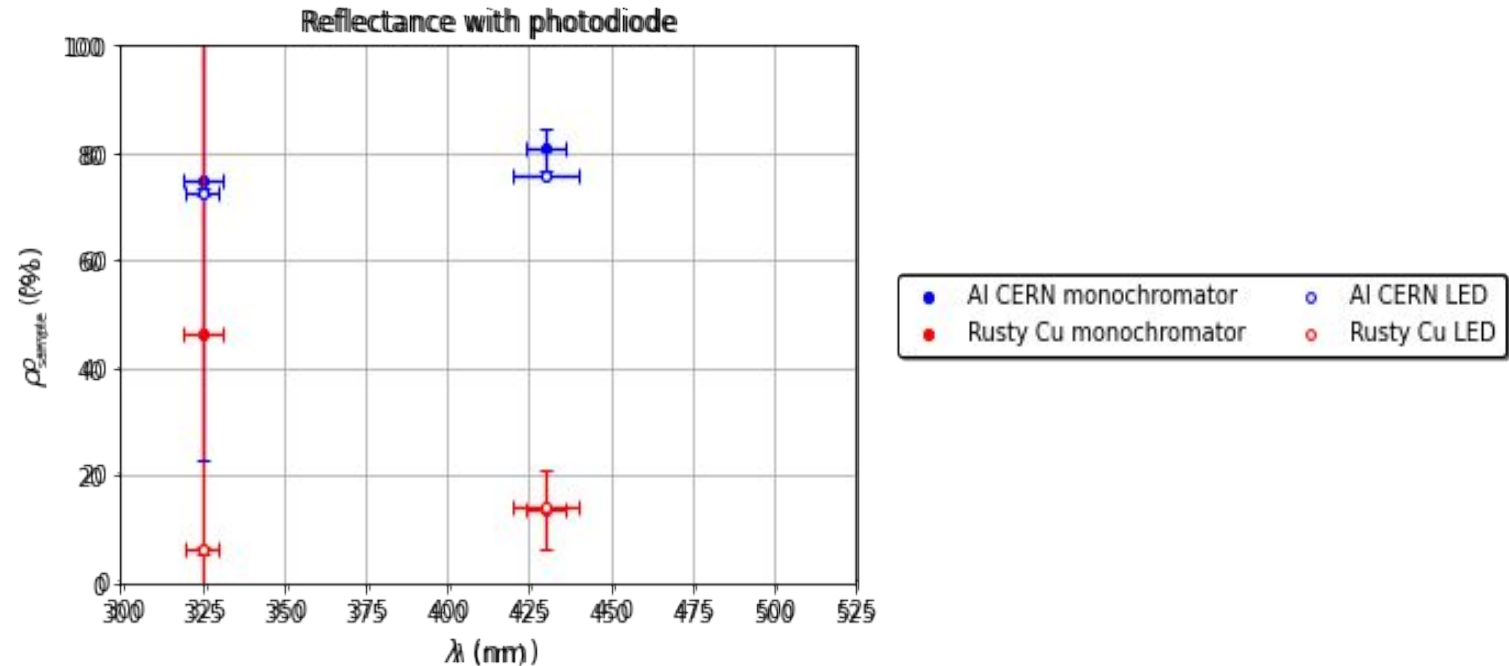
- Anode of **copper**.
- Field cage of **aluminium**.
- Cryostat of **stainless steel**.



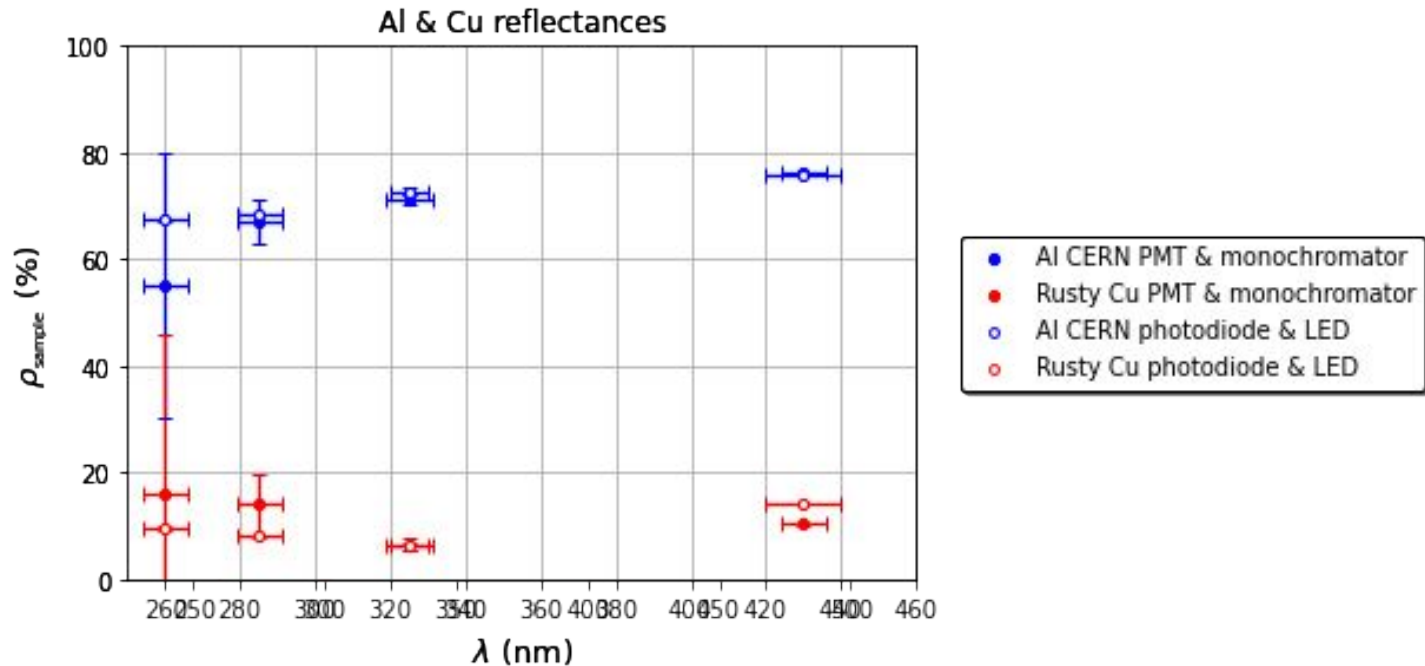
Results

- Cuando muestre las medidas añadir, si corresponde, algunos comentarios.
E.g.: aclarar el porqué de las incertidumbres tan grandes con los fotodetectores al final del rango.
- Añadir doubles flechas de colores para delimitar el UV (por debajo de 400 nm) y el visible (por encima de 400 nm).
- Añadir una diapo de backup con los parámetros de reflectividad introducidos en la simulación.

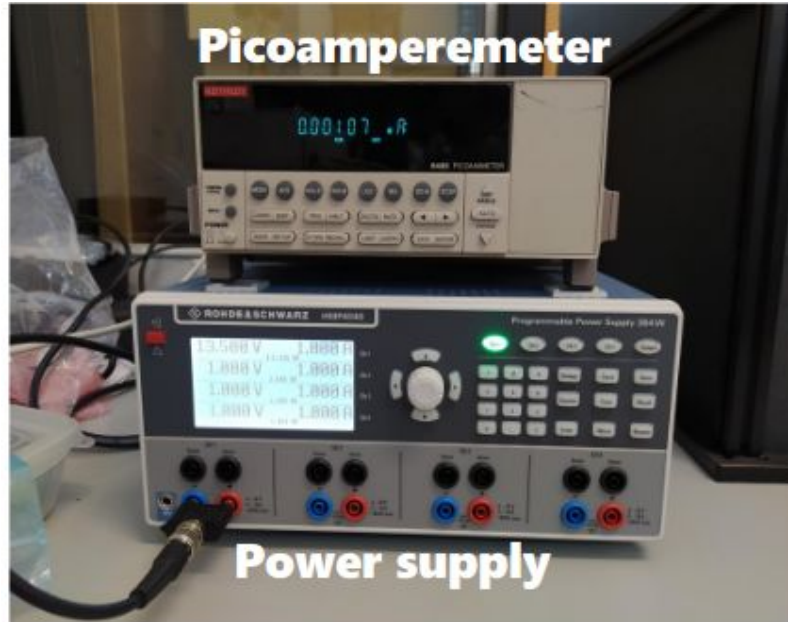
Reflectance measurements with photodiode



Reflectance measurements with PMT



Setup: former setup with a LED source



Source:

- LED
- Tungsten lamp

Reflectances with PMT & photodiode

