Impact of p-Terphenyl Surface Density on the Efficiency of Filters

Pagliuso; L.L.[1,*], Mendonça; A.P.A.[1], Santos;R.F.[1], Machado;A.A.[1], Segreto;E.[1]
[1] *Universidade Estadual de Campinas*
**luccalp@ifi.unicamp.br*

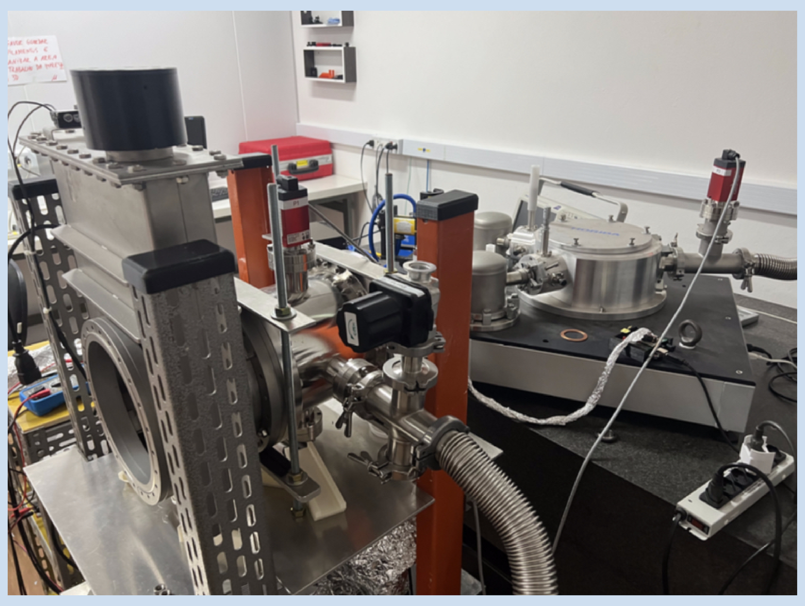
Introduction

- **DUNE Experiment**: The Deep Underground Neutrino Experiment (DUNE), led by the Fermi National Accelerator Laboratory (Fermilab), relies on an advanced photon detection system (PDS). This system is crucial for capturing the argon scintillation light (128 nm) which is produced during neutrino interactions in liquid argon.
- **X-ARAPUCA Role**: The X-ARAPUCA optoelectronic device plays a pivotal role in the PDS. It uses a P-Terphenyl (PTP) coated dichroic filter to shift the photon's wavelength, allowing entry. A light guide then shifts the wavelength again and direct it to eight Silicon Photomultipliers (SiPMs), which will generate an analog electrical current proportional to the number of photons detected.
- **Optimization Motivation**: Maximizing the detection efficiency of X-ARAPUCA is vital. This efficiency is heavily linked to the performance of the dichroic filter with evaporated PTP. Therefore, optimizing the evaporation process and substrate adhesion is essential for enhancing the device's overall performance.

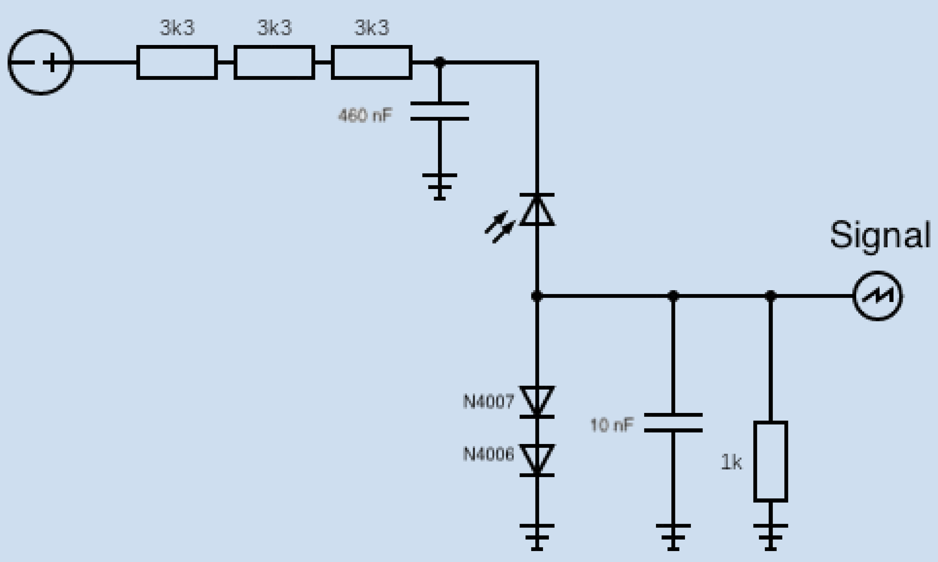
Optoelectronic Setup

The optoelectronic setup comprises three main components:

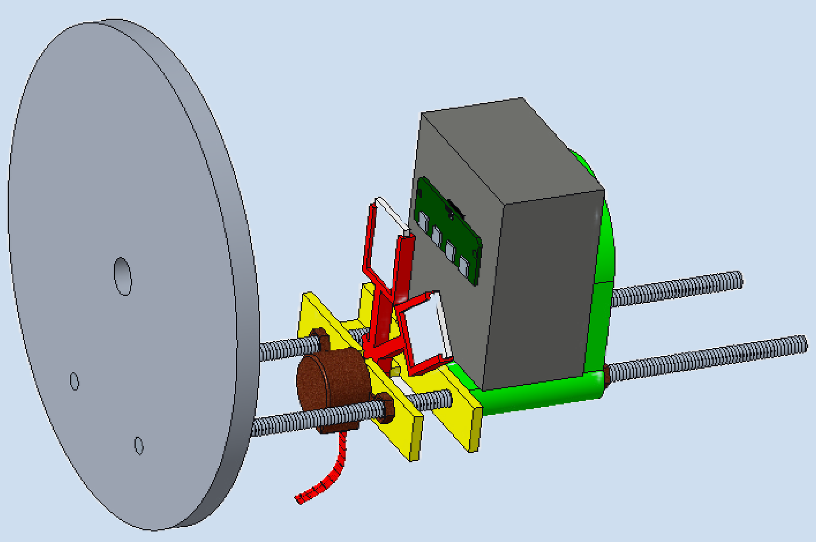
1. Horiba Scientific Vacuum Monochromator with a Hamamatsu VUV Lamp serving as the light source. Primary and secondary vacuum systems to reduce light absorption below 180 nm.



2. Light detection system using a Hamamatsu Silicon Photomultiplier (SiPM) connected to an electronic circuit that is grounded to attenuate noise, powered by the APSAIA device.



3. A mechanical structure designed to hold two filters, a reference (TPB) at 0 degrees and the sample at 50 degree. This structure is connected to a step motor, allowing control within the vacuum environment, enabling switching between both filters.



Coating Process and Surface Density Measurement

- PTP films were deposited on OPTO dichroic filters using vacuum evaporation, with varying densities achieved by strategically positioning the filters within the chamber. Surface density measurements were conducted by pre- and post-deposition weighing of the filters.

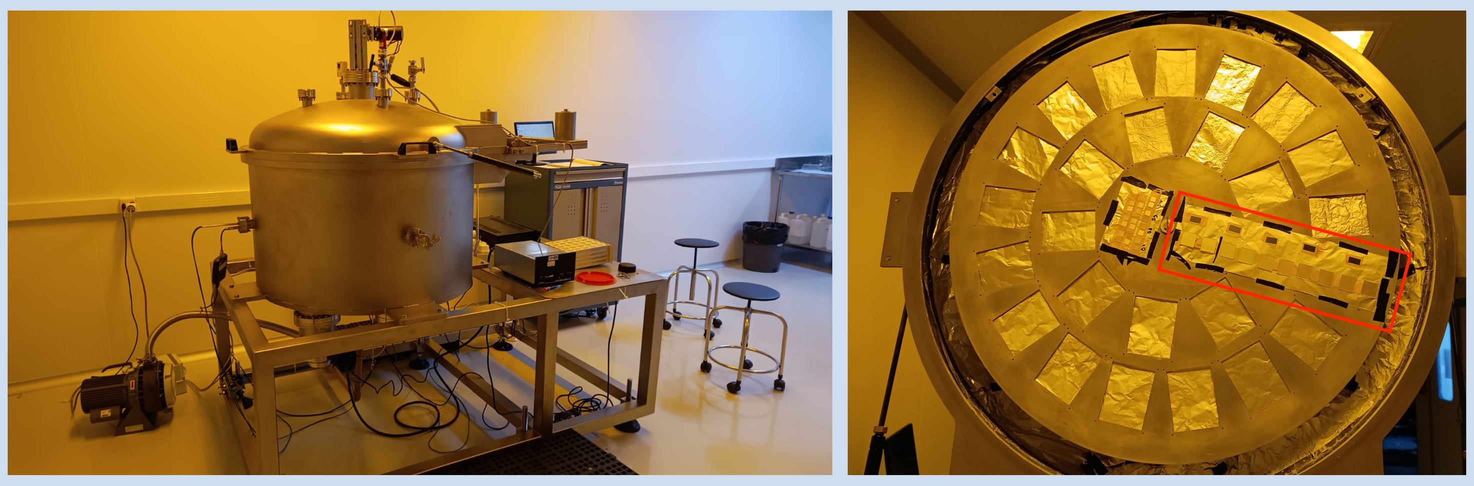


Figure 1: *Left:* Evaporation chamber using the vacuum evaporation method. *Right:* Filter distribution around the radius for surface density control.

Efficiency Definition

Efficiency "x_i" was calculated using chi-squared minimization, comparing the sample filter's signal amplitude squared distance to the reference. "σ^2" is the uncertainty contribution.

$$F(x)_i = \frac{(AMP_{PTP,i} - x_i \cdot AMP_{REF,i})^2}{\sigma^2} \quad (1)$$

Results

Filter	PTP Density $[10^{-4}\frac{g}{cm^2}]$	x_i	Filter	PTP Density $[10^{-4}\frac{g}{cm^2}]$	x_i
S1	(3.88 ± 0.02)	(0.94 ± 0.01)	S6	(3.40 ± 0.02)	(0.81 ± 0.01)
S2*	(4.79 ± 0.02)	(0.54 ± 0.01)	S7	(3.22 ± 0.02)	(0.71 ± 0.01)
S3	(4.77 ± 0.02)	(0.84 ± 0.01)	S8	(2.68 ± 0.02)	(0.74 ± 0.01)
S4	(4.67 ± 0.02)	(0.78 ± 0.01)	S9	(1.44 ± 0.02)	(0.69 ± 0.01)
S5	(3.38 ± 0.02)	(0.90 ± 0.01)	S10	(1.67 ± 0.02)	(0.69 ± 0.01)

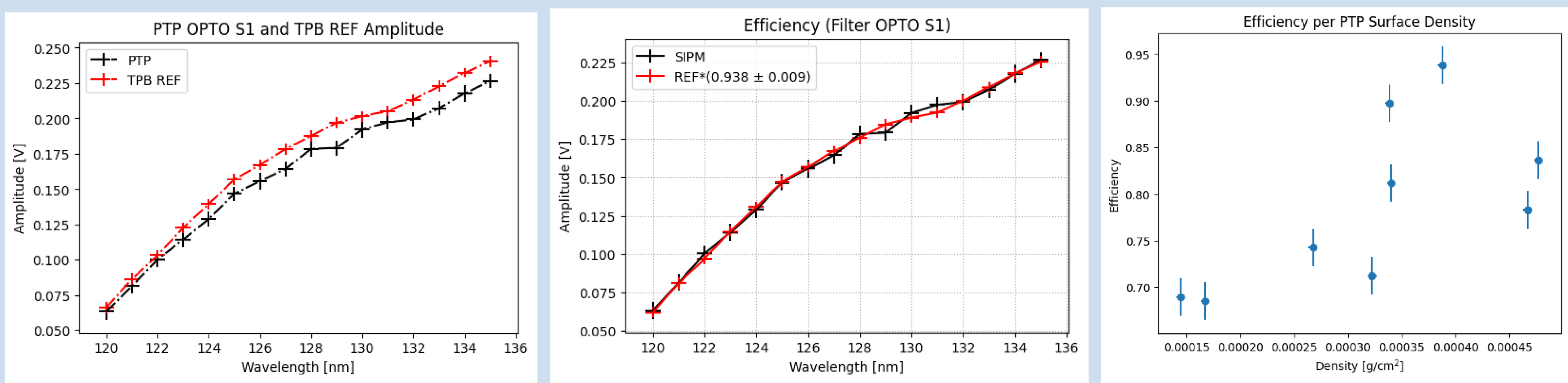


Figure 2: *Left*: Amplitude comparison of reference and S1 filter (120-135 nm) near liquid argon scintillation (128 nm). *Center*: Fit using Eq. 1. *Right*: Efficiency vs. surface density.

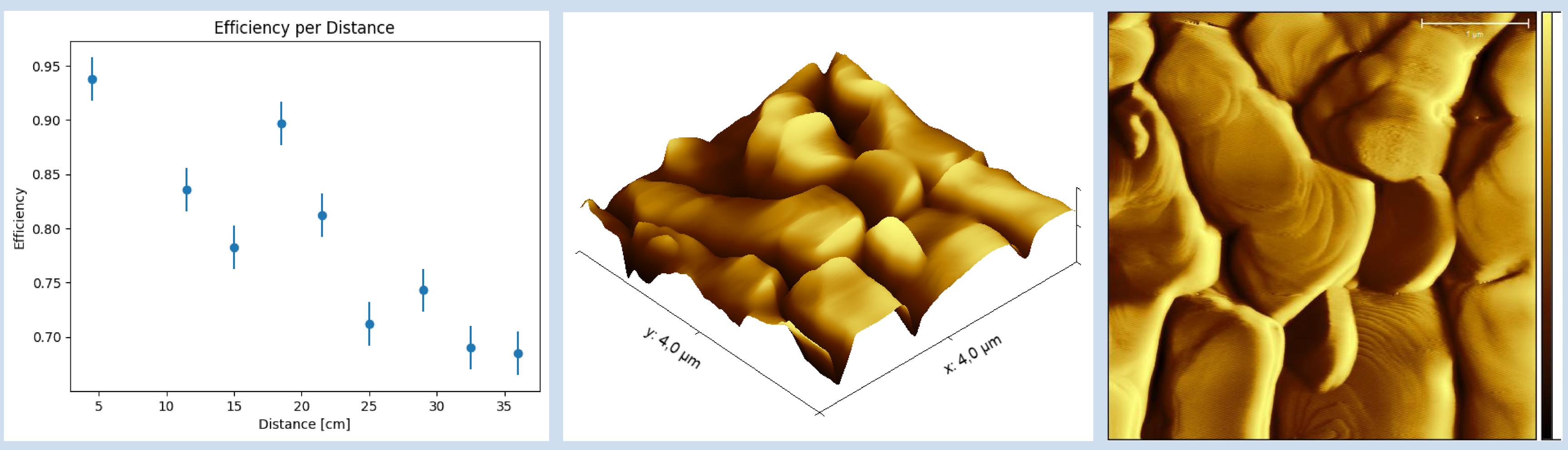


Figure 3: *Left*: Efficiency vs. Distance to disk center. *Center*: Surface 3D Reconstruction by AFM analysis. *Right*: Multilayer profile by AFM analysis.

Final Remarks

- **Conclusion**: Efficiency appeared to increase with the amount of PTP deposited on the surface. Filters closer to the center of the disk, and also to the PTP shutter, received a higher amount of deposited material, which tends to enhance efficiency. AFM measurements showed PTP layers with $> 2\ \mu m$ grains and stacked monolayers.
- **Next steps**: The uneven area of the filters after cutting made it difficult to correlate surface density with the amount of deposited material. For future tests, better control over the sample area is necessary. Additionally, morphological analysis of the filters using profilometry, AFM, and XRD could provide further insights into other factors influencing the system.

Acknowledgements

This work was supported by the São Paulo Research Foundation (FAPESP) through the scientific initiation scholarship number 2023/05143-6, the thematic grant number 2021/13757-9, and a postdoctoral fellowship 2023/01367-7.