# Noble-gas liquid detectors: measurement of light diffusion and reflectivity on commonly adopted inner surface materials

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Noble-gas liquids, such as xenon and argon, have been recently proposed as Vacuum Ultra Violet (VUV) light scintillators in some experiments dedicated to neutrino physics and dark matter research. Fundamental parameters for the photon detection are the diffusion coefficient and the reflectivity of the materials that surround the active volume of the apparatus.
We carried out a investigation on the most commonly used materials at the scintillation wavelength $\lambda \sim 172$ nm (close to the liquid xenon wavelength). The measurement has been performed at various incident angles by means of a collimated VUV source. The experimental set-up and the results obtained at room temperature with stainless steel, aluminum, peek and teflon targets are presented.

## 1. Introduction

Noble-gas liquids, such as xenon and argon, have been recently proposed as VUV light scintillators in some experiments dedicated to neutrino physics [1] and dark matter research [2]. The prompt ($o(\mu s)$) photon emission is useful as it provides an absolute measurement and a trigger for ionising events occurring in detectors filled with noble-gas liquids.
Materials which compose the detector inner surfaces can diffuse the VUV scintillation light, so that the study of the optical properties of such materials in this spectrum is fundamental to provide inputs for Montecarlo simulations of scintillation light. In this work, the optical properties of four commonly adopted inner surface materials exposed to a VUV light of known intensity with emission peak at $\lambda \sim 172$ nm have been investigated: stainless steel and aluminum, which are adopted for detector structure, and peek and teflon, which are common insulators.

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## 2. Experimental set-up

The experimental set-up was prepared in order to measure the light diffused by the analysed sample at several angles along a diffusion plane. The light hitting the sample consisted of a monochromatic VUV light beam, while a photomultiplier tube (PMT) allowed to collect the light. All the instrumentation described below was inserted inside a vacuum chamber supplied with gauge sensors for vacuum level measurement. The vacuum was provided by a Pfeiffer pump. Chamber inner walls were coated with black paper in order to avoid light back reflection.

- The **source** was a Hamamatsu L7293 deuterium lamp, long nose type put inside a vacuum chamber, with $MgF_2$ window and emission range (115-400) nm. A monochromatic filter allowed to select a wavelength $\lambda \sim 172$ nm (FWHM 24 nm). A lens and a collimator were used to focus the beam, whose spot diameter was $\phi \simeq 8$ mm.
- The **sample** to be studied was placed on a frame in the centre of the vacuum chamber. The mechanical support of the sample was verified to be exactly perpendicular to

the plane where the detector lied. All measurements were performed with the sample placed at 45° with respect to the incident beam.

- The **light detector** was a Hamamatsu R7311 PMT, with a $MgF_2$ window and a photocathode of Cs-Te which provided a Quantum Efficiency of 35% at 172 nm. The detector window active area had a surface of 4 x 5 $mm^2$. The PMT was placed on an external stepping motor that allowed to collect the light at several angles along the plane of the diffused light (see Fig. 1).

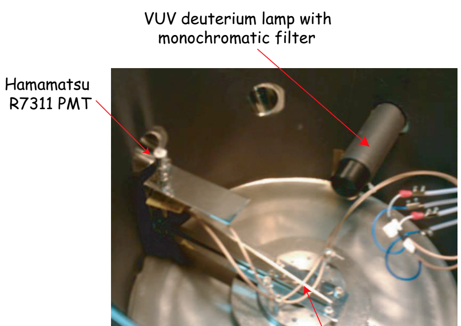


Figure 1. Measurement apparatus inside the vacuum chamber.

## 3. Results

Measurement output was the current $J$ extracted from the PMT in the several positions along the plane of displacement of the PMT itself. From the current $J$ and the PMT QE ($\sim$ 0.35), the number of photons collected per second can be determined as:

$$N_\gamma = \frac{J}{1.6 \times 10^{-19} \cdot QE} \quad (1)$$

A preliminary measurement with a mirror of known reflectivity $R_{mir} = 0.76$ placed on the frame at the center of the chamber allowed the evaluation of the total number of photons emitted per second by the lamp at angle $\theta$:

$$N_{\gamma,lamp}(\theta) = \frac{J(\theta)}{1.6 \times 10^{-19} \cdot QE} \cdot \frac{1}{R_{mir}} \quad (2)$$

By integrating over all solid angle, the total number of photons emitted per second by the lamp was evaluated as: $N_{tot} = 2.4 \times 10^{10}$ ph/s. In the following, the results concerning the four materials are resumed:

1. **Stainless steel** presents a roughly all-reflective behaviour (Fig. 2), though the reflection is not spot-like, but has a diffusive behaviour, with an opening angle $\sim 4°$ (FWHM). The integration over the solid angle gives the total number of photons diffused by the steel: $N_{tot} = 1.37 \times 10^{10}$ ph/s, that is about the 57% of the light emitted by the lamp.

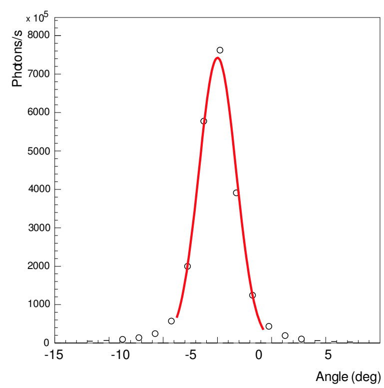


Figure 2. Number of photons per seconds collected by the PMT as a function of the angle of measurement (stainless steel).

2. **Aluminum** presents both reflective and diffusive behaviour (Fig. 3); the two contributions were disentangled after a gaussian fit of the two components, so that it was possible to measure the opening angle of the diffusive reflection ($\sim 26°$ - FWHM). The integration over the solid angle gives the number of photons per second, both for

| | Reflective component | | Diffusive component | | Emitted light | Absorbed light |
|---|---|---|---|---|---|---|
| | Emitted light | FWHM | Emitted light | FWHM | | |
| Stainless steel | 57% | 4° | - | - | 57% | 43% |
| Aluminum | 14% | 26° | 56% | 58° | 70% | 30% |
| Peek | 31% | 28° | 36% | 37° | 67% | 33% |
| Teflon | - | 30° | - | - | - | - |

Table 1
Summary of the results obtained for the samples analyzed.

the reflective and the diffusive components, as well as the total number oh photons diffused: $N_{ref} = 0.33 \times 10^{10}$ ph/s; $N_{dif} = 1.35 \times 10^{10}$ ph/s. $N_{tot} = 1.68 \times 10^{10}$ ph/s, that is about the 70% of the light emitted by the lamp.

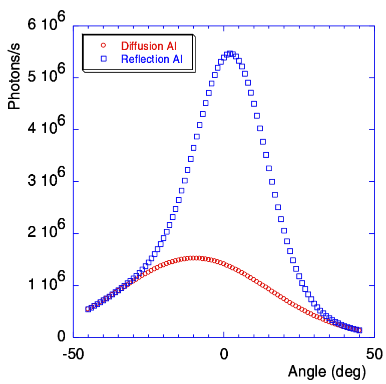


Figure 3. Number of photons per seconds collected by the PMT as a function of the angle of measurement (aluminum). Both reflective and diffusive components are present.

3. **Peek** also presents both reflective and diffusive behaviour; again, the two contributions were disentangled, and the opening angle of the diffusive reflection was evaluated to be $\sim 28°$ (FWHM). The integration over the solid angle gives: $N_{ref} = 0.75 \times 10^{10}$ ph/s; $N_{dif} = 0.85 \times 10^{10}$ ph/s. $N_{tot} = 1.60 \times 10^{10}$ ph/s, that is about the 67% of the light emitted by the lamp.

4. **Teflon** again presents both reflective and diffusive behaviour, but the diffusion now dominates; it is present a strong asymmetry in the PMT response going from -45° to +45°, probably due to the shadow from the support of the sample; the two contributions could not have been disentangled, so that it was possible just to estimate the opening angle of the diffusive reflection ($\sim$ 30° - FWHM).

Obtained results are resumed in Tab. 1, also in term of emitted and absorbed light by each sample.

## 4. Future measurements

These measurements allowed to evaluate the optical properties of some materials which are commonly adopted for the inner surfaces of cryogenic detectors. All work was carried out at the wavelength $\lambda \sim 172$ nm only (close to liquid xenon wavelength) and at room temperature. In order to complete the work, new measurements will be carried out at $\lambda = 128$ nm (liquid argon wavelength) and at other wavelengths, by using a vacuum monochromator. Also, different angles of incidence of the beam other than 45° will be used and, finally, measurements will be carried out at cryogenic temperatures, by mounting the sample on a cold finger.

## REFERENCES

1. S. Amerio et al., Nucl. Instrum. Meth. A527 (2004), 329.
2. R. Brunetti et al., New Astron. Rev. 49 (2005), 265.