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# Optical Properties of TetraPhenylButadiene as wavelength shifter for the detection of VUV scintillation light from liquefied noble gases

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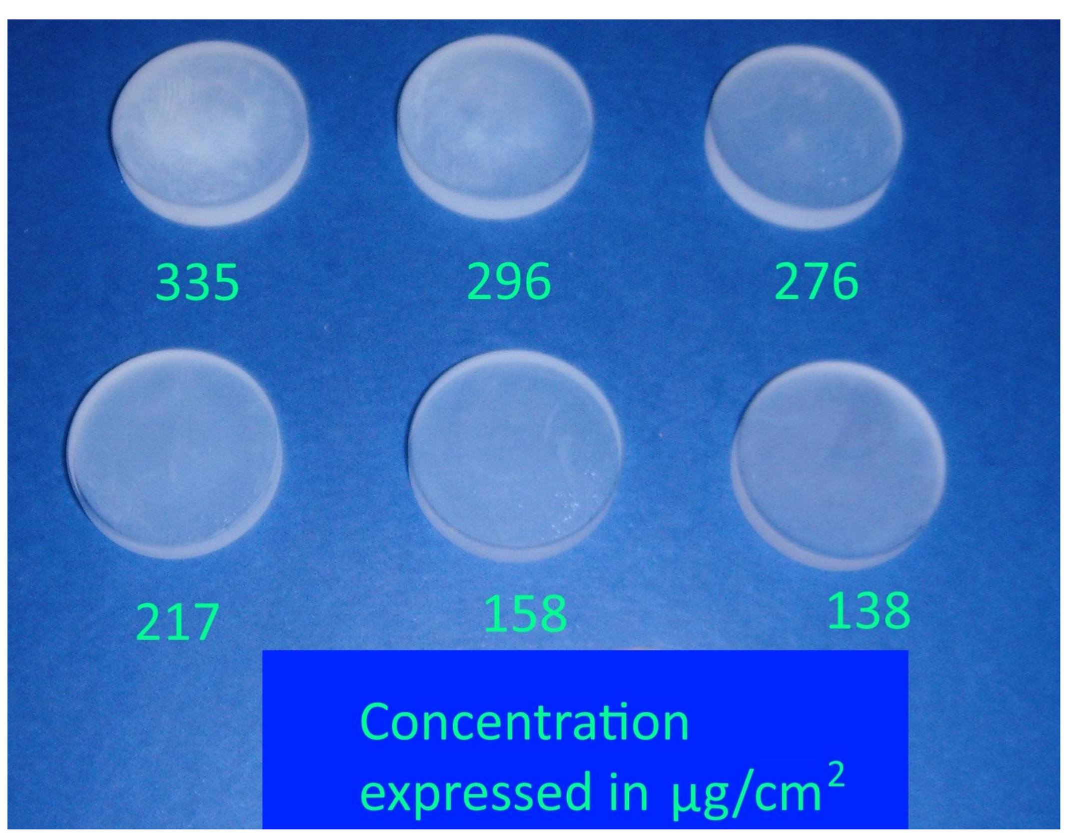
## Introduction

A number of innovative experiments dedicated to neutrino and rare-events physics are using liquefied noble-gases both as target and detector. These media have the remarkable property to efficiently produce scintillation photons after the passage of ionizing particles. Scintillation light, which is used for trigger and timing purposes, is emitted in the Vacuum UltraViolet region. The detection of these wavelengths is very difficult considering that most materials are not transparent and absorbs VUV radiation. A solution comes from depositing a wavelength shifter (WLS) on the standard window. TetraPhenylButadiene (TPB) is the most common wavelength shifter used in liquefied noble gases experiments, due to its extremely high efficiency to convert VUV light in visible photons. The conversion can occur directly on the sensitive surface of photon detectors or on the wall of the experimental apparatus, in both cases coated with TPB. This technique is adopted either by neutrino experiments or by detectors looking for Dark Matter. Considering that converted light is isotropic emitted, visible photons might be reflected or diffused by other TPB coated surfaces before being absorbed or detected. For this reason a careful study of transparency, diffusion and reflection properties of TPB at its emission wavelength was carried on and presented as function of the thickness of the TPB surface. By means of an evaporation system, various coatings were realized on standard glass disks following the procedure used for PMT deposition of the ICARUS experiment. Measurements were carried out using a laser source at TPB peak emission wavelength. Laser was directed to the glasses and the intensity of transmitted and diffused light was measured as a function of different angles in the space.

## TPB Coating

We decided to realize standard TPB coatings on 1” optical glasses. The coating has been performed by means of a vacuum evaporation chamber already used at CERN to coat the Photomultiplier tubes of the ICARUS experiment.




In the evaporation system, the glasses to be coated are placed upside, while TPB is inserted in a Knudsen cell in the lower part of the chamber. Evaporation will be carried out at 220ºC at a pressure of some $10^{-6}$ mbar. Deposition is monitored by means of a thickness monitor (Syrcon STM-100/MF). In Fig. 1 some glasses with various TPB concentration are shown.

Fig. 1: glasses with TPB coating

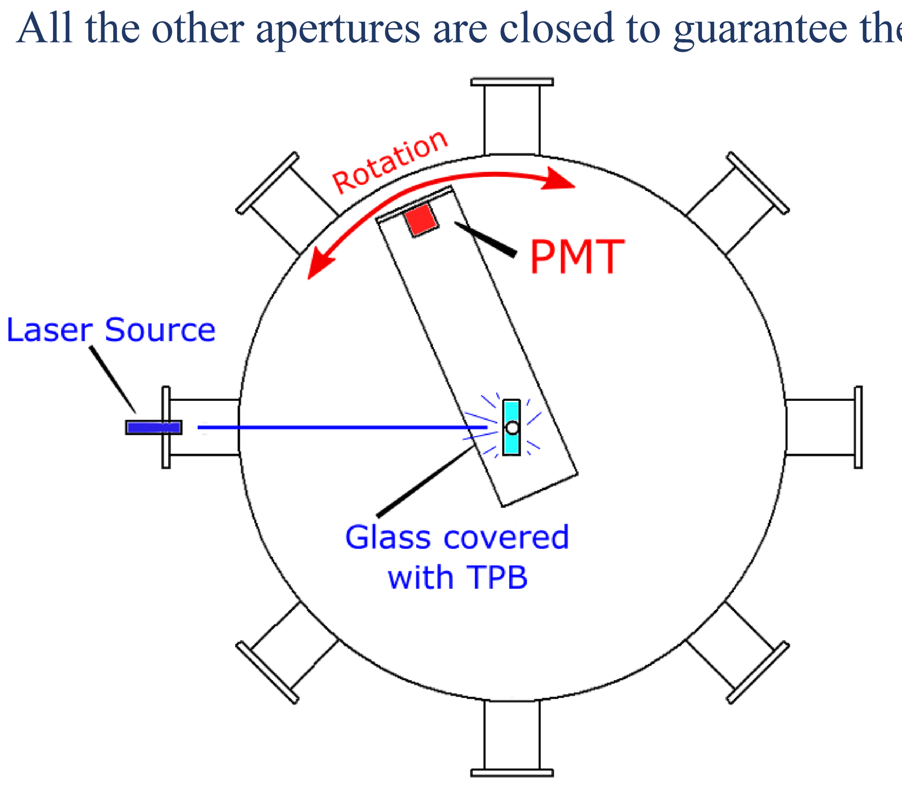
## The measurement

Our aim is the evaluation of the optical behavior of TPB coating when illuminated by a light of a wavelength inside the range of the emission of TPB. Light is partially transmitted by the coating, partially reflected , partially scattered; scattering can happen in the same direction of laser or in the back (backscattring, it means towards the laser itself).

So a laser source is directed orthogonally on 1 in. TPB coated glass; coating is on laser side. An optical detector is moved on cylindrical coordinates all around the sample to detect the scattered light. The current produced is measured by a picoAmmeter connected to a computer which controls the movements of the detector by means of a motor driver and synchronize the movement with the acquisition of the picoAmmeter.

## Experimental Set-up

The experimental set up consists of a cylindrical vacuum chamber in the center of which the glass disc (covered by TPB) is suspended by means of a rotating feedthrough. At the middle height of the cylinder there 8 aperture in vacuum standard KF40 placed each at 45º one from the other. In the center of one of them a Thorlabs laser module at 405nm is placed. All the other apertures are closed to guarantee the darkness, and used only at the beginning for alignment.




On the floor of the chamber, in the center a rotating feedthrough that can also move up and down is present. Rotation is made by means of a motor controlled by a computer. An L-shaped support is fixed to this feedthrough and holds the detector as can be seen in Fig. 2 , Fig.3 and Fig. 4.

Fig. 2: top view scheme of the system

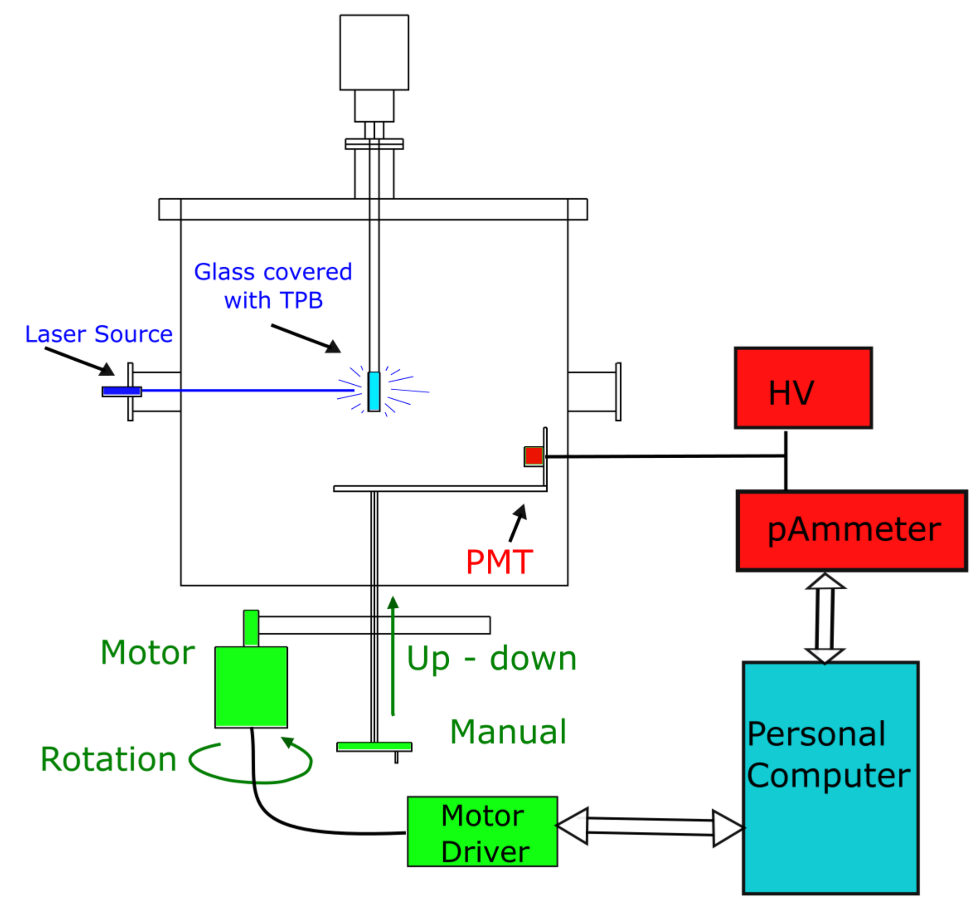



Fig.3: a scheme of the whole system

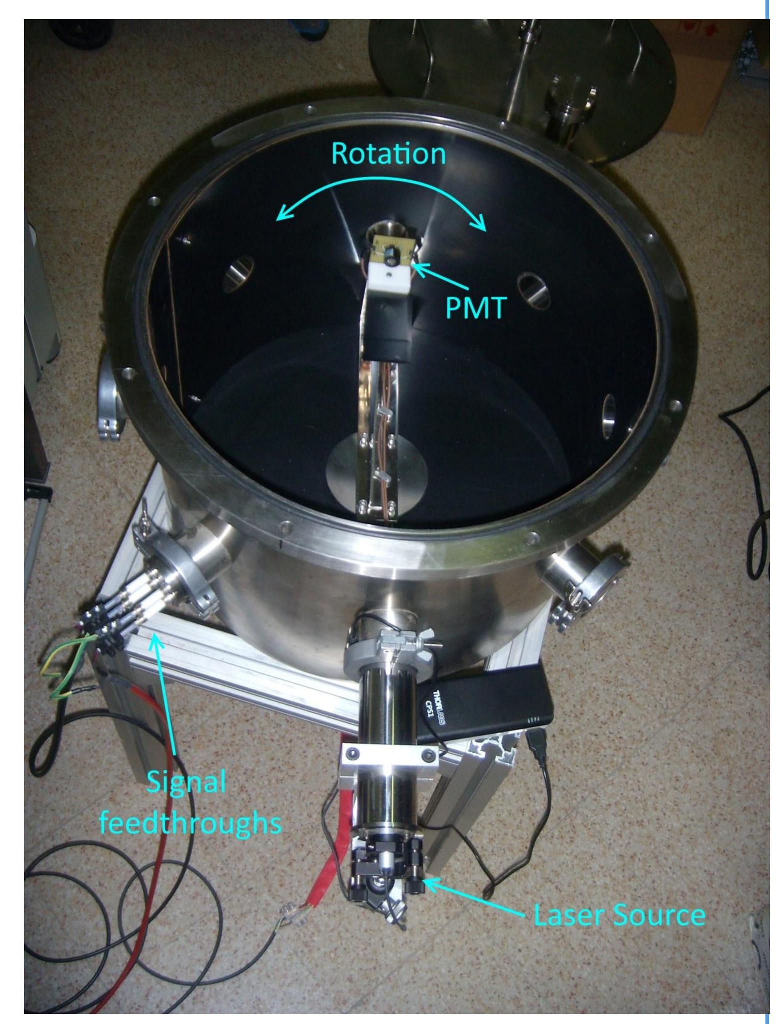



Fig.4: a picture of the system

## Results

We decided to test sample glasses of different concentration of TPB, but around the value that has been used for the photomultiplier tubes of the ICARUS LAr experiment (200μg/cm² has been demonstrated to be the best compromise between conversion efficiency and stability of the coating). Concentration tested are: 138, 158, 197, 217, 276, 296, 336 μg/cm².

Fig. 5 and 6 present the light intensity measured for 197μg/cm² concentration sample in front of the laser for various height measured from the laser plane (Z coordinate), and different angles on a cylinder of fixed radius (= 180mm). The cylindrical coordinate of the laser is angle 0º, Z= 0 [moving clockwise from the laser, you find 90º, then angle of 180º - which is downstream, in front of the laser - then 270º; moving anticlockwise from the laser, you find 90º]

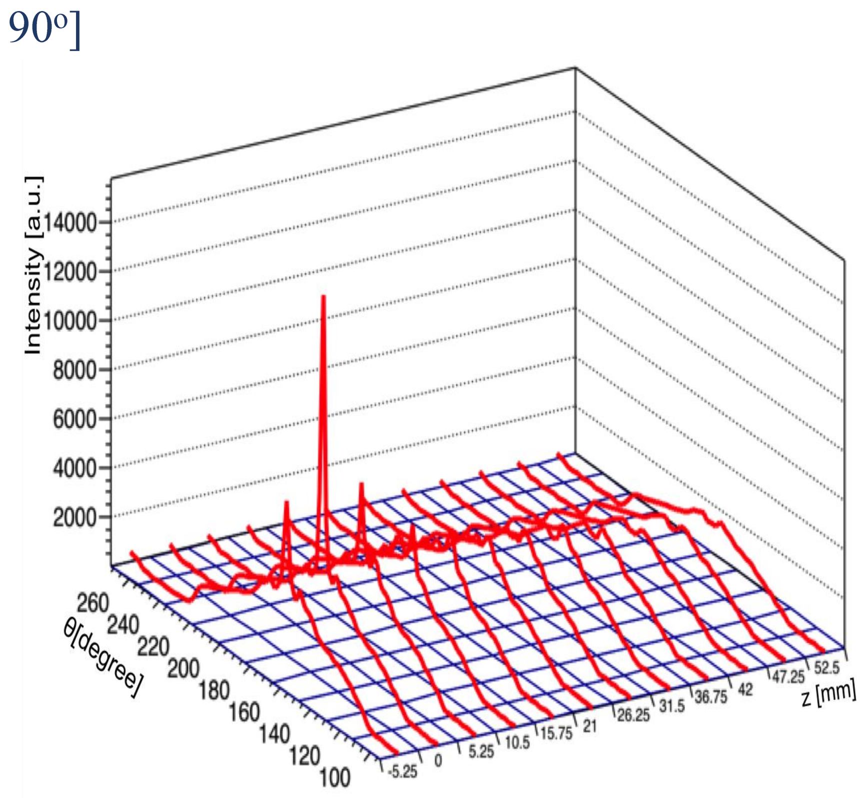



Fig.5: scattered light towards the laser as a function of the angle and the Z coordinate.

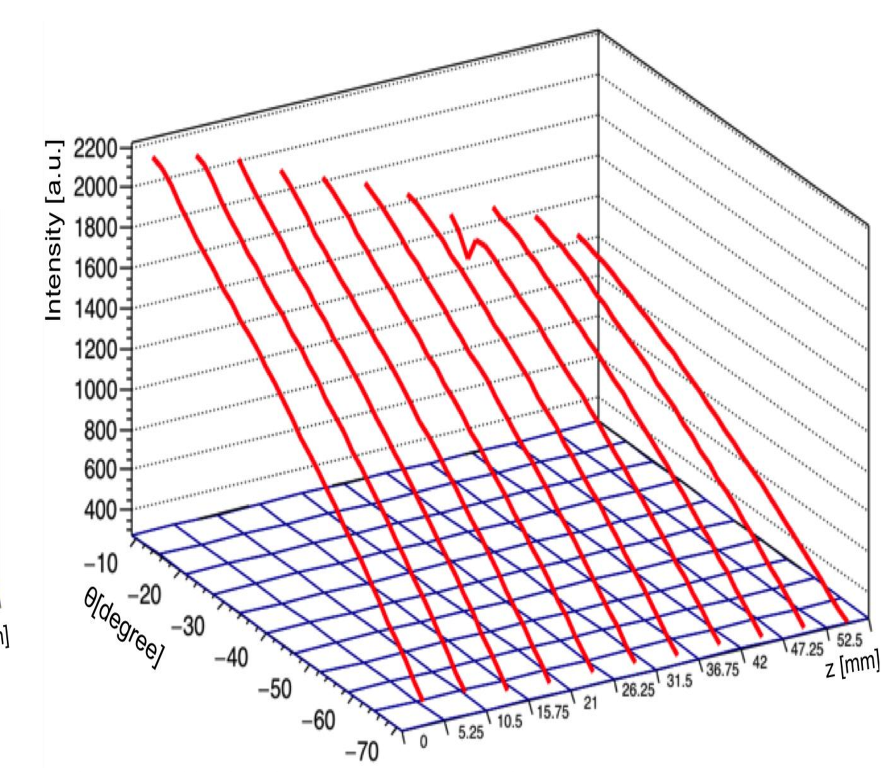



Fig. 6 light backscattered to the laser as a function of the angle and the Z coordinate

To be noted that the backscattered ligth measurement is limited to 60° because the presence on one side of the electrical feedthrough: the detector can’t measure when the laser beam is covered by the detector itself.

Fig. 7 and 8 show the scattered light for various TPB concentrations measured on the plane defined by the laser (Z=0) at various angles

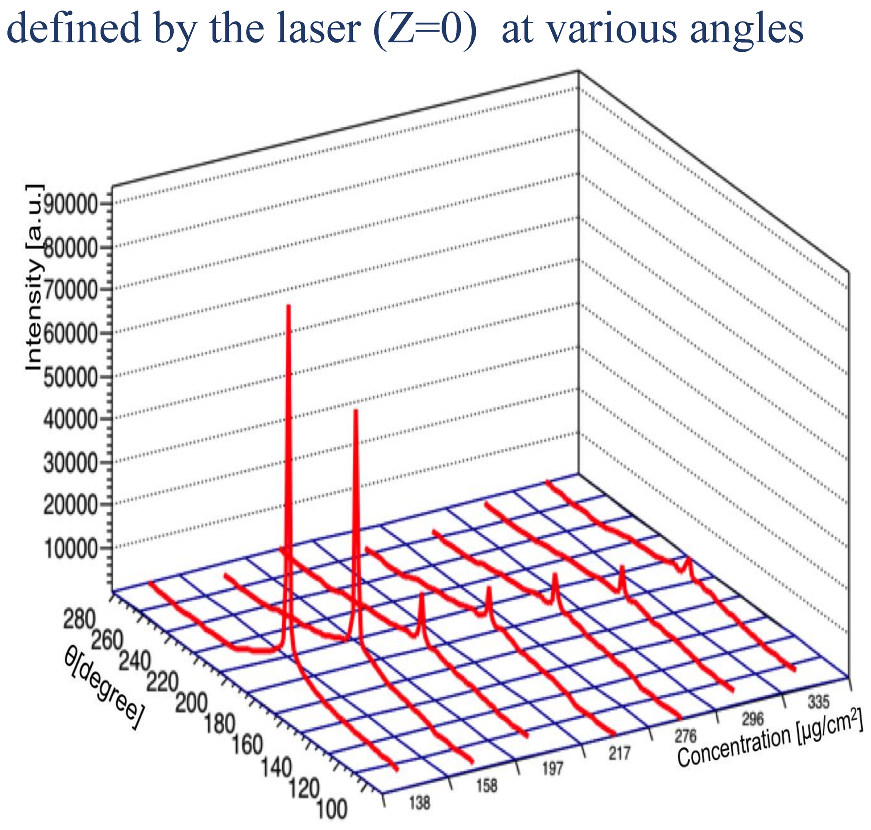



Fig.7: scattered light towards the laser as a function of angle and TPB concentration

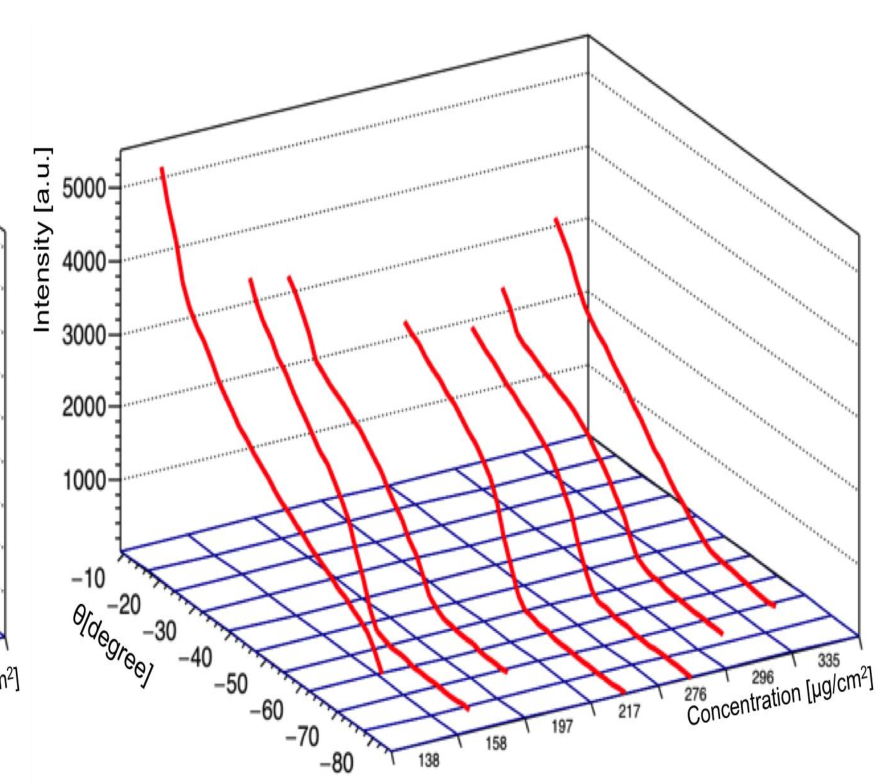



Fig. 8 light backscattered to the laser as a function of angle and TPB cocntration

## Conclusions

A careful study of transparency, diffusion and reflection properties of TPB at its emission wavelength was carried on as function of the thickness of the TPB surface. Data presented in this work can be used in simulation program of experimental detectors which use the TPB as wavelength shifter deposited on the surface of light sensors or on the internal equipment.