SINGLE PHOTON DETECTION IN THE SQS MODE

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ABSTRACT

Results are presented concerning the detection of single UV photons in self quenching streamer detectors by photoionization of one of the gas mixture components, in this case TEA (triethyl-amine), whose molecules have low photoionization potential and large absorption cross section. As a UV light source, a gas scintillation counter filled with krypton was used, whose emission light spectrum, centred at ~ 150 nm, overlaps well the photoionization spectrum of TEA. The mixtures studied were argon/ethane/TEA, argon/isobutane/TEA, argon/ethane/methylal/TEA and argon/isobutane/methylal/TEA.

I. INTRODUCTION

The present work addresses the use of self quenching streamers (or limited streamers), SQS, for the detection of single UV photons. One important application of this technique would certainly be the detection and counting of Cherenkov photons. SQS detectors offer some important advantages over proportional counters, namely due to their high charge gains associated with good localization of the discharge and the simple and cheap construction of large devices [1-3]. Battistoni et al. [4] showed that, in the SQS mode, an efficient operation range exists, for detecting single electrons extracted from an aluminium cathode by UV light, in an argon-isobutane mixture (35:65). In the present work we studied the response of our SQS detector to single photoelectrons extracted by UV photons from the molecules of TEA, a photoionizable vapour added to the gas mixture.

II. EXPERIMENTAL SET-UP

The experimental set-up is shown in Fig. 1. The SQS detector is a stainless steel cylindrical tube, with an inner diameter of 30 mm and a length of 170 mm. The anode wire is a 100 μm Cu-Be wire stretched along its axis. This detector is coupled to the scintillation counter through a LiF window. The gas mixtures were prepared passing the gas components through calibrated flowmeters (two for argon and one for the hydrocarbon) and admitted into the chamber in a continuous flow regime, at atmospheric pressure. Two lines are used for argon: in one of them argon flows through TEA, at room temperature, and in the other one it flows through methylal at 0°C. The scintillation counter is a stainless steel chamber with a small spherical anode (ϕ = 6 mm) so that the secondary scintillation is produced close to the centre of the counter. Krypton, at a pressure of about 1040 torr, is maintained in continuous circulation, by convection, through a purifier of calcium turnings kept at about 400 °C. Before filling, the system was evacuated and washed one or two times with krypton. The krypton light is seen by a photomultiplier (EMI 9656 QR), through a spectrosil window (facing the LiF one), with the inner surface covered with a wavelength shifting layer of p-terphenyl (~ 2mg/cm^2). As excitation source, 5.9 keV X-rays from a ^{55}Fe source were used. The gases were the commercially available argon (99.996%), ethane (99.995%), isobutane (99.98%) and krypton (99.998%).

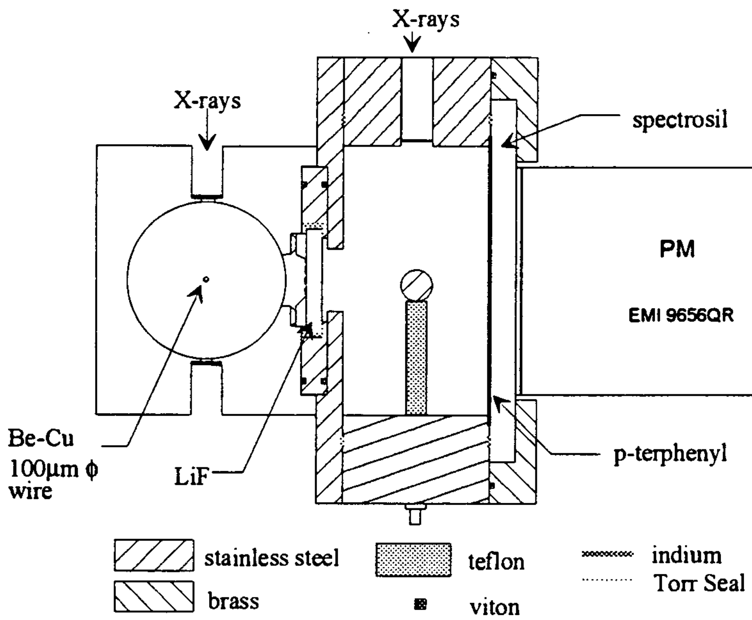

Figure 1. Experimental Setup.

III. RESULTS

The TEA and methylal additives were used in the following concentrations, respectively: 1-2 % and 5-15%. The concentration of the hydrocarbon was changed from 25 to 80%. In argon/isobutane mixtures, the concentration of the quencher was kept below 50% due to its high absorption cross section (~20 Mb) in the wavelength region of interest (~150 nm).

The counting rate in the SQS detector was measured as a function of the applied voltage both for irradiation with the X-ray source and with the Kr UV photons. The UV photon flux was controlled by varying the voltage applied to the spherical anode of the scintillation counter (see Fig. 2). The amplitude of the light signal seen by the photomultiplier, was used to estimate the number of photons that reach the SQS detector. For this purpose a calibration of the photomultiplier was previously performed with a NaI(Tl) scintillator irradiated by γ rays of several energies.

For all the mixtures studied only in the argon/isobutane/methylal/TEA ones a stable operation region could be found for the UV irradiation. In Fig. 3 the plateaux for X-rays and UV irradiation are shown. For the UV irradiation, as the rate was very low to assure single-photon conditions, the background of cosmic rays and environment radioactivity were subtracted. The ratio between the counting rate in the SQS detector, in the plateau region, and the counting rate in the scintillation counter was about 1:200, thus ensuring that only very few photons were being detected.

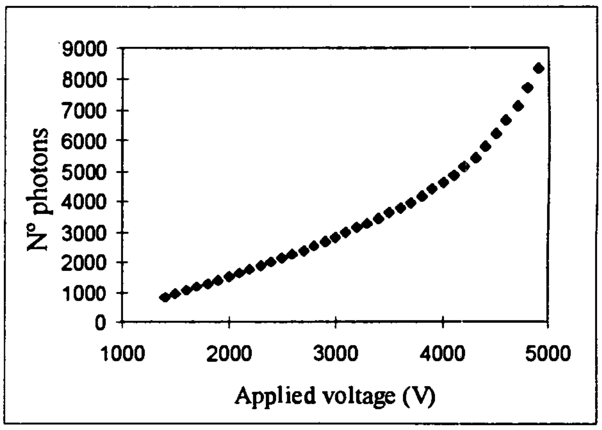

Figure 2. Number of Photons Collected by the PM as a Function of the Applied Voltage.

For this mixture the amplitudes of the current signals measured into 50 Ω are about 100-150 mV, in the plateau region. A typical charge spectrum (FW = 23%)

measured in the plateau region, under UV irradiation, is shown in Fig. 4.

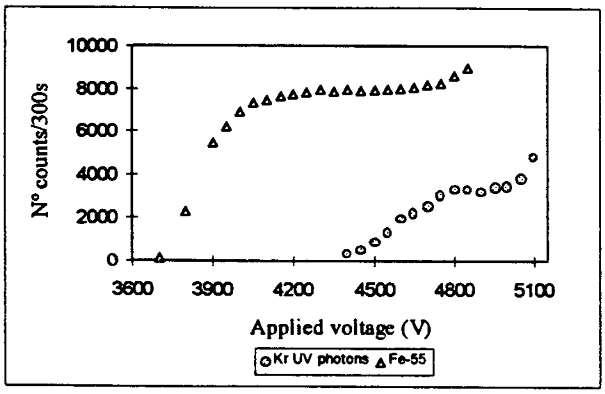

Figure 3. Number of Counts as a Function of the Applied Voltage, under X-ray and UV Irradiation, for the Ar(62%)+isoC_4H_{10}(28%)+methylal(9%)+TEA(1%) Gas Mixture.

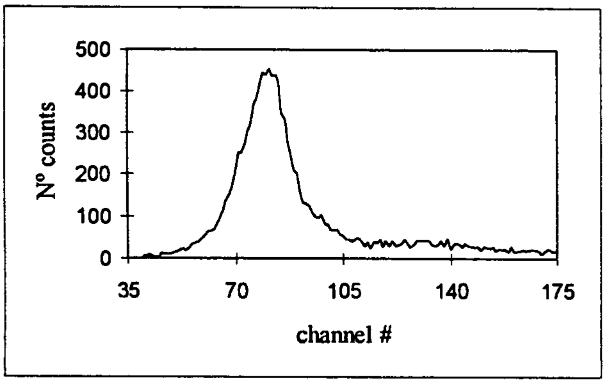

Figure 4. Typical SQS Charge Spectrum Measured under UV Irradiation.

To be sure that just single photoelectrons were detected, a Monte Carlo simulation was performed to estimate the photoionization rate of the TEA by the UV photons from the Kr scintillation counter.

IV. CONCLUSIONS

Through an appropriate choice of the gas mixture we could identify a stable operation region for SQS detection of single photoelectrons extracted by UV photoionization of TEA molecules. Although this preliminary result is encouraging, the possibility of applying this technique in real devices requires better quantitative knowledge of some parameters involved. Therefore, further studies are under way in order to improve the efficiency and the operation range of the detector. In particular, the possibility of using a CsI layer over the cathode, looking for higher efficiencies and larger ranges of wavelengths, is being considered.

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