Photon Emission in Self–Quenching Streamer Chambers

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Summary— **We have studied the properties of photons emitted by self–quenching streamer chambers. In particular the timing, intensity and wavelength distribution of these light pulses was measured with several gas mixtures.**

1. Introduction

Some year ago it had been observed that under certain conditions wire chambers produced large, almost saturated pulses of short duration [1]–[3]. It was shown later that this type of signal could be understood as a limited streamer mode [3]–[5], or avalanches extending short distances from the anode wire. At the same time it was realized that the large multiplication involved in this process was related to the emission of photons, some of which were absorbed near the high gain region, thereby increasing the multiplications [5][6]. Photographs of the light emitted showed that the discharge region was localized near the anode. During these studies several gas mixtures and geometries were studied, and the name of self–quenching streamer (SQS) mode was adopted. More recently [7] it was found that a gas mixture of argon–carbon dioxide also produced these types of pulses, with the advantage of not requiring hydrocarbons. Further studies [8] performed with hydrocarbons of large photoionization cross sections showed a decrease of the high voltage threshold of the streamer mode.

We undertook an investigation of the photoemission in the SQS mode of operation. The main purpose was to obtain information on the intensity, timing and the spectral distribution of the photons escaping the wire chamber.

2. Experimental System

We used a chamber $10cm \times 10cm \times 1.0cm$ thick, as illustrated in Fig. 1. The anode wires in the central plane were $100\mu m$ diameter. The cathode planes were made of

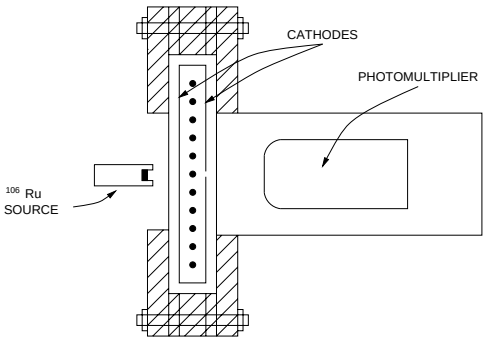

Fig. 1. The wire chamber and photomultiplier.

aluminized mylar. The signals from each anode wire were fed to a 50Ω resistor. On one side of the chamber a 56UVP photomultiplier (PM) with quartz window was mounted at $5cm$ from the anode plane and could detect photons from the central anode wire through a $0.2cm$ slit in the cathode plane. The window between the chamber and the PM was UVT acrylic. Two ionizing sources were used, ^{106}Ru (electrons) and ^{55}Fe (X rays).

The gas system allowed a mixture of up to three gases and the possibility of bubbling the mixture through hydrocarbons at $0°C$. Gas mixtures were measured with calibrated flowmeters. The chamber operated at atmospheric pressure in a continuous flow regime.

The transition from proportional to SQS mode occurred at about $4kV$ bias but varied somewhat for different gas mixtures.

The signals from the anode and the PM were large enough to be observed directly with an oscilloscope. The rise time was shorter than $2ns$ in all cases, and the total pulse length varied from $20ns$ to $150ns$ depending on the gas mixture. The anode pulse amplitude varied from $4mV$ to $100mV$. the largest anode signals had $50pC$, which corresponds to $\sim 3 \times 10^8$ electrons. The signals for X rays and electrons were similar.

3. Timing Properties of Photons

We studied the relative timing between the anode signals and the PM signals. In all cases we found that the pulse shape and duration in anode wire and the PM were approximately the same.

With a mixture of 95% CO_2 and 5% Ar we found that the relative timing between anode and PM signals remained constant, within $200ps$ for all biases in the anode. This was also the case for other gas mixtures tested, despite the fact that the pulse length varied with different gas mixtures. As found in Ref. 7, the shortest pulses were obtained with the smallest concentration of Ar.

4. The Relative Photon Intensity

We studied the light intensity with respect to the anode signals for several gas mixtures. The results are summarized in Fig. 2, which shows the ratio of PM signal amplitude divided by the anode signal amplitude. This ratio remains almost constant, independent of the bias of the anode, but depends strongly on the type of gas used. Near breakdown the ratio changes slightly.

From these results it is evident that the photons are a direct consequence of the charge multiplications process.

5. The Wave Length Distribution of Photons

In order to study the wavelength distribution of the

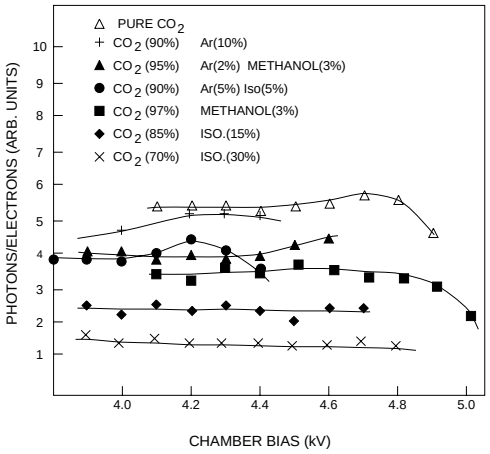

Fig. 2. Ratio of photons and anode pulse amplitudes.

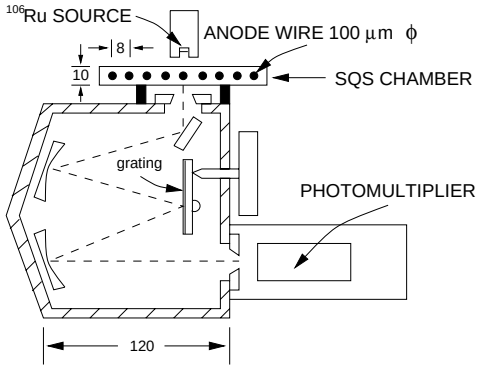

Fig. 3. Monochromator and wire chamber assembly.

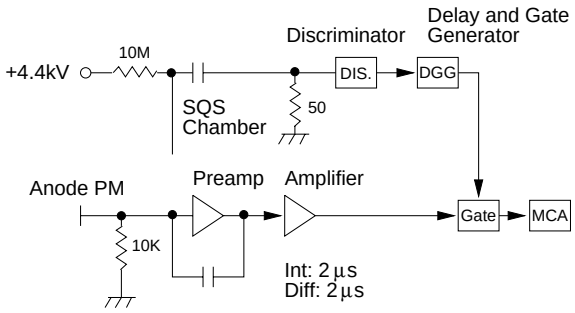

Fig. 4. Photon pulses gating and measurement.

photons emitted in the SQS mode, we used a grating monochromator (Czerny–Turner type) attached to the wire chamber, as shown in Fig. 3. The photon detection used the same PM as described above. To improve the signal–to–noise ratio, and select only those photons related to the SQS discharge, we gated the PM signals with the anode signals, as shown schematically in Fig. 4. Due to the low transmission of the monochromator, we had to operate with large slit openings, therefore reducing the resolution of the instrument. The number of photons per pulse at the maximum ($\lambda = 360nm$) was approximately 10^2 photons.

The observed photon spectrum is shown in Fig. 5. In order to determine the real photon intensity it was necessary to calibrate the total transmission of the instrument and PM as a function of wavelength. This was done with a calibrated mercury arc lamp. The wavelength and intensities of this light source are well known, and are indicated as arrows in Fig. 5. The points corrected for transmission are shown as black circles. Above $\lambda = 360nm$ the transmission was constant up to $\lambda = 600nm$. The resolution of the instrument is indicated in Fig. 5 with the horizontal bar.

These results indicate, as suspected previously, that most of the photons are in the UV region. However, the sensitivity of our instrument precludes detection of photons with $\lambda < 250nm$.

The above results were obtained with 95% CO_2 and 5% Ar. Different compositions of Ar and CO_2, and different biases of the anode above the SQS mode, had the same photon spectrum.

6. Conclusions

As shown in the above results, it is not necessary to have hydrocarbons in the gas for the SQS mode of operation. This is important for wire chambers which have to operate in a high rate environment.

The photon pulses are short in duration, and similar in shape to the anode signals, and are produced in the charge multiplication process.

The number of photons produced is large ($\sim 10^5 - 10^7$) and is always proportional to the charge collected at the anode.

The photon spectrum extends from $460nm$ to the VUV. The very short wavelengths are absorbed in the gas, producing further multiplication, while the larger ones escape the chambers and can be detected.

After–pulses of photons have been observed in all gas mixtures and they are always with after–pulses in the anode signals. They are most probably produced by emission of photoelectrons from the cathode, as suggested in Ref. 8.

It has been shown [5] that the anode wire diameter plays an important role in the SQS mode. This can be understood in the following way. The probability for the SQS mode is the product of the probability of emitting photons from electron recombination in the cascade multiplication volume, and the probability of these photons to be absorbed in the same region. If we call R the wire diameter and M the distance from the wire surfaces to the shell where multiplication begins, the probability for photon production is proportional to $(R+M)^{-1}$, and the probability for the photon absorption in the multiplication region is $[1-\exp(-(R+M)/D)]$, where D is the mean free path of the photons. The product of these two probabilities is a function of R with a maximum at $R = 2D - M$. In our case where $R = 50\mu m$, we had a value of $D = 80\mu m$ and this corresponds to a photoionization cross section of $\sim 5Mb$.

References

[1] H. Nuert, Kernphysikalische Messverfahren, (G. Braun, Karlsruhe, 1966).
[2] G. Charpak et al., Nucl. Instrum. Methods 80, 13 (1970).
[3] R. Bouclier et al., Nucl. Instrum. Methods 88, 149 (1970).
[4] J. Fisher et al., Nucl. Instrum. Methods 151, 451 (1978).
[5] G. D. Alekseev et al., Nucl. Instrum. Methods 177, 385 (1980) and 153, 157 (1978).
[6] M. Atac et al., Fermilab Report FM-339 (1981), IEEE Trans. NS-29, 388 (1982) and Nucl. Instrum. Methods 200, 345 (1982).
[7] T. A. Mulera and V. Perez–Mendez, Nucl. Instrum. Methods 203, 609 (1982).
[8] E. P. deLina et al., IEEE Trans. NS-30, 90 (1983).

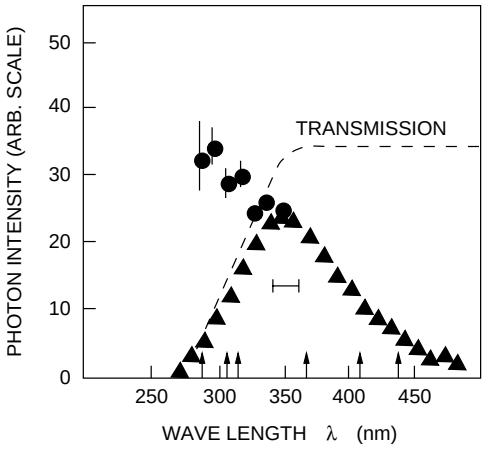

Fig. 5. Wavelength distribution of photons.