Dual-Cathode CsI Covered Microstrip Plate as VUV High Efficiency Photosensor

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***Abstract*—A Gas Proportional Scintillation Counter based on a dual-cathode Microstrip Plate covered with a CsI film is described. This new dual-cathode technique has the advantage of increasing the VUV sensitive area of the Microstrip Plate. A detailed description of the technique is presented together with a discussion of the performance. The results obtained for a xenon filled Gas Proportional Scintillation Counter show an improvement of the energy resolution for 5.9 keV X-rays from 12.7%, for a single cathode device, to 11.1% for the dual-cathode device.**

***Index Terms*—Gaseous radiation detectors, microstrip detectors, photocathodes, X-ray spectroscopy detectors, scintillation detectors.**

I. INTRODUCTION

SINGLE Cathode Microstrip Plates (MSP) covered with a CsI film have been used for some time [1] as VUV photosensors for xenon filled Gas Proportional Scintillation Counters (GPSC) yielding energy resolutions of 12.7% for 5.9 keV X-rays [2], [3] for equivalent geometry devices as the one presented herein, although 11.4% resolution has been achieved with optimised geometry devices [4], which is a resolution not as good as that for GPSCs instrumented with photomultipliers (8.0%), but better than that for standard Proportional Counters (14%).

CsI covered MSP based GPSCs have the advantage of being much more compact than the photomultiplier based ones.

The schematic of a MSP based GPSC is shown in Fig. 1. X-rays are absorbed in an absorption region where they produce primary electrons. These electrons drift towards a fairly strong electric field region $(\mathrm{E/p} \sim 6\ \mathrm{V\ cm^{-1}\ Torr^{-1}})$ delimited by a grid and the CsI covered MSP; in this region, the so-called scintillation region, the primary electrons excite the xenon atoms which in the decay process produce VUV photons in quite large numbers (typically 500 photons per primary electron). These photons when absorbed in the CsI film covering the cathodes of the MSP release photoelectrons which drift towards the anodes of the MSP where they are charge multiplied by an avalanche process, leading to a fairly large signal, approximately proportional to the energy of the X-ray photon absorbed in the xenon gas.

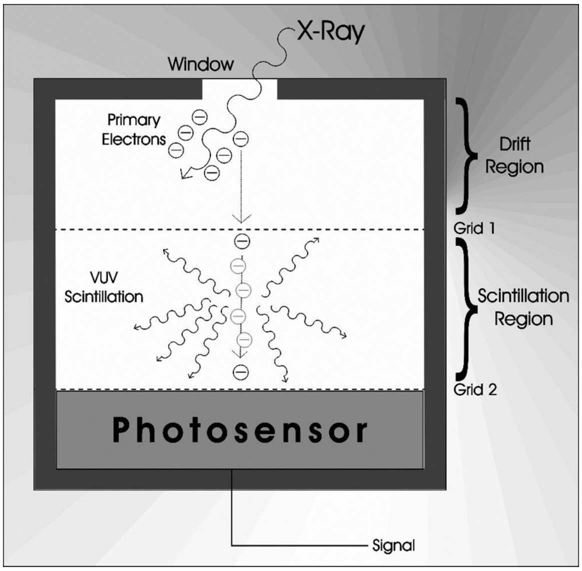

Fig. 1. Schematic of a MSP based gas proportional scintillation counter.

However, as soon as the photo-electrons leave the photocathode they collide with the xenon atoms and may be backscattered towards the CsI photocathode itself, and so lost. This effect reduces the efficiency of the photocathode for the VUV scintillation.

The study of VUV photoelectric emission of a CsI film in a gaseous atmosphere has been the subject of both experimental [5] and theoretical [6] treatments. It was shown that the electric field intensity at the surface of the CsI film has to be stronger than about 3 V $\mathrm{cm^{-1}\ Torr^{-1}}$ for proper photoelectron extraction. However, we must point out that this extracting electric field must have a pointing direction opposed to that of the field in the scintillation region, which means that if we want to have improved photoelectron extraction, the electric field intensity in the scintillation region must be reduced, so reducing the number of VUV photons and thus the number of photoelectrons.

Fig. 2 shows the electric field lines obtained with Ansoft Maxwell 2D Field Simulator in the case of a standard MSP with 80 $\mu\mathrm{m}$ wide cathodes, 10 $\mu\mathrm{m}$ wide anodes and 55 $\mu\mathrm{m}$ anode-cathode gap. For this example, the anodes were biased at 200 V and the MSP placed in a xenon (800 Torr) scintillation region with the electric field set at 2500 V $\mathrm{cm^{-1}}$ electric field

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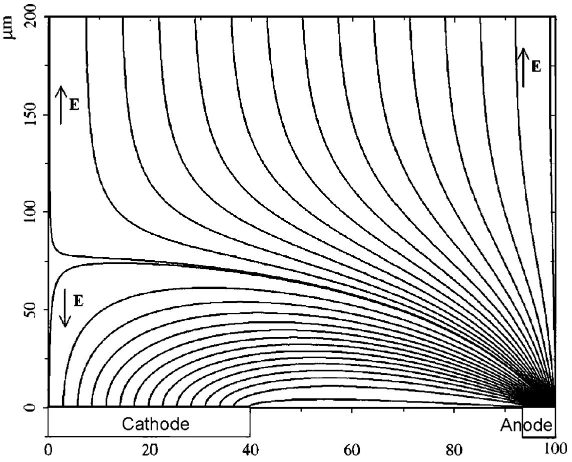

Fig. 2. Calculated electric field lines for a standard MSP.

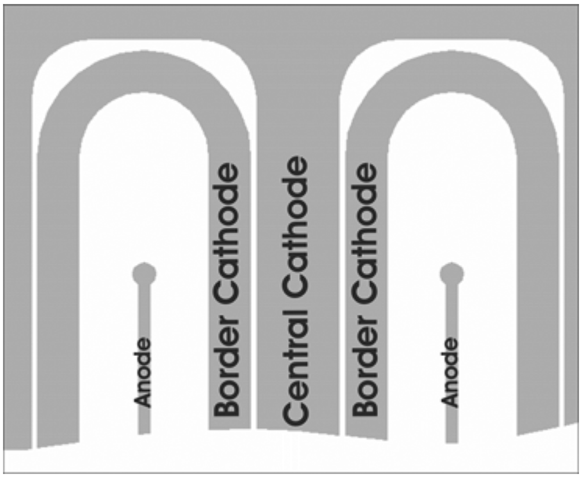

Fig. 3. Dual-cathode microstrip plate geometry.

intensity (reduced electric field: 3 V cm^{-1} Torr^{-1}). With these conditions, the electric field calculations show that for 100% of the photocathode area the electric field intensity is above the threshold for proper photoelectron extraction.

However, if the scintillation field intensity is increased up to the optimum value of 5000 V cm^{-1} (E/p $\sim$ 6 V cm^{-1} Torr^{-1}), only for a 20 $\mu\mathrm{m}$ wide region in the cathode border is the electric field strong enough for complete photoelectron extraction. In this case, the efficiency of the MSP based photosensor is reduced by a factor of 50%.

II. THE DUAL-CATHODE MSP PHOTOSENSOR TECHNIQUE

To overcome this problem a new microstrip design was developed with cathode split into two parts: a central cathode, surrounded by a border cathode, as shown in Fig. 3.

If the central cathode is biased at a few volts more negative potential than the border cathode, then the electric field at its surface is increased and the opposing effect of the scintillation field, described before, is compensated. This way the electric field reaches values above the 3 V cm^{-1} Torr^{-1} threshold for photoelectron extraction, not only on the border cathode, but also on the central cathode, thus increasing the overall efficiency of the microstrip, even for scintillation fields close to the optimum value ($\sim$ 6 V cm^{-1} Torr^{-1}). Fig. 4 shows a plot of the equipotential curves for the dual-cathode MSP used in the present work (anode width, 10 $\mu\mathrm{m}$, central cathode width, 80 $\mu\mathrm{m}$, border cathode width, 35 $\mu\mathrm{m}$, on each side, anode-to-border cathode gap, 50 $\mu\mathrm{m}$, border cathode-to-central cathode gap, 5 $\mu\mathrm{m}$). The plots are for 300 V at the anode, 0 V at the border cathode and central cathode voltages of 0 V and -20 V. The closer spaced equipotential curves at the central cathode surface for the -20 V case, indicate a stronger electric field.

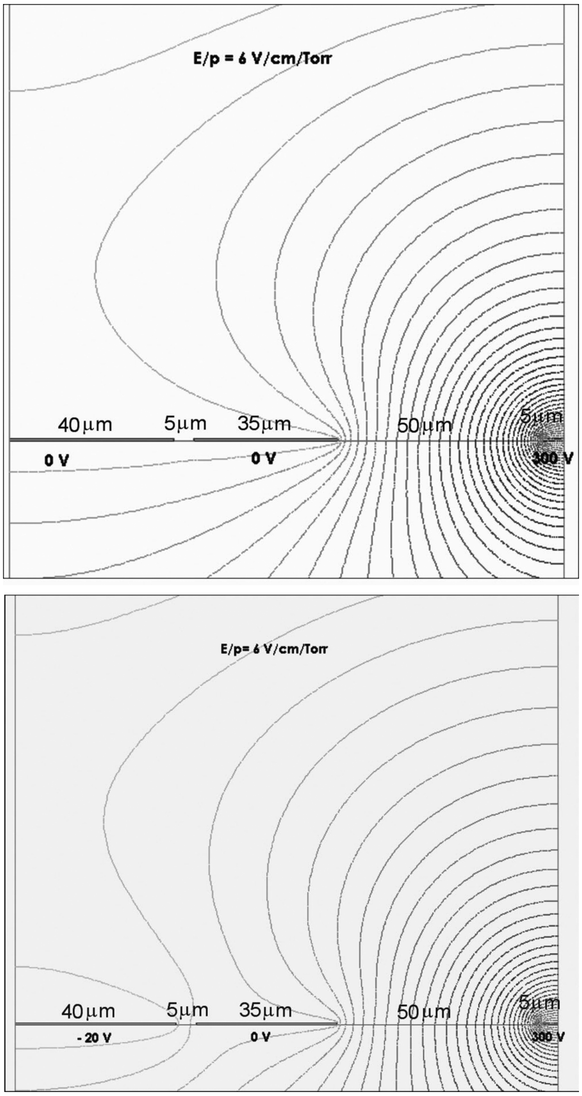

Fig. 4. Equipotential curves for a dual-cathode MSP with the anode biased at 300 V, the border cathode at 0 V, a scintillation region field of about 5000 V cm^{-1}, and central cathode at 0 V and -20 V.

III. EXPERIMENTAL SYSTEM

The Gas Proportional Scintillation Counter used for the present experiments has a drift region 43 mm thick and a scintillation region 10 mm thick. It was filled with xenon at about 800 Torr. The dual-cathode MSP used has anode and cathodes with the dimensions referred to above, deposited on a 5 cm × 5cm wide and 0.5 mm thick glass (Desag D263) plate. It was covered with a 500 $\mu\mathrm{m}$ thick CsI film deposited by vacuum evaporation.

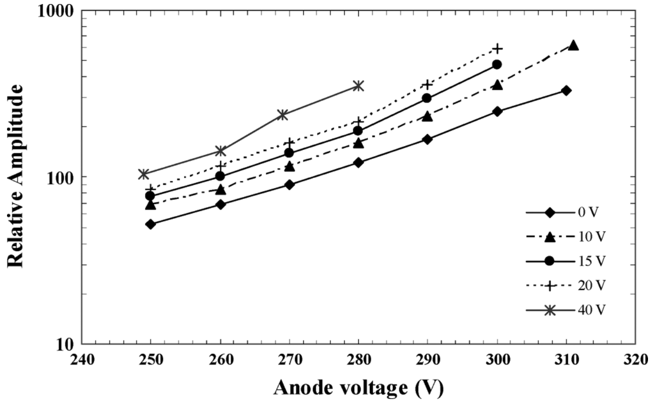

Fig. 5. Variation of the pulse amplitude with the dual cathode MSP anode voltage for central-to-border cathode voltages of 0 V, −10 V, −15 V, −20 V and −40 V, where $\mathrm{E/p} = 6\ \mathrm{V\ cm^{-1}\ Torr^{-1}}$.

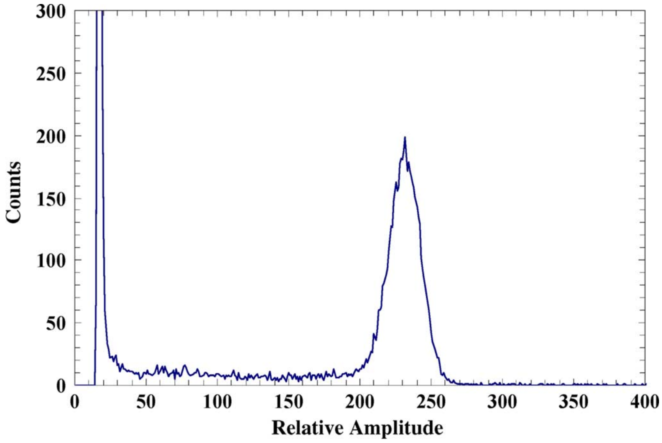

Fig. 6. X-ray spectrum for a 5.9 keV x-rays obtained with the dual-cathode MSP based gas proportional scintillation counter presenting an energy resolution of 11.1%.

IV. RESULTS

The performance of this detector for 5.9 keV X-rays from a $^{55}\mathrm{Fe}$ radioactive source, was studied for a constant reduced electric field, in the scintillation region, close to the optimum value ($6\ \mathrm{V\ cm^{-1}\ Torr^{-1}}$), and for a variety of MSP central cathode and anode voltages.

The variation of the pulse amplitude with anode-to-border cathode voltages for a variety of central cathode negative voltages is plotted in Fig. 5 as shown the pulse amplitude increases with both the anode voltage and the central-to-border cathode voltages. This behavior is partly the result of the increased difference of potential, between central cathode and anode, as we place at a more negative potential the central cathode.

The experimental results for the performance of the dual-cathode MSP based GPSC as an X-ray spectrometer are illustrated in Fig. 6 which shows an X-ray spectrum for 5.9 keV presenting an energy resolution of 11.1%.

The variation of the energy resolution as a function of the MSP anode voltage for central-to-border cathode voltages ranging from 0 to −40 V is plotted in Fig. 7. The lowest value $(\mathrm{R} = 11.1\%)$ was obtained for an anode voltage of 290 V and −10 V in the central cathode.

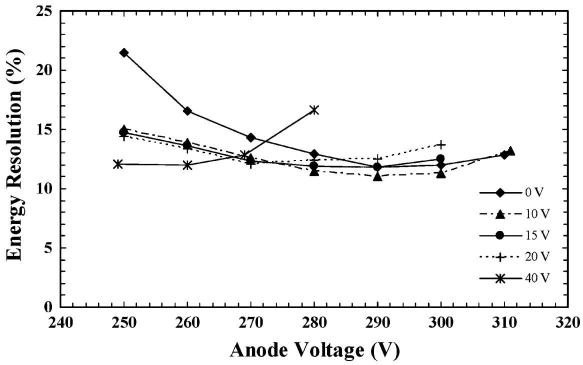

Fig. 7. Variation of the energy resolution of the dual-cathode MSP based gas proportional scintillation counter, as a function of the anode voltage, for central cathode voltages of 0 V, −10 V, −15 V, −20 V and −40 V, where $\mathrm{E/p} = 6\ \mathrm{V\ cm^{-1}\ Torr^{-1}}$.

V. CONCLUSIONS

We have described a new Gas Proportional Scintillation Counter having integrated as photosensor a dual-cathode Microstrip Plate covered with CsI.

With this dual-cathode MSP the scintillation detection efficiency is increased and the energy resolution of the GPSC improved.

For the dual-cathode MSP design here described (anode width, 10 $\mu\mathrm{m}$, central cathode width, 80 $\mu\mathrm{m}$, border cathode width, 35 $\mu\mathrm{m}$, on each side, anode-to-border cathode gap, 50 $\mu\mathrm{m}$, border cathode-to-central cathode gap, 5 $\mu\mathrm{m}$) the energy resolution obtained for 5.9 keV X-rays was 11.1%.

For a standard single cathode MSP with similar dimensions (10 $\mu\mathrm{m}$ anode width, 160 $\mu\mathrm{m}$ cathode width, 55 $\mu\mathrm{m}$ anode-to-cathode gap) the energy resolution obtained [4] was not as good: 12.7%.

As shown in Fig. 5 the relative amplitude increases, for a fixed anode voltage, as the central cathode becomes more negative, since then the voltage difference along the path of the photoelectrons released from the central cathode in their way to the anode, also increases. For more negative central cathode voltages the electric field at its surface also increases and so increases the photoelectron extraction efficiency. These effects lead to the observed amplitude dependence on the central cathode voltage.

However, unexpectedly, as shown in Fig. 7, the energy resolution for central cathode voltages of −20 V is slightly worse than for −10 V. This effect may result from the fact that as the central cathode becomes too negative more electric field lines will end up in the border cathode, rather than in the anode, leading to the loss of the photoelectrons following these lines.

Although the results here presented for the energy resolution, are not much better than those for the standard single-cathode devices, the dual-cathode concept works and has the further advantage that the best energy resolution is not very much dependent on the anode voltage, as shown in Fig. 7.

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