PLASMA PANEL DETECTORS AS ACTIVE PIXEL BEAM MONITORS

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Abstract

We are developing a charged particle radiation detector based on plasma display panel (PDP) technology used in plasma–TVs. The plasma panel sensor (PPS) is a proposed micropattern radiation detector that inherits many operational and fabrication principles common to PDPs. The PPS would be comprised of a dense array of small, gas plasma discharge cells within a hermetically-sealed glass panel. As in PDPs, it uses non-reactive, intrinsically radiation-hard materials – e.g. glass substrates, refractory metal electrodes, and mostly inert gas mixtures. We anticipate that it would be possible to fabricate these devices as very thin, low-mass detectors with gas gaps of hundreds to a thousand microns. The PPS would be a high gain, inherently digital device with the potential for very fast response times, very fine position resolution (< 100 μm) and low cost [1]. We report here on the PPS development program, including experimental results in detecting betas, protons and cosmic muons. We anticipate that the PPS technology can eventually be applied to the detection of alphas, heavy ions at low to medium energy and, with the addition of suitable converter materials, thermal neutrons, X-rays and optical photons.

INTRODUCTION

The plasma panel sensor (PPS) is a new radiation detector technology being developed for a number of scientific and commercial applications [1]-[3]. The PPS (see Fig. 1), which is based on the PDP, is designed to leverage off of the low cost, consumer electronics, PDP technology. PDPs comprise millions of cells per square meter, each of which when provided with a signal pulse can initiate and sustain a plasma discharge. However, rather than the plasma discharge being initiated externally by a signal from a driver chip (i.e. address pulse) as in a PDP, the PPS discharge is initiated internally by an ionization event created within the device by an ionizing particle interacting with the detector. Instead of applying voltage to produce light emission via a plasma discharge, we detect the plasma discharge generated by ionizing radiation entering a PPS cell.

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RESULTS

The results presented here pertain primarily to the application of PPS devices as active pixel beam monitors for ionizing particle radiation. In Fig. 1 we show a simple 2-electrode, open-cell PDP structure where the discharge takes place between the front substrate column electrodes (e.g. HV-cathodes) to the back substrate row electrodes (e.g. sense anodes). In Fig. 2 we show the electric field simulation of the columnar discharge in 1 cell.

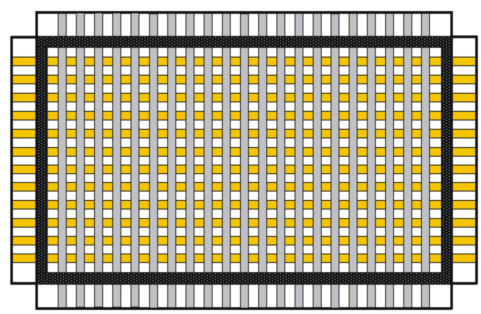

Figure 1: Columnar-discharge, modified-PDP electrode structure. Front cathodes are gray; perimeter seal is black.

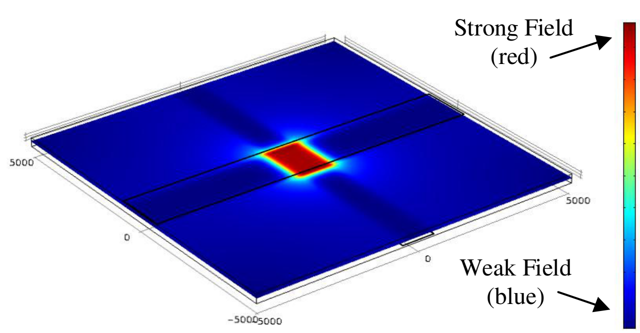

Figure 2: COMSOL simulation of normalized electric field strength inside a PDP single cell.

Fig. 3 shows a 2-electrode, columnar-discharge, modified-PDP glass panel (3.2” x 12.8” active area) in an aluminum frame, fitted with a valve to allow testing of different gas mixtures and pressures. The panels have either transparent SnO_2 or Ni column cathodes, and Ni

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row anodes; the anodes are operated at ground. The electrode pitch is 2.5 mm. Such panels produced the gas discharge pulses in Figures 5, 7, 9 and 10.

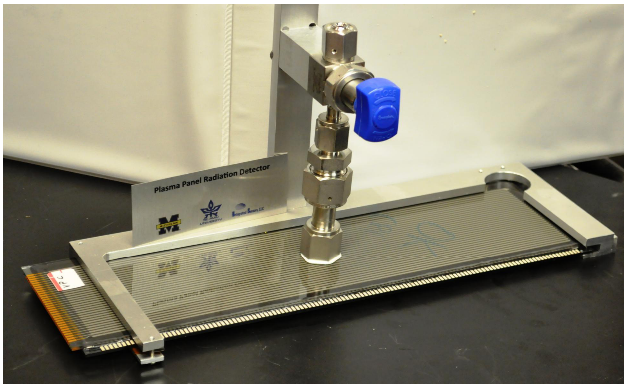

Figure 3: Modified-PDP test panel.

Fig. 4 below shows the setup used for triple coincidence measurements from either cosmic muons or an external ^{106}Ru source.

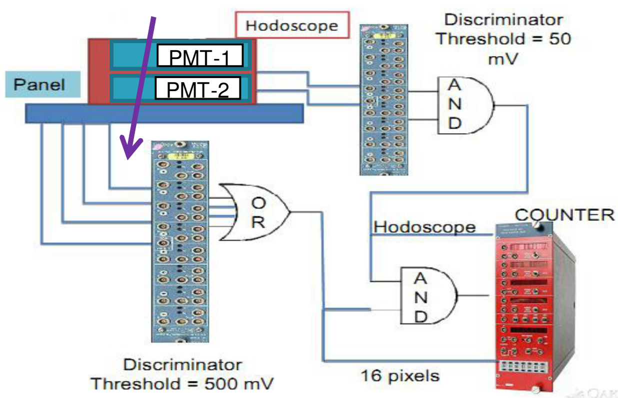

Figure 4: Triple coincidence measurement setup.

The gas discharge pulse is shown in Fig. 5 below from an all-Ni, 2-electrode PDP similar to that in Fig. 3, filled with 1% CO_2 in 99% Ar at 600 torr and operated at 840V. The experiment employed a ^{106}Ru beta-source in conjunction with the triple coincidence hodoscope (i.e. trigger) in Fig. 3. The 20%-80% rise time was ~ 1 ns (< 2 ns for 10%-90%), with a 1.9 ns pulse duration (FWHM).

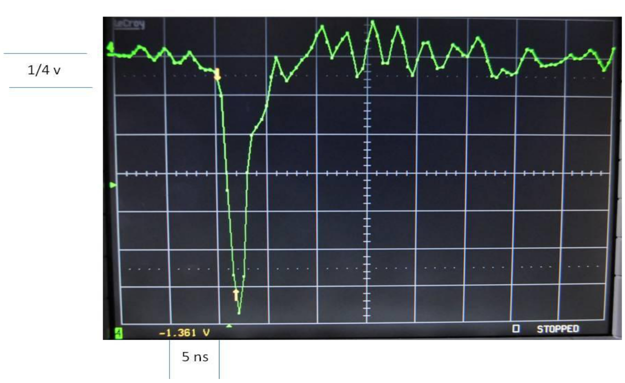

Figure 5: Typical PDP pulse rise time and duration.

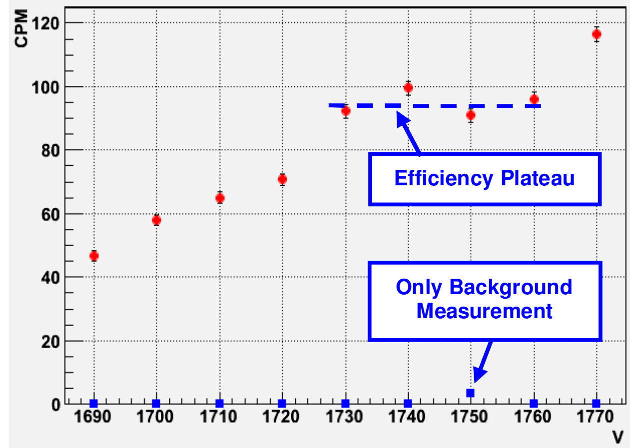

Figure 6: Cell signal and background.

We have run a number of modified-PDP panel tests using primarily four different particle sources of radiation: betas from ^{90}Sr, and higher energy betas from ^{106}Ru; cosmic-ray muons; and 226 MeV protons from an IBA-C235 medical accelerator. In all cases the actual signal pulses looks remarkably similar (e.g. see Fig. 5) for a given panel geometry, gas mixture, cathode voltage, and quench and signal resistors. In other words, it does not appear to make any difference what causes the initial gas ionization, and there is nothing surprising about this observation. We present in Fig. 6, a plot of the cell count rate in cpm (20 minutes/point) vs. high voltage for hits detected by a "single cell" using a 1.5 mm collimated ^{90}Sr source in a modified-PDP panel similar to that shown in Fig 3, with "transparent" SnO_2 cathodes and filled with CF_4 at 500 torr. As can be seen, the total number of background counts (i.e. without the source present) shown in "blue" is virtually "zero" at every point except 1750 volts, and thus represents less than 0.5% over the range from 1690 to 1770 volts. We point out however, that low background counts absent an efficiency value can be misleading; nevertheless, we consider the measured low background (or noise) rates to be a promising indication of good performance.

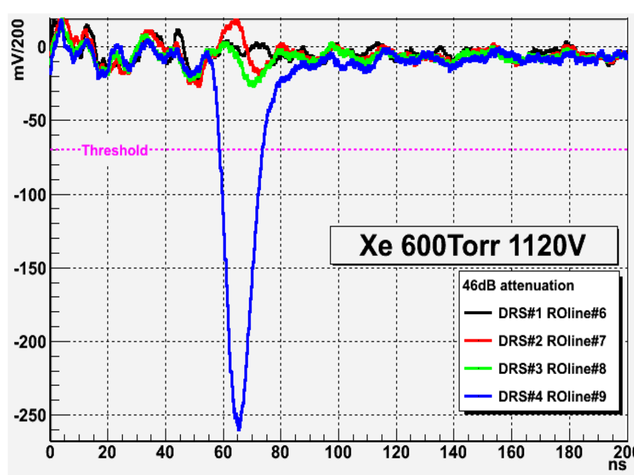

Figure 7: Discharge spreading experiment.

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We show in Fig. 7 a gas discharge pulse (i.e. "blue" readout line #9) from an all-Ni, modified-PDP filled with 600 torr of 100% Xe. The source was ^{106}Ru (beta-source) used in conjunction with the triple coincidence hodoscope in Fig. 4. The adjacent anode wires (i.e. channels 6, 7 & 8) appear as the black, red and green lines, and show no indication of any discharge spreading.

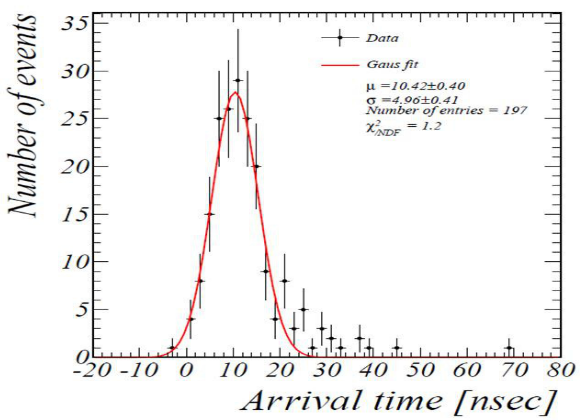

Figure 8: Temporal response – arrival time distribution.

Fig. 8 is the cosmic-ray muon arrival time distribution for the modified-PDP in Fig. 3 with SF_6 and operating at 1530 volts. The arrival times are relative to the hodoscope trigger (Fig. 4) with circuit and cable delays removed. Both CF_4 and SF_6 show similar response time signals.

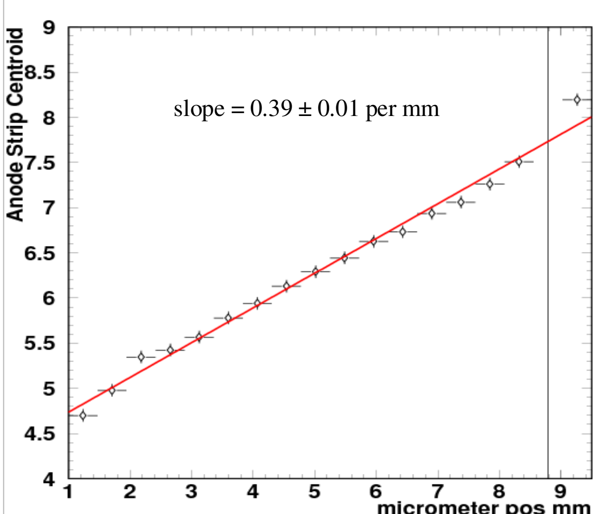

Figure 9. Position resolution beta scan measurements.

Fig. 9 shows the results of translation of a "collimated" ^{106}Ru beta-source through a 1.25 mm wide graphite slit (20 mm thick) in 0.5 mm increments across the sense electrodes in the modified-PDP in Fig. 3, with 1% CO_2 in 99% Ar, at 600 torr and 890 volts. The plot shows the Gaussian means vs. the source position. The mean position resolution is ~ 1 mm, in a panel with a 2.5 mm electrode pitch. We obtain a slope of 0.39 ± 0.01 per mm, where the error is estimated from fitting the plot over three ranges. This slope is consistent with the electrode pitch.

In Fig. 10 (Right) we show the results of a scan using a 1 mm diameter, 226 MeV proton beam for 16 sequential runs in which the panel in Fig. 3 was shifted in each run by increments of ~ 1 mm relative to the proton beam from an IBA-C235 medical accelerator. Unfortunately the panel movement could not be well-controlled, and so the error in the actual panel position location was quite significant. Each bin of the histograms is the counts observed on one of the sense-electrode (anode) lines. In Fig. 10 (Left) we show a linear fit plot of the reconstructed position centroid of the "hit" map from Fig. 10 (Right) versus the panel relative displacement with respect to the initial position. In spite of the location error, the beam position is well reproduced by the panel anode readout.

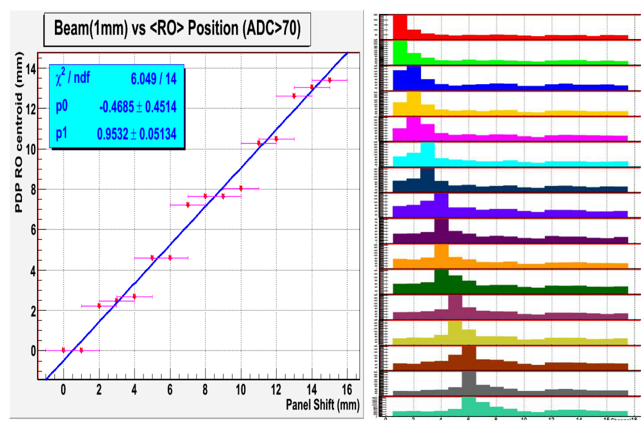

Figure 10: Proton beam position scan with 1 mm aperture.

CONCLUSIONS

We have shown that the PPS is capable of detecting proton beams in the energy range used for proton therapy. The detection of betas and muons has also been demonstrated, as has the PPS for high position resolution. The potential impact of the PPS technology includes a broad range of commercial and scientific applications.

ACKNOWLEDGMENT

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