SLAC-PUB-2629
October 1980
(I)

HIGH GAIN MULTIGAP AVALANCHE DETECTORS FOR ČERENKOV RING IMAGING*

R.S. Gilmore†, W.M. Lavender, D.W.G.S. Leith, S.H. Williams
Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

We report on a continuing study of multigap parallel plate avalanche chambers, primarily as photoelectron detectors for use with Čerenkov ring imaging counters.

By suitable control of the fields in successive gaps and by introducing screens to reduce photon feedback to the cathode the gain may be increased considerably.

We have obtained gains in excess of 6×10^7 for photoelectrons with a good pulse height spectrum and expect to increase this further.

We discuss the use of resistive anodes to give avalanche positions in two dimensions by charge division.

INTRODUCTION

The development[1] of a Čerenkov ring imaging chamber continues to be of interest because of the attractiveness of the method for particle discrimination in high energy physics experiments, especially in the large four pi detectors recently brought into vogue at colliding beam machines. The development by various groups has focused on the basic requirements of the device: a high yield Čerenkov radiator, an efficient conversion of photons to electrons, amplification of the single photoelectrons and finally a two-dimensional readout method. We have described previously[2] our plans to use liquid helium as a high yield radiator with good UV transparency. Other groups[3] have studied gaseous (TEA, TMAE) and solid (CsI) photocathode agents for the electron conversion and have met with some success, so our efforts described below concentrate on the electron amplification and 2D readout methods, especially with multistep avalanche gap proportional chambers.

MULTIGAP CHAMBERS

The multigap avalanche chamber has been suggested previously as a suitable device for the detection of far ultraviolet photons.[4-7] Usually it has been considered as a preamplifier in front of a spark chamber or a PWC with transparent screen cathodes. As an alternative approach to obtain a simple high gain device, we are developing a chamber which would provide the total gain needed in a series of parallel plate avalanche gaps including, if required, a transfer gap to provide gating of the avalanches. This is a continuation of previous work on single avalanche gaps[2] which obtained gain of $\sim 5 \times 10^5$ with a mixture of neon and helium (90 to 10 percent) and acetone. Figure 1 shows a section through the test chamber. This had interchangeable components, but normally contained a cathode and up to four intermediate electrode screens, constructed of fine, high transmission wire mesh, together with an anode consisting of a printed circuit board divided into pads 6 mm square. The chamber is divided into an initial conversion region of 2.5 cm depth followed by amplification or drift gaps 4 mm wide. In the conversion region primary electrons may be generated by x-rays from an Fe^{55} source or by UV photons illuminating an aluminum wire near the cathode.

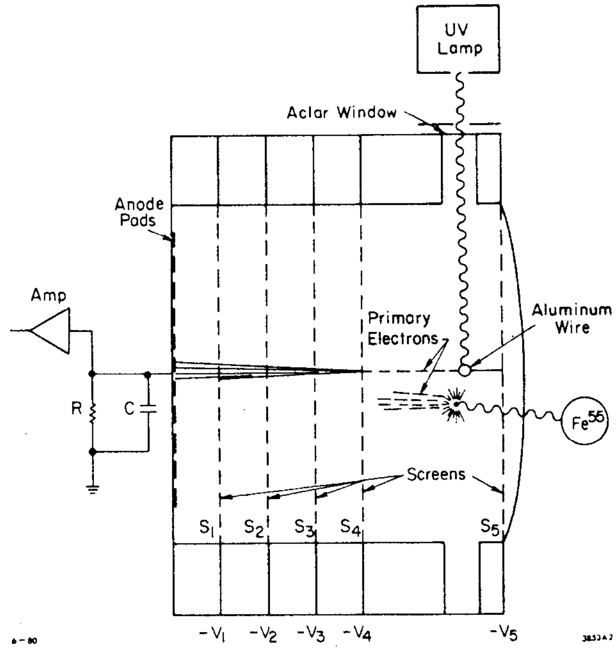


Fig. 1. Cross section of the multigap test chamber. The number and type of the screens was adjustable.

In a parallel plate chamber the avalanches are wide, of the order of 1 mm or more, rather than being confined to a small region around a sense wire as in a proportional wire chamber. The effect of space charge on the gain is correspondingly much reduced, and the gain is limited in practice by the formation of sparks. If one can inhibit spark production, the maximum gain attainable would be increased considerably. Sparks are caused mostly by photon feedback from the final stages of the avalanche to the cathode, giving rise to further avalanches. With a multigap chamber there are a number of adjustable parameters which can be used to control this feedback. The relative strengths of the fields in different gaps may be varied. Figure 2 shows the effect on the maximum gain obtained in a system with two amplifying gaps as the voltage across the

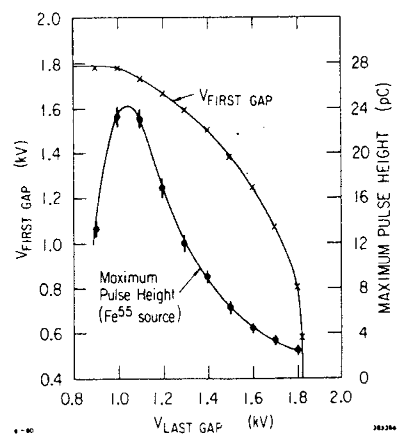


Fig. 2. Variation in maximum pulse amplitude before sparking for two amplifying gaps as a function of the voltage on the last gap.

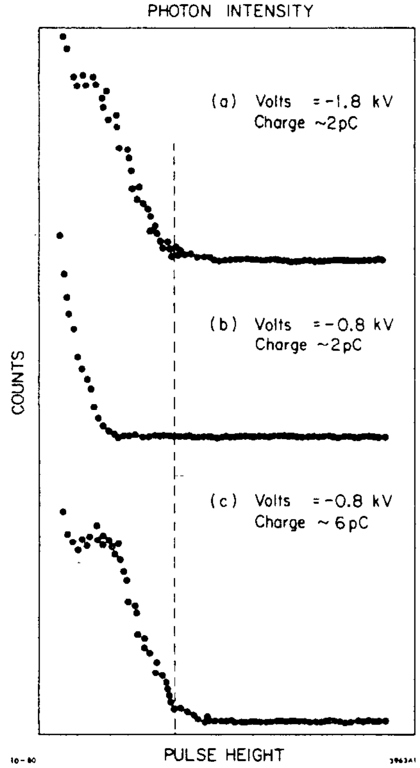
*Work supported in part by the Department of Energy, contract DE-AC03-76SF00515, and by the Bristol University.

†On study leave from Bristol University, Bristol, England.

(Contributed paper to the 1980 Nuclear Science and Nuclear Power Systems Symposium, Orlando, Florida, November 5-7, 1980.)

nal gap is varied and that on the earlier gap altered compensate. The chamber contained 2½ percent acene in neon for this measurement. The maximum output found for a low voltage in the final gap and the incipal gain in the earlier gap. Further reduction the field in the final gap reduces its gain below e point where it can compensate for the transmission ss through the mesh and the system is effectively a ngle gap chamber.

In general one gets greater output if the field is w in the last gap, where the charge density is high. seems likely that spark formation is caused largely photons with energy below the value for strong abrption by the acetone, as these can readily penetrate ross the chamber to the cathode. Figure 3 shows



ig. 3. Pulse height spectra for the number of phoons detected from avalanches for different values f total charge and voltage in the final chamber gap.

lse height spectra for the number of photons emitted om the avalanche for different chamber voltages which e detected by a photomultiplier through an Aclar winw. Comparison of plots (a) and (b) shows that, for e same final charge, more light is emitted for higher lues of the field in the final gap.

Some of the emitted photons may be prevented from aching the cathode by replacing one or more of the gh transmission screens by ones of lower optical ansmission, as proposed by Vincent.[8] Unfortunately, r wire mesh screens the electron transmission falls re quickly than the optical transmission. As the alanche is wide compared with the spacing of the reen mesh the charge transmission may be averaged er the mesh, and may be assumed to be the same as the netration of electric flux through the mesh. Figure shows how the flux transmission is reduced due to inced charges on the finite wires, and plots measured lues of electron transmission for a mesh of 80% opcal transmission, compared with a calculation similar that of Bunemann, Cranshaw and Harvey.[9] This calcution ignores the effect on the field around a wire e to the induced charges on neighboring wires.

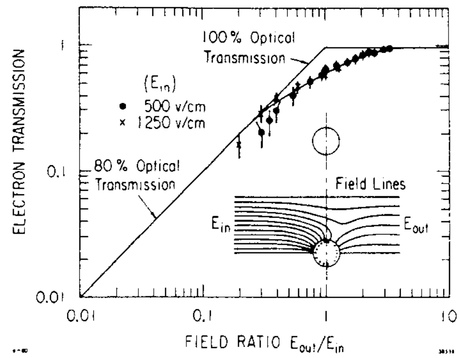


Fig. 4. Predicted electron transmission through a wire mesh versus the ratio of the electric fields on either side of the mesh, compared with a measured value at low field strenghts. The inset sketch shows how the transmission is reduced due to field lines ending on induced charges in the wire.

It appears satisfactory for high transmission meshes, but must be wrong when the wires are close together. For a mesh of 30% optical transmission it predicts zero electron transmission for similar fields on the two sides. A measurement of the drop in charge detected when such a mesh is inserted in place of a high transmission one shows that the electron transmission is in fact less than one percent. In principle, one can make up the loss in transmission by increasing the gain in the later gap, but if the loss is too great the higher fields will cause breakdown. The 30% mesh was found to give an increase in the maximum output by a factor of more than two.

A better performance is obtained with an electroformed screen .0076 mm thick which has .076 mm square holes on a center spacing of .25 mm, giving an optical transmission of ~ 10%. As the hole size is large compared with the screen thickness, the induced charges on the edges of the holes have less effect than for the wire screens. Measurements give an electron transmission of about 8% for equal fields on either side. The use of this electroformed screen gave a maximum output similar to that obtained with two 30% wire meshes.

CHAMBER PERFORMANCE

As the gain is limited by spark formation, which appears to depend on the charge density in the final stage of the avalanche, greater gains may be obtained for single photoelectrons than for particles giving large ionization, such as the x-rays from Fe^{55}. Figure 5 shows a pulse height spectrum obtained for photoelectrons produced by shining UV photons through an Aclar window onto an aluminum wire near the cathode, using a gas mixture of 2½ percent acetone in helium. The peak of the distribution corresponds to 6×10^7 electrons, which is a gain of 6×10^7. This gain was measured by calibrating the pulse height analyzer with the spectrum from an Fe^{55} source, the gain being adjusted to give the 5.9 KeV peak in the same place as the observed photoelectron peak. Figure 6 shows the Fe^{55} spectrum, which has a sharp peak that is clearly identifiable on an oscilloscope display of pulses direct from the chamber. By measuring the pulse height produced across a known capacitance the total charge may be estimated.

The single electron pulse height spectrum shows a clear peak which is well separated from noise. With the multigap arrangement it should be possible to improve the pulse shape by increasing the field strength at the beginning of the avalanche[10]. One could envisage having a very narrow gap with a high field and still not have excessive gain.

When detecting ionizing particles we used a gas

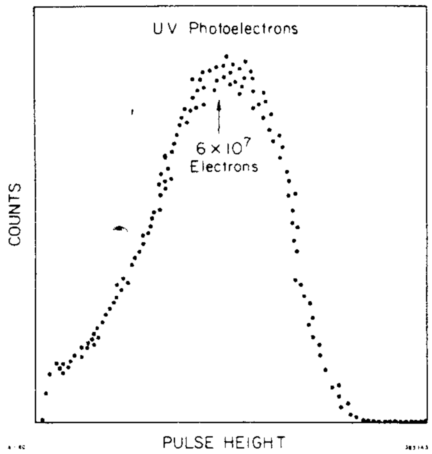


Fig. 5. Pulse height spectrum for photoelectrons from UV light shining on an aluminum wire. The chamber contained 2½% acetone in helium.

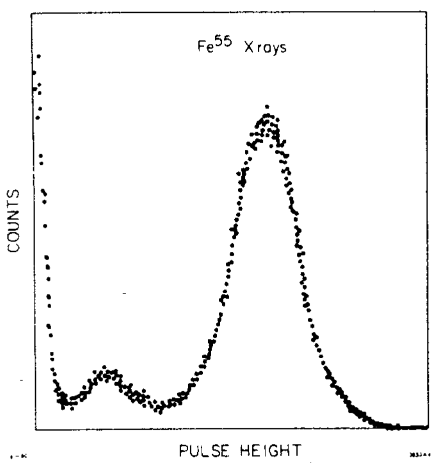


Fig. 6. Pulse height spectrum for Fe^{55} x-rays. The chamber contained 2½% acetone in neon.

mixture of 2½% acetone in neon as this was found to give high gains at low voltages. To observe photoelectrons, where the particles were not detected by ionization in the majority gas, we used a mixture of 2½% acetone in helium. This reduced the problem of sparking due to ionization from cosmic rays through the chamber and was observed to give a better pulse height spectrum. We have also made preliminary measurements with a mixture of 2% TEA (TriEthylAmine) in neon which gave results similar to those obtained with acetone.

The width of the avalanche in the final gap is of the order of 1 mm but varies with the gas mix and voltage distribution on the screens. Figure 7 shows the distribution of charge across an avalanche as indicated by an anode which consists of parallel strips approximately 1 mm apart. In this instance the full width of the avalanche at half height is greater than 2 mm.

The pulses from photoelectrons may readily be discriminated from noise, but this does not show that the chamber is efficient for detecting single electrons as they could be lost before an avalanche is formed. The only reliable check would be a direct measurement of the photo detection efficiency, which we have not yet done. We have attempted to observe electron attachment in the gas by measuring the charge which penetrates a low field drift region as a function of the drift field. If there is significant loss you would expect the charge to decrease with the drift field. Figure 8 shows

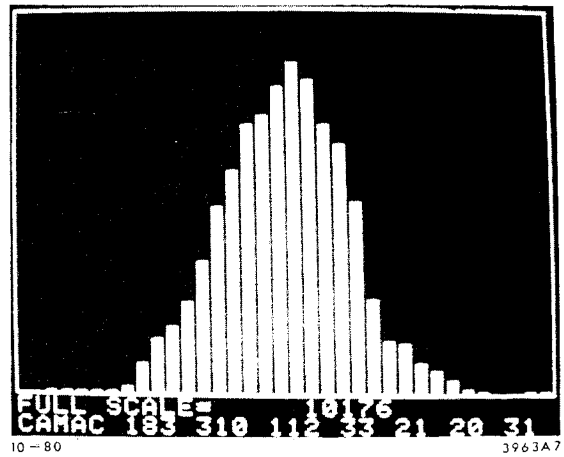


Fig. 7. Distribution of charge across an avalanche as detected by an anode consisting of thin parallel strips. Each bin represents 0.25 mm.

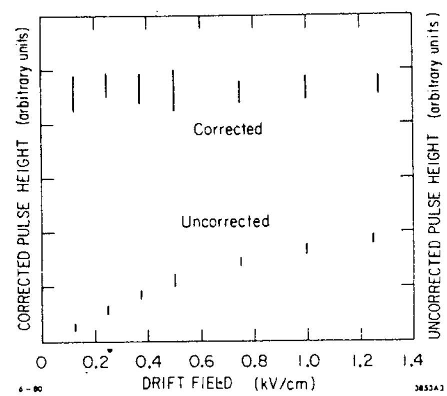


Fig. 8. Relative amount of charge which survives a 4 mm drift region as a function of the applied voltage, before and after correction for transmission through the wire meshes.

the results; insofar as the correction for transmission through the mesh is valid there is no sign of electron loss.

With high gain in the chamber there is a significant drop in output pulse height at moderately high rates. With pulses of 8×10^7 electrons there is a 5% drop in amplitude for a rate of 5×10^3 events cm^{-2} sec^{-1}, while smaller pulses allow a proportionately higher rate. This is compatible with loss of gain due to the reduction of the field in the final gap by the space charge present. If a high gain multigap chamber is to operate in a high background flux it will require some form of gating of the avalanches.

READOUT

In the multigap avalanche chamber the amplification mechanism is largely independent of the nature of the anode. This gives considerable freedom in the choice of readout method. In Čerenkov ring imaging applications we expect to observe simultaneously many photoelectrons distributed around the ring image. This means that one requires a true two-dimensional readout, as any form of X-Y projection would give too many ambiguities.

The simplest readout technique is in effect that used in our test chamber. The charge collected on each small anode pad is amplified and the output stored in a register. This gives minimum confusion between avalanches, but requires many amplifiers and registers for a large detector, probably in excess of 10^5. It might be possible to avoid the use of amplifiers and store the charges directly in some form of charge transfer device. An alternative readout technique, if the output pulse is sufficiently large, is the use of a capacitor diode readout system. With 60 pF pulses you could store 2V on 30 pF capacitors attached to small anode pads. Such small capacitors should be practicable as the stray capacitance of the pads is of the order of one or two pF. We have obtained pulses of this size from Fe^{55} x-rays, but not so far for the peak of the photoelectron distribution.

We are investigating the use of resistive anodes to locate the avalanches by charge division in two dimensions. This technique is currently used in UV astronomy[11] where a precision of 20 μm over a 20 mm anode has been obtained with 6×10^7 electrons.[12] The charge division technique gives the centroid for an extended avalanche, which is an advantage for the wide avalanches obtained with parallel plate chambers. We have made preliminary tests with a resistive anode of the type described by Lampton et al.[11] Figure 9 shows a picture obtained for photoelectrons produced from the cathode

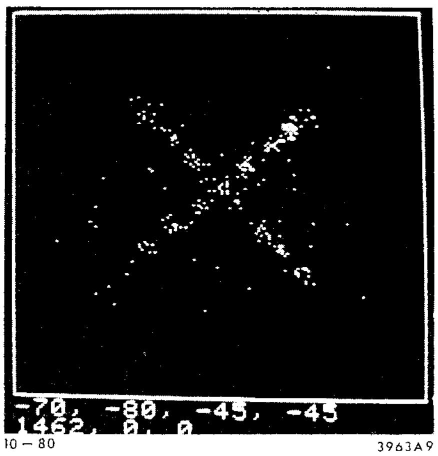


Fig. 9. Picture obtained from a two-dimensional resistive anode by charge division, for photoelectrons produced by illuminating the cathode mesh through a pattern of 1 mm holes.

screen when illuminated by an ultraviolet lamp through a pattern of holes each 1 mm in diameter. There is significant background due to light backscattered onto the cathode from subsequent screens and variation in the photoemission from different regions of the cathode may be observed. The width of the X shaped pattern is compatible with the expected area of illumination.

A Čerenkov ring image may give two or more avalanches onto the same anode cell. The anode will give a measure of the centroid for the total charge of all the avalanches which will be displaced toward the center of the ring. This will give a slight reduction in the measured radius, but provided the radius of the Čerenkov ring is large compared with the size of the anode cells the error so introduced is acceptable.

An alternative possibility to the resistive anode is to use a Wedge-and-Strip anode as described by Martin et al.[13] This gives the position of the charge cloud from the relative amounts of charge picked up by a pattern of tapering pads. It requires that the width of the avalanche be greater than the period of the anode pattern.

Anodes with periods as small as 1 mm may be made by printed circuit techniques, so this is consistent with the avalanche width shown in Figure 7. Printed anodes could be produced economically in sufficient quantities to make a detector with a large multicell anode.

CONCLUSION

Multigap parallel plate proportional chambers give high gains and good pulse height spectra for single electrons. With a suitable photoionizing gas, such as TEA, they should provide a simple and reliable detector for UV photons. We have not yet decided on the type of readout to use, but a free choice is possible as the avalanche multiplication is independent of the nature of the anode, especially with a low field in the last gap. We hope soon to build a prototype Čerenkov detector using such chambers.

ACKNOWLEDGMENTS

The authors are grateful to A. Kilert for his efforts in finding suitable materials for use in our test chamber, and to W. Walsh for general technical assistance. One of us, R. Gilmore, wishes to thank Bristol University for financial support during his leave of absence from the University.

REFERENCES

1. J. Seguinot and T. Ypsilantis, Nucl. Instrum. Methods 142, 377 (1977); S. Durkin, A. Honma and D.W.G.S. Leith, SLAC-PUB-2186; R. Gilmore et al., Nucl. Instrum. Methods 157, 507 (1978).
2. S.H. Williams, D.W.G.S. Leith, M. Poppe and T. Ypsilantis, IEEE Trans. Nucl. Sci. 27, No. 1, 91 (1980).
3. J. Sequinot, J. Tocqueville and T. Ypsilantis, CERN/ED 79/161 (submitted to Nucl. Instrum. Methods); T. Ypsilantis, oral presentation of invited paper at IEEE Nuclear Science Symposium (1979); D. F. Anderson, LAUR 80 1567 (submitted to Nucl. Instrum. Methods).
4. G. Charpak and F. Sauli, Phys. Lett. 78B, 523 (1978).
5. A. Breskin, G. Charpak, S. Majewski, G. Melchart, G. Petersen and F. Sauli, Nucl. Instrum. Methods 161, 19 (1979); also CERN 78-5.
6. G. Charpak, S. Majewski, G. Melchart, F. Sauli and T. Ypsilantis, Nucl. Instrum. Methods 164, 419 (1979).
7. G. Melchart, G. Charpak and F. Sauli, IEEE Trans. Nucl. Sci. 27, No. 1, 124 (1980).
8. C.H. Vincent, Nature 177, 391 (1956).
9. O. Bunemann, T.E. Cranshaw and J. A. Harvey, Can. J. Res. 27A, 191 (1949).
10. G.D. Alkhazov, Nucl. Instrum. Methods 89, 155 (1970).
11. M. Lampton and C.W. Carlson, Rev. Sci. Instrum. 50 (9), 1093 (1979); J. Alberi and V. Radeka, IEEE Trans. Nucl. Sci. 23, No. 1, 251 (1976).
12. W. Parkes, K.D. Evans and E. Mathieson, Nucl. Instrum. Methods 121, 151 (1974).
13. C. Martin, P. Jelinsky, M. Lampton, R.F. Malina and H.O. Anger, submitted to Rev. Sci. Instrum.