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DEVELOPMENT OF DUMONT PHOTOMULTIPLIER TUBES

Report No. 20 for December 1, 1955 to February 28, 1956

By
B. R. Linden
Philip A. Snell
F. W. Schenkel

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Tube Research Laboratories
Allen B. DuMont Laboratories, Inc.
Passaic, New Jersey

Technical Information Service Extension, Oak Ridge, Tenn.

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DEVELOPMENT OF DUMONT PHOTOMULTIPLIER TUBES

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December 1, 1955 to February 28, 1956

Prepared by: B. R. Linden, Asst. Engrg. Manager
P. A. Snell
F. W. Schenkel

Approved by: S. J. Koch, Director

Allen B. Du Mont Laboratories, Inc.

Tube Research Laboratories

2 Main Avenue

Passaic, New Jersey

DEVELOPMENT OF PHOTOMULTIPLIER TUBES

A. Large Area Multiplier Phototubes

The development of the K1328 (16" diameter tube) has reached a point where it is now being put into the pilot production stage. The tubes with split cones have been coming through satisfactorily and as the experience with this tube increases the characteristics of the tube improve. This tube is now considered to have passed out of the developmental stage. The use of split cones on these tubes has made the problem of mounting and sealing quite a bit easier and it is felt that the split cone technique has improved the average characteristics of the tubes.

Work has proceeded satisfactorily on the 12½" diameter tube (type K1384). This tube also uses a split metal cone. It is estimated that the use of a metal cone on this tube has cut its weight in half. Two such tubes have been constructed in the period covered by this report. The data is given in Table II at the end of this report.

As mentioned in the last quarterly report, a special addition for the flying spot scanner has been constructed to allow testing the large area tubes with this equipment. Such tests were performed and Fig. 1 and 2 show the results. Fig. 2 shows the signal as seen on an oscilloscope when a single line (rather than a full raster) is projected upon the cathode. A single line was used because a full raster gives too complicated a picture. The oscillograph pictures correspond to the same tubes as are shown in Fig. 1. The surprising uniformity of the 21" tubes is of great interest. The oscillograph picture for the 16" tube shows two traces. The upper one is with the shield potential adjusted for optimum uniformity while the lower one shows the signal with the shield at dynode one potential. These pictures clearly demonstrate that the collection uniformity is by far the more important variable in attaining uniformity of response across the cathode area.

B. Potassium-Free Glass

One of the vexing problems in low intensity gamma ray detection is the presence of radioactive potassium in the body of multiplier phototubes. Since wherever natural potassium occurs a certain amount of radioactive K^{40} will be present it is important to use materials which are potassium free. In an effort to locate the main source of such potassium in the tubes and to check out other possible materials, samples of various glasses have been sent to Oak Ridge and Argonne Laboratories for testing. Also, samples of the basing cement and bases were sent. The types of glass sent were Corning types 0080, 0012, 7052 and 9010. Type 0080 is used in the main body of the tubes while type 0012 is used in the stem. This latter glass is particularly suspect since it is known to contain a large percentage of potash. As soon as information on these tests is available, it will be reported in these reports.

C. Pulse Height Shift

Recently an effect has come to light which is being investigated at this time. The effect is that the gain of the multiplier phototubes using silver-magnesium dynodes is a function of the counting rate. In general, the gain increases with counting rate as against cesium-antimony where the gain decreases at high counting rates because of dynode fatigue effect. It is possible, however, to get a decrease in gain with increased counting rate for Ag-Mg dynodes. There appears to be no definite information on the cause of this effect. Two possible causes have been put forth, namely (1) the migration of the cesium from the dynode surfaces under high current bombardment causes a shift (2) the charging up of the thin oxide layer on the surface gives rise to a modified malter effect.

In an attempt to find a surface which did not show this effect, an Al-Be alloy was investigated as a possible secondary emission surface. A ten stage tube was constructed after having determined a possible activation procedure for the dynodes. The variation of gain with voltage for the dynodes in this tube is shown in Fig. 3 where it is compared to Ag-Mg. This ten stage structure which was incorporated into a 3" blank was sent to

Brookhaven National Laboratory for a check on the variation of pulse height with counting rate. Dr. W. Bernstein who performed the tests reports the same order of magnitude of pulse height shift as is observed with Ag-Mg.

To make a more extensive investigation of this phenomenon it has been decided to build a demountable tube system with which it will be possible to investigate various secondary emission surfaces in more detail. Plans are underway to set up this device and preliminary design has begun.

E. Transit Time Spread

A new experimental tube for measuring transit time spread has been constructed. As was stated in report #19, difficulty with respect to focusing of the secondary electron beam was encountered in the previously constructed tube. The newly constructed tube employs a revised design in the secondary gun structure, permitting the beam to be focused into a spot size of approximately 1/4".

Various difficulties with regard to interference pickup were encountered. A revision of the grounding of the entire system was found necessary. Operating the probe wire of the tube as close to ground as possible gives a large improvement in the signal to noise ratio. With additional amplification of the pulse as taken from the wire probe, a signal of satisfactory amplitude is obtained and may be viewed on an oscilloscope.

Measurements have been made on the tube using a frequency of 425 kc. At this low frequency the input pulse is much wider than any expected transit time spread so that one expects the output to be the same as the input. This was found to be substantially correct. However, with some minor refinements in the present system, accuracies of a much higher order are expected. Once better accuracy has been obtained in making the actual measurements at this low frequency, it will be possible to conduct the experiment at 10 mc. where a true indication of the transit time spread may be obtained. Fig. 4 shows a photograph of the output pulse as taken from the wire probe of the experimental tube. Some slight phase distortion is evident in the lissajous pattern.

At present a transit time spread tube is being constructed containing a new experimental linear type dynode structure, which is now under development in these laboratories. Fig. 5 gives the configuration of the new structure.

F. 3/4" Diameter, Cs-Sb Dynode Tubes (K1382)

As reported in the last quarterly report another batch of the K1382 tubes was run through. In these tubes the amount of cesium and antimony were varied in an attempt to improve the gain of the tubes. The results are shown in Table I at the end of this report.

Table I shows that while reasonably good cathode sensitivity was readily attained, the gain of the structures are still very low in general. Since good cesium-antimony tubes were obtained on our other types during the period that these tubes were constructed, it is not believed that the dynode activation is at fault in this tube. This is backed up by the fact that similar results were obtained with Ag-Mg dynodes on the 10 stage 3/4" diameter tubes. Examination of the structures showed that the ceramics are such that the dynodes are not as close as they should be for optimum collection from stage to stage. Indeed, it appeared that the absolute distance between dynodes was even larger than for the standard Du Mont type 6292 tubes. Accordingly steps have been taken to decrease the inter-dynode distances. Several tubes are in processing now and it is believed that this will improve the gain of the tubes to a great degree.

Other possibilities for low gain such as poor photoelectron collection efficiency have been eliminated by viewing the output of the tubes in the flying spot scanner. Tests of the tubes have been performed in which the gain of each dynode was measured by itself. These tests indicate that the gains are uniformly low on all dynodes. Since the dynodes (both Cs-Sb and Ag-Mg) were processed simultaneously with similar dynodes for tubes that showed normal gains it seems likely that the main difficulty is in the structure itself. As mentioned above, tests are now underway to investigate this possibility.

TABLE I

Tube No.	Photocathode Sensitivity uA/l	Gain (105V/stage)	Anode Leakage(uA) (105V/stage)
9190EJ	35.2	6,000	.003
814 EK	21.6	8,500	.012
2458EK	22.4	7,800	.006
9188EJ	46.4	25,000	.03
8374EJ	50.0	5,600	.003
1586EK	35.2	8,150	.13
1591EK	49.5	4,600	.003
1587EK	32.0	7,150	.003
1590EK	35.2	10,500	.004
1589EK	25.6	16,000	.005
1592EK	10.6	3,300	.004
262 EK	38.4	20,300	.12
9189EJ	48.0	9,900	.003
1588EK	17.6	160,000	.007
258 EK	48.0	4,000	.04
125 EK	28.8	23,200	.3
9329EJ	30.4	28,000	.003
729 EK	38.8	6,600	.01
No Number	21.6	113,000	.043
815 EK	46.4	49,000	.16
2456EK	22.4	35,500	.07
731 EK	36.8	39,500	.062

G. Linear Photomultiplier Structures

Further investigation has been carried out to determine the more intricate characteristics of linear type dynodes. As a result of carrying out extensive field plotting, it can be concluded that the first stage of the dynode structure is a major factor governing the transit time spread. A tube has been constructed employing the new linear structure. A sketch of the structure is shown in Fig. 5 of this report. It is believed essential that an accelerator electrode be incorporated in the tube in order to avoid space charge saturation. This tube employs very close spacing of the dynodes and is expected to produce very good results with respect to transit time spread and high output currents. At present, the complete test results from the tube are not available. The tube had just been subjected to the normal operational tests as conducted on our standard tube types. Under these conditions a gain measurement of 600,000 was obtained with 12 stages operating at 105 volts per stage. It is evident that higher gains are obtainable by optimizing the individual voltages between each stage of the structure. That is to say, obtaining the voltage individually for each stage that will give a maximum output. Due to using long and narrow first dynode it is believed that the collection efficiency is somewhat poorer than might be desired. Further investigation is being carried on in order that some revisions might be incorporated into the front end and thereby improve the collection efficiency.

The tube shows a fair degree of promise at present, however, more extensive tests with regard to transit time spread, resolution, and peak current outputs must be conducted in order to further substantiate these beliefs.

TABLE II

CHARACTERISTICS OF $12\frac{1}{2}$" DIAMETER MULTIPLIER PHOTOTUBES

TYPE K1384

Tube No.	Photocathode Sensitivity uA/l	%Blue Sensitivity	Gain	Anode Dark Current(uA)
8990EJ	33	7.4	100,000	0.11
9674EJ	22	14.3	2,860,000	0.24

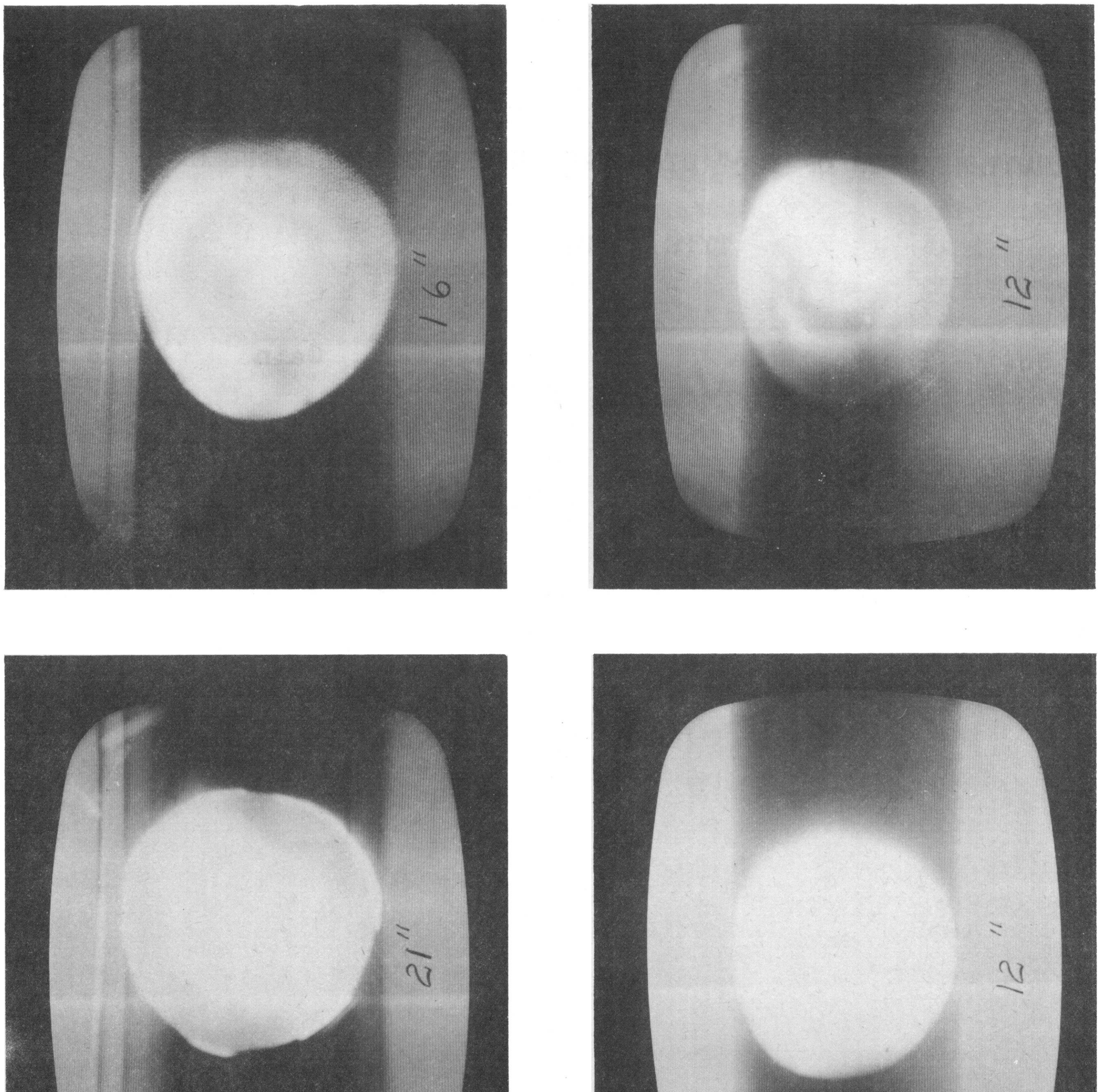

Fig. 1

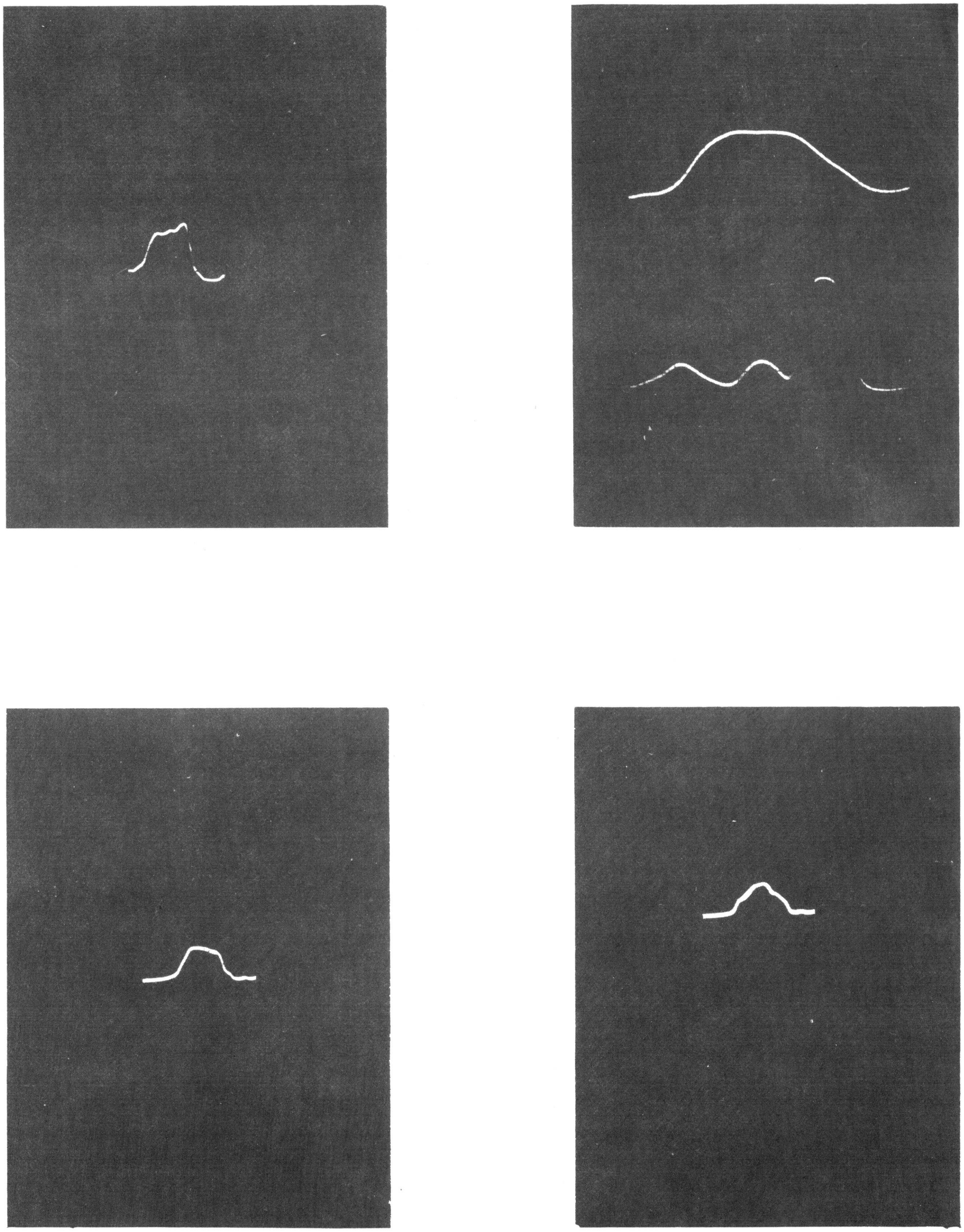

Fig. 2

SECONDARY EMISSION RATIO VS. VOLTAGE

For Ag-Mg+Cs and Al-Be+Cs

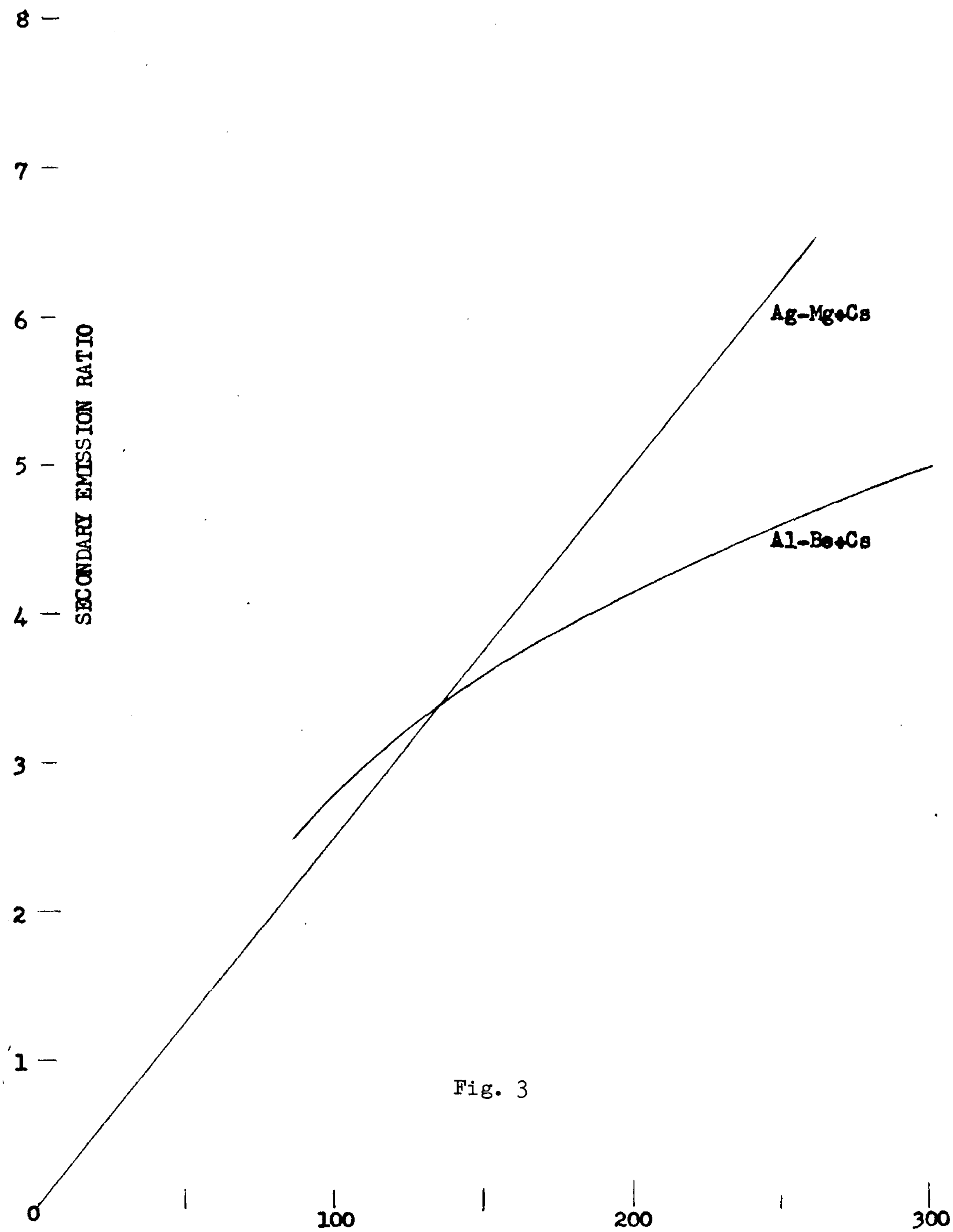

Fig. 3

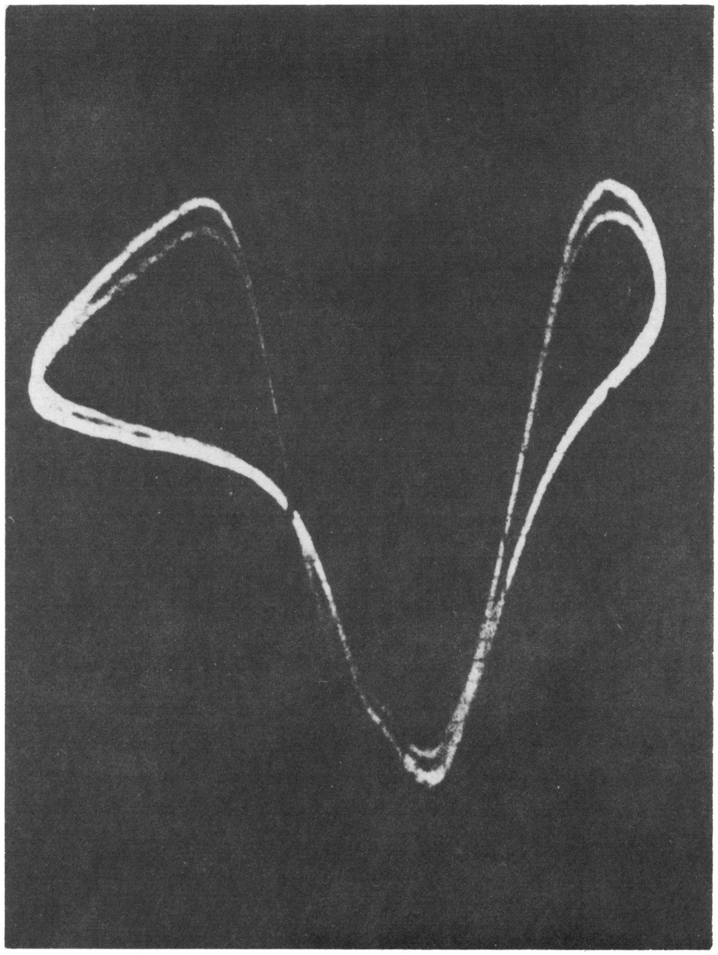

Fig. 4

Linear Dynode Structure

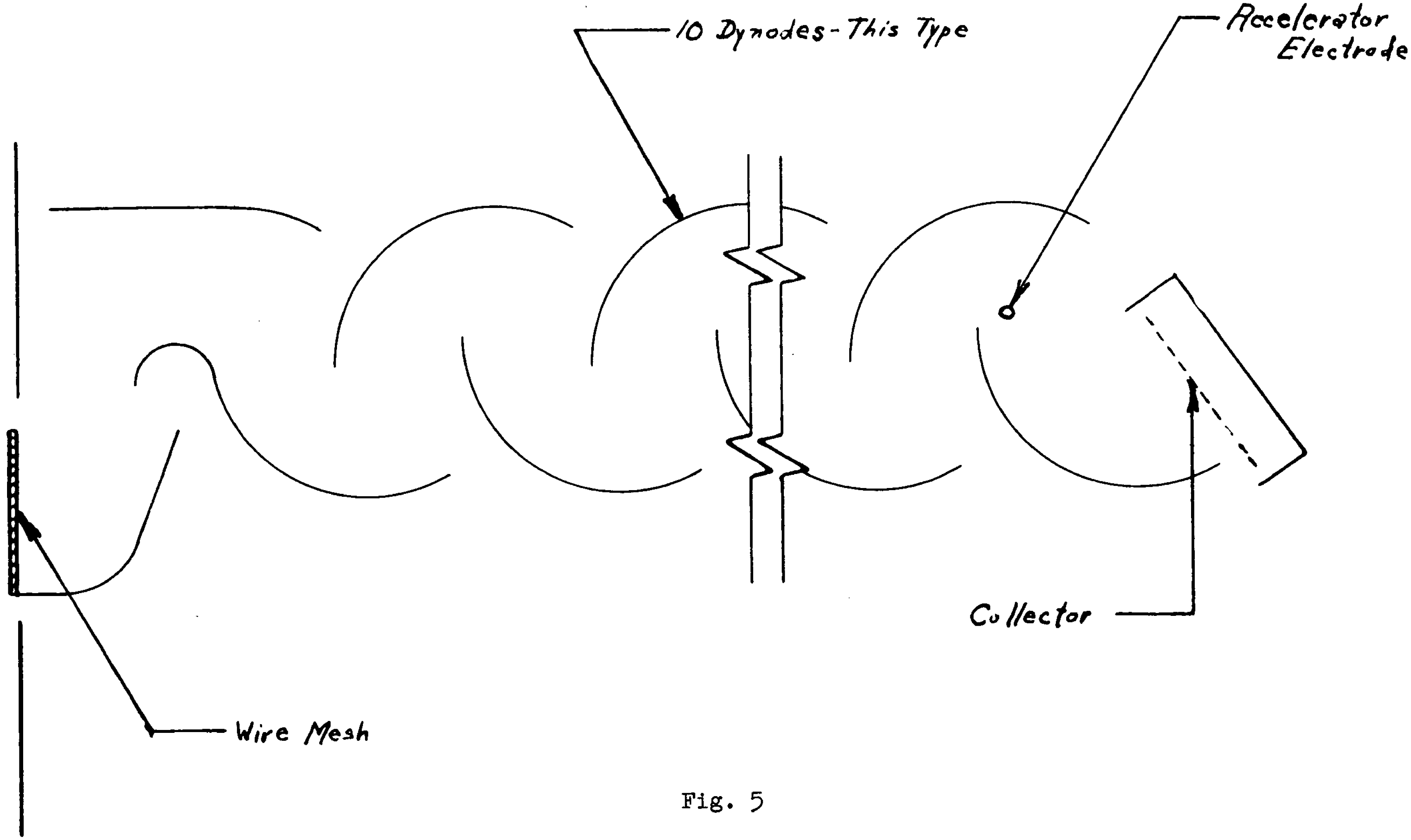

Fig. 5