May 27, 1958 A. H. SOMMER 2,836,755

ELECTRON MULTIPLIERS

Filed May 11, 1953

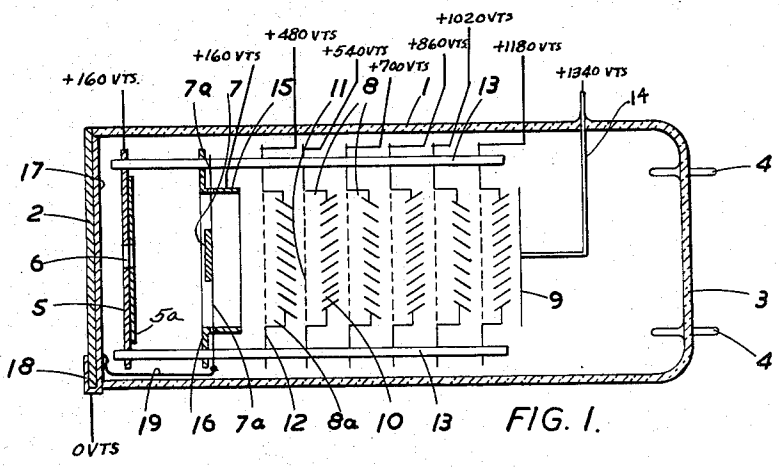

FIG. 1.

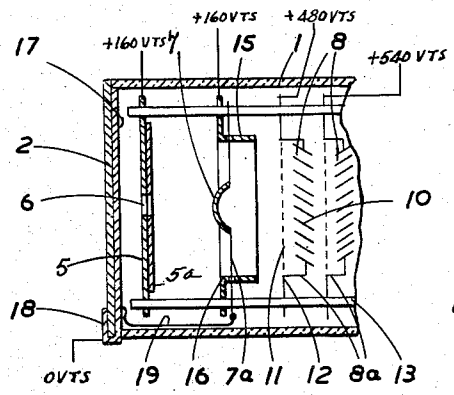

FIG. 2.

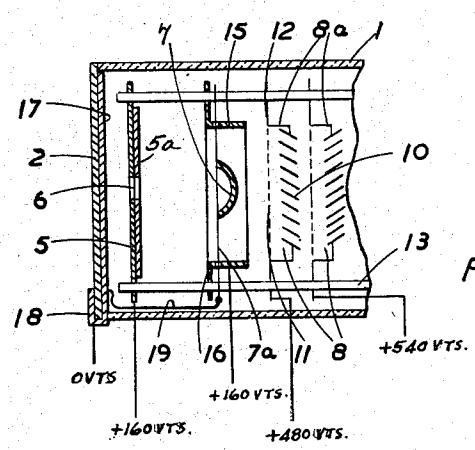

FIG. 3.

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United States Patent Office 2,836,755 Patented May 27, 1958

2,836,755

ELECTRON MULTIPLIERS

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Application May 11, 1953, Serial No. 354,112
Claims priority, application Great Britain May 27, 1952
6 Claims. (Cl. 313—95)

This invention relates to electron multipliers of the type wherein one or more secondary electron emissive electrodes or dynodes are disposed within an envelope in which is also disposed a photo-electric cathode and an electron collecting electrode, the arrangement being such that the incidence of light on the photo-cathode causes electrons to be emitted therefrom and the impact of said electrons on the secondary emissive electrode or electrodes causes secondary electrons to be emitted in greater numbers than the primary electrons whereby the electron current arriving at the collector is greater than the electron current proceeding from the cathode.

For optical reasons it is desirable that the light intercepted by the photo-cathode should be incident in a direction normal to the surface of the cathode and for electron-optical reasons it is also desirable that the dynode electrodes should be so arranged as to ensure a uniform transit time of the electrons and a uniform collection efficiency.

In a known form of high sensitivity multiplier phototube these requirements are achieved by employing a semi-transparent photo-cathode formed on the planar glass end wall of the envelope of the tube, and a series of "venetian blind" type of dynodes are provided so that they are substantially parallel to the surface of the cathode. However, the photo-electric sensitivity that can be obtained with semi-transparent cathodes is less than that which is obtainable with opaque cathodes and hence, the usefulness of the tube, particularly with regard to the signal-to-noise ratio could be greatly enhanced if a tube of this type could be provided with an opaque photo-cathode.

It is therefore an object of the invention to provide an electron multiplier device with an opaque photo-cathode arranged so that light may be directed on to the cathode surface normally and wherein the electron transit time from the cathode to the first dynode is substantially uniform.

According to the invention an electron multiplier comprising an envelope having a translucent window, an apertured dynode electrode mounted in said envelope to face said window, an electron emitting layer on the surface of said dynode remote from said window, a further electrode spaced from said dynode, and an opaque photo-electric cathode, means mounting said cathode between said dynode and further electrode with the active surface of said cathode facing said aperture in said dynode, said cathode having an area small in relation to said dynode and said further electrode, to allow electrons released from said dynode to pass said cathode to said further electrode.

Said further electrode may comprise a dynode or a collecting electrode depending on whether the multiplier is a multi-stage or single stage device.

In order to ensure that the secondary electrons emitted by said dynode, are directed onto said further electrode past said cathode focussing means may be provided and said focussing means may be in the form of a ring surrounding the region between the cathode and further electrode and maintained at or near the potential of the apertured dynode.

In order that the said invention may be clearly understood and readily carried into effect, various embodiments will now be described with reference to the accompanying drawings, in which:

Figure 1 shows one embodiment of the invention applied to a multi-stage electron multiplier, and

Figures 2 and 3 show alternative forms of cathode which may be employed.

Referring to Figure 1 a tubular glass envelope **1** is provided at one of its ends with a planar transparent glass window **2** and at its other end with a base **3** having sealed therethrough a plurality of contact making elements **4** to which leads not shown, are taken from the various electrodes. Arranged within the envelope **1** near to and parallel with the window **2** is a metal disc which forms the first dynode **5** of the device said dynode **5** having an active electron emitting surface **5a**. This dynode **5** is provided with an aperture **6** so arranged that its centre is in line with the axis of the envelope **1**. The dynode **5** may, for example be 20 mm. in diameter and the aperture **6**, 3 mm. in diameter, the surface of the dynode **5** which is remote from the window **2** being coated with an active material such as antimony caesium. A photo-cathode **7** in the form of a metal disc of 5 mm. diameter is mounted from radial wires **7a** so as to be substantially parallel with the dynode **5** with its axis in line with the centre of the aperture **6** in the dynode **5**; the active surfaces of the two electrodes **5** and **7** being arranged facing each other but spaced apart by a distance of 15 mm. The distance between the cathode **7** and dynode electrode **5** has been found to be fairly critical and should be of the order of 3 times the diameter of the cathode **7**.

A series of secondary electron emitting dynodes **8** and an electron collecting electrode **9** are arranged between the cathode **7** and the base **3**, the first of this series of dynodes **8** being mounted so as to be at a distance of 5 mm. from the cathode **7** so that it faces the uncoated side thereof.

Each of the dynodes **8** comprises a box like structure **8a** having arranged therein a number of obliquely disposed louvres **10** the side of the structure **8a** facing the cathode **7** being covered by wire mesh **11**.

Extending from each structure **8a** is a flange **12** provided with apertures whereby the whole series of dynodes **8** may be mounted by means of insulating rods **13** with the louvres **10** of adjacent dynodes **8** oppositely directed as shown. In the drawing six dynodes **8** are illustrated by way of example although it will be understood that the number provided may be varied for different tubes depending on the degree of amplification required. The collector electrode **9** is supported from an arm **14** sealed through the wall of the envelope **1**.

In the region between the cathode **7** and the first dynode **8** there is arranged a tubular electrode **15** of a diameter of 15 mm. provided at the end nearest to the cathode with an outwardly directed flange **16**, said electrode being positioned so as to be coaxial with the cathode **7** and serving in the operation of the tube as a means for focussing electrons from the apertured dynode **5** past the cathode **7** on to the first dynode **8** and thence through the further dynodes **8** to the collector **9**. The inner surface of the window **2** may be provided as shown at **17** with a translucent conducting coating having a contact **18** passing through the envelope **1**, the purpose of this coating **17** will be described later.

The photo-cathode **7** and the dynodes **5** and **8** are preferably all provided with active coatings of antimony-caesium although it will be understood that if desired the photocathode **7** may be activated with a material which is different from that employed for the dynode electrodes. After activation of the electrodes **5**, **7**, **8** the envelope **1** is finally sealed off.

In operation of the device the apertured dynode **5** is preferably maintained at 160 volts positive and the first of the series of dynodes **8** at 480 volts positive with respect to the cathode **7** with the focussing cylinder **15** at or near the same potential as the apertured dynode **5**, increasing positive potentials being applied to the further dynodes **8** so that each dynode is 160 volts positive with respect to the preceding one the collecting electrode **9** being 160 volts positive with respect to the last dynode **8** of the series.

Light reaching the cathode **7** by passing through the aperture **6** in the dynode **5** releases photo-electrons which are attracted to the active surface **5***a* of the dynode **5** to cause secondary electrons to be released therefrom. It has been found that by suitably choosing the diameter of the cathode **7** and the spacing between the cathode **7** and dynode **5** electrostatic field conditions can be set up so that very few electrons emitted by the cathode **7** proceed to the area defining the aperture **6** in the dynode **5**, said electrons being substantially directed on to the active surface thereof. Secondary electrons released from the dynode **5** will travel in the direction of the more positive dynode **8** and due to the focussing field set up by the tubular electrode **15** and cathode **7** these secondary electrons will be directed past the cathode **7** so as to impinge on the first dynode **8** of the series thereby giving rise to further secondary electrons which are amplified in number by the succeeding dynodes **8** in their passage to the collecting electrode **9**.

Instead of making the cathode **7** of planar disc form, cathodes having convex or concave active surfaces may be employed. In the case of a convex cathode **7** illustrated in Figure 2 the photo-electrons released therefrom are less likely to pass through the aperture in the dynode **5** although there may be a slight tendency for such electrons to travel directly to the further electrode adjacent the cathode e. g. dynode **8**. With a cathode **7** of concave shape as illustrated in Figure 3 direct collection of the photo-electrons by the further electrode e. g. dynode **8** is not possible and provided it is arranged that a cross-over point exists between the cathode **7** and the apertured dynode **5**, loss of photo-electrons by passage through the aperture **6** is also reduced to a very low level.

As previously stated the inner surface of the window **2** in the region of the apertured dynode **5** may be coated with a translucent conducting layer **17** and this layer is preferably, maintained at or near cathode potential by means of a connecting strap **19**, so as to set up an electrostatic field in this region which has a repelling action on the photo-electrons so that substantially none of them are able to pass through the aperture **6**. Such a conducing layer **17** may be formed by applying to the surface of the window **2** a solution of stannous chloride whilst the glass is maintained at a high temperature.

Although the focussing cylinder **15** has been described as being positioned between the cathode **7** and first dynode **8**, this electrode may be arranged at other suitable positions between the apertured dynode **5** and the first dynode **8** so as to provide means for focussing the secondary electrons past the cathode **7**.

It will be understood that in the case of a single stage multiplier a suitable collecting electrode would be provided instead of the series of dynodes **8** and such an electrode would be positioned so as to face the uncoated side of the cathode **7**.

What I claim is:

1. An electron multiplier comprising an envelope having a translucent window, an apertured dynode electrode mounted in said envelope to face said window, an electron emitting layer on the surface of said dynode remote from said window, a further electrode spaced from said dynode, and an opaque photo-electric cathode, means mounting said cathode between said dynode and further electrode with the active surface of said cathode facing

said aperture in said dynode, said cathode having an area small in relation to said dynode and said further electrode so as to provide an open space surrounding said cathode, to allow electrons released from said dynode to pass said cathode to said further electrode, and electrostatic focussing means arranged co-axially with the centre of said cathode so as to lie between said dynode and said further electrode but spaced from said cathode to direct electrons from said dynode past said cathode onto said further electrode.

2. An electron multiplier comprising an envelope having a translucent window, an apertured dynode electrode mounted in said envelope to face said window, an electron emitting layer on the surface of said dynode remote from said window. a further electrode spaced from said dynode, and an opaque photo-electric cathode, means mounting said cathode between said dynode and further electrode with the active surface of said cathode facing said aperture in said dynode, said cathode having an area small in relation to said dynode and said further electrode, to allow electrons released from said dynode to pass said cathode to said further electrode, and means disposed between said window and said apertured dynode to set up an electric field to repel electrons thereby to prevent substantially the passage of electrons from said cathode through the aperture in said dynode electrode.

3. An electron multiplier according to claim 2 wherein said means disposed between said window and said apertured dynode, is a translucent electrically conductive coating arranged on said window.

4. An electron multiplier comprising an envelope having a translucent window, an apertured dynode electrode mounted in said envelope to face said window, an electron emitting layer on the surface of said dynode remote from said window, a further electrode spaced from said dynode, and an opaque photo-electric cathode, means mounting said cathode between said dynode and further electrode with the active surface of said cathode facing said aperture in said dynode, said cathode having an area small in relation to said dynode and said further electrode, to allow electrons released from said dynode to pass said cathode to said further electrode, electron focussing means to direct electrons from said dynode passed said cathode onto said further electrode and means disposed between said window and said apertured dynode to set up an electric field to repel electrons thereby to prevent substantially the passage of electrons from said cathode through the aperture in said dynode electrode.

5. An electron multiplier according to claim 4 wherein said means disposed between said window and said apertured dynode is a translucent electrically conductive coating arranged on said window.

6. A multi-stage electron multiplier comprising an envelope having a translucent window, an apertured dynode electrode mounted in said envelope to face said window, an electron emitting layer on the surface of said dynode remote from said window, at least one further dynode electrode spaced from said apertured dynode an electron collecting electrode arranged to receive electrons from said further dynode and an opaque photo-electric cathode, means mounting said cathode between said apertured dynode and said further dynode with the active surface of said cathode having an area small in relation to the active surface area of said apertured dynode so as to provide an open space surrounding said cathode, to allow electrons released from said dynode to pass said cathode to impinge on said further dynode and electrons released from said further dynode to be collected by said collecting electrode.

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