March 19, 1963 G. PIETRI 3,082,342

PHOTO-ELECTRIC TUBE

Filed Feb. 24, 1960 2 Sheets-Sheet 1

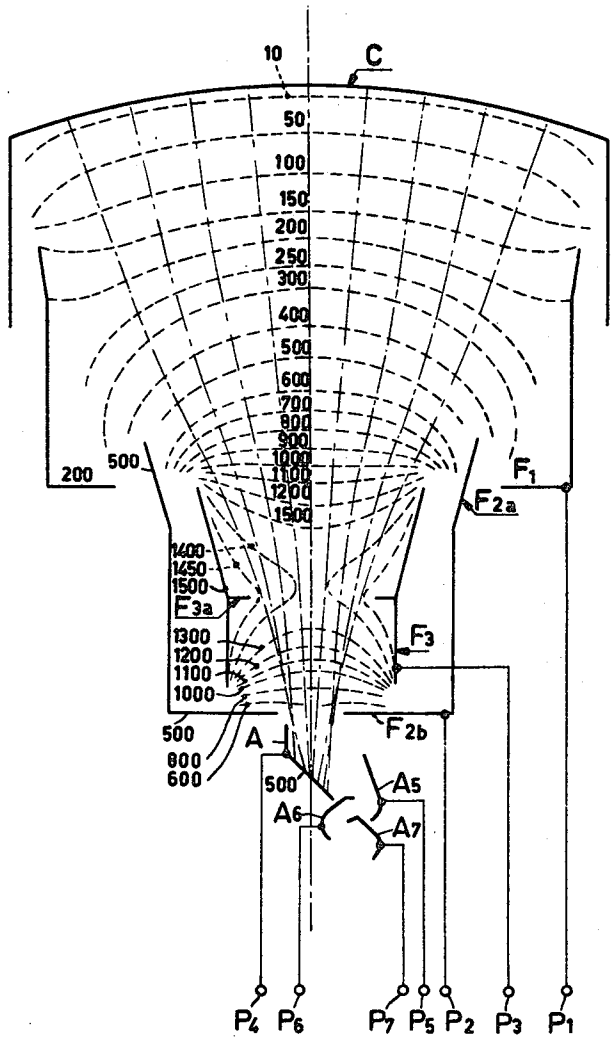


FIG. I

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Filed Feb. 24, 1960 2 Sheets-Sheet 2

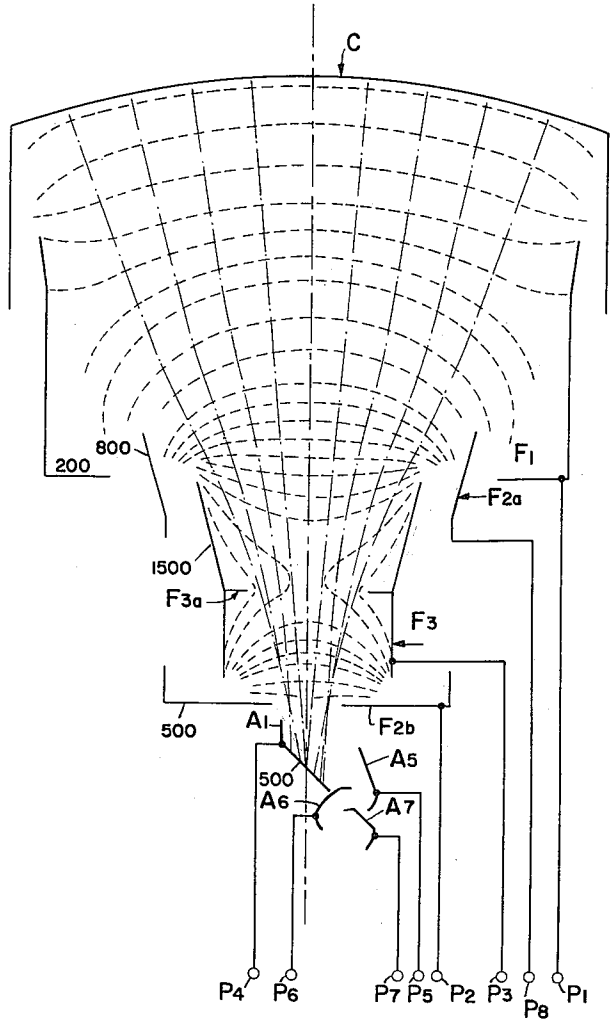


FIG. 2

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3,082,342

PHOTO-ELECTRIC TUBE

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This invention relates to a special electrode structure of a photo-electric tube which permits the electrons emitted by a photo-cathode to be concentrated in a suitable manner, and it relates more particularly to such electrodes for use in conjunction with photo-electric electron multiplier tubes. In the latter case, the invention refers more particularly to the electron-optical system following the photo-cathode and which feeds the input of the associated multiplier with electrons.

A photomultiplier tube employing a triode focussing system has been described previously in French Patent No. 1,196,334 which is suitable for relatively small cathodes, e.g. 40 mms. in diameter. For larger cathodes, the potentials which are applied to the electrodes are so high as to be impractical.

The invention permits of obviating this disadvantage for the first dynode by means of a new structure of the electron-optical system in which the divergence in the transit time along the paths extending in the axial direction and at the margin is maintained within permissible limits and, in addition, only small fluctuations in the transit times occur (correlated to the division of the initial velocities).

The invention substantially consists in that an electron optical system capable of focusing the photo-electrons emitted by a photo-cathode onto a collecting anode (for example the first dynode of an electron multiplier system) has added to it a greatly accelerating hollow co-axial electrode having a very high positive potential with respect to the photo-cathode, a decelerating electrode having a potential lower than that of the accelerating electrode, in the form of a screen having an axial aperture of a diameter smaller than that of the accelerating electrode, is positioned between the last-mentioned electrode and the collecting anode, which is arranged opposite this aperture and which has a potential equal to, or materially lower than, that of the accelerating electrode.

In fact, it is possible to bring the collecting anode to a potential equal or substantially equal to that of the decelerating electrode. After this electrode, the photo-electrons are then in a field substantially equal to zero. The potential of the collecting anode may thus be given a permissible value, although for dislodging the photo-electrons from the photo-cathode one has at one's disposal the above-mentioned accelerating electrode of very high positive potential.

In a second embodiment according to the invention, the electron-optical system comprises at least four electrodes, i.e. in the same order from the photo-cathode: a focusing electrode, an electrode of which the front portion adjacent the photo-cathode accelerates and focuses and the rear portion of which decelerates, and a fourth, greatly accelerating electrode which is located inside the preceding electrode, the conventional means for applying the potentials to the electrodes being such that the positive voltages of the electrodes with respect to the photo-cathode increase in the sequence of the above-mentioned enumeration of the electrodes.

The term "at least four electrodes" is to be understood herein to mean that it is not intended to be bound to the tetrode structure proper as mentioned above, i.e. that in certain cases it is not only preferable to provide additional electrodes, but also to subdivide several of the

above-mentioned electrodes. For example, the second electrode, as reckoned after the photo-electrode, may be divided into two parts, one part being the aforementioned front part which fulfils the function of the accelerating and focusing electrode, and the other being the rear part which is active as the decelerating electrode, it being possible, if desired, to apply different potentials to these two separate parts.

The invention will be described with reference to the accompanying drawing in which:

FIG. 1 shows one embodiment; and

FIG. 2 shows another embodiment of a tube according to the invention.

FIG. 1 shows a photomultiplier tube employing an electron-optical system according to the invention in conjunction with a plurality of dynodes.

This electron-optical system is thus based on an accelerating electrode F_3 having a very high potential (say 1500 volts) so that the suction field at the surface of the photo-cathode C has considerably increased and is at right angles thereto, resulting in at least the equipotential lines extending most closely to this surface being substantially parallel to this surface.

If this step were carried out without further expedients, the photo-electrons would impinge on the first dynode A_4 at excessive speed so that this dynode would not be working under optimum conditions. Consequently, according to the invention, provision has been made of an electrode F_2 having a lower potential (500 volts) than the preceding electrode, which electrode F_2 has a bent edge F_{2b} arranged behind the electrode F_3 so that this part F_{2b} is active as a decelerating electrode and brakes the photo-electrons passing through the diaphragm, constituted by the part F_{2b} of a diameter smaller than that of the electrode F_3. The potential of the first dynode A_4 may thus be equal to, or substantially equal to, that of the electrode F_2.

The front part F_{2a} of the electrode F_2 preferably projects forwardly from the electrode F_3 and is a little widened so that, when the photo-cathode C is provided with the conventional cylindrical focusing electrode F_1, which has been brought to, for example, +200 volts with respect to the photo-cathode, the part F_{2a} of the electrode F_2 fulfils the function of an accelerating and focusing electrode, thus permitting the form of the equipotential lines to be controlled. These lines each corresponding to a given potential shown as a function of the potentials applied to the electrodes, are indicated in dotted lines. As can be seen, the optical system according to the invention is equivalent to two lenses, the first convergent and the second divergent. The figure also shows an inner diaphragm F_{3a} which is integral with F_3 and which serves to give the field the most suitable profile.

Following the first dynode A_4, there are three sequential dynodes A_5, A_6, A_7, which may be followed by any desired number of analogous stages.

Each electrode F_1, F_2, F_3, A_4, A_5, A_6, A_7 is connected (here diagrammatically) to an output terminal P indicated by a corresponding figure, for applying the required potential (P_1: 200 volts, P_2: 500 volts, P_3: 1500 volts, P_4: 500 volts).

FIG. 2 shows another embodiment in which the parts F_{2a} and F_{2b} are separate and are at different potentials.

The photoelectrons need not be collected by a multiplier system, e.g. dynodes, but may be collected by an ordinary anode.

What is claimed is:

1. An electron optical system for a photomultiplier tube and the like comprising a photo-cathode, a focussing electrode, a hollow accelerating electrode, an anode, and a decelerating electrode surrounding a portion of the

accelerating electrode, said decelerating electrode having a screen portion between the accelerating electrode and the anode for decelerating photoelectrons emitted by the photocathode, said screen portion of the decelerating electrode having an aperture therein opposite the anode which is substantially smaller than the diameter of the portion of the accelerating electrode opposite the anode, said aperture being approximately adjacent a focussing point of photoelectrons from said photocathode between the accelerating electrode and the anode, means to apply a comparatively high positive potential to the accelerating electrode for accelerating photoelectrons emitted from said photocathode, means to apply a comparatively small potential to the anode to collect photoelectrons emitted by the photocathode, and means to apply a potential approximately equal to the anode potential to the decelerating electrode to thereby provide a substantially field-free space between the decelerating electrode and the anode.

2. An electron-optical system as claimed in claim 1, in which the potential of the collecting anode is equal to that of the decelerating electrode.

3. An electron-optical system as claimed in claim 1, in which one portion of said decelerating electrode is substantially cylindrical with a diameter larger than that of the accelerating electrode and is positioned co-axially with the accelerating electrode, said portion having a length approximately equal to that of the accelerating electrode, another portion of said accelerating electrode being an annular disc which is at right angles to the axis of the accelerating electrode and which has an aperture sufficiently small to ensure that the field strength is approximately zero in the space between the disc and the anode.

4. An electron-optical system as claimed in claim 3, which further includes, between the photo-cathode and the accelerating electrode, a cylindrical focusing electrode having a diameter larger than that of the last-mentioned electrode and which is connected to a potential with respect to the cathode, lying between the highest and lowest potentials, said focusing electrode having an annular portion located adjacent the accelerating electrode and substantially at right angles to the cylindrical part of the focusing electrode, the decelerating electrode extending further towards the photo-cathode through a portion projecting forwardly from the accelerating electrode.

5. An electron-optical system as claimed in claim 1, in which the decelerating electrode comprises, in the axial direction, a front portion and a rear portion, and means for applying different potential to each of said portions.

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