My invention relates to two-stage electron multipliers, and more particularly to a two-stage electron multiplier which is particularly adaptable for use within a television dissector tube following, broadly, the teaching of my prior patent, No. 1,773,980, entitled "Television system".

Among the objects of my invention are: To provide a simple D.C. energized electron multiplier; to provide a simple two-stage electron multiplier; to provide an electron multiplier of small size and of the proper dimensions to be used within a television dissector tube; to provide a dissector target containing a two-stage electron multiplier; to provide an improved dissector tube; to provide a means and method for increasing the output of a dissector tube without substantially increasing shot noise; to provide a means and method of multiplying electrons comprising an elemental portion of an electron image in a cathode ray tube; and to provide an electron multiplier with a minimum number of stages but with maximum gain per stage.

My invention possesses numerous other objects and features of advantage, some of which, together with the foregoing, will be set forth in the following description of specific apparatus embodying and utilizing my novel method. It is therefore to be understood that my method is applicable to other apparatus, and that I do not limit myself, in any way, to the apparatus of the present application, as I may adopt various other apparatus embodiments, utilizing the method, within the scope of the appended claims.

Referring to the drawing:

Figure 1 is a longitudinal sectional view of one form of my invention utilized as a straight electron multiplier, together with an operating circuit diagram.

Figure 2 is a diagrammatic sectional view of a television dissector tube showing the positioning of my invention within the envelope.

Figure 3 is a sectional view of the multiplying structure utilized in the tube of Figure 2, enlarged to show greater detail.

In my patent above referred to, an electron image is formed within an envelope by projecting a light image on a photoelectric cathode and maintaining the electronic emission therefrom in a parallel array so that an electron image is formed, each elemental area of which corresponds in electron density to the light on the elementary area from which the electrons were emitted. An aperture is placed in the path of this electron image, this aperture being of elemental dimensions, thus allowing only electrons from a single elementary area to pass through the aperture at any one time, and thereafter be collected. The electron image is then oscillated in two dimensions so that the entire electron image is scanned across the aperture. Thus, during the scanning cycle, all elementary areas of the electron image pass through the aperture and are collected to form a train of television signals which may then be amplified and transmitted in a manner well known in the art.

I have found that it is greatly desirable to increase the output of the dissector tube, and the present application deals with the use of a two-stage electron multiplier operating on the secondary emission principle, and with a multiplier structure which can be made small enough to be placed within a shield or cylindrical finger, itself sufficiently small so that it may be placed in the path of the light image being projected on the photovoltaic cathode without interfering with the operation of the device. The electron multiplier utilized herein, in conjunction with the dissector finger, operates broadly on the same principles outlined in my Patent No. 2,087,111 of April 21, 1936, for Method and apparatus for television, but herein I utilize only a two-stage generation of secondaries, and utilize a simple three-electrode structure having two opposed surfaces capable of generating secondary electrons at a ratio greater than unity, and an anode therebetween, one of the surfaces only being exposed to the electrons in a single elementary area of the electron image.

A more detailed understanding of my invention may be had by a direct reference to the preferred embodiments shown in the figures.

In Figure 1 I have shown the electron multiplier of my present invention utilized as a straight electron multiplier of signal inputs. Here, an envelope 1 is provided with a side stem 2 carrying a thermionically emissive gun cathode 3, a grid 4 and a gun anode 5, these electrode representing any form of the well known electron gun. The electron stream issuing from this gun is projected against an angular multiplier cathode 6, the latter having the surface against which the electrons are projected sensitized to produce secondary electrons at a ratio greater than unity. In this regard I have found that secondary electrons at a ratio of 10 or 12—1 may be obtained by forming the cathode 6 of silver, oxidizing the silver, and exposing the oxidized surface to metallic caesium until maximum secondary emission is obtained.
However, any surface having the properties desired may be used.

The angular cathode 6 is supported on a lead 7 sealed through an end stem 9, and is surrounded by a cylindrical shield 10. At one end of the cylindrical shield 10 is positioned a multiplier anode 11, and back of the multiplier anode 11 is positioned an opposed multiplier cathode 12. The angle of the angular multiplier cathode 6 is such that secondaries emitted therefrom are directed toward the second cathode 12 after passing through anode 11, and the cylindrical shield 10 creates a focusing field, when energized, to prevent divergence of the electrons during their travel toward the second cathode.

The circuit diagram includes a gun cathode source 14 connected to the gun cathode 3, and a gun anode source 15 providing a potential sufficient to project source electrons against multiplier cathode 6. The input signal is impressed upon gun grid 4 through input line 16.

Various potentials are placed upon the multiplier electrodes, preferably through a voltage divider 17, the potential thereon being obtained by passing current therefrom from multiplier source 18. The various multiplier electrodes are connected so that angular multiplier cathode 6 has the lowest potential, cylindrical shield 10 has the next higher potential, opposed cathode 12 has the next higher potential, and multiplier anode 11 has the highest potential, the current picked up by the anode 11 being passed through an output resistor 20 from which the output may be taken through output lead 21.

In operation, initial electrons are emitted from gun cathode 3 controlled by gun grid 4, and projected against angular multiplier cathode 6. Upon impact with this cathode, secondary electrons are generated at the ratio, say, of 10 to 1, and the increased electron stream is then accelerated, under the influence of multiplier anode 11 and the opposing cathode 12, to pass through the apertures in the anode screen 14 and impact the opposing cathode 12 where additional secondary electrons are generated, inasmuch as I prefer to form this electrode also of silver and sensitive it as described for the first cathode 6. The stream is thus again augmented by secondary emission at the ratio of 10 to 1, and the emitted secondaries are drawn to and collected by anode screen 11.

In order that this action may take place, I prefer to have the potential of anode 11 only a sufficient amount above that of cathode 12 so that the emitted secondaries will be collected rather than accelerated back toward the first cathode 6.

In this respect, in one embodiment which has been built, voltages were used as follows:

<table>
<thead>
<tr>
<th>Volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gun anode 5</td>
</tr>
<tr>
<td>First multiplier cathode 6</td>
</tr>
<tr>
<td>Cylindrical shield 10</td>
</tr>
<tr>
<td>Second cathode 12</td>
</tr>
<tr>
<td>Multiplier anode 11</td>
</tr>
</tbody>
</table>

Thus, it will be seen that for every electron impacting the angular multiplier cathode 6, approximately one hundred electrons are collected by multiplier anode 11, and the collected electrons will be a function of the electrons entering the cylindrical shield 10 to impact the multiplier cathode 6, as controlled by the grid 4.

In Figures 2 and 3 I have shown this form of multiplier mounted in a television dissector tube. In this construction the image of an object 24 is focused on a planar photoelectric cathode 25 through a lens system 26. An electron image is initiated by the photoelectric action of the cathode, and this image is accelerated toward the opposite end of the tube, the electrons in the image being maintained in parallel array by the use of a strong magnetic field produced by the action of a focusing solenoid 27 energized by focusing source 28. Electrostatic focusing means is, of course, a full equivalent.

At the opposite end of the tube from the cathode 25 is positioned an anode finger, shown more in detail in Figure 3. This anode finger comprises an external anode shield 30 comparable to shield 10 in Figure 1, which has a scanning aperture 31 therein facing cathode 25. The cylindrical shield 30 is fixed to the envelope by being fitted into an envelope arm 22, and an external lead 33 is brought through the envelope wall.

Inside the shield 30 is positioned the angular cathode 6, the multiplier anode 11 and the opposing multiplier cathode 12, in exactly the same order as has been described for the device of Figure 1, with the angular cathode 6 positioned to receive electrons passing through the scanning aperture 31.

Each of the multiplier electrodes is provided with a lead passing through the envelope wall, and the electrodes are all supplied from a primary source 33. In this instance, the cathode 25 is at the lowest potential and is usually grounded. The angular multiplier cathode 6 is at the next highest potential, the tubular shield still higher, the opposed multiplier cathode 12 the next highest, and finally, the multiplier anode 11 being at the highest potential and connected to the source 18 through an output resistor 20 so that the output may be taken from lead 21, as described for the device of Figure 1.

The electron image is oscillographed in two directions across the scanning aperture by means of scanning oscillators 35 and 36 energizing scanning coils 37 and 38, preferably with a sawtooth waveform, or by equivalent means. Thus, each elementary area of the electron image is passed across the aperture 31, and electrons from each elementary area in succession pass through the aperture and impact the angular cathode 6, as shown by the electron path line 40 in Figure 3. Secondaries are generated by the impact of these primaries, are accelerated through anode 11 to impact opposing cathode 12, and there generate additional secondaries which are collected by anode 11. A greatly increased output of the dissector tube is thus obtained over that which would be obtained simply by collection of electrons passing through the aperture 31.

There is a very distinct reason for utilizing anode 11 as the final collector instead of having the electrons collected by cathode 12. For example, there are electron multiplier structures where the electrons are passed through successive screens, generating secondaries in passage through the screens, because of the fact that certain of the electrons will impact the screen material, whereas others will pass directly through. If this were done, however, in a device of the sort described, particularly in a television dissector tube, it can be shown that certain electron components would go through the screen 11 to be collected by the electrode 12 without being multiplied by impact with screen 11, whereas others would impact screen 11, generate secondaries, and these secondaries would then be pulled through the screen to be collected by electrode 12.
However, it is obvious that the two groups of electrons representing a single initial stream would not be likely to arrive at collector 12 at the same time, and therefore a shot effect would be entered into the operation of the device. With the herein described mode of operation, the electrons generate secondaries only on solid surfaces; all those electrons starting at the same time are collected at the same time and after an equal multiplication. Therefore, the advantage of utilizing the opposed surfaces with the intermediate collector becomes apparent. Furthermore, with the utilization of only two stages, as shown, the multiplication per stage can be made extremely large without the intervention of space charge effects, and with such large multiplications an overall multiplication of 100 to 1 can be readily obtained, and this multiplication is sufficient to greatly reduce the necessity for extreme sensitivity in the following amplifiers. Thus, an efficient output is obtained, with a minimum of shot effect and a minimum of noise, together with faithful transformation of light values into signal values.

I claim:
1. An electron discharge device having an envelope containing a plurality of surfaces capable of emitting secondary electrons at a ratio greater than unity upon electron impact therewith, and a photoelectric surface capable of emitting when illuminated, an electron stream of electron image cross section, means for selecting a portion of said stream of elemental dimensions, means for directing said portion against one of said surfaces to produce secondary electrons therefrom, means for directing the produced secondary electrons to another one of said surfaces, said first surface being positioned at a 45° angle to said stream portion and said second surface at right angles to the path of secondary electrons emitted from said first surface.
2. An electron multiplier comprising an envelope containing means for producing a beam of electrons, a hollow elongated conductor in the path of said beam and having an aperture for admitting electrons from said source, an electrode capable of emitting secondary electrons upon electron impact therewith positioned within said conductor in the path of electrons passing through said aperture, said electrode being positioned at substantially a 45° angle to the path of electrons entering said conductor and to the axis of said conductor, a secondary electron emissive electrode in the path of secondary electrons emitted from said first electrode, and an apertured electrode between said secondary emitting electrodes.

PHILO T. FARNSWORTH.