June 27, 1939. R. L. SNYDER 2,163,966

BOX ELEMENT MULTIPLIER

Filed June 22, 1937

Fig. 2.

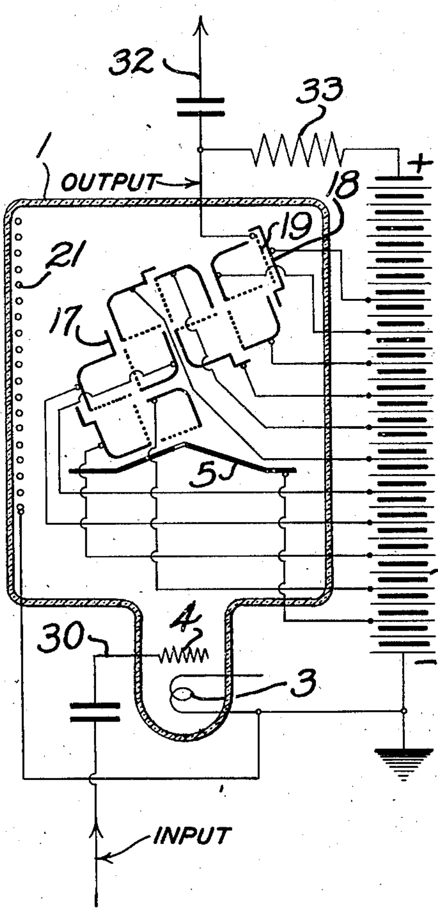


Fig. 1.

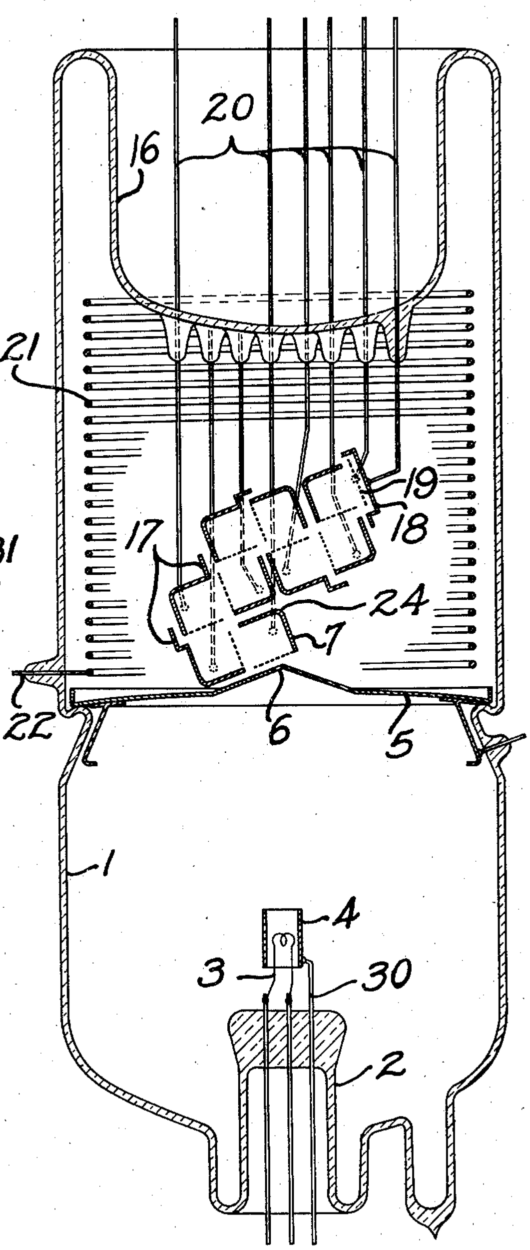
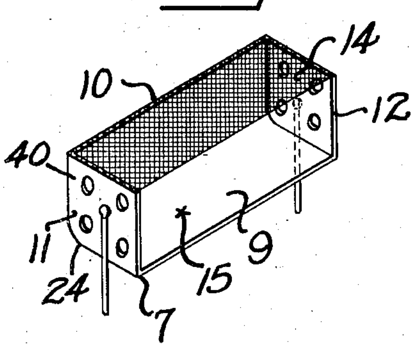


Fig. 3.



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Patented June 27, 1939

2,163,966

UNITED STATES PATENT OFFICE

2,163,966

BOX ELEMENT MULTIPLIER

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Application June 22, 1937, Serial No. 149,654

5 Claims. (Cl. 250—175)

My invention relates to electron multipliers, and more particularly to electron multipliers of the d-c type wherein the individual multiplying elements are in the form of apertured boxes.

This invention is a continuation in part of my prior application Serial No. 146,641, filed June 5, 1937, and entitled "Electron multiplier", wherein multiplying stages of the annular cup type are employed, and embodies the broad method of controlling electrons by electrostatic focusing between stages such as that described and claimed in the Philo T. Farnsworth application Serial No. 80,194, filed May 16, 1936, and entitled "Means and method for producing electron multiplication".

The present application, while embodying many features of the two applications referred to above, differs from those prior applications in that while the cross-section of the individual stages is similar to that shown in the first of the two applications cited above, the other dimensions are different, and also in that the individual stages in the present application are in the form of equipotential spaces with box-like walls rather than cylindrical walls as described and claimed in the second of the above identified applications. The present application also differs from the annular cup type of multiplier described and claimed in my prior application supra, in that the electrons are directed into the initial stages of the device in a particular manner, as will be hereinafter set forth.

It is highly desirable in an electron multiplier where electrons are directed successively against a plurality of surfaces capable of secondary omission at a ratio greater than unity upon electron impact therewith, to form the electron multiplying structure in such a manner that the impacting electrons hit the active surfaces at the proper place in each succeeding stage.

It is therefore the main object of the present invention to provide a multiplying structure composed of chambers so constructed and arranged that the electrons will be subjected to a focusing field insuring their arrival on the active surface in a predetermined manner and over a predetermined area.

It is also an object of the present invention to so construct and arrange the multiplying chambers that the electrons, on entering the primary chamber at a definite angle, will have their succeeding impact areas determined by the area impacted in the first stage. Thus, by properly arranging the internal fields the impact area of initial electrons to be multiplied can be used to determine the impacting areas throughout the device.

It is still another object of my invention to shield the individual stages in such a manner that the electron leakage is reduced to a minimum; and to provide a means for collecting ions from the space surrounding the device in order that these ions may not enter into the operation of the multiplier.

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.

Without further reference to other broad objects of my invention, which will be apparent to those skilled in the art, I will proceed with the description of a preferred form of my invention which will illustrate the several points brought out above in addition to others.

In the drawing, Fig. 1 is a longitudinal sectional view (certain parts being shown in elevation) of the electron multiplier of my invention utilized in combination with a conventional electron source.

Fig. 2 is a schematic diagram showing how the device of Fig. 1 may be operated as a straight multiplier.

Fig. 3 is a perspective view of a single box-like multiplying stage or element.

An envelope 1 is provided at one end with a reentrant stem 2 carrying a filamentary electron emitter or cathode 3 and a control electrode 4. Appropriate leads are brought out through the stem in order that these two electrodes may be energized in the usual manner. Cathode 3 is utilized as the initial source of electrons, but it is to be distinctly understood that the device as herein to be described and claimed is adaptable to multiply electrons emitted from any source whatsoever, and that the conventional cathode-control electrode assembly shown herein is purely symbolical of any initial source of electrons, either varying or steady.

An input shield 5 is positioned in the path of electrons from cathode 3, and this shield 5 is provided with an electron aperture 6. The electron aperture may be small or large in accordance with whether all the electrons from cathode **3** are to be multiplied or only a portion thereof. It is desirable, in many cases, to admit to the multiplier only a portion of the electron stream, as for example, when an electron image is scanned by electrostatic or equivalent means across the aperture 6 in order that successive elementary components of this electron image be admitted so that the image may be analyzed into a signal. Such a method of operation is well known to those skilled in the art as being the function of the Farnsworth dissector tube utilized in television as exemplified by United States Patent No. 1,773,980.

Immediately behind aperture **6** is placed the first stage of an electron multiplier assembly, all stages of which are preferably substantially identical as to size and shape in order that the maximum advantage may be taken of the focusing field developed by individual stages. A description, therefore, of the initial stage **7** will serve, except for minor variations, for a description of all succeeding stages, except the final stage, which will be described separately.

The actual shape of the initial stage **7** is shown in Fig. 3. The multiplying chamber **7** is of box shape, having two adjacent solid sides **9** and **10**, two end walls **11** and **12**, an electron permeable wall **14**, and an open side **15**. Thus, there are two solid sides, two apertured ends, one screened side, and one open side. By virtue of the two sides **11** and **12**, a field is produced in the cross-section parallel to these sides which varies along the length of the box.

Starting from a point in the space of the box shown in Fig. 3, where there are three linear dimensions, we have a field which varies along all three dimensions and which is symmetrical to a plane parallel to the end plates **11** and **12** erected in the center between these end plates. Thus, a definite electrostatic focusing effect is exerted on the electron stream.

The individual stages are then mounted upon a multiplier stem **16** in such a manner that the open side of one element is presented to the electron permeable side of the next element. The various elements are positioned relatively close together and, in addition, certain of the solid sides may be provided with overhangs **17** in order that the separations between elements be electrostatically covered. Various elements are serially mounted until the desired number of stages has been attained, whereupon a final secondary emissive stage **18** is mounted opposite the open wall of the final box element stage, and an output electrode **19** in the form of a screen is positioned between the open wall of the next to the last stage, and the last stage **18**. Leads **20** are brought out separately from each element, and the entire multiplying structure is surrounded by an ion collecting shield **21** which, in the drawing, is shown as being a coil of wire, but obviously may be a solid electrode if desired, or even a deposit on the wall of the envelope **1**. A lead **22** is provided, sealed through the wall of the envelope to allow for energization of this ion collector.

As shown in Figs. 1 and 2, I prefer to tilt the entire multiplying structure with relation to the axis of the entering electron stream, through a certain angle. This is to enable the entering initial electrons to strike upon such a region of the first secondary emitting stage as may seem desirable. This region is preferably the region around the curved bend **24** of the box where the solid sides **9** and **10** join. Secondaries emitted in this area are subjected to the electrostatic focusing action of the field in that box and are thus securely guided to the corresponding area in the following box. The value of the tilting angle for a certain electrode structure is chosen according to the position that it is desired the electrons shall hit, and in the case of the preferred form of multipliers shown herein the tilting angle is approximately 60°.

To operate the device filament **3** is heated in the usual manner and an input impulse led on to the grid through input lead **30**. A potential source **31** is provided, the most negative portion of which is preferably connected to the filament and the most positive to the screen output electrode **19**, the input shield **5** being connected at a slight positive potential to cathode **3**, the first multiplying element **7** at the next highest potential, and so on serially through the assembled elements until output screen **19** is reached, which is positioned at the highest positive potential through an output resistor **33**. The output is taken in the usual manner through an output lead **32**. Ion collector **21** is preferably connected to the most negative portion of the device, namely the cathode. Electrons emitted from the cathode **3** are controlled by the action of the control electrode **4**, and enter the aperture **6** in the input shield, and, due to the angle of position of the multiplying structure, pass through the electron permeable screen of the first element **7** and impact the junction of the solid walls **9** and **10**, whereupon secondary electrons are emitted.

In order, however, that the multiplying action of the device be as efficient as possible, I prefer to treat the elements in such a manner that secondaries are emitted at the ratio of 8 to 12 secondaries for each primary impact. One manner in which the elements may be treated to accomplish this end is to form the solid portions of the box out of silver, oxidize the silver, and deposit metallic caesium thereon until maximum sensitivity for the emission of secondary electrons is obtained. The electron permeable wall **14** is preferably made of material which will not sensitize during this process, and, if desired, end walls **11** and **12** can be made of similar material. However, for the electron permeable wall **14** I may prefer to utilize a screen formed of very fine tungsten wire, knitted or otherwise fashioned into an extremely fine fabric with a high void-to-land ratio, in order that as few as possible of the electrons may be intercepted by the screen. After the electrons have impacted the first element **7** they are attracted by the higher potential of the next subsequent stage, and pass through the electron permeable wall of this second stage to impact the side walls **9** or **10** over approximately the same area as was impacted on the first stage.

It is obvious, however, that while this area may be controlled by making each element of identical size and shape and having an equal potential drop between each adjacent stage, it will also be possible to vary the size of the stages and compensate for this variation in size by varying the potential thereon. Such expedients are deemed equivalents. Multiplication will continue at each stage until the final stage **18** is reached, and the electrons emitted from stage **18** will be collected by output screen **19** inasmuch as the potential on this screen is made insufficient to accelerate them back to the next to the last element. The output may then be utilized in any desired manner.

The individual overlapping portions **17** of the various stages are to prevent stray electrons from leaving the structure, because these electrons will be liable to liberate ions by collision with gas or metal vapor molecules in the space surrounding the electrode structure. If these ions were generated in any large degree they would tend to enter the first stage of the structure and cause severe interference with the action of the device. The shielding skirts also prevent interference with the electrons in their paths between stages by exterior fields, and also from any interference with the field created by the ion collectors surrounding the device. This ion collector, being maintained at a negative potential to the various elements of the multiplier, attracts stray ions existing outside of the device and prevents them from thereafter entering the operation of the device.

It should be distinctly understood, however, that my device is perfectly operable without the ion collector, and that the important features lie in the shape of the individual stage elements and their relative positions.

A multiplier of the sort just described is extremely practical. For example, it may be made of minimum size, so small, indeed, that it may be placed within a light path without seriously affecting the definition of an optical image. Devices have been made where the individual multiplier structures have dimensions of the order of a few millimeters and the currents have remained extremely large. In one form of device the dimensions of each individual element were approximately $\frac{3}{8}$ of an inch by $\frac{3}{4}$ of an inch with a radius of curvature where the solid sides 9 and 10 join of $\frac{3}{16}$ of an inch. In a multiplier having stages of the latter dimensions between 700 and 2000 volts total in source 31, gains of 60,000 were obtained at 800 volts, and a gain of 250,000 was obtained at 2000 volts.

The box element structure described herein has the advantage of having an unsymmetrical field in the first stage with respect to the admittance aperture 6, and thus prevents the secondary electrons from being focused back toward the aperture. The box type device also admits metallic caesium readily, and in order that the device may admit caesium more readily I may prefer to provide end walls 11 and 12 with apertures 40.

I claim:

1. An electron multiplier comprising an envelope containing a box-like electron multiplier chamber having a substantially rectangular cross-section, one wall of said chamber being open, the opposite wall and one adjacent wall being solid, the remaining wall being electron permeable, the solid walls being capable of emitting secondary electrons at a ratio greater than unit upon electron impact therewith, and means for directing electrons through said permeable wall to impact said solid walls adjacent their junction.

2. An electron multiplier having a plurality of chambers according to claim 1 and where the open wall of one chamber is presented to the electron permeable wall of the next chamber, and means for introducing the electrons into the first chamber.

3. An electron multiplier having a plurality of chambers according to claim 1 and where the open wall of one chamber is presented to the electron permeable wall of the next chamber, means for introducing the electrons into the first chamber, and means forming a part of one chamber overlapping the adjacent wall of the next chamber to prevent electron leakage from said chambers.

4. An electron multiplier having a plurality of chambers according to claim 1, and where the open wall of one chamber is presented to the electron-permeable wall of the next chamber, a source of primary electrons, and means for directing said primary electrons into the first chamber to impact the solid walls of said first chamber adjacent their junction.

5. An electron multiplier having a plurality of chambers according to claim 1, and where the open wall of one chamber is presented to the electron-permeable wall of the next chamber, a shield adjacent the electron-permeable wall of said first chamber, a single aperture in said shield, and a source of electrons alined with said aperture and the junction of the solid walls of said first chamber, said source being positioned on the opposite side of said shield from said chamber.

RICHARD L. SNYDER.