Nov. 1, 1938. W. A. KNOOP 2,134,718

ELECTRON DISCHARGE APPARATUS

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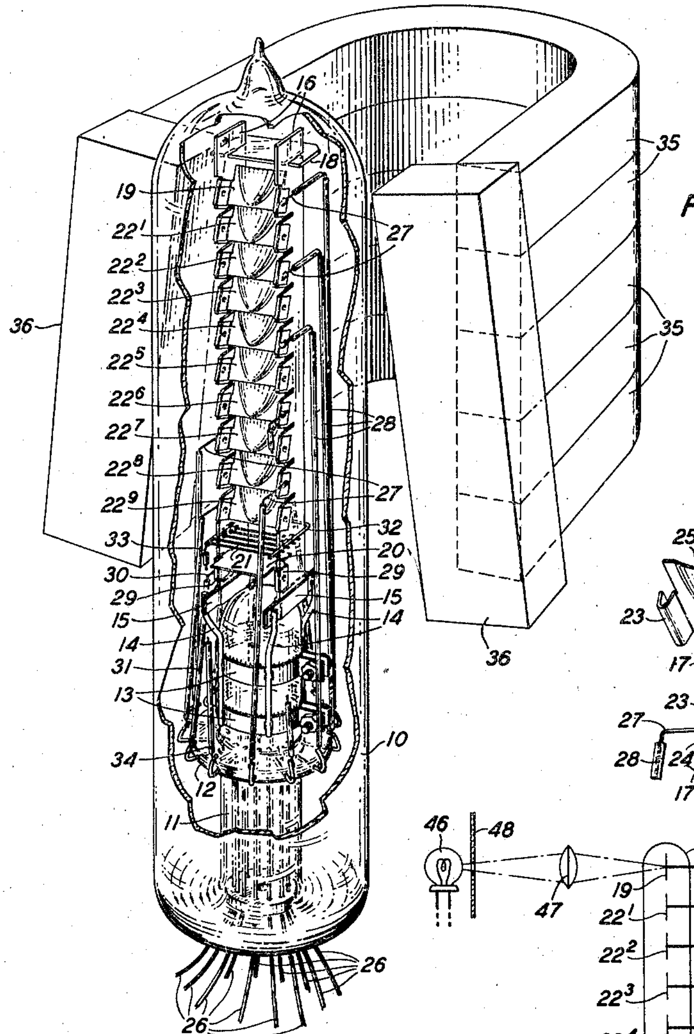

FIG. 1

FIG. 2

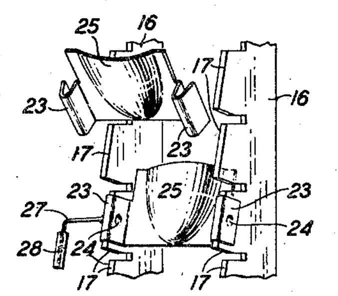

FIG. 3

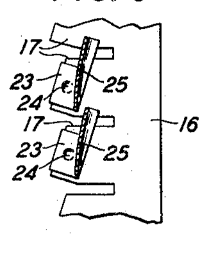

FIG. 7

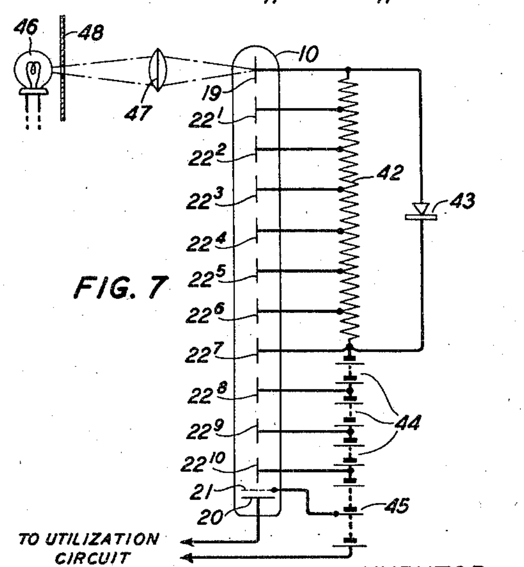

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FIG. 4

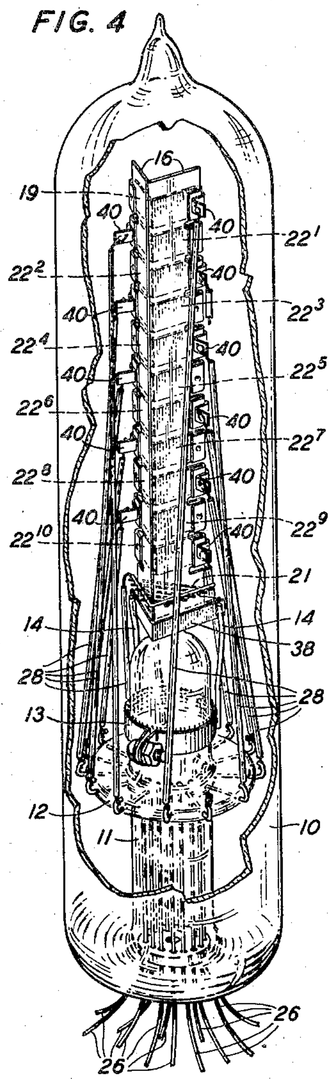
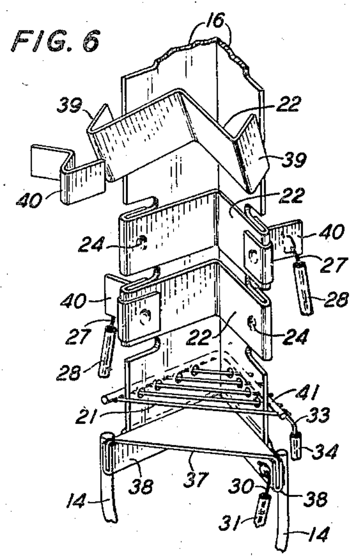


FIG. 6



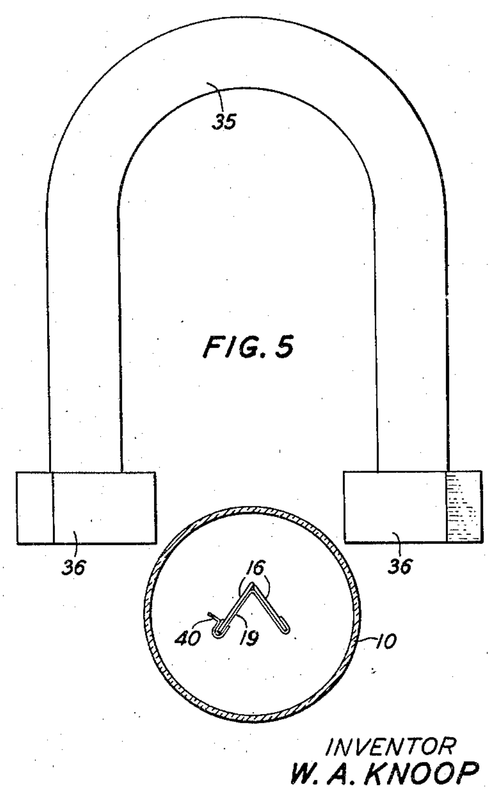


FIG. 5

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ELECTRON DISCHARGE APPARATUS

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Application November 20, 1936, Serial No. 111,796

20 Claims. (Cl. 250—27.5)

This invention relates to electron discharge apparatus and more particularly to such apparatus including electron discharge devices of the electron multiplier type.

In general, electron multipliers comprise a primary cathode, a collector electrode or anode and a plurality of auxiliary electrodes or secondary cathodes disposed between the primary cathode and the collector electrode or anode. During operation of the devices, a magnetic field is produced adjacent the electrodes, and the secondary cathodes and anode are operated at successively increasing positive potentials with reference to the primary cathode. When the primary cathode is energized, electrons are emitted therefrom and, under the influence of the magnetic field and the potential upon the secondary cathodes and the anode, these electrons are directed to and impinge upon the secondary cathode nearest the primary cathode and cause the release of secondary electrons therefrom. These secondary electrons are directed to and impinge upon the next secondary cathode and cause the release of other secondary electrons therefrom. This phenomenon is repeated at each of the secondary cathodes and the secondary electrons emanating from the last of the secondary cathodes, that is the one farthest removed from the primary cathode, flow to the anode or collector electrode and constitute the output current of the device.

Portions of the primary and secondary cathodes are coated with a material having good electron emitting characteristics so that for each electron impinging upon the secondary cathodes, a plurality of secondary electrons are released. Consequently an electron multiplication occurs at each of the secondary cathodes and great amplification of a signal corresponding to the emission from the primary cathode results.

One object of this invention is to prevent substantial dispersion of the primary and secondary electrons whereby concentrated electron streams between the several cathodes obtain.

Another object of this invention is to increase the electron multiplication and thereby to improve the efficiency and to increase the power output of electron multipliers.

A further object of this invention is to simplify the structure of electron discharge devices of the electron multiplier type and thereby to expedite the fabrication of such devices.

In accordance with one feature of this invention, the primary and secondary cathodes are provided with substantially V-shaped portions disposed one above the other and with their apices in alignment.

In accordance with another feature of this invention, the magnetic field adjacent the several cathodes is varied uniformly in intensity from a maximum in the vicinity of the primary cathode to a minimum in the vicinity of the anode or collector electrode.

The invention and the foregoing and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawings, in which:

Fig. 1 is an elevational view in perspective of electron discharge apparatus illustrative of one embodiment of this invention, a portion of the enclosing vessel of the electron discharge device being broken away to show the internal structure more clearly;

Fig. 2 is an enlarged detail view in perspective and partly exploded showing the construction of the cathodes of the device illustrated in Fig. 1 and the association thereof with the supports therefor;

Fig. 3 is an enlarged detail view in cross-section illustrating the form of the cathodes of the device shown in Fig. 1 and the alignment thereof;

Fig. 4 is another elevational view in perspective of another electron discharge device constructed in accordance with this invention, a portion of the enclosing vessel being broken away to show the electrode structure more clearly;

Fig. 5 is a top view illustrating the relative position of the cathodes of the device shown in Fig. 4 and the magnet for producing the field adjacent the electrodes;

Fig. 6 is an enlarged detail view in perspective, partly exploded, of a portion of the electrode structure of the device shown in Fig. 4; and

Fig. 7 is a circuit diagram of electron discharge apparatus including devices constructed in accordance with this invention.

Referring now to the drawings, the electron discharge device shown in Fig. 1 comprises an elongated enclosing vessel **10** having a stem **11** at one end provided with an intermediate annular flange **12**. A pair of split metallic bands or collars **13** are clamped about the stem and have affixed thereto a plurality, for example four, of rigid uprights or supports **14** which carry channel-shaped cross pieces or straps **15**. Each of the cross pieces or straps **15** securely grasps and supports an insulating upright or support **16**, such as a mica strip, provided with a plurality fingers **17**. The supports or uprights **16** are frictionally fitted adjacent their upper ends in slots in an insulating spacer 18, which also may be a strip of mica or the like.

The frame structure comprising the insulating members 16 and 18 supports a primary cathode 19, a collector electrode or anode 20, a shield electrode 21, and a plurality of auxiliary electrodes or secondary cathodes 22^1 to 22^9 inclusive.

The primary and secondary cathodes, as shown more clearly in Figs. 2 and 3, may be metallic plates having U-shaped side flanges or arms 23 for receiving the fingers 17, the flanges or arms being securely affixed to the fingers 17 as by indentations 24 pressed into the insulating material. Each of the cathodes is inclined at a small angle, for example of the order of 20 degrees, to the longitudinal axis of the insulating uprights 16 and is provided with a bulged or dished central portion 25 of V-shaped peripheral outline. As shown clearly in Fig. 3, the apices of the bulged or dished portions 25 are in alignment. The peripheries of these portions also are in alignment. The surfaces of the cathodes, preferably only the convex surface of the bulged or dished portions 25, may be treated to assure copious electron emission therefrom. For example, the cathodes may be of silver and all or portions of one surface thereof oxidized and treated with caesium to form a coating of silver, caesium oxide and free caesium thereon. Alternately, the cathodes may be of copper and portions or all of one of the surfaces thereof oxidized and treated with caesium.

Suitable potentials may be applied to the various cathodes through leading-in conductors 26 extending through and sealed in the annular flange 12 on the stem 11. Suitable tie wires 27 are affixed at one end to the conductors 26 and at the other end to the flanges 23 on the cathodes. Preferably the tie wires 27 are substantially completely encased in insulating material such as glass sleeves 28.

The anode or collector electrode 20 comprises a metallic plate disposed, for example, at right angles, to the longitudinal axis of the enclosing vessel 10, and having depending side flanges 29 bent around and securely locked to the insulating uprights 16. A tie wire 30, encased in an insulating sleeve 31, electrically connects the anode or collector electrode to one of the leading-in conductors 26.

The shield or screen electrode 21 may include a U-shaped metallic frame 32, having its arms adjacent and outside of the insulating uprights 16, and a plurality of wires, parallel to one another and to the anode 20, extending through suitable apertures in the uprights 16 and affixed at their ends to the arms of the frame 32. Electrical connection to the shield or screen electrode 21 may be established through a tie wire 33 connected to the frame 32 and to one of the leading-in conductors 26 and encased in an insultating sleeve 34.

The electron discharge device may be mounted in any suitable manner in proximity to a magnet structure for producing a magnetic field of high intensity at substantially right angles to the longitudinal axis of the enclosing vessel 10 and across the coated or activated surfaces of the cathodes 19 and 22. This magnetic structure, for example, may be composed of a number of horseshoe magnets 35 having affixed thereto pole-pieces 36. The pole-pieces 36 preferably are of substantially the same length as the electrode structure and are disposed at small angles, for example approximately 10 degrees, to the longitudinal axis of the enclosing vessel 10 so that the magnetic field is of greatest intensity in the vicinity of the primary cathode 19 and decreases uniformly to a minimum in the vicinity of the collector electrode or anode 20.

In another illustrative embodiment shown in Figs. 4, 5 and 6, the anode or collector electrode may be a triangular metallic plate 37 having channel-shaped depending flanges 38 which are affixed to the supports or uprights 14 and securely hold and support the insulating uprights 16. The primary and secondary cathodes are V-shaped strips having ends 39 bent around and clamped against the uprights 16. In order to securely lock the cathodes to the uprights, the strips may be provided with indentations 24 pressed into the insulating material. Each of the cathodes may be provided with a metallic clip 40 clamped to one end thereof and serving as a terminal lug to which the connecting wire 27 may be attached.

The inner surfaces of the primary and secondary cathodes may be treated, as described heretofore in connection with the device shown in Fig. 1, to assure copious electron emission therefrom. The several cathodes are disposed edge to edge and preferably with their apices in alignment and their corresponding sides in common planes. The cathode strips may be approximately 1.5 centimeters wide and the spacing between opposite edges may be of the order of 0.5 centimeter. The included angle of the cathodes may be, for example, of the order of 90 degrees.

The wires of the screen grid 21, as shown clearly in Fig. 6, extend through apertures in the insulating uprights 16 and are affixed at their ends to a metallic V-shaped rod or wire 41. These wires preferably are disposed parallel to one another and to the plate 37.

During operation of the electron discharge devices, the several secondary cathodes 22 are maintained at positive potentials, the potential upon each secondary cathode being higher than that upon the next preceding one with reference to the primary cathode 19. For example, the first secondary cathode 22^1 may have a potential of the order of 135 volts positive with respect to the primary cathode 19 applied thereto and the next secondary cathode 22^2 may be at a positive potential of the order of 135 volts higher than that upon the cathode 22^1. Each of the other secondary cathodes 22^3 to 22^{10} inclusive may be operated at a potential of the order of 135 volts higher than that upon the next preceding one. The screen or shield electrode 21 may have applied thereto a positive potential of the order of 135 volts above the last secondary cathode, 16^9 in Fig. 1 and 16^{10} in Fig. 4, and the anode 20 may be maintained at a positive potential of the order of 250 volts above the last secondary cathode.

The potentials for the various electrodes may be provided conveniently as shown in Fig. 7. For example, the primary cathode 19 and secondary cathodes 22^1 to 22^7 inclusive may be connected to suitable taps on a potentiometer 42 connected across a source such as a rectifier 43. Because of the high current drains, the secondary cathodes 22^8 to 22^{10} inclusive may be provided with separate potential sources, such as batteries 44, and the anode or collector electrode 20 may be connected in series with a source, such as a battery 45, through a utilization or output circuit. A suitable potential for the shield or screen electrode may be obtained through a tap on the battery 45.

The primary cathode 19 may be energized to cause the emission of electrons therefrom, as by a beam of light emanating from a source such as a lamp 46 and focused upon this cathode by a lens 47. The intensity of this beam may be varied in any suitable manner, as for example, by a film 48.

The electrons emanating from the primary cathode 19, under the influence of the magnetic field and the potential upon the secondary cathode 22^1, are attracted to and impinge upon the secondary cathode 22^1 to cause the release of secondary electrons therefrom. These secondary electrons, under the influence of the magnetic field and the potential upon the secondary cathode 22^2, are drawn to this cathode and impinge thereupon to produce secondary emission therefrom. This action is repeated down to the last secondary cathode 22^{10} (or 22^9 in the device shown in Fig. 1) and the secondary electrons emitted from this cathode flow to the anode or collector electrode 20 and constitute the output current of the device. Inasmuch as the several secondary cathodes have treated surfaces, as heretofore described, each electron impinging upon these surfaces will cause the release of a plurality of secondary electrons so that, in effect, an electron multiplication occurs at each of the secondary cathodes. Consequently the electron current from the last secondary cathode to the collector electrode or anode 20 will be immensely greater than the primary electron stream emanating from the cathode 19. As a result, an effective large amplification of the primary electron stream, and hence of the signal corresponding to the light beam focused upon the primary cathode, obtains.

The shield electrode 21 screens the last secondary cathode 22^9 or 22^{10}, from the anode or collector electrode 20 or 37, respectively and thereby prevents reaction of variations in the anode or collector electrode potential upon the last secondary cathode.

The form of the cathodes constructed in accordance with this invention prevents dispersion of the primary and secondary electrons and assures concentrated electron streams between the cathodes whereby a high efficiency and desirable operating characteristics, specifically a substantially linear relation between the intensity of the energizing light beam and the output current of the device, are attained.

The use of a magnetic field of varying intensity along the electrode structure has been found to result in a greater amplification by the device than the use of a field of constant strength.

Although specific embodiments have been shown and described, it will be understood that these embodiments are merely illustrative of this invention and that modifications may be made therein. For example, although the device in Fig. 1 has been shown as including nine secondary cathodes and that in Fig. 4 as including ten secondary cathodes, a greater or lesser number may be employed depending upon the degree of amplification desired. Furthermore, although the primary cathode has been described as of the photo-electric type, it may be of other types, for example thermionic, directly or indirectly heated, and a control grid may be employed for varying the intensity of the primary electron stream from the primary cathode 19 to the first secondary cathode 22^1 in accordance with the signal to be amplified. Other modifications may appear to those skilled in the art without, however, departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. Electron discharge apparatus comprising a primary cathode, a collector electrode, and a plurality of superposed secondary cathodes arranged successively between said primary cathode and said collector electrode, said secondary cathodes having substantially coaxial, laterally divergent V-shaped electron emitting portions.

2. Electron discharge apparatus comprising a primary cathode, a collector electrode, and a plurality of superposed secondary cathodes between said primary cathode and said collector electrode, said secondary cathodes including laterally divergent V-shaped electron emitting portions having their apices in alignment, and corresponding sides of said portions of said secondary cathodes lying in common boundaries.

3. Electron discharge apparatus comprising a primary cathode, a collector electrode, and a plurality of secondary cathodes disposed between said primary cathode and said collector electrode, said secondary cathodes comprising V-shaped strips disposed edge to edge and with their corresponding sides coplanar.

4. Electron discharge apparatus in accordance with the next preceding claim wherein the included angle of said strips is of the order of 90 degrees.

5. Electron discharge apparatus comprising an enclosing vessel having a stem, a collector electrode supported from said stem, a pair of insulating uprights supported by said collector electrode, and a plurality of superposed V-shaped electrodes supported by said uprights.

6. Electron discharge apparatus comprising an enclosing vessel having a stem, a triangular collector electrode supported on said stem and having channel shaped flanges, elongated insulating uprights fitted in said channel shaped flanges and secured thereto, and a plurality of substantially V-shaped cathodes in alignment with one another and said collector electrode, said cathodes having flanges secured to said uprights.

7. Electron discharge apparatus comprising a primary cathode, a collector electrode, a plurality of superposed secondary cathodes between said primary cathode and said collector electrode having axially aligned substantially V-shaped portions, and means for producing a magnetic field adjacent said V-shaped portions.

8. Electron discharge apparatus in accordance with the next preceding claim wherein said means produces a magnetic field at substantially right angles to the axis of alignment of said V-shaped portions.

9. Electron discharge apparatus comprising a primary cathode, a collector electrode, a plurality of secondary cathodes between said primary cathode and said collector electrode, each comprising a V-shaped metallic strip having its inner surface coated with an electron emitting material, said secondary cathodes being disposed edge to edge with the apices of said strips in alignment and the corresponding sides thereof in common planes, and means for producing a magnetic field adjacent said strips and at substantially right angles to a plane bisecting the included angle thereof.

10. Electron discharge apparatus comprising a primary cathode, a collector electrode, a plurality of superposed secondary cathodes between said primary cathode and said collector electrode, and

means for producing a magnetic field adjacent the electrodes of varying intensity between said primary cathode and said collector electrode.

11. Electron discharge apparatus comprising a primary cathode, a collector electrode, a plurality of superposed channel-shaped secondary cathodes between said primary cathode and said collector electrode and in alignment therewith, and means for producing a magnetic field adjacent the electrodes and at substantially right angles to the axis of alignment thereof, said magnetic field decreasing in intensity from the vicinity of said primary cathode to the vicinity of said collector electrode.

12. Electron discharge apparatus comprising a primary cathode, a collector electrode, a plurality of superposed secondary cathodes between said primary cathode and said collector electrode, said secondary cathodes including V-shaped electron emitting portions having their apices and peripheries in alignment, and means for producing a magnetic field adjacent the electrodes and at substantially right angles to a plane bisecting the included angle of said V-shaped portions, said magnetic field decreasing uniformly in intensity from a maximum in the vicinity of said primary cathode to a minimum in the vicinity of said collector electrode.

13. Electron discharge apparatus comprising a primary cathode, a collector electrode, and a plurality of V-shaped secondary cathodes between said primary cathode and said collector electrode composed of metallic strips disposed edge to edge with their apices in alignment and corresponding sides in common planes, the included angle of said secondary cathodes being of the order of 90 degrees.

14. Electron discharge apparatus comprising a primary cathode, a collector electrode, and a plurality of superposed secondary cathodes between said primary cathode and said collector electrode, said secondary cathodes having aligned bulged portions.

15. Electron discharge apparatus comprising a primary cathode, a collector electrode, and a plurality of superposed secondary cathodes between said primary cathode and said collector electrode, said secondary cathodes having aligned substantially V-shaped portions convexly curved toward said primary cathode.

16. Electron discharge apparatus comprising a primary cathode, a collector electrode, and a plurality of superposed secondary cathodes between said primary cathode and said collector electrode, said secondary cathodes including substantially V-shaped portions dished toward said primary cathode and having their apices and peripheries in alignment.

17. Electron discharge apparatus comprising a primary cathode, a collector electrode in alignment with said primary cathode, and a plurality of secondary cathodes between said primary cathode and said collector electrode, disposed one above the other and at angles to the line of alignment of said primary cathode and said collector electrode.

18. Electron discharge apparatus comprising a primary cathode, a collector electrode, and a plurality of superposed channel shaped secondary cathodes between said primary cathode and said collector electrode and in alignment with said primary cathode, said secondary cathodes having their bases substantially parallel and disposed at an angle to the axis of alignment of said primary and secondary cathodes.

19. Electron discharge apparatus comprising an enclosing vessel having a stem, a polygonal collector electrode supported from said stem and having channel-shaped flanges, parallel insulating uprights seated in said flanges and affixed thereto, and a plurality of superposed sheet metal cathodes carried by said uprights, said cathodes having substantially V-shaped portions disposed with their apices in alignment parallel to said uprights.

20. Electron discharge apparatus comprising a primary cathode, an anode spaced from said cathode, and a plurality of superposed, axially aligned secondary cathodes between said primary cathode and said anode, said secondary cathodes having substantially V-shaped portions the corresponding divergent sides of which lie in common boundaries on opposite sides of the axis of alignment of said secondary cathodes.

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