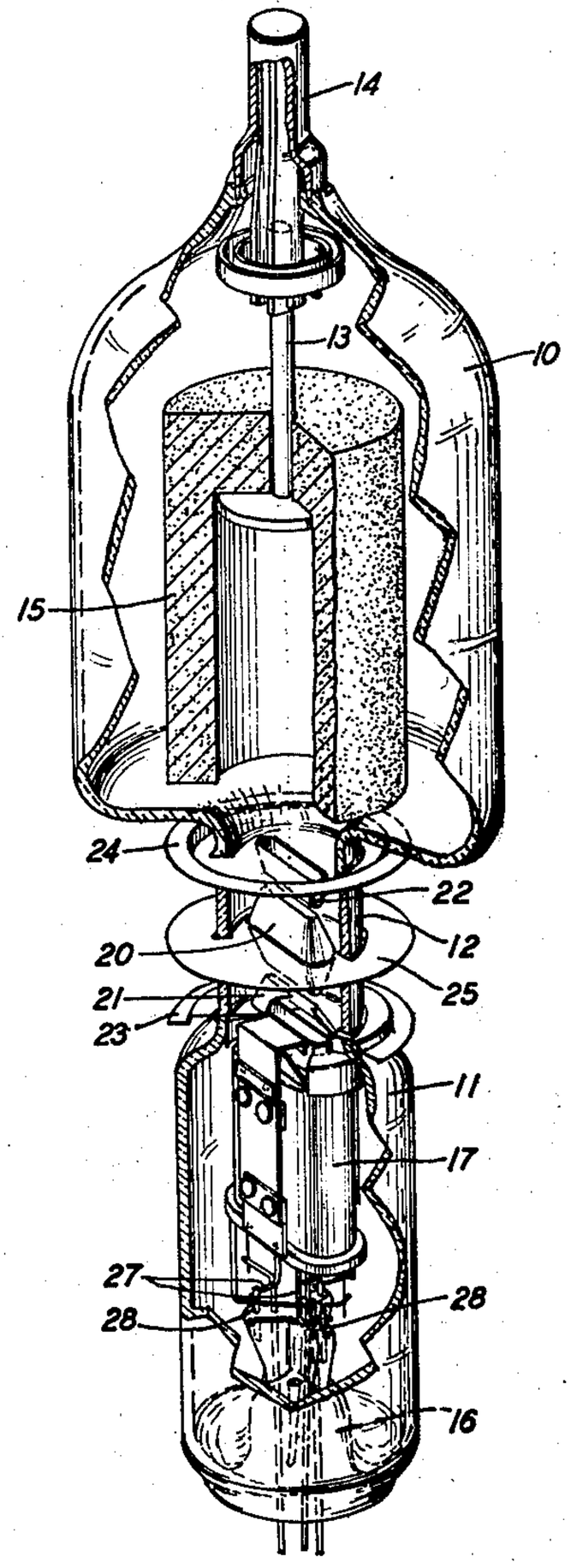
June 18, 1946. J. W. CLARK 2,402,147

ELECTRON DISCHARGE DEVICE

Filed May 26, 1942 2 Sheets-Sheet 1

FIG. 1



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Filed May 26, 1942 2 Sheets-Sheet 2

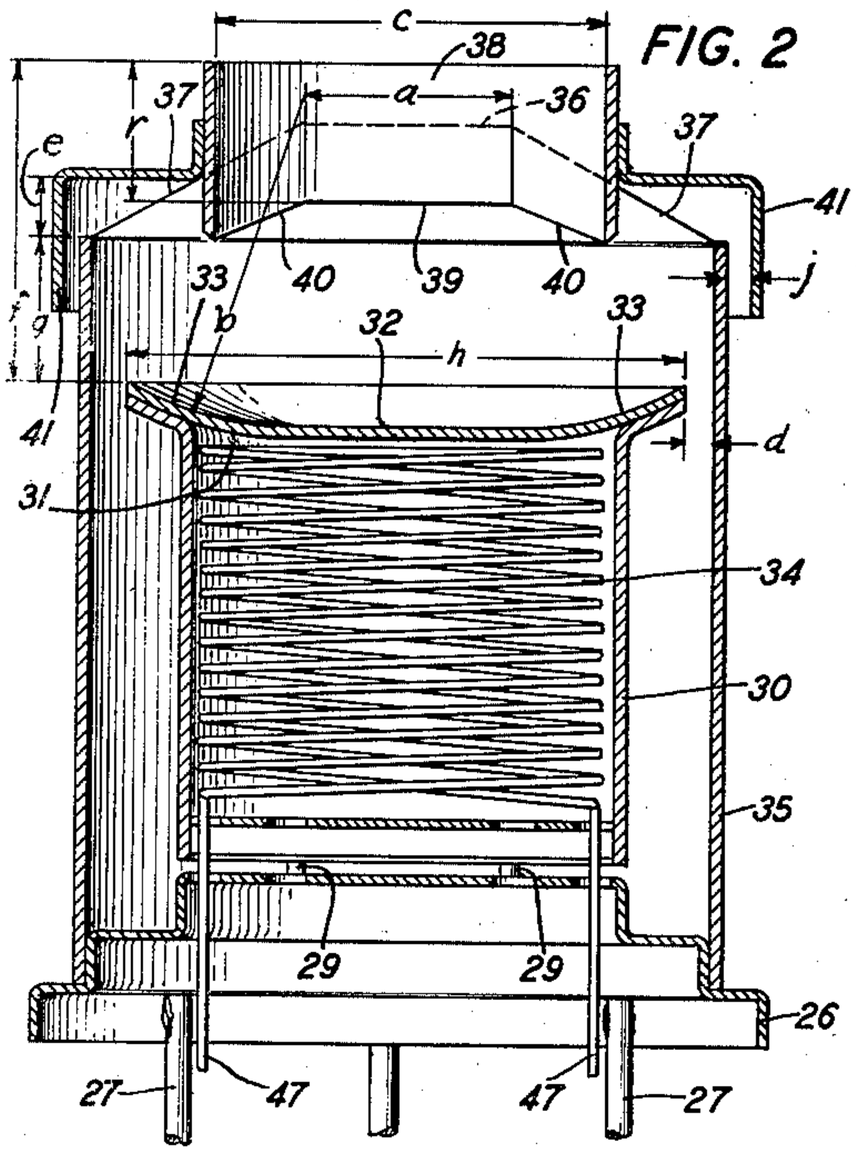

FIG. 2

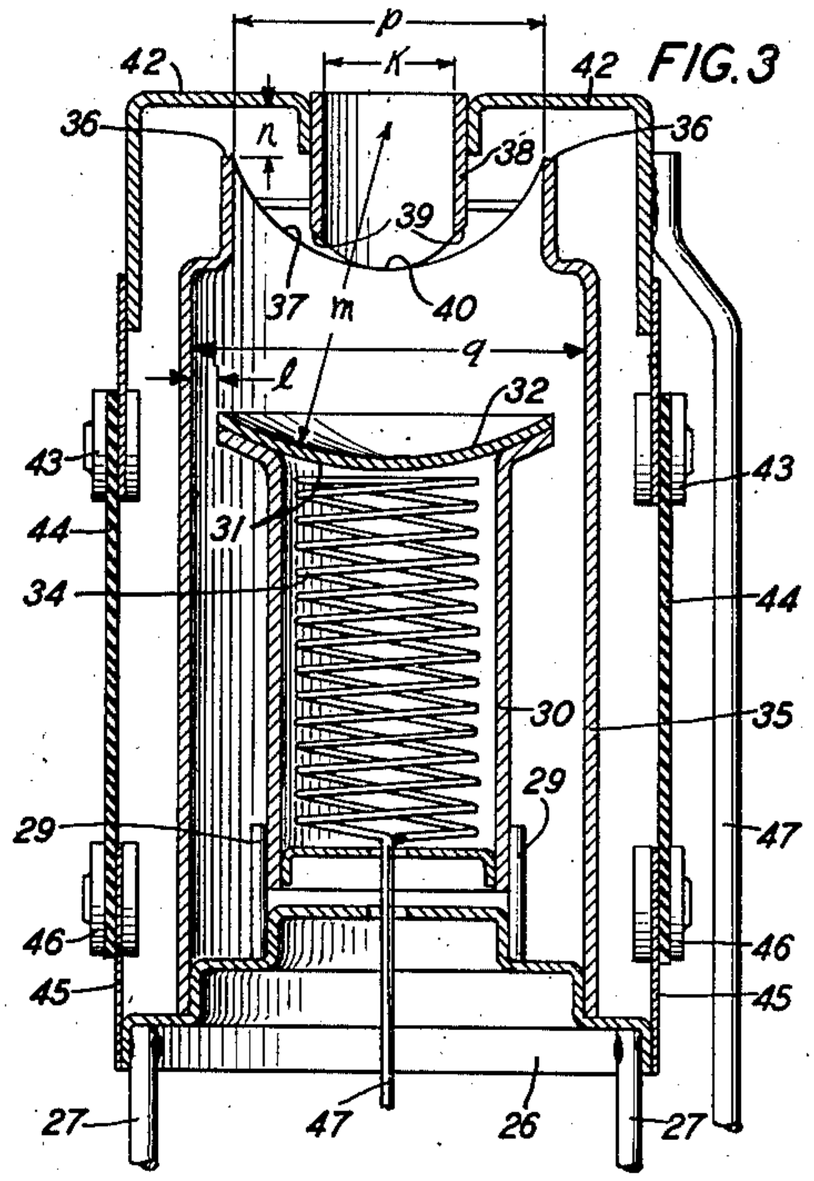

FIG. 3

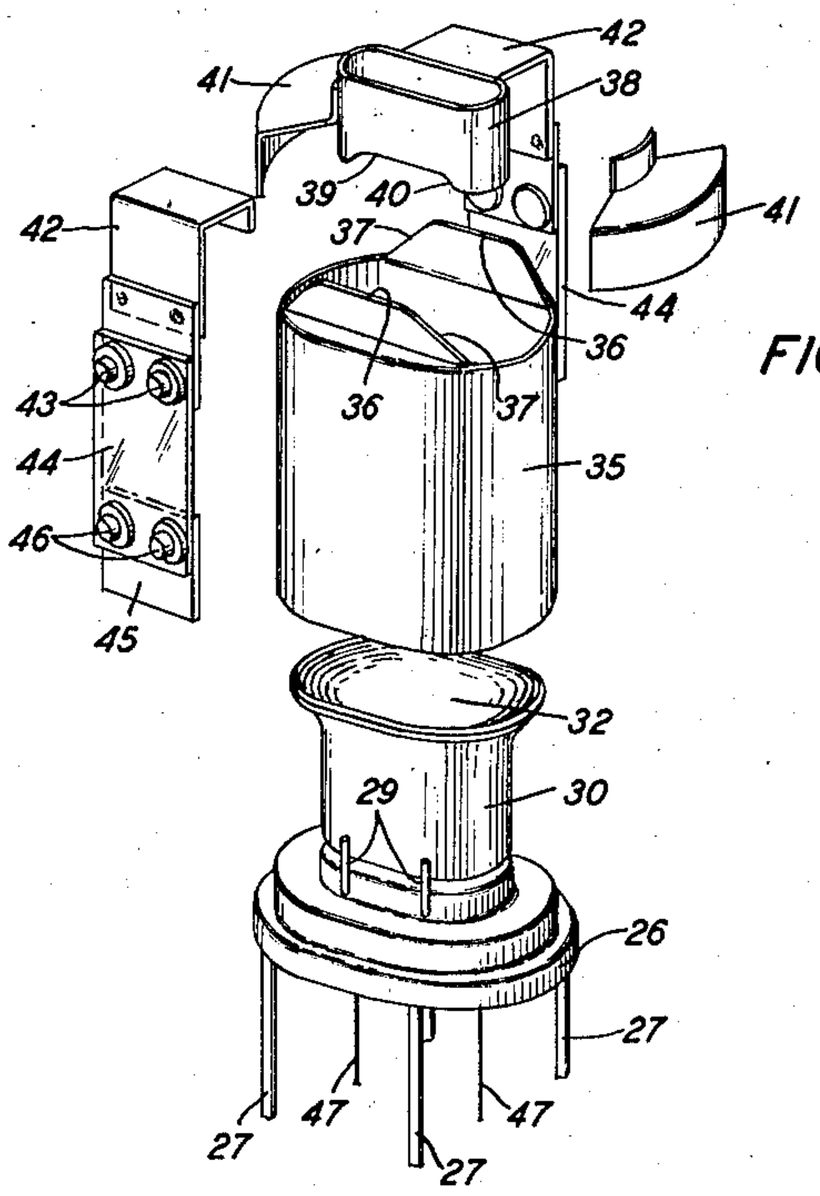

FIG. 4

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ELECTRON DISCHARGE DEVICE

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Application May 26, 1942, Serial No. 444,517

4 Claims. (Cl. 250—27.5)

1

This invention relates to electron discharge devices and more particularly to electron guns for such devices of the velocity variation type.

In velocity variation devices, in general, an electron stream is projected across a gap or through a region wherein it is subjected to a high frequency field and thus is velocity varied. The velocity varied stream then traverses a substantially radio frequency field free region wherein the velocity variations are converted into density variations by a grouping or bunching of the electrons, and the density varied stream subsequently traverses a region or gap in such manner as to deliver energy to a suitable circuit associated with the latter region or gap.

The degree to which the velocity variations are converted into density variations is dependent upon the extent to which the electrons in the stream are grouped or bunched. In the region where the conversion of the velocity variations into density variations is effected, space charge effects tend to occur, due to the electrostatic repulsive forces of the electrons, and such effects tend to hinder the grouping or bunching of the electrons. Substantial prevention or reduction of these effects has entailed heretofore material restrictions upon the total current which could be utilized with given potentials upon the electrodes or, conversely, has necessitated relatively high electrode potentials for moderate stream currents.

One general object of this invention is to improve the efficiency and operating characteristics of electron discharge devices of the velocity variation type. More specifically, objects of this invention are to:

Increase the power obtainable from electron discharge devices of the velocity variation type;

Decrease the electrode potentials requisite for the realization of electron grouping or bunching in an electron stream of a given current in such devices;

Produce efficiently a highly concentrated line focus electron beam; and

Prevent substantial edge effects in a high current line focus electron beam.

In one illustrative embodiment of this invention, an electron discharge device of the velocity variation type comprises electrodes defining a velocity variation region or gap and adapted to have associated therewith a suitable circuit, such as a cavity resonator, one or both of the electrodes having a narrow, rectangular opening therein, and an electron gun for projecting an electron stream through said opening. The electron gun includes a cathode and a beam focusing electrode and an accelerating anode cooperatively associated therewith.

2

In accordance with one feature of this invention, the electrodes constituting the electron gun are constructed and arranged to produce a converging beam of substantially rectangular cross section having a line focus at substantially the entrance to the velocity varying gap or region. More specifically, in accordance with one feature of this invention, the electrodes constituting the electron gun are made of such configuration and so related that substantially all the electrons emanating from the cathode are concentrated into the beam, including those electrons emitted from the lateral extremities of the cathode emissive surface whereby edge effects are substantially eliminated and high operating efficiencies are realized.

The invention and the aforenoted 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 a perspective view of an electron discharge device illustrative of one embodiment of this invention, portions of the enclosing vessel and of the collector or target and one of the gap-defining electrodes being broken away to show the construction more clearly;

Figs. 2 and 3 are longitudinal sectional views of the electron gun, taken at planes at right angles to each other; and

Fig. 4 is an exploded perspective view of the electrodes and other elements constituting the electron gun.

Referring now to the drawings, the electron discharge device illustrated in Fig. 1 is of the velocity variation type and comprises an enclosing vessel, for example of vitreous material, having bulbous axially aligned end portions 10 and 11 and an intermediate constricted portion 12 joining the end portions. Supported within the end portion 10, as by a leading-in conductor structure 13 affixed within a metallic thimble 14 hermetically sealed to this end portion, is a generally cup-shaped target or collector electrode 15. The other end portion 11 of the enclosing vessel is provided with an inwardly extending stem 16 from which an electron gun, designated generally as 17 and described in detail hereinafter, is supported in axial alignment with the target or collector electrode 15.

Disposed within the intermediate portion 12 of the enclosing vessel and in axial alignment

with the electron gun 17 and the target or collector electrode 15 are end gap-defining electrodes and an intermediate electrode 20. The end electrodes include central, rectangularly apertured tapered portions 21 and 22, respectively, and outer annular portions 23 and 24, respectively, which extend through and are sealed hermetically to the intermediate portion 12 of the enclosing vessel. The intermediate electrode 20 is hollow and of rectangular cross section and is mounted by a metallic annulus 25 extending through and sealed hermetically to the intermediate portion 12 of the enclosing vessel.

The electron gun, as shown in Figs. 2, 3 and 4, constitutes a unitary assembly including a stepped base or supporting plate 26 which is supported by a plurality of rigid rods or wire members 27 secured to rigid pins 28 embedded in the stem 16. Mounted upon the plate 26, as by a pair of rigid wires 29 affixed thereto, is a cathode including a metal, flattened cylindrical shell 30 and a dished end member 31, the outer surface of which is coated with a thermionic material. The dished electron emissive surface of the cathode includes an intermediate portion 32 conforming to a section of a cylindrical surface and end portions 33 conforming to segments of a spherical surface of the same or substantially the same radius as the cylindrical surface mentioned.

Within the cathode is a heater element 34 which may be, for example, a double helical filament coated with a suitable insulating material.

The cathode is encompassed by a flattened cylindrical beam forming electrode 35 which is fitted upon one of the stepped portions of the base or supporting plate 26 and secured thereto as by welding. The beam forming electrode 35 extends beyond the end of the cathode toward the target or collector electrode 13 and the edge thereof includes linear sections 36 parallel to the edges of the intermediate portion 32 of the cathode emissive surface, and oppositely inclined U-shaped end sections 37.

Mounted in cooperative relation with the cathode and the beam forming electrode 35 is an accelerating anode which comprises a flattened cylindrical portion 38 extending into the space bounded by the beam forming electrode and in axial alignment with this electrode. The edge of the accelerating anode within this space comprises linear sections 39 parallel to the linear edge sections 36 and similar U-shaped end sections 40 inclined toward the cathode and substantially parallel to the edge sections 37. The accelerating anode includes also flanged plate members 41 which overlie the edge portions 37 of the beam-forming electrode. Secured to the flattened cylindrical anode portion 38 are a pair of bracket members 42 which are affixed, as by rivets 43, to insulating supports 44, such as mica strips. The insulating supports 44 are mounted by metallic strips 45, secured to the supports, as by rivets 46, and secured also, as by welding, to the base plate 26.

Electrical connection to the cathode, the heater filament and the accelerating anode may be established through leading-in conductors 47 embedded in the press. The beam-forming electrode 35, by virtue of its connection to the base plate 26 is operated at cathode potential, although it will be understood that it may be so mounted as to be electrically separate from the cathode, and thus operable at any suitable potential relative to the cathode.

Because of the configuration of the cathode

emissive surface 32, 33 and of the beam-forming and accelerating electrodes, the electrons emanating from the emissive surface are projected into fields of such character that these electrons are concentrated into a converging beam of substantially rectangular cross section passing through the anode portion 38 and having a very small width at the outlet end of the accelerating anode. It will be noted particularly that the electrons emanating from the end portions 33 of the cathode emissive surface are brought under the influence of electric forces having a resultant component tending to direct these electrons toward the longitudinal axis of the electron gun so that edge effects are substantially eliminated and a sharp substantially line focus beam is obtained.

Realization of optimum or substantially optimum operating characteristics for the electron gun entails a particular design of the electrodes of the gun. In general, these electrodes may be designed in accordance with the principles set forth in Patent 2,268,197, granted December 30, 1941 to John R. Pierce so that substantially all the electrons emanating from the surface 36, 37 are concentrated into the beam. In a specific gun of the construction illustrated in Figs. 2, 3 and 4, the following dimensions, indicated in Figs. 2 and 3 and expressed in units, have been found to be very satisfactory. A typical unit is $^1/_{100}$ inch.

$a=25.0$	$g=16.5$	$m=37.5$
$b=37.5$	$h=62.5$	$n=6.0$
$c=44.0$	$j=3.1$	$p=34.5$
$d=2.4$	$k=15.0$	$q=43.5$
$e=6.25$	$l=3.0$	$r=15.9$
$f=35.5$		

The device illustrated in Fig. 1 is particularly suitable for use as an ultra high frequency oscillation generator. Inasmuch as the general principles of operation of similar devices for this purpose are known, a detailed exposition thereof is not necessary. It may be noted briefly, however, that the device shown in Fig. 1 may have a suitably tuned circuit, such as a cavity resonator, associated with the electrodes 21, 23 and 23, 24. The electron beam produced by the electron gun is projected across the gap between the electrodes 20 and 21 and is velocity varied. As the beam traverses the path through the electrode 20, the velocity variations are converted into density variations and, as a result, electrons are projected across the gap between the electrodes 20 and 22 in bunches or groups so as to deliver energy to the field within the cavity resonator whereby an oscillating field is established and maintained in the resonator.

The device may be used also as a power amplifier with independent cavities associated with the two gaps.

It will be noted that in the device shown in Fig. 1 the electron beam is a line focus beam and is of relatively large cross-sectional area as compared with that of a point focus beam of the same current magnitude. Hence, in this device, the space charge density within the beam is relatively small and the electrostatic repulsive forces effective upon the electrons is correspondingly small. Hence, the bunching or grouping of the velocity varied electrons requisite for operation of the device can be realized in devices constructed in accordance with this invention with relatively low voltages on the electrodes for a particular beam current. Viewed in another way,

in devices constructed in accordance with this invention, higher currents can be obtained for a given voltage upon the electrodes before the space charge forces become sufficiently large to materially prevent the grouping or bunching of the electrons. Thus, the invention enables the attainment of both high power and high operating efficiency.

It will be noted also that at the gap between the electrodes **20** and **21**, the beam, although of relatively large cross-sectional area, is extremely thin so that a close coupling between the electrons and the radio frequency field at the gap and uniformity of action of the field upon the electrons are obtained.

Although a specific embodiment of this invention has been shown and described, it will be understood that it is but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. An electron gun comprising a cathode having a dished electron emissive surface including an intermediate portion conforming substantially to a segment of a cylinder and end portions conforming substantially to segments of spheres, a beam-forming electrode having a flattened cylindrical portion in alignment with said surface and having an edge in front of said surface which includes intermediate sections substantially parallel to said intermediate portion of said surface and inclined end sections converging away from said surface, and a second beam-forming electrode including a flattened cylindrical portion in alignment with and in front of said surface, the edge of said second flattened cylindrical portion toward said surface including inclined end sections and intermediate sections substantially parallel to said intermediate portion of said cathode.

2. An electron gun comprising a cathode having a dished electron emissive surface including an intermediate portion conforming substantially to a segment of a cylinder and end portions conforming substantially to segments of spheres, an accelerating anode including a hollow flattened cylindrical portion opposite and in alignment with said surface, the edge of said flattened cylindrical portion toward said surface including intermediate sections substantially parallel to said intermediate portion of said cathode and inclined end sections flaring toward said surface, and a beam-forming electrode having a hollow flattened cylindrical portion encompassing and in alignment with said cathode and said accelerating anode, the edge of said portion of said beam-forming electrode in front of said surface including intermediate sections substantially parallel to said intermediate portion of said surface and end sections inclined in the same direction as said end sections of said accelerating anode.

3. An electron gun comprising a cathode having a dished electron emissive surface including an intermediate portion conforming substantially to a segment of a cylinder and end portions conforming substantially to segments of a sphere, said intermediate and end portions having substantially the same radius of curvature, an accelerating anode having a hollow flattened cylindrical portion opposite and in alignment with said surface, the edge of said accelerating anode toward said surface including intermediate sections substantially parallel to said intermediate portion of said cathode and inclined end sections extending toward said surface, and a beam-forming electrode having a hollow flattened cylindrical portion encompassing said cathode and said portion of said accelerating anode and in alignment therewith, the edge of said second flattened cylindrical portion nearest said accelerating anode including inclined end sections substantially parallel to said first end sections and intermediate sections substantially parallel to said intermediate sections of said accelerating anode.

4. An electron gun comprising a cathode having an elongated dished electron emissive surface including an intermediate substantially linear portion and concave end portions, an accelerating anode including a hollow flattened cylindrical portion opposite and in alignment with said surface, the end of said flattened cylindrical portion toward said surface including an intermediate portion substantially parallel to said intermediate portion of said surface and end portions inclined toward said surface, and a beam-forming electrode including a hollow flattened cylindrical portion encompassing and in alignment with said cathode and said first cylindrical portion, said second cylindrical portion having an end bounded by an edge including intermediate sections substantially parallel to said intermediate portion of said cathode and further removed therefrom than said intermediate portion of said accelerating anode, said edge including also end sections inclined toward said end portions of said anode.

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