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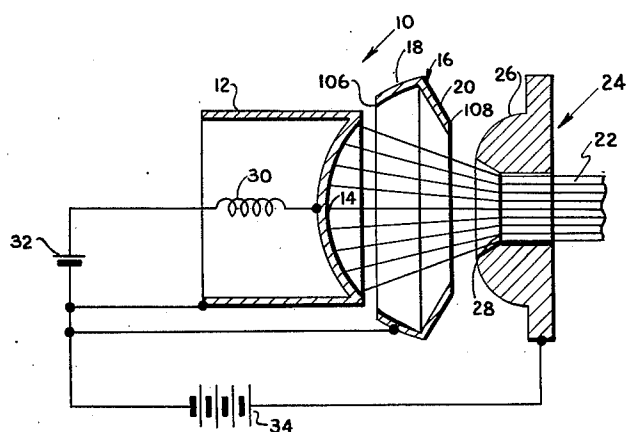
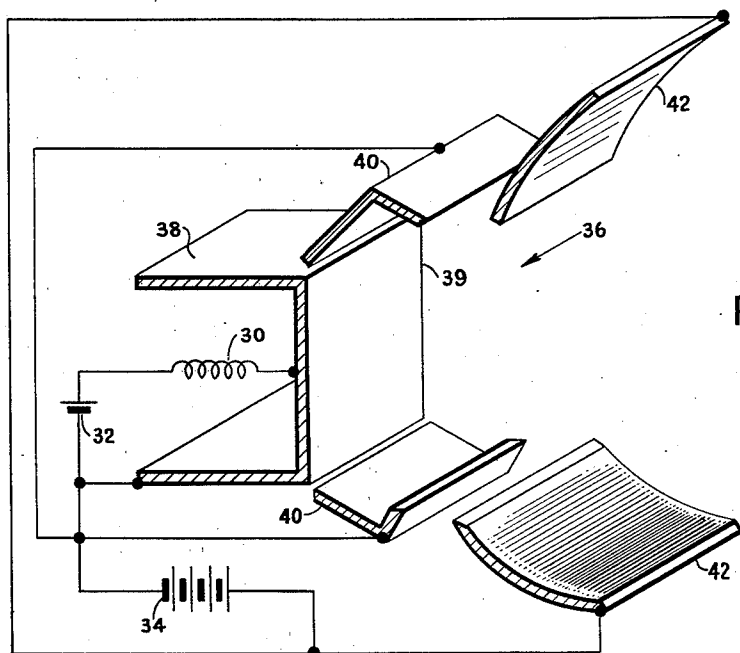
G. R. BREWER

2,817,033

ELECTRON GUN

Filed April 8, 1955

2 Sheets-Sheet 1



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INVENTOR

BY

Henry Heyman
ATTORNEY

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2 Sheets-Sheet 2

FIG. 3

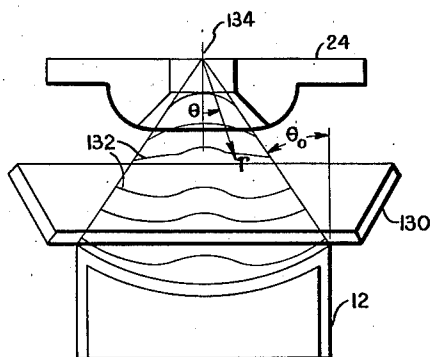
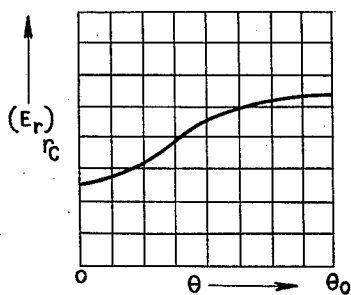


FIG. 4

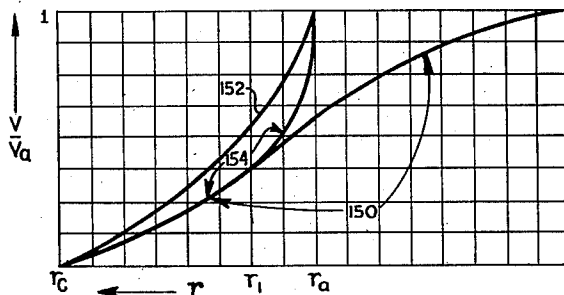


FIG. 5

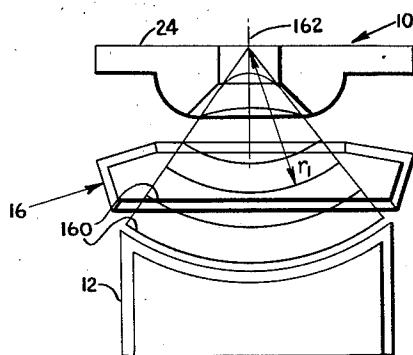


FIG. 6

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2,817,033

ELECTRON GUN

George R. Brewer, Palos Verdes Estates, Calif., assignor to Hughes Aircraft Company, Culver City, Calif., a corporation of Delaware

Application April 8, 1955, Serial No. 500,181

13 Claims. (Cl. 313—82)

This invention relates to electron discharge devices and more particularly to an electron gun for producing an electron stream having a substantially uniform current density over its cross section.

In electron steam amplifiers, e. g. in traveling-wave tubes, an electron gun, comprising a cathode, a focusing electrode, and an accelerating anode, is employed to project an electron stream through a conductive helix whereby interaction between the stream and an electromagnetic wave propagated along the helix may be produced to cause the wave to grow or be amplified. In order to obtain optimum performance from such a tube, it is obviously desirable to minimize the beam current intercepted by both the accelerating anode and the conductive helix. In order to accomplish this objective, it is desirable to employ an electron gun and confining magnetic field system which provide a collimated electron flow, i. e. a flow of electrons whose trajectories are similar from the cathode throughout substantially the entire length of the stream path.

The focusing electrodes of electron guns designed according to current practices are inadequate for use in relatively high-perveance guns because of the poor electron stream collimation they produce. A high-perveance gun is defined generally in terms of structure as a gun in which the transverse size of the anode aperture provided is substantial in comparison to the cathode-anode spacing.

It is therefore an object of the invention to provide an improved electron gun for producing a relatively high-perveance electron stream.

It is another object of the invention to provide an electron gun for producing a well collimated high-perveance electron stream.

When focusing electrodes of conventional design are used in gridless high-perveance electron guns, the normal electric field at the cathode surface becomes substantially smaller than that near the edge of the cathode. This is true because focusing electrodes of conventional design do not compensate for the effects of the large anode aperture through which the beam passes. Transverse outward radial motion is thus imparted to the center electrons by the transverse component of electric fields caused by this variation of the normal field over the stream cross-section. This motion is undesirable and makes it virtually impossible to obtain a well collimated beam.

The shape of the equipotential surfaces contiguous to the cathode has been corrected for the effects caused by the anode aperture by the use of additional structure which is disclosed in a copending application entitled "Electron Gun," Serial No. 474,078, filed December 8, 1954, by George R. Brewer. This application discloses apparatus which causes the axial potential distribution along the center of the beam to approach the same distribution that is normally found at the beam edge.

In accordance with the present invention, focusing means similar to a trough-shaped focusing electrode are

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employed in a relatively high-perveance electron gun to produce a potential distribution along a portion of the edge of the electron beam which is substantially the same as that found at the center of the beam, thereby providing partial compensation for the effects of the anode aperture on the electric fields, whereby a collimated electron flow may be obtained.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawings in which several embodiments of the invention are illustrated by way of example. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only, and are not intended as a definition of the limits of the invention.

Fig. 1 is a sectional view of a gridless high-perveance converging beam electron gun of the present invention employed to produce a frusto-conical stream of electrons;

Fig. 2 is an isometric sectional view of one alternative embodiment of the gun of the present invention;

Fig. 3 is a schematic view of a conventional electron gun;

Fig. 4 is a graph of the potential gradient contiguous to the cathode of Fig. 3 versus a parametric angle, θ , shown therein;

Fig. 5 is a graph of the potential distributions existing at the center and at the edge of the electron stream shown in Fig. 3; and

Fig. 6 is a schematic view of an electron gun of the present invention.

Referring to the drawing, an electron gun 10 is shown in Fig. 1 comprising a cylindrical cathode 12 which may have a spherical-section, concave electron emissive surface 14. The gun 10 also includes an annular trough-shaped focusing electrode 16 including two frusto-conical conductive sheets 18 and 20 which may be mechanically and electrically connected at their outer extremities, as shown, although this is by no means a requirement. The gun 10 is employed to produce an electron stream along a path 22 about which focusing electrode 16 is positioned adjacent the cathode 12. An accelerating anode 24, having a dish-shaped surface 26 disposed adjacent the focusing electrode 16, is arranged about the stream path 22. The electron stream emanating from the cathode 12 proceeds through focusing electrode 16 and an aperture 28 within the accelerating anode 24. The cathode 12 is provided with a filament 30, current through which is maintained by a filament source of potential 32. Focusing electrode 16 may be conveniently maintained at the same potential as cathode 12, as shown, although this is not a critical restriction. Accelerating anode 24 is maintained at a potential positive with respect to cathode 12 by means of an accelerating source of potential 34 connected between anode 24 and cathode 12.

In the design of converging beam guns, such as the gun 10, it is frequently desirable to make the emission surface 14 of the cathode 12 spherically concave, although the general principle of the present invention is not limited to guns using such cathodes. To obtain the best results, that is, to obtain best beam collimation and to minimize the anode interception of electrons emitted from the cathode 12, it is desirable that the internal surface of the conductive sheet 18 be disposed at an angle of approximately 67 degrees more or less from the edge of the electron beam. The exact positions of two internal edges 106 and 108 on conductive sheets 18 and 20 are very critical for the proper performance of focusing electrode 16. These and other critical dimensions may be determined by electrolytic tank studies as will be explained

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subsequently. The dish-shaped surface 26 of anode 24 may conveniently be provided in accordance with the teachings of two United States Patents Parker 2,268,165 and Pierce 2, 268,197.

Fig. 2 is an isometric sectional view of a planar electron gun 36 employing filament 30, filament source of potential 32 and accelerating source of potential 34. The gun 36 also includes a rectangular cathode 38 which may have a flat, cylindrical or other suitably shaped emission surface 39, focusing electrodes 40, and anode sheets 42. It is obvious from the comparison of Figs. 1 and 2 that the gun 36 of Fig. 2 may be designed in a manner analogous to that of the gun 10 of Fig. 1. The gun 36 of Fig. 2 illustrates the fact that the electron gun of the present invention is not limited to converging beam guns, such as gun 10 nor to planar guns such as the gun 36. Further, the invention is not limited to guns for producing solid electron streams but may be used to produce hollow electron streams or wedge-shaped beams, a wedge-shaped beam being produced by a linear translation of the sectional view of the gun 10 shown in Fig. 1 rather than by a revolution of that view as is shown.

Conventional or contemporary converging beam electron guns are designed for electron flow through a cone-shaped section between concentric spheres. In actuality, an aperture in the inner or anode sphere must be provided through which the beam can pass. In the case of a gun having a relatively low perveance, the diameter of the anode aperture is small compared with the distance from the anode surface facing the cathode to the cathode electron emissive surface. In this case, as well as in the case when a grid is used in the anode aperture, electron flow is, as a practical matter, between concentric spheres, that is, the focusing effect of the anode aperture will exist only in the immediate vicinity of the aperture. For example, at a distance more than one anode aperture diameter from the anode, the focusing effect may not exist at all. In order to construct a relatively high-perveance converging beam electron gun the anode must be moved closer to the cathode and the angle of convergence, i. e., the half-angle of the conical surface through which electrons flow must generally be increased. A gun of such geometry exhibits substantial variations of the electric field contiguous to the cathode emission surface across that surface. Specifically, instead of the equipotential surfaces near the cathode being concentric with the cathode, they are distorted in such a way that the normal electric field at the center of the cathode becomes less than that at the edge of the cathode. This can be seen in Fig. 3 where the outlines of cathode 12 and anode 24 are shown with a conventional focusing electrode 130. A plurality of equipotential lines 132 are there shown with irregularities along their centerline 134. It can be shown that the emission current density from the cathode is related to the two-thirds power of the space-charge-free off-cathode potential gradient, so that inequality in the radial field at the cathode results in variations in the current density with an angle, θ , as shown. In addition, the distortion of the equipotential lines 132 in the vicinity of the centerline 134 near the cathode 12 results in transverse, that is, θ -directed components of electric fields which deflect the electrons from their convergent, rectilinear paths.

A converging beam gun designed according to known criteria having a geometry consistent with that of a high-perveance gun, i. e., an anode aperture of a size comparable to the distance between anode and cathode 12, will exhibit two undesirable characteristics. The first is a non-uniform current density over the beam cross section. The second is a defocusing effect on inner electrons which prevent them from forming into a well collimated beam and in extreme cases they can be intercepted by anode 24. These generalizations, of course, apply normally only to the type of gun in which the anode aperture is open, that is, a gridless anode. While a perfect com-

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pensation for the undesirable effects of the anode aperture cannot be achieved, the procedure outlined hereafter in accordance with the present invention will result in good partial compensation for the poor collimation effects of the anode aperture thus effecting a substantial improvement in the beam focusing characteristics. This partial compensation is effected by the use of the focusing electrode 16 of Fig. 1 or 40 of Fig. 2.

In a relatively high-perveance converging beam gun, for example, in a gun having a perveance of

$$2.0 \text{ or } 2.5 \times 10^{-6} \text{ amperes/volt}^{3/2}$$

a half-angle of beam convergence, θ_0 , indicated in Fig. 3 may be 35 degrees with a ratio of anode to cathode radius of $1/2$, resulting in a diameter of anode aperture equal to, or slightly greater than the distance between anode and cathode. A typical plot of the off-cathode gradient versus half-angle of convergence θ in a conventional space-charge-free structure is shown in Fig. 4 from which the variation in the emission current density may be deduced. The problem is to construct a relatively high-perveance gun which will produce a reasonably well collimated beam of electrons. The most important region of the gun, as far as affecting electron trajectories is concerned, is that region near the cathode where the electrons move relatively slowly and in relatively weak radial electric fields. By being subjected to a substantial transverse electrostatic force, they are thus easily deflected from their desired paths. It is then desirable to create equipotential lines which are substantially concentric to the cathode in the general vicinity of the cathode in order to get electrons started in the proper direction.

In making the equipotential lines 132 near the cathode concentric with the cathode, it is possible to change the shape of those lines near the centerline 134 or to change the shape of the lines near the boundary of the beam. The former was disclosed and claimed in the aforementioned Brewer application. For a three-element gun the potential distribution along the axis of the gun is relatively unaffected by changes in the shape of the anode or of any of the other elements, so that this distribution may be generally taken as fixed. When the potential distribution along the boundary of the beam is caused to be of the same shape as that portion of the distribution on the axis near the cathode, the equipotential lines near the cathode are concentric with it. Referring to Fig. 5, a normalized potential,

$$\frac{V}{V_a}$$

where V is the potential at any value of radius r , and V_a is the anode potential, is plotted as a function of the normalized radius, r/r_c , where r is indicated in Fig. 3 and r_c is the cathode radius. A curve 150 in Fig. 5 represents a typical potential distribution along the axis of the gun from cathode radius r_c to an anode radius r_a . In accordance with the invention, it is desirable to produce a potential distribution along the edge of the beam substantially identical with the curve 150 for at least a portion of the distance from the cathode to the anode.

Along the boundary of the beam the normalized potential must have the value unity at the anode radius, r_a . The Langmuir potential distribution along the edge of the beam is shown by curve 152, which is that potential distribution appropriate to space-charge limited electron flow between complete concentric spheres and that which has formed the basis for conventional electron gun design procedure. What is desired, therefore, is a potential distribution along the boundary of the beam represented by a curve 154 which follows curve 150 up to a certain value of radius, r_1 , and which passes through the point of

$$\frac{V}{V_a}$$

equal to unity at the anode radius r_a . The potential dis-

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tribution between r_1 and the anode radius r_a where curve 154 departs from curve 150 is thus considered relatively unimportant in view of the fact that the electrons there are moving fast enough to be impervious to excessive deflections. An equipotential plot of the gun 10 in the presence of space charge is shown in Fig. 6. It is seen that here a plurality of equipotential lines 160 near the cathode are substantially concentric resulting in a uniform emission current density and rectilinear electron paths, i. e., a collimated electron flow up to radius r_1 after which the electrons are not unsatisfactorily deflected. The form of the focusing electrode 16 necessary to produce the desired potential distribution shown in curve 154 in Fig. 5 may be obtained through the use of an electrolytic tank as is well known.

The appropriate location of the radius r_1 at which the potential along the boundary begins to deviate from that on the axis, is of interest, in that if r_1 is too large the equipotential lines will be distorted near the cathode yielding the undesirable effects mentioned above, while if r_1 is too small, that is, too near the anode, the radial electric field near the anode along the boundary will be quite large resulting in large transverse or θ -directed fields causing excessive electron deflection. The θ -directed fields in the region of the anode aperture cause the electrons to be deflected outward from their radial paths, an effect similar to that of an optical lens. It is desired that the deflected electron paths have a common focus, i. e. that the anode lens has little or no spherical aberration. An optimum position for the radius r_1 exists for minimizing the spherical aberration of the anode lens. Since the paths of the electrons near the center of the gun, that is, near an axis 162 in Fig. 6, are relatively unaffected by changes in the boundary conditions, spherical aberration in the anode lens can be affected and therefore reduced by the proper positioning of the radius r_1 , which changes the fields principally near the edge of the beam. The optimum value of r_1 can be determined accurately only by detailed studies of the electron trajectory in the gun. However, a rather rough approximation indicates that the position of r_1 should be at a point two-thirds of the distance from the cathode to the anode, or

$$r_1/r_c \cong 1/3 + (2/3)r_a/r_c$$

e. g. when the ratio of anode-to-cathode radii is 60:100, the ratio of r_1 to the cathode radius will be 73:100.

A procedure of electron gun construction according to the present invention is one which partially compensates for the effects of the anode aperture on the distortion of the electric fields between anode and cathode by applying suitable and unconventionally shaped fields external to the beam boundaries. The potential along the boundary is thus composed of two curves, smoothly joined at $r=r_1$. The first of these curves, nearest the cathode, follows the Langmuir distribution corresponding to an anode position farther from the cathode than the actual anode 24 is positioned at the edge of the beam, this distribution being followed up to radius r_1 . After this point the potential rises fairly rapidly to the value at the anode. The electric field normal to the beam boundary between radii r_c and r_1 is zero, but will have a finite value between r_1 and r_a , depending on the rate of potential variation in this region. These boundary conditions are substantially different than those proposed in U. S. Patents to Parker 2,268,165; Pierce 2,268,197; Wang 2,564,743; and Rich 2,687,490 in that what is proposed there is a potential variation following the Langmuir distribution over the entire region between cathode and anode, with the normal electric field at the beam boundary being hopefully assumed to be zero over this entire range. A high-perveance gun built in accordance with the teachings of these patents will exhibit the undesired effects mentioned above.

The details of construction of the shape of the focusing

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electrode 24 necessary to produce the boundary conditions at the edge of the beam stated above is accomplished in an electrolytic tank. Since this work is carried out in a somewhat unconventional way, the steps will be described in detail.

First, with the proper boundary conditions applied to the edge of the beam, it is desired to produce equipotential lines near the cathode which are concentric with the cathode. This can be accomplished by making the electric gradient normal to the cathode uniform over the surface of the cathode. The electric gradient normal to the cathode can be measured conveniently with the use of a double probe in the electrolytic tank, that is, a probe composed of two closely spaced wires, the voltage difference being proportional to the electric field. This probe may be moved in front of the cathode surface to yield a simple determination of the electric field variation in this region. In order to duplicate in the tank the conditions of zero normal potential gradient at the beam boundary, one must use a dielectric strip along the boundary of the beam but on the outside of this boundary. This strip will extend over that region of the beam boundary on which the normal electric field is zero, that is, from radius r_c to radius r_1 . Along the inside surface of this dielectric sheet is placed a series of probes, which can be held at desired potentials by means of a suitable potential dividing system, so that any required potential distribution can be forced on the beam boundary. Since the electric fields in the tank obey the Laplace equation, one will force the appropriate space-charge-free potential distribution on the boundary of the beam. The potential distributions for plane, cylindrical and spherical cases are respectively shown in equations below:

$$\frac{V}{V_a} = \frac{z}{a} \quad (1)$$

$$\frac{V}{V_a} = \log \cdot \frac{r_c}{r_a} \quad (2)$$

$$\frac{V}{V_a} = \frac{\frac{r_c}{r} - 1}{\frac{r_c}{r_a} - 1} \quad (3)$$

where z is an axial coordinate and a is a constant. One adjusts the slope of this forced potential distribution until the off-cathode gradient is uniform over the cathode surface. This adjustment is equivalent to changing the position of the equivalent anode. When the gradient is uniform, the equivalent anode position corresponding to an element of the cathode near the center, or axis, will be the same as that for an element of the cathode near the edge of the beam. When the off-cathode potential gradient is adjusted to be uniform over the cathode surface, one can conclude that the emission current density will be very nearly uniform over the cathode surface in the actual tube. There is a slight difference due to the fact that the electron flow from a cathode element near the axis is not always flowing along a flux line whereas the flow near the beam boundary will, in general, be very nearly near the flux line. The space-charge potential depression will be slightly different in the two cases, but this effect will generally be small. The equations for the position of the equivalent anode in terms of the off-cathode gradient are given below for plane, cylindrical and spherical geometries, respectively:

$$d_{ea} = \left(\frac{V_a}{\frac{dV}{dz}} \right) \quad (4)$$

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$$\left(\frac{r_c}{r_a}\right)_{eq} = \log_e^{-1} \left[\frac{1}{r_c \left(\frac{dV}{dr} \right)_c} \right] \quad (5)$$

$$\left(\frac{r_c}{r_a}\right)_{eq} = 1 + \frac{1}{r_c \left(\frac{dV}{dr} \right)_c} \quad (6)$$

where eq denotes an equivalent value. One can also determine the position of the equivalent anode by the potential distribution forced along the beam boundary which is necessary to produce a uniform off-cathode potential gradient.

When the equivalent anode position corresponding to the potential distribution desired along the beam edge between r_c and r_1 has been determined, one can find the correct position and shape of the focusing electrode. This is done by reversing the position of the dielectric strip in the tank so that it is inside of the desired beam boundary, the outer edge of the strip corresponding to the beam boundary. A series of thin metallic electrodes placed along this dielectric strip can now be used as probes to sample the potential distribution along the beam boundary, being displayed for example on an oscilloscope. The potential distribution desired along this boundary is the Langmuir distribution with the anode position equal to that of the equivalent anode determined above. The focusing electrode shape can be found by adjusting the position and shape of a metallic focusing electrode in the electrolytic tank until the desired potential distribution is obtained. In the case of the converging beam gun, one generally obtains the shape of the focusing electrode similar to that shown in Fig. 1. In general, since the desired potential of a given radius on the beam boundary is less than that "naturally" existing inside of the beam boundary, i. e. the same as that provided by a conventional focusing electrode, the focusing electrode designed according to the present invention will be of such shape that, in general, the internal edge 108 of focusing electrode 16 shown in Fig. 1 will be relatively close to the beam boundary. In the case of a converging beam gun, the diameter of the internal edge 108 will generally be less than the diameter of internal edge 106. In order that the fields be of the desired shape near the cathode edge, the angle of sheet 18 should be about 67 degrees with the beam boundary as stated previously. These conditions lead to a focusing electrode of the general shape shown in Fig. 1.

While the above description of gun construction has been occasionally related to only the geometry of the converging beam gun 10 of Fig. 1, it is apparent that the same principles can be applied to the design of high-perveance cylindrical or wedge-shaped flow guns or to planar guns, either of the solid or hollow beam type.

What is claimed is:

1. An electron gun for producing an electron stream with a predetermined current density distribution over its cross section and a predetermined spherical aberration provided by its anode lens, said electron gun comprising a cathode, an anode electrode and a focusing electrode, said focusing electrode being disposed about the beam and between said cathode and said anode electrode and being constructed and positioned to produce predetermined electrical boundary conditions along the boundary of the beam in the gun region, said boundary conditions providing maintenance of a potential distribution varying with distance from the cathode according to the Child-Langmuir law for space-charge limited electron flow in the geometry appropriate to said gun up to a predetermined point located between said cathode and said anode electrode on the stream boundary, the potential gradient normal to said beam boundary up to said point being equal to zero, the potential distribution over the

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remainder of the boundary between said point and said anode electrode varying in a manner determined by the shape of said electrodes and being different from that existing between said cathode and said point, the rate of variation of potential along the stream boundary between the cathode and said point following the Child-Langmuir distribution appropriate to electron flow to an equivalent anode, said equivalent anode being located beyond said anode electrode in the direction of the electron flow of said beam.

2. The invention as defined in claim 1, wherein the potential V_1 at said point r_1 is given approximately by the following equation in plane geometry:

$$V_1 = V_a \left(\frac{r_c - r_1}{d_{eq}} \right)^{4/3}$$

where

$$d_{eq} = \frac{V_a}{\left(\frac{dV}{dz} \right)_c}$$

where d_{eq} is the distance between said cathode and said equivalent anode, determined so as to produce the desired variation of normal space-charge-free electric gradient across the cathode surface, and z is distance along said stream; $r_c - r_1$ is distance from said cathode to $z = r_1$; V_a is the potential of said anode electrode; and V is the potential at any point along said stream.

3. The invention as defined in claim 1, wherein the potential V_1 at said point r_1 is given approximately by the following equation in cylindrical geometry:

$$V_1 = V_a \left(\frac{\beta_1}{\beta_{eq}} \right)^{4/3}$$

where

$$\left(\frac{r_c}{r_a}\right)_{eq} = \log_e^{-1} \left[\frac{1}{r_c \left(\frac{dV}{dr} \right)_c} \right]$$

and r_c is the radius of said cathode; r_a is the radius of said anode electrode; r is the radius; β is the Langmuir function for cylindrical geometry; β_1 is the value of β at

$$\frac{r_1}{r_c}$$

β_{eq} is the value of β at

$$\left(\frac{r_c}{r_a}\right)_{eq}$$

V_a is the anode potential of said anode electrode; and V is the potential at any point along said stream.

4. The invention as defined in claim 1, wherein the potential V_1 at said point r_1 is given approximately by the following equation in spherical geometry:

$$V_1 = V_a \left(\frac{\alpha_1}{\alpha_{eq}} \right)^{4/3}$$

where

$$\left(\frac{r_c}{r_a}\right)_{eq} = 1 + \frac{1}{r_c \left(\frac{dV}{dr} \right)_c}$$

and α is the Langmuir function for spherical geometry; α_1 is the value of α at

$$\frac{r_1}{r_a}$$

α_{eq} is the value of α at

$$\left(\frac{r_c}{r_a}\right)_{eq}$$

V_a is the anode potential of said anode electrode; V is

the potential at any point along said stream; r_c is the radius of said cathode; r_a is the radius of said anode electrode; and r is the radius.

5. A high-perveance electron gun for producing a collimated electron stream, said gun comprising a cathode, an anode, and a focusing electrode disposed contiguous to said stream between said cathode and said anode to provide equipotential surfaces substantially parallel to the emission surface of said cathode for a predetermined distance from said emission surface, said focusing electrode being curved outwardly away from said stream and having a first outer edge adjacent said cathode and disposed farther from said stream than the boundary of said cathode, and said focusing electrode having a second outer edge located between said first outer edge and said anode and disposed closer to the axis of said stream than said first edge.

6. An electron gun for producing an electron stream having a substantially uniform cross section throughout its length, said gun comprising a flat thermionic cathode, a trough-shaped focusing electrode disposed adjacent said cathode and disposed about said stream, and an accelerating anode disposed adjacent said focusing electrode and disposed about said stream, said focusing electrode having a first edge adjacent said cathode and disposed farther from said stream than the boundary of said cathode, and said focusing electrode having a second edge located between said first edge and said anode and disposed closer to the axis of said stream than said first edge.

7. An electron gun for producing an electron stream comprising a cylindrical thermionic cathode, focusing means including two metallic sheets having juxtaposed outer edges and providing a frusto-conical aperture, said focusing means being disposed adjacent said cathode about said stream, and a dish-shaped anode disposed adjacent said focusing electrode and about said stream.

8. An electron gun for producing a frusto-conical stream of electrons, said gun comprising a substantially concave spherical-section cathode, a trough-shaped focusing electrode including two juxtaposed conductive sheets forming a frusto-conical aperture and having their outer edges connected, said focusing electrode being disposed adjacent said cathode and about said stream, and an apertured dish-shaped anode disposed adjacent said focusing electrode and about said stream.

9. An electron gun for producing a frusto-conical stream of electrons, said gun comprising a concave spherical-section cathode, a trough-shaped focusing electrode including two oppositely inclined conductive sheets forming frusto-conical aperture and having their outer edges connected, said focusing electrode being disposed adjacent said cathode and about said stream, an apertured dish-shaped anode disposed adjacent said focusing electrode and about said stream, and means for maintaining said anode at a potential positive with respect to that of said cathode.

10. An electron gun for producing a frusto-conical stream of electrons, said gun comprising a substantially concave spherical-section cathode, a trough-shaped

focusing electrode including two oppositely inclined conductive sheets forming a frusto-conical aperture and having their outer edges connected, said focusing electrode being disposed adjacent said cathode and about said stream, an apertured dish-shaped anode disposed adjacent said focusing electrode and about said stream, and means for maintaining said focusing electrode at substantially the same potential as that of said cathode.

11. An electron gun for producing a frusto-conical stream of electrons, said gun comprising a concave spherical-section cathode, an apertured dish-shaped anode disposed about said stream and spaced from said cathode, a trough-shaped focusing electrode including two oppositely inclined conductive sheets forming a frusto-conical aperture and having their outer edges connected, and means for maintaining said focusing electrode at substantially the same potential as said cathode, said focusing electrode being spaced from said cathode between said cathode and said anode and positioned about said stream to cause equipotential surfaces contiguous to said cathode to be parallel for a predetermined distance from said cathode.

12. An electron gun for producing a frusto-conical stream of electrons, said gun comprising a concave spherical-section cathode, an accelerating anode spaced from said cathode about said stream, said anode having an aperture of a substantial diameter in comparison to the distance between said cathode and said anode, a trough-shaped focusing electrode including two oppositely inclined frusto-conical conductive sheets electrically connected at their outer edges, said focusing electrode being disposed about said stream between said cathode and said anode, means for maintaining said focusing electrode at approximately the same potential as that of said cathode, and means for maintaining said anode at a potential positive with respect to that of said cathode.

13. An electron gun for producing an electron stream comprising a cathode, an anode electrode spaced from said cathode to accelerate electrons within said stream along a predetermined path, and a focusing electrode disposed adjacent said path between said cathode and said anode electrode for producing a potential distribution at the outer boundary surface of said stream substantially equal to the potential distribution along the axis of said stream for a predetermined distance from said cathode to said anode electrode, said focusing electrode having a first edge adjacent said cathode and disposed farther from said stream than the boundary of said cathode, and said focusing electrode having a second edge located between said first edge and said anode electrode and disposed closer to the axis of said stream than said first edge.

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