

Dec. 30, 1941.

R. C. WINANS

2,268,195

ELECTRON DISCHARGE DEVICE

Filed Dec. 2, 1939

2 Sheets-Sheet 1

FIG. 1

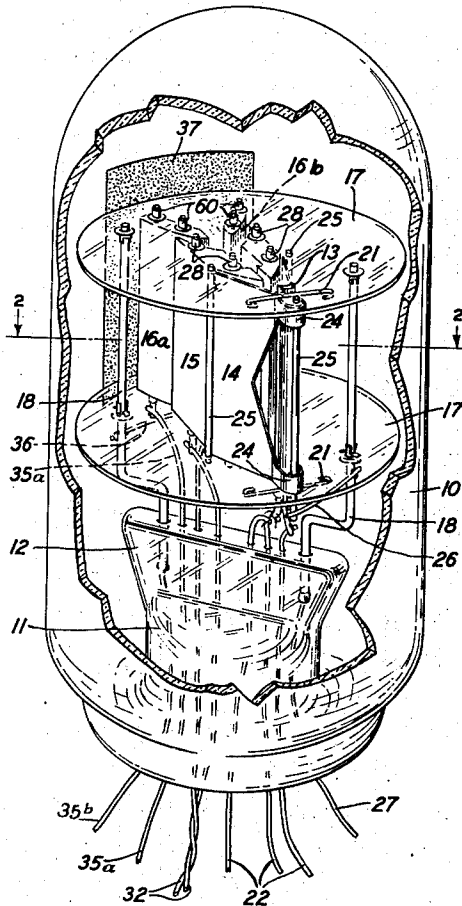


FIG. 2

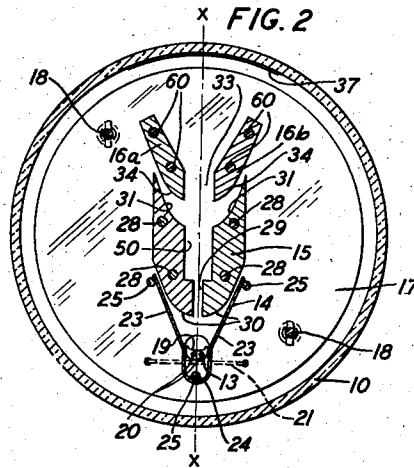


FIG. 3

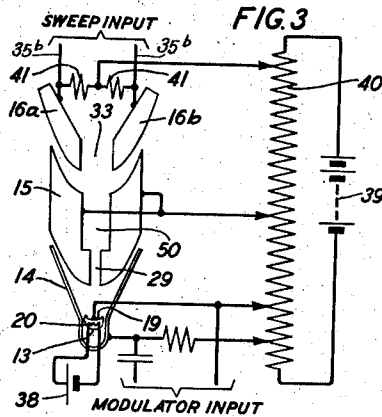
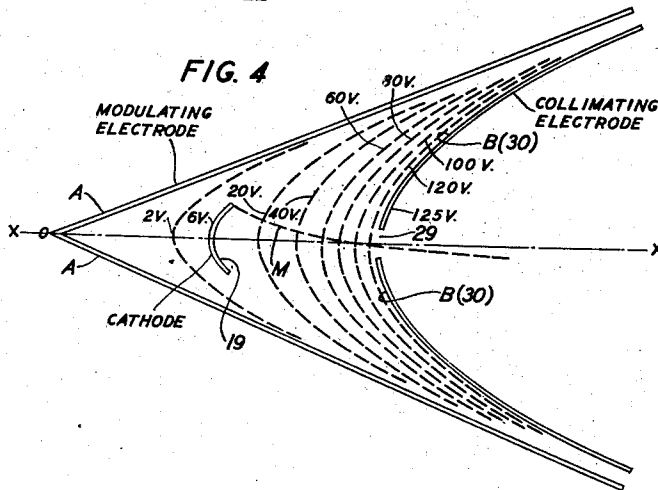


FIG. 4



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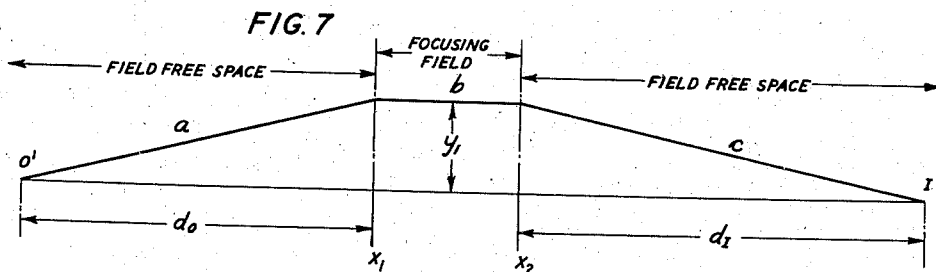
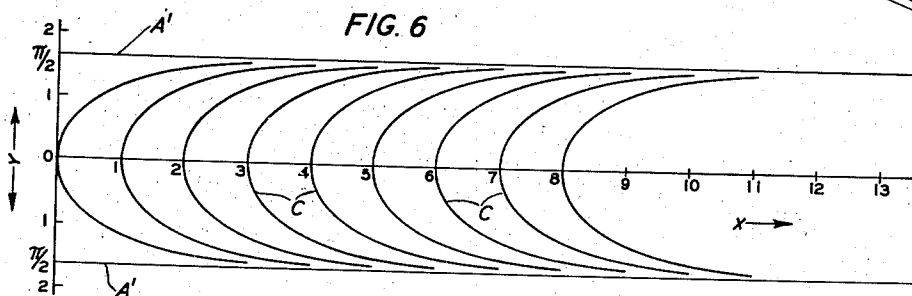
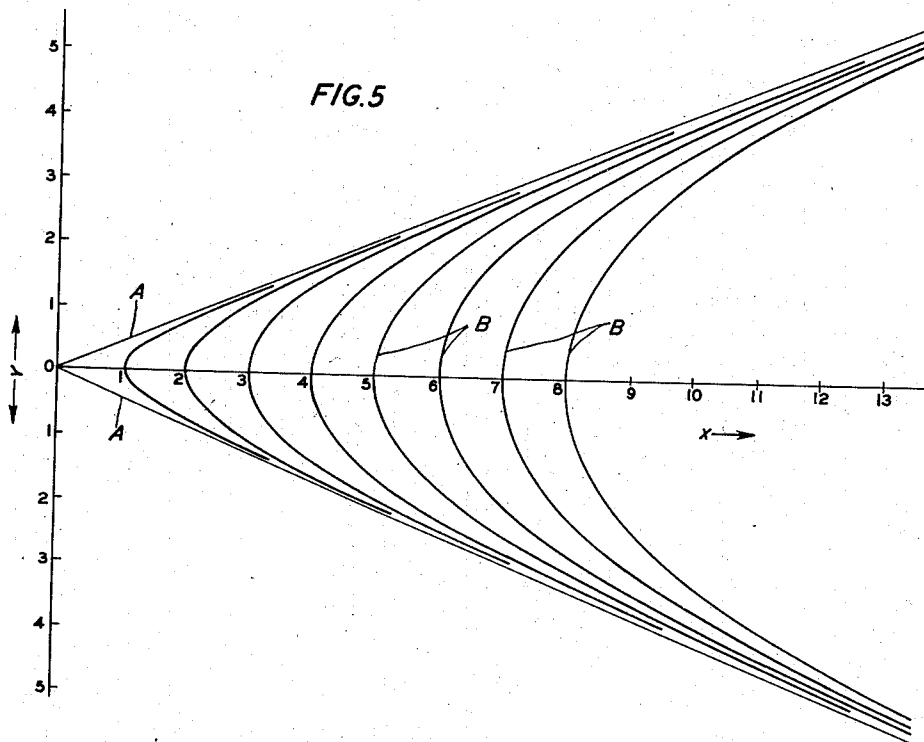
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2 Sheets-Sheet 2



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2,268,195

ELECTRON DISCHARGE DEVICE

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Application December 2, 1939, Serial No. 307,255

12 Claims. (Cl. 250—27.5)

This invention relates to electron discharge devices and more particularly to electrode systems, such as disclosed in the application Serial No. 307,232, filed December 2, 1939, of Myron S. Glass for producing a concentrated stream of electrons in electron beam discharge devices.

Electron beam discharge devices comprise, in general, an electron source, a target, such as a fluorescent screen, spaced from the source, an electrode system for forming the electrons emanating from said source into a beam, an electrode system for focussing the electron beam upon the target, and means for controlling the beam whereby the current to the target may be modulated.

The efficiency and operating characteristics of such devices are dependent primarily upon the fields extant between the various electrodes. The determination of such fields is a rather involved problem with the result that such devices heretofore have been designed mainly upon a qualitative basis in the light of experience. Under such circumstances, not only are the operating characteristics unpredictable with accuracy but the efficiency in general is low principally because but a relatively small percentage of the electrons emanating from the source are concentrated into the electron beam.

One general object of this invention is to improve the efficiency and operating characteristics of electron beam discharge devices.

More specifically, objects of this invention are:

To produce a concentrated stream of electrons having a sharply defined line focus;

To increase the efficiency of the electron beam forming system in discharge devices whereby a large proportion of the electrons emanating from the electron source is concentrated into a thin beam of rectangular cross-section;

To enable the focussing of a thin electron beam of rectangular cross-section upon a line focus;

To obtain efficient and uniform modulation of a rectangular electron beam without disturbing the focussing thereof; and

To enable the construction of electron beam discharge devices having accurately predictable operating characteristics.

In one illustrative embodiment of this invention, an electron beam discharge device comprises an elongated cathode, an electrode system for concentrating the electrons emanating from the cathode into a thin rectangular beam, a fluorescent screen, and an electrode system for focussing the electron beam to produce a sharp, clearly defined line upon the fluorescent screen.

In accordance with one feature of this invention, the beam forming system comprises a pair of electrodes having elongated apertures or slots in alignment with one another and the cathode and having opposed surfaces conforming to equi-

potential boundaries of fields of predetermined magnitude and configuration whereby a large percentage of the electrons emanating from the cathode is concentrated into a beam passing through the elongated slots.

In accordance with another feature of this invention, the focussing system comprises a plurality of electrodes having surfaces conforming to equipotential boundaries of fields of predetermined magnitude and configuration whereby the electron beam is brought to a clearly defined line focus upon the fluorescent screen.

In accordance with a further feature of this invention, one of the electrodes of the beam forming system is so constructed and arranged that variations in the potential of this electrode, with respect to the cathode, will produce corresponding variations in the length of the line focus upon the fluorescent screen without substantially altering the intensity of the electron beam.

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 a perspective view of an electron beam discharge device illustrative of one embodiment of this invention, a portion of the enclosing vessel being broken away to show the electrode assembly more clearly;

Fig. 2 is a view in section along plane 2—2 of Fig. 1;

Fig. 3 is a circuit diagram illustrating one manner in which the device shown in Fig. 1 may be operated;

Fig. 4 is a diagram illustrating the configuration of the cathode and the electrodes of the beam forming system in the device shown in Fig. 1;

Figs. 5 and 6 are diagrams showing the configuration of illustrative equipotential lines to which surfaces of electrodes in the device shown in Fig. 1 may conform in accordance with this invention; and

Fig. 7 is a diagram illustrating the electron paths and the determination thereof to produce a focus upon the fluorescent screen.

Referring now to the drawings, the electron beam discharge device shown in Fig. 1 comprises an evacuated enclosing vessel 10 having at one end thereof an inwardly extending stem 11 from which a unitary electrode assembly is supported, the stem terminating in a press 12 in which leading-in conductors for the various electrodes are sealed.

The electrode assembly comprises a cathode 13, a modulating electrode 14, a collimating and focussing electrode 15 and a pair of focussing and accelerating electrodes 16a and 16b, all of these

electrodes being maintained in spaced relation by a pair of parallel insulating members 17, such as mica discs, supported from the stem by a pair of rigid uprights 18.

The cathode 13, as shown more clearly in Fig. 2, may be of the equipotential indirectly heated type and comprises an elongated metallic sleeve having a dished surface 19 coated with thermionic material, and a heater filament 20 within the sleeve and insulated therefrom. The cathode sleeve may be fitted in apertures in the insulating discs 17 and secured in position by brace wires 21 affixed to the sleeve and to the discs. Electrical connection to the cathode sleeve and the heater filament 20 may be established through leading-in conductors 22.

The modulating electrode 14 may be formed of sheet metal, for example nickel, and comprises plane divergent arms 23 extending at equal angles with respect to a plane $x-x$ passing centrally through the cathode, and U-shaped end portions 24, similar, for example triangular, portions of the modulating electrode being cut away as shown in Fig. 1. The electrode 14 may be supported by a plurality of rigid wires 25 fitted in apertures in the insulating discs 17, one of the wires 25 being connected to one of the uprights 18, as by a conductor 26, having a leading-in conductor 27 connected thereto.

The collimating electrode 15 comprises two identical halves, for example metallic blocks, positioned by rods 28 fitted in apertures in the insulating discs 17, the two halves being equally spaced on opposite sides of the plane $x-x$ to define an elongated aperture 29 in parallel alignment with the dished surface 19 of the cathode. As shown clearly in Fig. 2, the two halves of the electrode 15 have identical curved surfaces 30 and 31, respectively, the configuration of which will be described fully hereinafter. A suitable potential may be applied to the collimating electrode 15 through leading-in conductors 32.

The focussing electrodes 16a and 16b, which may be metallic blocks, are alike, are equally spaced on opposite sides of the plane $x-x$ to define an aperture 33 in alignment with the aperture 29, and have similarly curved surfaces 34. The electrodes 16a and 16b are positioned by rods 35 fitted in apertures in the insulating discs 17, one of the rods having a leading-in conductor 35a connected thereto and another of the rods being connected to one of the uprights 18 by a tie wire 36, this upright having a leading-in conductor 35b connected thereto, whereby a potential may be impressed between the electrodes 16a and 16b.

A portion of the inner side wall of the vessel 10 is coated, as indicated at 37, to form a fluorescent screen in alignment with the apertures 29 and 33.

During operation of the device, as illustrated in Fig. 3, the heater filament 20 may be energized, as by a battery 38, and the collimating electrode 15 may be maintained at a positive potential with respect to the cathode 13 through a potentiometer including a battery 39 and a resistance 40. The modulating electrode 14 may be biased negatively with respect to the cathode by the potentiometer, and the modulating potential may be impressed between the cathode 13 and modulating electrode 14 as shown. The focussing electrodes 16a and 16b are maintained at a positive potential with respect to the cathode 13 and are electrically balanced with respect to the cathode by resistances 41. A suitable potential

may be impressed between the electrodes 16a and 16b through a sweep input, as shown, to deflect the electron beam.

In general, electrons emanating from the emissive surface 19 of the cathode 13 are influenced by the fields extant between the modulating and collimating electrodes and are formed into a beam passing through the aperture 29. The electrons in the beam then come under the influence of the fields extant between the collimating and focussing electrodes and finally impinge upon the screen 37 whereby a fluorescent image is produced upon the screen. The intensity or size of the image may be controlled by varying the potential of the modulating electrode.

Stated objectively, operation of the device requires that the electrons emanating from the cathode be formed into a beam, that the beam be directed upon the screen and that the beam be capable of modulation. Efficient and satisfactory operation requires that a large proportion of the electrons emanating from the cathode be concentrated into the beam, that the beam be brought to a sharp focus upon the screen, and that modulation of the beam may be effected by small changes in the potential of the modulating electrode.

The concentration of the electrons into the beam and the focussing of the beam and modulation of the beam are dependent primarily upon the fields extant between the several electrodes. The attainment of fields of the configuration and intensity necessary for efficient and satisfactory operation of the device in accordance with a feature of this invention will be apparent from the following considerations.

The fields to be considered, it will be apparent, are two dimensional, that is, fields which satisfy the Laplacian equation for two dimensions, i. e.

$$\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = 0$$

These fields also are symmetrical with respect to the plane $x-x$, that is, if the direction perpendicular to the plane of symmetry is taken as the y direction, $\phi(y) = \phi(-y)$. The plane of symmetry then contains the x coordinate, which is perpendicular to the line of intersection of the cathode and the plane.

It can be shown that in a system symmetrical with respect to a plane, the potential at any point in the field may be expressed as

$$V(x, y) = \phi(x) - \frac{y^2}{2!} \phi''(x) + \frac{y^4}{4!} \phi^{IV}(x) \dots \quad (1)$$

where

$V(x, y)$ is the potential at any point, having coordinates x and y and

$\phi(x)$ is the potential along the axis as a function of the axial distance x .

In order that electrons will be subjected to a field directing them toward the x plane and a beam will be formed, it is necessary that there be moderately small potential gradients in the vicinity of the cathode and that there be a gradient toward the x plane, which increases progressively with distance from the cathode. From Equation 1 it will be seen that these requisites are satisfied if $\phi(x)$ has a positive second derivative and if this derivative is a function of the distance x . Hence, $\phi(x)$ should be at least a second degree equation in x and preferably a higher than second degree equation. A variety of functions, of course, will satisfy these conditions. For simplicity of calculation, however,

the simple functions, i. e. powers of x are preferable. Two illustrative general functions are

$$\phi(x) = Kx^n \text{ and } \phi(x) = \epsilon Kx \quad (2)$$

where K is an arbitrary constant, ϵ is the Napierian base, and n is 2 or greater.

The desired potential distribution may be obtained by making two electrodes of such configuration that the opposed surfaces thereof conform to equipotential surfaces resulting from the desired distribution. As pointed out heretofore, for two-dimensional fields the equation for the field must satisfy the Laplacian equation

$$\frac{\partial^2 V}{\partial x^2} = -\frac{\partial^2 V}{\partial y^2} \quad (3)$$

where V is the potential at any point (x, y) in the field. This equation will be satisfied by the relation expressed by Equation 1 above. Equation 1 then may be used to determine the equation for the requisite equipotential surfaces.

As a specific illustration, the case where $\phi(x) = Kx^4$ may be used. Then, from Equation 1,

$$V(x, y) = Kx^4 - 6Kx^2y^2 + Ky^4 \quad (4)$$

The last term, Ky^4 , is small and may be neglected for practical purposes. For any equipotential line passing through the axis at a point having the coordinates $a, 0$,

$$V(a, 0) = Ka^4 = Kx^4 - 6Kx^2y^2 \quad (5)$$

and solving for y

$$y = \frac{\sqrt{6}}{6} \sqrt{x^2 - \frac{a^4}{x^2}} \quad (6)$$

This is the equation for a family of curves B, illustrated in Fig. 5, asymptotic to straight lines A, $y = .407x$, making an angle of 22.2 degrees with the x axis. Each curve B corresponds to a particular value of a in Equation 6, the values of a being indicated on the x axis. An accurate solution of Equation 4, that is without neglecting the y^4 term, gives the asymptotes A as straight lines making an angle of 22.5 degrees with the x axis. The error involved in neglecting this term, it will be seen, is very small and, therefore, the approximate solution may be utilized for practical purposes.

For the axial potential distribution $\phi(x) = \epsilon Kx$, it can be shown, following the method used for $\phi(x) = Kx^4$, that the equation for the equipotential lines is

$$y = \frac{1}{K} \cos^{-1}[\epsilon^{K(a-x)}] \quad (7)$$

This, it will be apparent, is the equation for a family of curves C, illustrated in Fig. 6, asymptotic to two lines A' parallel to the x axis and spaced

$$\frac{\pi}{2K}$$

units therefrom. Each curve C of the family has exactly the same form irrespective of the value of a .

Inasmuch as there is no variation of potential in the direction parallel to the line of intersection between the cathode and the x plane, any line in this plane perpendicular to the line of intersection may be considered as an axis. Hence, equipotential surfaces will be generated by moving the equipotential lines of Figs. 5 and 6 parallel to themselves, that is, the equipotential surfaces will be such that any right section conforms to the same equipotential line.

Thus, inasmuch as the surface of an electrode,

such as the collimating or modulating electrode in the device shown in Fig. 1, is an equipotential surface, the desired field between two electrodes may be obtained by making the opposed surfaces of the electrodes of such configuration as to conform to equipotential surfaces of the desired field, as determined hereinabove, and applying proper potentials to the electrodes. Thus, in a specific case, $\phi(x) = Kx^4$, illustrated in Fig. 4, the arms 23 of the modulating electrode 14 conform to the zero potential boundary A and the surfaces 30 of the collimating electrode 15 conform to the equipotential 125-volt boundary B (5 units from the origin O, a typical unit being r_0'') and in operation of the device the collimating electrode 15 is maintained 125-volts positive with respect to the modulating electrode 14. The various hyperbolae in Fig. 4 represent equipotential lines in the region between the modulating and collimating electrodes, the potential of each line being as indicated in the figure and corresponding to a value of $K = \frac{1}{5}$ in Equation 5.

The cathode 13 is positioned within the modulating electrode 14 and the emissive surface 19 is shaped to conform to the equipotential boundary corresponding to the cathode position in the field. It will be apparent that there will be a definite, moderately small, positive gradient at the cathode surface 19 which, as noted heretofore, is one of the requirements for the efficient production of an electron beam. The electrons emanating from the cathode surface 19 enter a field which has a gradient toward the plane $x-x$, are accelerated toward this plane, and are concentrated into a thin beam of rectangular section passing through the aperture 29 in the electrode 15. An approximate electron trajectory is indicated by the dotted line M in Fig. 4.

As indicated hereinabove, the cathode surface 19 conforms to an equipotential boundary in the field between the modulating and collimating electrodes. If a potential corresponding to the position of the cathode in the field is applied to the cathode, there will be a known positive gradient at the surface 19 of the cathode. If the cathode potential is increased, the gradient at the cathode surface becomes zero which corresponds to cut-off of the cathode current. If the cathode potential is decreased, the off-cathode gradient increases. Hence, if the limit condition occurs when the cathode and modulating electrode are at the same potential, maximum off-cathode gradient obtains for this potential.

In practice, it is preferable to have the cathode at a fixed potential and to vary the potential of another electrode, e. g. of the modulating electrode 14 as illustrated in Fig. 3. For some value of potential, negative with respect to the cathode, of the modulating electrode, the cathode potential will correspond to that of the equipotential surface at which it is positioned. If the potential upon the modulating electrode is made more negative, the off-cathode gradient is decreased until it becomes zero. Reducing this potential to that of the cathode increases the off-cathode gradient to a maximum. Although the ideal fields may be distorted slightly due to the cathode potential and the physical dimensions of the cathode, variations in the potential of the modulating electrode do not affect the action of the field with respect to concentrating the electrons into a beam to an extent appreciable for practical purposes. The exact position of the cathode in any particular case will be determined, of course, by

the cut-off potential desired. Thus, if the cut-off potential desired is one twentieth of the potential of the electrode 15, the cathode surface 19 would be placed 2.34 units from the origin O.

The electrons emerging from the slit 29 are directed toward the screen 37 and come under the influence of the fields extant between the collimating and focussing electrodes. As pointed out heretofore, it is highly desirable that the beam be brought to a thin, sharply defined line focus upon the screen. The degree of focussing obtained will be dependent, of course, upon the fields to which the beam is subjected. Fields of the form requisite to produce the desired sharp line focussing may be obtained in accordance with this invention by following a procedure similar to that described hereinabove in connection with the beam forming system.

In general, fields which are suitable for the beam forming system, that is, such fields as correspond to potential distribution of $\phi(x) = Kx^n$ and $\phi(x) = e^{Kx}$, are suitable for the focussing system. Thus, in the specific embodiment illustrated in Figs. 1 and 2, the surfaces 31 and 34 may conform to equipotential boundaries for the relation $\phi(x) = Kx^n$. The surface 31 for simplicity, may conform to the same equipotential boundary as the surface 30.

The parameters of the focussing system may be determined from the following considerations with particular reference to Fig. 7. For practical purposes, space charge is neglected, electrons are assumed to move in straight lines when in field free space and the electrons are assumed to remain the same average distance from the axis as they pass through the focussing field. The electron path, then, may be represented by the line *abc* in Fig. 7, the electrons originating at a point O' at a distance d_0 from x_1 , the point at which the electrons enter the focussing field. The image point I (on the screen 37) is at a distance d_1 from x_2 , the point at which the electrons leave the focussing field. In the device shown in Figs. 1 and 2 the points indicated in Fig. 7 would be located as follows: O' at the end of the slit 29 toward the screen 37, x_1 at the point on the axis $x-x$ where the surface 31 would intersect this axis if the contour were complete, x_2 at the corresponding point on the axis $x-x$ for the surfaces 34, and I at the screen 37.

For any particular axial potential distribution it can be shown, by equating the change in lateral velocity necessary to bring the electrons to a focus at I to the change in lateral velocity received in the focussing field (between surfaces 31 and 34), that

$$-y_1 \sqrt{\frac{2e}{m} \left[\frac{\phi^{1/2}(x_1)}{d_0} + \frac{\phi^{1/2}(x_2)}{d_1} \right]} = \sqrt{\frac{2e}{m}} \int_{x_1}^{x_2} \frac{\partial V}{\partial y} \frac{\partial x}{\phi^{1/2}(x)} \quad (8)$$

where

y_1 is the distance the electron remains from the axis in the focussing field, i. e. between x_1 and x_2 ,

e is the electron charge,

m is the electron mass, and

V is the potential at any point x, y in the field.

For the particular case of $\phi(x) = Kx^4$, Equation 8 becomes

$$\frac{x_1^2}{d_0} + \frac{x_2^2}{d_1} = 6x_2 - 6x_1 \quad (9)$$

which, it will be noted includes four variables.

x_1 and x_2 may be obtained directly from the

equipotential surfaces used. Thus, if in the specific embodiment shown in Figs. 1 and 2 surface 31 is of the same configuration as surface 30, for which, as noted heretofore $a=5, x_1=5$. If the ratio of the potentials upon the focussing and collimating electrodes is desired to be about 4:1, the surfaces 34 should conform to the curve B in Fig. 5 for which $a=7$. The actual voltage ratio will then be 3.84. Hence $x_2=7$. d_0 may be estimated fairly accurately from experience. For the particular case under consideration, $d_0=4$. Solving Equation 9 for these values of x_1, x_2 and d_0 , $d_1=8.52$ units. Hence, for the values of x_1, x_2 and d_0 employed, in order that a line focus will be produced upon the screen 37, the screen must be 8.52 units beyond x_2 .

It may be noted that the slit 29 in the collimating and focussing electrode 15 preferably is made of appreciable depth (for example, three units in the specific embodiment described) to act as a limiting slit. The surface 31 is made such as to be four units from the outlet end of the slit 29. The enlarged slit 50 in the electrode 15 is made large enough to accommodate a beam of maximum divergence allowable with the depths of the slit 29. The slit 33 in the electrode 16 is made of appreciable depth, e. g. 2 units in the specific embodiment described, to obtain a quick transition to a field free space, thus reducing distortion of the field.

In devices constructed in accordance with this invention, three forms of control of the electron beam are obtainable. In the specific embodiment illustrated in Figs. 1 and 2, because portions of the arms 23 of the modulating electrode 14 are cut away, the modulating electrode may be operated to suppress electron emission from the end portions of the cathode surface 19 before affecting emission from other parts of this surface. Inasmuch as the modulator electrode encompasses only the ends of the cathode and is well in front of other portions of the cathode, the off-cathode gradient at the ends of the cathode may be made zero before the gradient at other portions of the cathode is so reduced. Hence, modulation by varying the length of the line image on the screen 37 is effected without substantial variation of its intensity. Thus, devices constructed in accordance with this invention may be used where such form of modulation is required, for example, in variable area recording systems.

If the modulating electrode is not cut away as shown, the off-cathode gradient will be uniform over the entire length of the surface 19 and the intensity of the image may be modulated without varying the length thereof. Devices of such construction may be used, for example, in variable density recording systems.

Finally, the electrodes 16a and 16b may be utilized as deflector plates and a sweep input potential impressed between them. For example, if a saw-tooth sweep potential is applied, the beam traces a rectangle upon the screen. If a modulating potential is applied to the modulating electrode of the cut-away construction shown in Fig. 1, the length of this rectangle will be varied and a modulated figure is produced upon the screen.

Although a specific embodiment of the invention has been shown and described, it will be understood that it is but illustrative. For example, although the surfaces 30, 31 and 34 have been shown as conforming to equipotential boundaries for an axial distribution of $\phi(x) = Kx^4$,

they may conform to equipotential boundaries corresponding to $\phi(x) = eKx$ or to other powers of x such as $\phi(x) = Kx^2$, $\phi(x) = Kx^3$, $\phi(x) = Kx^5$, etc.

Other modifications in the specific embodiment shown and described may be made without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. An electron gun for electron discharge devices comprising a cathode having an elongated electron emissive surface, and means for concentrating the electrons emanating from said cathode into a thin beam of rectangular cross-section, said means including an electrode having an elongated slit in alignment with said emissive surface and a second electrode having diverging arms extending from adjacent the sides of said surface and toward said first electrode, opposed surfaces of said electrodes being dished in the same direction and conforming to equipotential boundaries of a field symmetrical with respect to a plane passing through said slit and said surface, increasing progressively away from said surface and decreasing away from said plane.

2. An electron gun in accordance with claim 1 wherein said opposed surfaces conform to equipotential boundaries of a field corresponding to a potential which increases away from said surface substantially according to the relation

$$E = Kx^n$$

where E is the potential, K is a constant, x is the distance from said surface and n is 2 or greater.

3. An electron gun in accordance with claim 1 wherein said opposed surfaces conform to equipotential boundaries of a field corresponding to a potential which increases away from said surface substantially according to the relation

$$E = e^{\epsilon Kx}$$

where E is the potential, e is the Napierian base, K is a constant, and x is the distance from said surface.

4. An electron gun for electron discharge devices comprising a cathode having an elongated electron emissive surface, and means for concentrating the electrons emanating from said surface into a thin beam of rectangular cross-section, said means including an electrode spaced from said cathode, having an elongated aperture extending parallel to and in alignment with said surface and having the surface thereof toward said cathode corresponding to a surface developed by a generatrix moving parallel to itself and conforming to a curve of at least a second degree function of the distance from said surface, and a second electrode having diverging arms extending from adjacent said emissive surface and asymptotic to said surface of said first electrode.

5. An electron discharge device comprising a cathode having an elongated electron emissive surface, an electron receiving element spaced from said surface, and an electrode system between said surface and said element including a pair of spaced electrodes having elongated openings in alignment with each other and said emissive surface and extending parallel to said emissive surface, opposed surfaces of said electrodes being dished symmetrically with respect to a plane normal to said emissive surface and conforming to equipotential boundaries of a field corresponding to a potential which increases progressively away from said surface and the sec-

ond derivative of which potential as a function of distance from said surface is positive and a function of said distance.

6. An electron discharge device in accordance with claim 5 wherein said opposed surfaces conform to equipotential boundaries of a field corresponding to a potential which varies substantially according to the relation

$$E = Kx^n$$

where E is the potential, K is a constant, x is distance from the cathode and n is 2 or greater.

7. An electron discharge device in accordance with claim 5 wherein said opposed surfaces conform to equipotential boundaries of a field corresponding to a potential which varies substantially according to the relation

$$E = e^{\epsilon Kx}$$

where E is the potential, e is the Napierian base, K is a constant and x is distance from the cathode.

8. An electron discharge device comprising a cathode, an electron receiving element spaced from said cathode, means for concentrating electrons emanating from said cathode into a thin beam of rectangular cross-section, and means for bringing said beam to a line focus upon said electron receiving element including a pair of spaced electrodes having elongated apertures in alignment and having opposed surfaces symmetrical with respect to a plane passing through said apertures and conforming to equipotential boundaries of a field corresponding to a potential which increases away from said cathode and the second derivative of which as a function of distance from said cathode is positive and a function of said distance.

9. An electron discharge device comprising a cathode having an elongated electron emissive surface, an electron receiving element spaced from said cathode, and means for concentrating electrons emanating from said cathode into a thin beam of rectangular section having a line focus on said electron receiving element, said means including a pair of opposed electrode surfaces between said emissive surface and said element and flaring away from said emissive surface and including also a second pair of opposed electrode surfaces between said first surfaces and said element, said opposed surfaces being symmetrical with respect to a common plane, and each pair of opposed surfaces conforming to equipotential boundaries of a field corresponding to a potential which increases away from said emissive surface and the second derivative of which as a function of distance from said cathode is positive.

10. An electron discharge device comprising an elongated cathode, an electron receiving member spaced from said cathode, means for concentrating electrons emanating from said cathode into a beam having a line focus on said electron receiving member, and means for modulating the length of the line focus without altering the intensity of the electron beam.

11. An electron discharge device comprising a cathode having an elongated emissive surface, an electron receiving element spaced from said cathode, means for concentrating electrons emanating from said surface into a beam having a line focus on said element, and means for varying the off-cathode gradient along said surface non-uniformly along the length of said surface, the variation being greatest adjacent the ends of said

surface and decreasing progressively toward the center thereof.

12. An electron discharge device comprising a cathode having an elongated electron emissive surface, an electron receiving element spaced from said surface, and means for concentrating electrons emanating from said surface into a thin beam having a line focus on said element,

said means including a modulating electrode of substantially V shape, the apex of which is on the side of said cathode remote from said emissive surface and the arms of which diverge toward said element, intermediate portions of said arms adjacent said apex being cut away.

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