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Silzars et al.

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[45] **June 19, 1973**

[54] **LAMINAR FLOW ELECTRON GUN AND METHOD**

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[52] **U.S. Cl.** .... **315/15,** 313/82 BF, 313/83, 313/DIG. 1, 315/31

[51] **Int. Cl.** **H01j 29/56**

[58] **Field of Search** .... 315/14, 15, 16, 31; 313/81, 82 BF, 83, DIG. 1, 82 R

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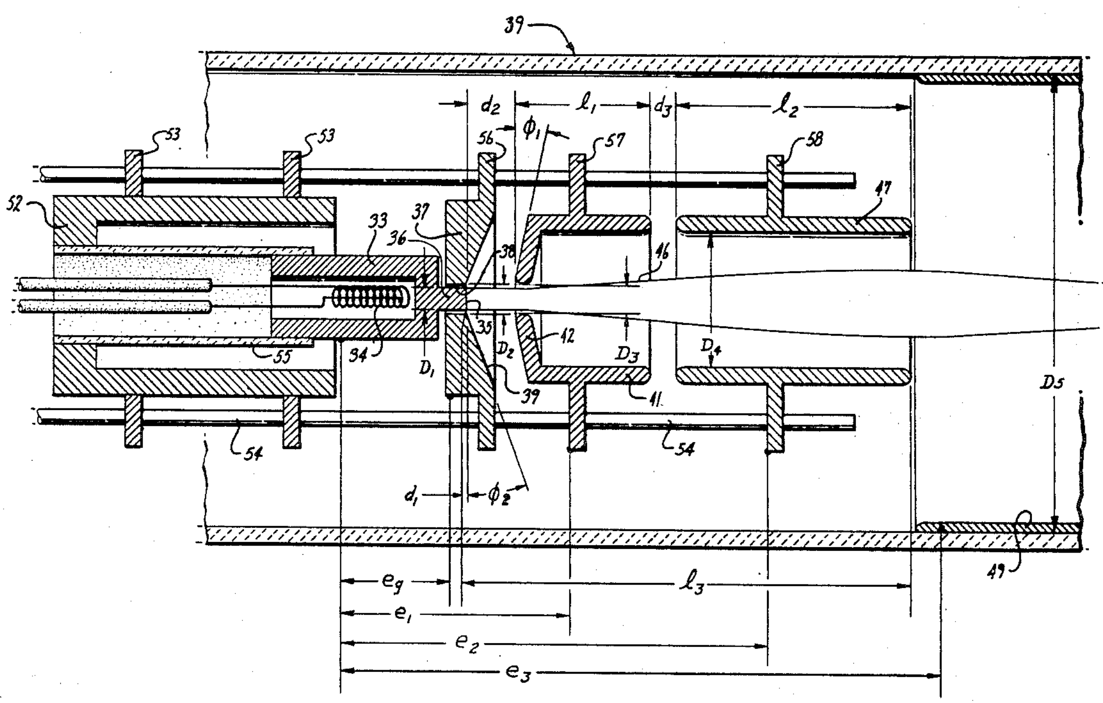
[57] **ABSTRACT**

A laminar flow electron gun for forming an electron beam including a cathode for emitting electrons, an apertured dish-shaped electrode surrounding the cathode surface and an anode spaced from said cathode and electrode and cooperating therewith to provide a substantially uniform electric field at the surface of said cathode to cause electrons to emit normally from the entire surface in a beam, said anode also forming a divergent electrostatic lens along the path of the beam and accelerating and focusing means disposed further along the path of the beam to accelerate and focus the beam at a target.

24 Claims, 9 Drawing Figures



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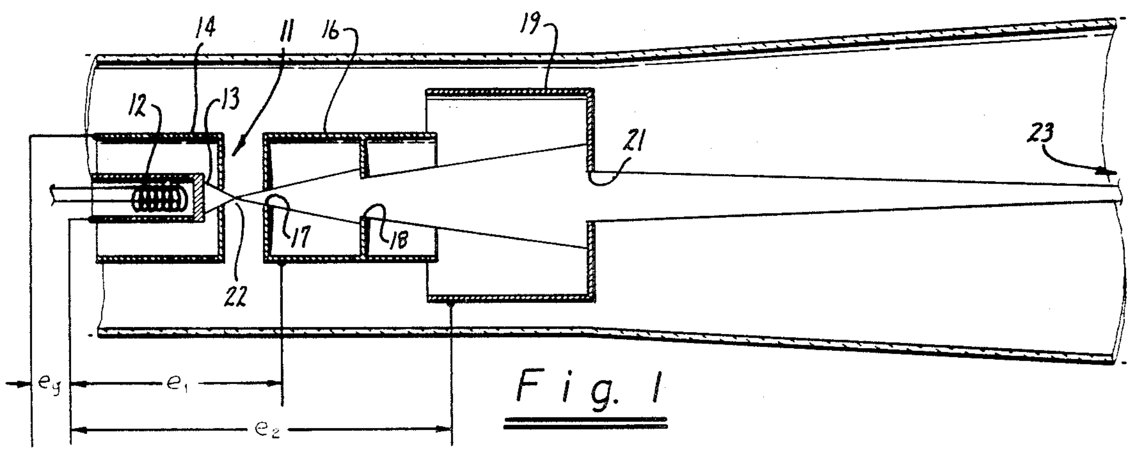

Fig. 1

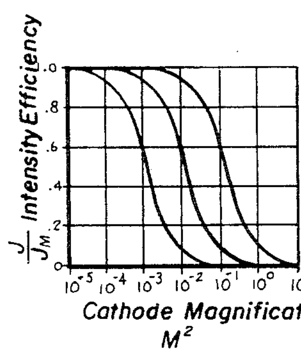

Fig. 2

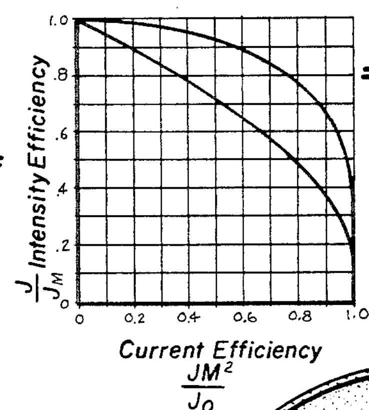

Fig. 3

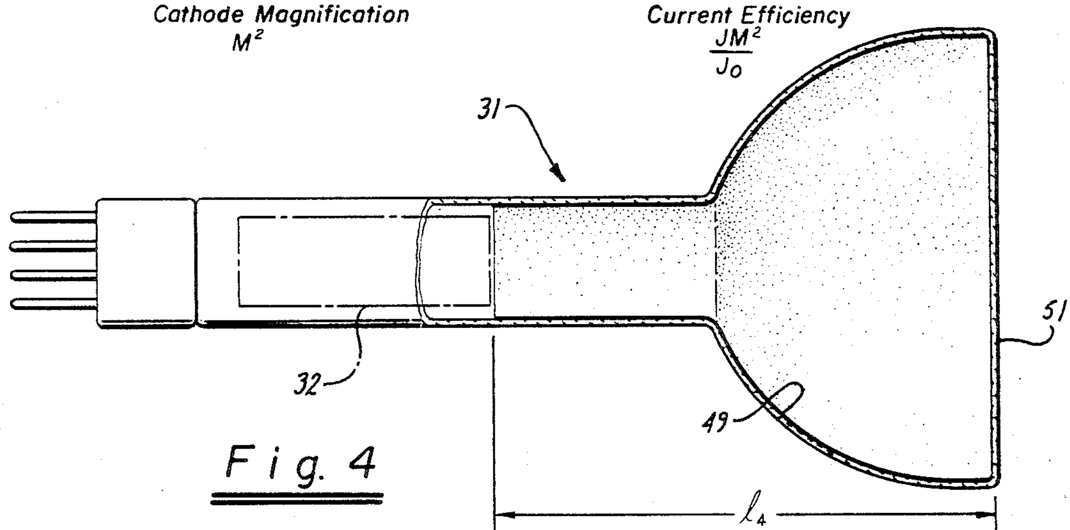

Fig. 4

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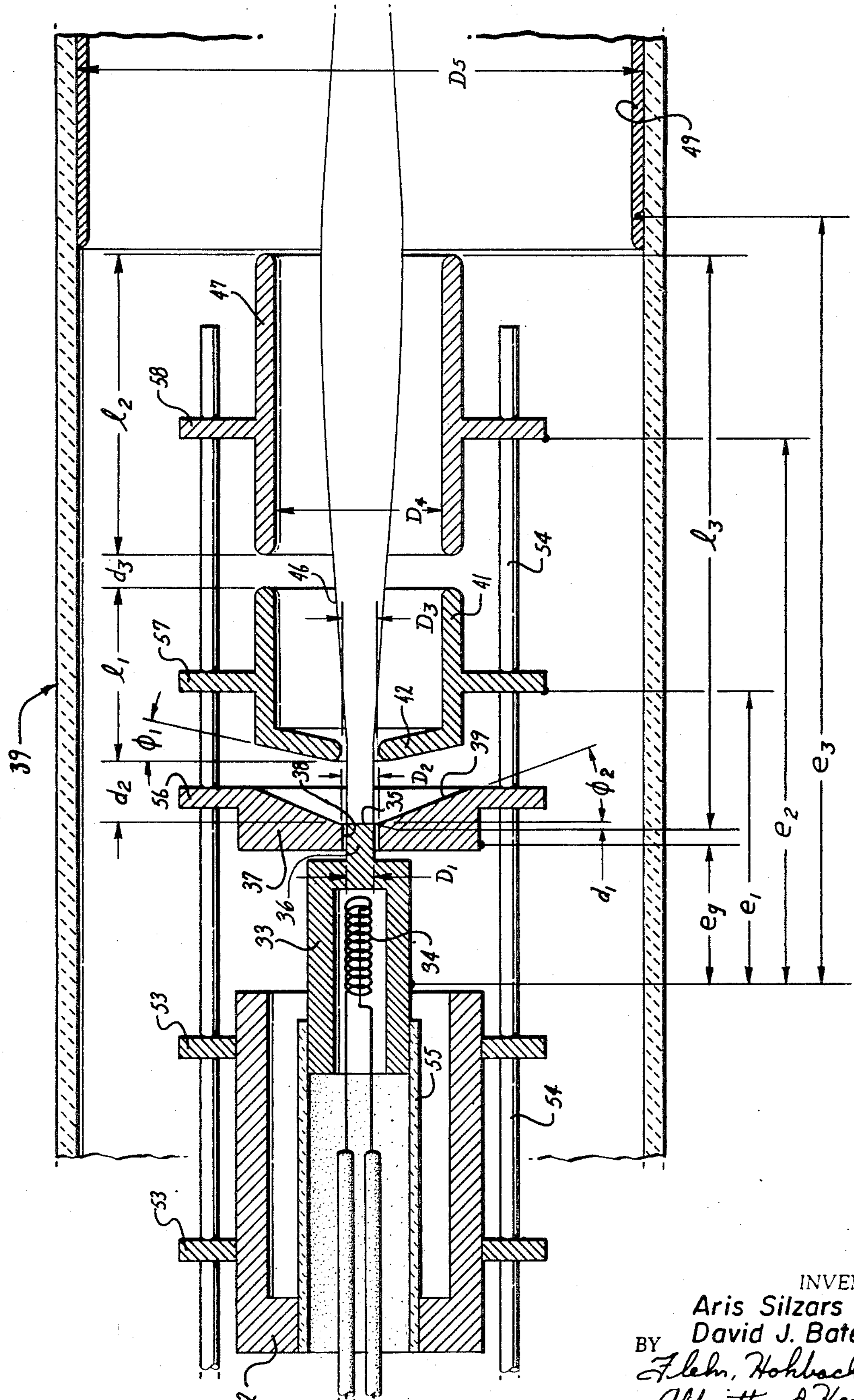

Fig. 5

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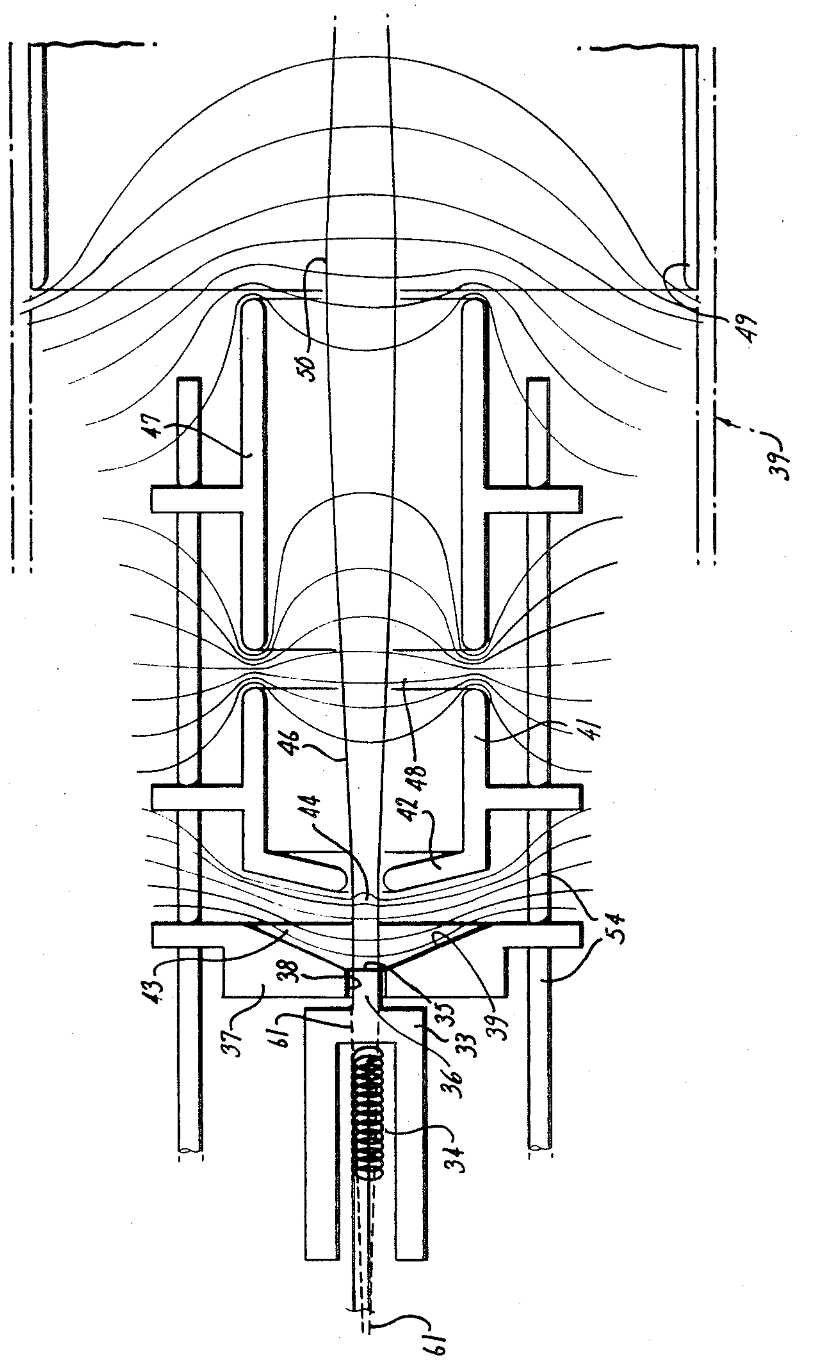

Fig. 6

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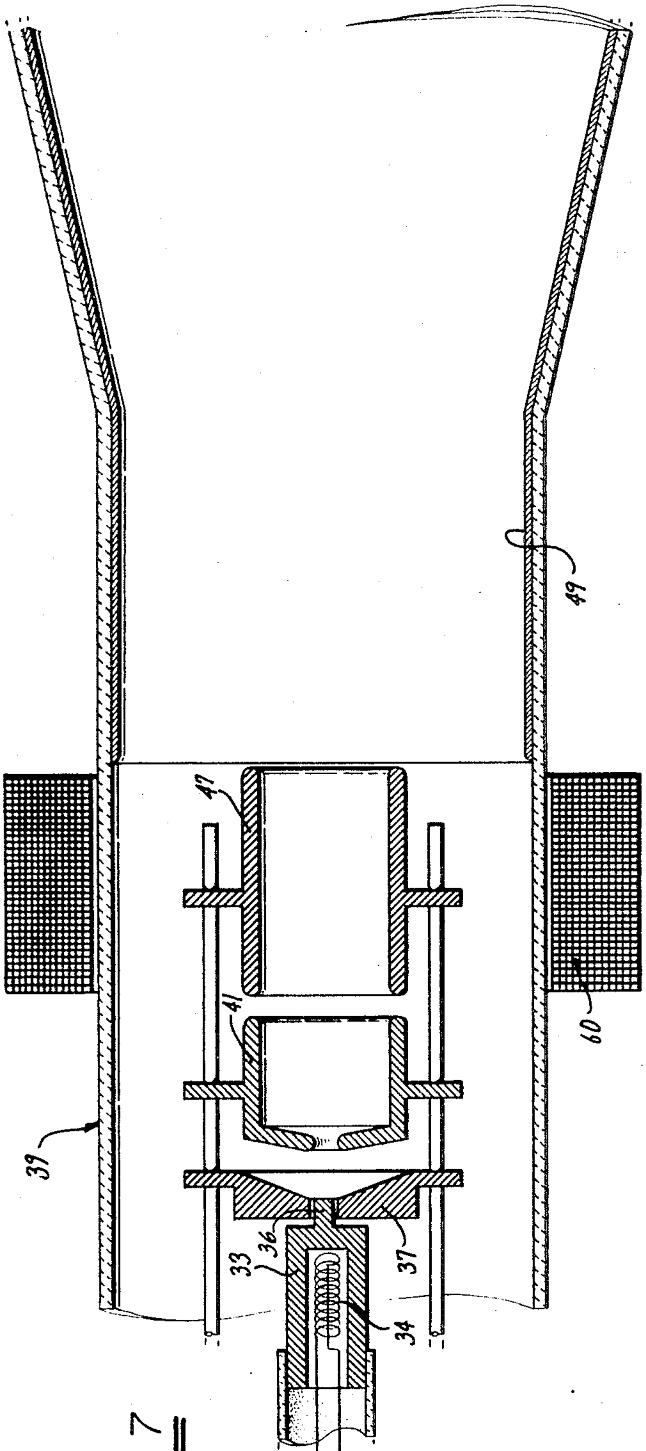


Fig. 7

Fig. 9

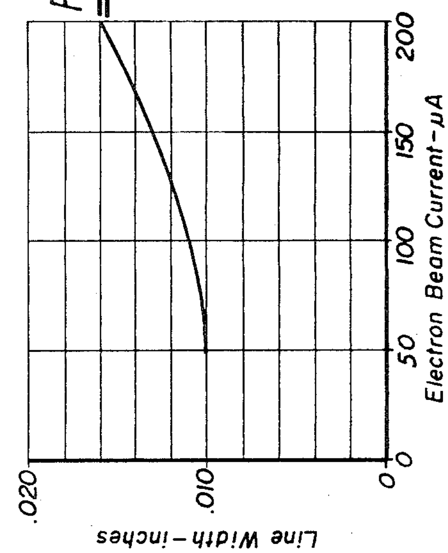
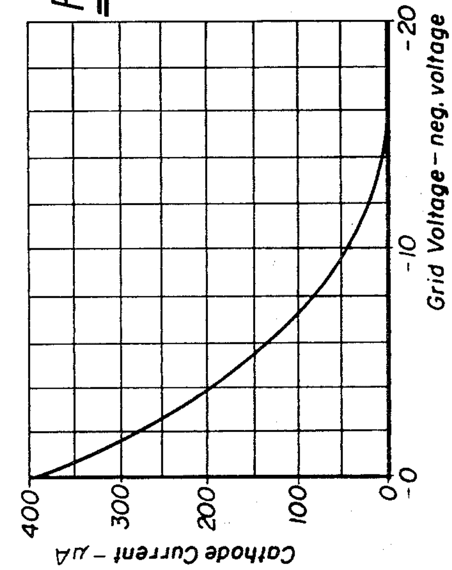


Fig. 8



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LAMINAR FLOW ELECTRON GUN AND METHOD

GOVERNMENT RIGHTS

The invention herein described was made in the course of or under a contract with the Department of the Navy.

BACKGROUND OF THE INVENTION

This invention relates generally to an electron gun and more particularly to a laminar flow electron gun which provides a small electron beam with high current density and which requires minimum power for beam generation, modulation and deflection with minimum gun length.

Presently, electron guns for display tubes or long beam lengths in a field-free region are of the crossover type. This type of gun is schematically illustrated in FIG. 1. It consists of two basic sections, one, a beam forming section frequently called the "triode section" and, second, a focusing section which focuses the beam either electrostatically or electromagnetically.

The key elements of the triode section are the cathode, the grid and the accelerating electrode. The cathode serves as the electron source and is usually an indirectly heated plane surface. The grid or modulating electrode is usually a cup with a perforated bottom. Typically, the aperture area is much less than the cathode surface area. The first anode or accelerator electrode is usually a cylinder with a limiting aperture. Operation of crossover guns have been treated in detail by several authors. One description of operation is given by I. G. Maloff and E. W. Epstein in "Electron Optics in Television", Mcgraw-Hill Book Company, 1938.

The crossover gun has certain inherent defects and limitations. A non-uniform cathode loading due to variations in the magnitude of the electric fields across the surface of the cathode. Non-uniform cathode loading means that the cathode has to be run hotter than in a gun with uniform cathode loading and results in shorter operating life. Non-uniform loading also forms a focused spot having non-uniform brightness distribution.

In the crossover gun there are substantial changes in spot size with variations in grid drive. As a result, the resolution of the gun is best at low beam currents (low brightness in the case of a CRT) and degrades as the beam current (brightness) increases. The changes in spot size with grid drive result from the geometry of the triode section of the crossover gun which is such that changes in grid potential not only alter the emitted current density but also the size of the emitting area.

Physically long gun lengths are necessary to minimize beam magnification. Apertures inserted to improve resolution result in inefficient current utilization because of beam interception. It has been shown, based on the consideration of the optics of thermally emitted electrons, that the maximum current density, with perfect focusing, at crossover of the cathode image is given by

$$J/J_o = 1/M^2\,[1 - (1 - M^2 \sin^2\phi)\exp(-Ve/kT)\,M^2 \sin^2\phi/(1 - M^2 \sin^2\phi)]$$

where J is the current density at the focused spot, J_o is the cathode current density, M is the geometrical magnification (the ratio of the crossover or cathode-image diameter to cathode diameter which is proportional to the image distance divided by the object distance) Φ is the half angle of the beam envelope measured at the target including all electron paths reaching the point in question, T is the cathode temperature in degrees Kelvin, k is the Boltzman constant and V is the potential at the point in question.

Limiting values are of interest. For M large (magnification),

$$J_m/J_o = 1/M^2$$

and for M small (demagnification)

$$J_m/J_o = [1 + (eV/kT)]\sin^2\phi$$

where J_m is the largest possible value of current density that can be achieved under any condition. The intensity efficiency J/J_m measures how well any gun performs as a function of the magnification.

A curve of the J/J_m available at the screen for various values of M and ϕ is shown in FIG. 2 for the case of $(eV/kT) = 10,000$ (this corresponds to a voltage of about 800 volts since e/V has a value of 11,000 and T is about 1,000°K. for an oxide cathode). ϕ in this case is the value determined by a limiting aperture.

Examination of FIG. 2 indicates that as the magnification decreases, the intensity efficiency increases. To achieve a small spot size, the magnification should be less than unity. As the intensity efficiency increases, the amount of cathode current that reaches the screen decreases, the balance being intercepted by limiting apertures. The fraction of cathode current used can be called the current efficiency which is:

$$\text{Current efficiency} = (JM^2/J_o)$$

FIG. 3 is a plot of the intensity efficiency versus the current efficiency. These curves show that to approach the limiting value of intensity efficiency, most of the current must be wasted.

In most applications of the crossover gun, the requirement for minimum tube depth severely limits the performance of the gun so that the intensity efficiency is far from the maximum. This can be understood by considering that the object focused on the viewing screen is located near the cathode, the distance from the focus lens being a matter of a few inches. The image is formed several or more inches from the focus lens at the screen. Thus, the ratio of the image to object distance is substantially greater than unity which is contrary to achieving high resolution. In those cases where high resolution is essential, the tube becomes quite lengthy to reduce the magnification. Thus, a typical microspot tube with a 5 inch screen diameter is 25 inches long.

Finally, some crossover guns have a high sensitivity to dimensional tolerances because of the short focal length lenses and limiting apertures used. The aberrations present in the relatively short focal length triode section cause transverse velocities to be introduced in the beam trajectories. These transverse velocities result in beam spreading. Even if the cathode current density were uniform, the spot size at a given focal point would increase.

Another type of electron gun which has found wide application in electron tubes such as travelling wave tubes and klystrons is an electron gun employing a Pierce Electrode. The cathode in this type of gun operates with high current density and high efficiency. This type of cathode or gun employs a cathode surrounded by a closely spaced dish-shaped electrode at zero potential and an anode spaced from and confronting the cathode. The beam is substantially at its final velocity when it leaves the anode. Because of the high current density in the beam, there is space charge spreading. A focusing structure is needed along the beam path. Since the principal acceleration of the beam is from the anode, the only control over the beam current is essentially a control of the anode voltage. As a consequence, so-called Pierce Guns have not found application in cathode ray tubes and related devices requiring low beam current, beam current control and focusing on a target disposed at the end of a field-free region.

OBJECTS AND SUMMARY OF THE INVENTION

It is a general object of the present invention to provide an improved electron gun for use in cathode ray tubes, camera tubes, storage tubes, electron bombarded semiconductor devices and other devices utilizing electron beams.

It is a further object of the present invention to provide an electron gun of the above type which may be unmodulated, intensity modulated, or deflection modulated.

It is another object of the present invention to provide an improved electron optics system for electron guns.

It is a further object of the present invention to provide an electron gun which projects a high current density beam of circular or other cross-section and which requires no focusing of the electron beam in the field-free region beyond the gun and which will focus a beam at a point whose distance beyond the gun is in the order of one hundred times or more the beam diameter at the focus point.

It is another object of the present invention to provide an electron gun with uniform current density distribution across the beam.

It is a further object of the present invention to provide a laminar flow electron gun which can be made smaller in length and diameter than existing crossover guns.

It is another object of the present invention to provide an electron gun which will project a relatively small constant spot size with variations in grid drive.

It is another object of the present invention to provide an electron gun which has improved efficiency, that is, a gun in which essentially the entire cathode current arrives at the target and all of the cathode surface is used for emission.

It is a further object of the present invention to provide an electron gun in which the electric field lines at the cathode are uniform and normal to produce a uniform loading to thereby reduce the peak current density at the cathode surface for a given total beam current and to provide a beam having no transverse velocities other than thermal velocities.

It is another object of the invention to provide an electron gun in which small grid voltages are required to control the beam current.

The foregoing and other objects of the invention are achieved by an electron gun which is adapted to provide a laminar flow electron beam comprising a cathode for providing electrons, an apertured dish-shaped control electrode surrounding said cathode surface and providing a continuation thereof, a cylindrical anode spaced along the axis from said cathode, one end of said anode being shaped to cooperate with the control electrode to provide a substantially uniform electric field at and adjacent to the cathode surface thereby to provide substantially uniform current emission from the surface of the cathode and laminar flow and a field forming an electrostatic lens spaced from the cathode along the path of the beam and additional electrode means disposed along the path of the beam for receiving the beam leaving said anode and focusing and accelerating the beam.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic diagram of a prior art crossover electron gun.

FIG. 2 is a graph showing the intensity efficiency as a function of magnification for prior art guns of the type shown in FIG. 1.

FIG. 3 is a graph showing the density efficiency as a function of current efficiency for prior art guns of the type shown in FIG. 1.

FIG. 4 is a schematic diagram of a cathode ray tube including a laminar flow electron gun in accordance with the invention.

FIG. 5 is an enlarged view of the electron gun of FIG. 4.

FIG. 6 is a view of the gun of FIG. 5 showing the equipotential lines and the electron beam.

FIG. 7 shows a gun in accordance with the present invention including magnetic focusing.

FIG. 8 is a graph showing cathode current as a function of grid voltage for a gun in accordance with the present invention.

FIG. 9 is a graph showing the spot size as a function of beam current for a gun in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 is a schematic drawing of a crossover electron gun in accordance with the prior art. It includes triode section **11** having a heated cathode **12** with emitting surface **13**. An apertured cup-shaped control electrode **14** is spaced in front of the cathode surface. A first anode **16** accelerates the electrons and forms the last element of the triode section **11**. The anode **16** includes current limiting apertures **17** and **18**. The focusing section includes a second or focusing electrode **19** spaced along the path of the beam. The anode includes a current limiting aperture **21**. The action of the triode section is to focus the electrons leaving the surface at a point **22** where the electrons spread and are intercepted by the limiting apertures **17, 18** and **21** and focused to impinge upon a target **23**. As is well known, the focusing section may include magnetic means rather than electrostatic means. Deflection means are not shown.

The grid voltage e_g, accelerating voltage e_1 and focusing voltage e_2 are applied to the electrodes. The defects and limitations of this type of gun were previously described. FIGS. 2 and 3 show the intensity efficiency as a function of current efficiency for a crossover gun of the type illustrated in FIG. 1 and described.

FIGS. 4, 5 and 6 show a cathode ray tube **31** and an electron gun **32** in accordance with the invention. The improved electron gun may also be used in camera tubes, storage tubes, beam semiconductor devices and in other applications where a high efficiency, high current, sharply focused electron beam is required.

The gun includes an indirectly heated cathode **33** heated by a resistive heater **36** disposed in the cup-shaped rear portion of the cathode. A small cathode emitting surface 35 is disposed at the end of projection 36 to define an area of predetermined size. An electrode 37 including aperture 38 surrounds and is spaced from the cathode projection 36. The dish-shaped surface 39 of electrode 37 is adjacent to and cooperates with the cathode surface 35. An anode 41 is placed in front of the cathode surface 35 and electrode surface 39. The anode 41 may be a cylinder including a rim or lip 42. The rim or lip 42 cooperates with the cathode and electrode to provide a substantially uniform electric field 43, FIG. 6, across the emitting surface 35 of the cathode whereby electrons are uniformly emitted substantially normal to the surface of the cathode to form a laminar beam. The electrode 41 also forms an electrostatic lens as indicated by the field lines 44 whereby the beam leaving the cathode is defocused. In accordance with the invention, the lens is divergent whereby the beam 46 is expanding as it travels into the focusing section. In the present example a second anode 47 cooperates with the first to form a convergent lens which converges the beam field lines 48. The beam then travels into the region including conductive surface 49 in the inside of the cathode ray tube. This is in essence a third electrode which provides the final accelerating field, the final converging lens 50 and a field-free region for the beam to flow and focus on the screen 51 of the cathode ray tube.

Once the electron beam leaves the final anode, it is not under the influence of any focusing forces. There are, however, effects which tend to spread or defocus the beam such as space charge repulsion forces, transverse thermal velocities and transverse velocities due to aberrations and/or gun assymetries. Typically, the beam diameter has to be increased by the divergent lens of anode 41 from its original diameter (equal to that of the cathode), so that it can subsequently be focused by the focusing fields onto the target or screen at a diameter the same or less than that of the cathode. It is to be noted that in contrast to a Pierce Gun, the beam does not have its final velocity until it leaves the gun assembly. As a result, it is possible to control the emission from the cathode (beam current).

The cathode 33 is supported at one end of refractory cylinder 55 which acts as a heat shield. The other end of the cylinder is supported as a support 52 which has support discs 53. Spaced ceramic pins 54 are supported by the tube envelope and extend through the discs to support the cathode. The electrode 37, anode 41 and anode 47 include discs 56, 57 and 58 which are also engaged by the ceramic pins which support the gun assembly in the envelope with the various members in alignment.

Referring to FIG. 5, the length, diameter and spacing of the various electrodes is shown as well as the applied voltages. The grid voltage e_g, the anode voltage e_1, focusing electrode voltage e_2 and accelerating voltage e_3 are shown applied between the cathode 33 and grid 37, anode 41, focusing electrode 47 and accelerating electrode 48, respectively. The slope of the dish-shaped electrode is represented by ϕ_1 and the slope of the lip or rim 42 of anode 41 is represented by ϕ_2, both measured from a line perpendicular to the axis of the tube. The spacing between the bottom of the grid 37 adjacent to the opening 38 and the cathode surface is represented by the distance d_1. The spacing between the bottom of the grid 37 and the end of the lip 42 is represented by the distance d_2. The spacing between the anode 41 and the electrode 47 is represented by the distance d_3. The diameter of the cathode is represented by the diameter D_1 and the opening 35 of the dish-shaped grid by the diameter D_2. The diameter of the opening in the lip 42 is represented by the diameter D_3 and the diameter of the cylindrical portion of the anode 41 and electrode 47 by the diameter D_4. The diameter of the final accelerating electrode which may comprise the conductive coating in the inside of the cathode ray tube is represented by the diameter D_5. The length of the anode 41 and the electrode 47 is represented by l_1 and l_2, respectively. The overall length of the gun beyond the end of the cathode surface is represented by the length l_3 and the length of the field-free space is represented by the length l_4.

The electron-optical design for an electron gun of the type described is as follows. Referring to FIG. 5, the angles ϕ_1 and ϕ_2 and the distance d_1 and the cathode curvature are selected so that the electrons leave the surface of the cathode in substantially parallel paths (laminar flow) normal to the surface. The voltages and shapes are selected whereby the equipotentials are substantially parallel, and the gradient or field is substantially perpendicular to the cathode surface in the vicinity of the surface and the fields are such as to form a diverging lens adjacent the aperture in the lip 42. This is accomplished by selecting the distances, angles, voltages and diameter D_3 of the lip 42 to control the angle at which the beam is launched from the cathode. The beam 46 is schematically illustrated in FIG. 6 and is a beam which is essentially perpendicular to the cathode. The positive focusing action of the fields 48 and 50 and the field-free region within the electrode 49 provide an image at the screen. It is apparent to one skilled in the art that the electrostatic focusing may be aided by the electromagnetic focusing structure 60, as schematically shown in FIG. 7, which serves to form a converging lens to converge and focus the beam at the screen.

The size of the spot at the screen will be determined by the position and size of the virtual cathode image which serves as the object for the converging lens. Trajectories are such that ideally an infinitely small cathode image can be produced at any desired position behind the cathode. This is indicated by the dotted line 61 projected behind the cathode in FIG. 6. In practice, however, the size of the virtual cathode image will be limited by transverse thermal velocities and various imperfections such as spherical aberrations and astigmatism. However, the laminar flow gun minimizes these limitations in three ways: the cathode virtual image is produced much further from the focal point of the converging lens than in a crossover gun; thermal velocity effects are reduced by uniformly accelerating the beam to its final velocity or voltage with electrodes 41, 47 and 49 in a comparatively short distance; and aberration effects are reduced by using long focal length lenses without limiting apertures.

The virtual cathode position and size are of primary importance since the converging lenses magnify this virtual cathode in direct proportion to the distances of the object image from the lens focal points. In comparison, a crossover gun, by design, must also produce a cathode image near the cathode. This causes excessive magnification of the crossover spot and, therefore, when high resolution devices are required, they must be made very long with much of the beam intercepted by the apertures in the focusing electrodes.

The focus point and the cathode emitting area are relatively unaffected by changes in the voltage v_g on the control electrode **37**. Furthermore, relatively low voltages are required to make substantial changes in the beam current. The primary effect of changing the grid voltage in the laminar flow gun is to uniformly change the cathode current density and not the cathode emitting area. Thus, the uniformity of current density and focus spot positions are substantially less affected by changes in grid drive used to change the total beam current. If the beam current is extremely small, such as used in existing cathode ray tubes, the beam in the gun region need not significantly be expanded, if at all, and yet the beam can be focused on the screen by the converging lens to form an extremely small, high current density spot.

The cathode image in the laminar flow gun of the present invention is ideal because of the uniform current density emission from the cathode and the parallel electron beam in the cathode-anode region. The optical analog is that the beam originates from a point source an infinite distance away so that the illumination is perfectly uniform and parallel at the cathode. The combined result of this invention is a much more uniform high current density beam at the screen. This is achieved with improved cathode life and a much smaller overall gun length. As previously described, the gun design beyond the anode is conventional since it basically consists of two cylindrical electron focusing lenses. A single electrostatic lens or a magnetic lens could also be used. The only requirement is that the virtual cathode image produced in the cathode-anode region be imaged on the screen with minimum aberration or image distortion. It is, of course, apparent that deflection means, either magnetic or electrostatic, may cooperate with the beam after it leaves the gun to control its deflection or position at the target. Such means were not shown to simplify the disclosure. They are well known in the art.

A cathode ray tube incorporating an electron gun in accordance with the invention was constructed and it had the following dimensions:

d_1	0.012 inches
d_2	0.065 inches
d_3	0.035 inches
l_1	0.188 inches
l_2	0.320 inches
l_3	0.620 inches
l_4	3.50 inches
D_1	0.028 inches
D_2	0.060 inches
D_3	0.040 inches
D_4	0.190 inches
D_5	0.300 inches
ϕ_1	12°
ϕ_2	22° 30′

The applied voltages were as follows:

e_g (grid)	0 volts (normal full on)
e_1	480 volts
e_2	1,700 volts
e_3	12,500 volts

The grid cut-off characteristic for an electron gun in accordance with the foregoing is shown in FIG. **3**. It is to be noted that with a grid swing of 15 volts, the cathode current is controlled over a range from 0 to 400 microamps. It is also to be observed that substantially the total cathode current reaches the screen thereby providing essentially 100 percent cathode efficiency. In FIG. **9** a curve showing the line size as a function of beam current is set forth for the above gun. The line width was obtained in a tube in which the deflection of the beam was 2,000 inches per second at a 60 Hertz repetition rate. It is to be noted that with a change in beam current of four times, the spot size only changes about 46 per cent.

By way of example, another cathode ray tube having an electron gun in accordance with the invention was constructed and operated as follows:

d_1	0.006 inches
d_2	0.150 inches
d_3	0.030 inches
l_1	0.200 inches
l_2	1.24 inches
l_3	1.626 inches
l_4	3.50 inches
D_1	0.010 inches
D_2	0.018 inches
D_3	0.160 inches
D_4	0.375 inches
D_5	0.750 inches
ϕ_1	0°
ϕ_2	22° 30′

With the grid voltage eg at −10 volts, the anode voltage e_1 at 480 volts and the voltage e_2 at 1,700 volts, the beam was very highly convergent in the region of the anode aperture **42** and the line width 0.014–0.015 inches and substantially independent of the screen voltage e_3. This indicates that the beam size is aberration limited. With the grid voltage eg at 0 volts, the anode voltage e_1 at 145 volts and the voltage e_2 at 1,700 volts, the line width was 0.006 inches for e_3 at 12,500 volts and varied between 0.0095 and 0.0055 with screen voltages between 6,500 and 14,500 respectively. This indicates that the beam size is Langmuir limited.

It is apparent from the above description that the gun may be used in connection with other charged particles to accelerate them from a source and project and focus a beam at a screen or target.

We claim:

1. A particle gun for providing a beam of charged particles comprising a source of particles, an apertured dish-shaped control electrode surrounding said source and providing substantially a continuation thereof, an electrode spaced along the axis from said source and being at a potential with respect to the source and control electrode which will accelerate particles from the source, said electrode being shaped to cooperate with the control electrode and source to provide a substantially uniform electric field at the source surface for initially accelerating the charged particles to substantially the same velocity to provide a substantially perpendicular uniform laminar flow of particles at the source surface and also providing an electric field spaced from the source along the path of the beam defining an electrostatic lens and at least an additional electrode along the path of the beam at a higher potential than said electrode for further accelerating the particle beam leaving said first electrode and focusing it on a target.

2. A particle gun as in claim **1** wherein said source is a cathode for providing electrons.

3. A particle gun as in claim 1 wherein said electrode spaced along the axis from said source includes an aperture for passing the beam, the diameter of said aperture being substantially larger than the diameter of the beam.

4. A particle gun as in claim 1 wherein means providing a magnetic focusing field cooperates with said additional electrode means.

5. A particle gun as in claim 1 wherein the angle of the surface of said dish-shaped electrode with respect to a plane perpendicular to the axis of the gun is between 0° and 45°.

6. An electron gun for providing an electron beam comprising a cathode having a surface providing a source of electrons, an apertured control electrode surrounding said cathode and having a surface providing substantially a continuation of the cathode surface, an anode spaced from said cathode surface and control electrode and being at a more positive potential than said cathode and control electrode to cooperate therewith to accelerate electrons at said surface to substantially the same velocity to provide a substantially uniform laminar flow of electrons in a beam substantially perpendicular at said cathode surface and toward said anode, said anode providing a diverging field along the path of the beam, and additional electrode means at a more positive potential for receiving and accelerating said beam and also serving to focus said beam.

7. An electron gun as in claim 6 wherein said anode means includes an cylindrical portion with an apertured-shaped end facing said cathode and control electrode.

8. An electron gun as in claim 7 wherein the diameter of said anode aperture is substantially larger than the diameter of the beam.

9. An electron gun as in claim 6 wherein the surface of said apertured control electrode defines an angle with a plane perpendicular to the axis of the tube which angle is between 0° and 45°.

10. An electron gun as in claim 7 wherein said additional electrode means comprises a cylindrical electrode for accelerating said beam and means providing final acceleration to said beam, said cylindrical electrode and said means providing final acceleration forming a focusing field.

11. An electron gun as in claim 10 wherein said last named means also provides a field-free region along the path of said beam after it leaves the cylindrical electrode.

12. An electron gun as in claim 10 wherein said cylindrical anode and cylindrical electrode are circular cylinders.

13. An electron gun as in claim 6 including means providing a magnetic focusing field cooperating with said additional electrode means.

14. A cathode ray tube having an envelope adapted to accommodate an electron gun at one end and having a screen at the other end including an electron gun comprising a cathode having a surface providing a source of electrons, an apertured control electrode surrounding said cathode surface and having a surface providing substantially a continuation of the cathode surface, an anode spaced from said cathode surface and control electrode having a surface portion facing and cooperating with said cathode surface and control electrode surface, said anode being at a more positive potential than said cathode and control electrode, said anode surface being shaped to provide a substantially uniform electric field at said cathode surface to cause a laminar flow of electrons in a beam substantially perpendicular to said cathode surface at substantially the same velocity toward said anode, and additional means for receiving and acting on said beam after it leaves the anode to focus said beam.

15. A cathode ray tube as in claim 14 wherein said anode means includes a cylindrical portion with an apertured-shaped end facing said cathode and control electrode.

16. A cathode ray tube as in claim 15 wherein said additional electrode means comprises a cylindrical electrode further accelerating said beam and wherein the interior of the cathode ray tube envelope is conductive whereby to provide an additional electrode for giving the beam its final acceleration and cooperating with said electrode to focus the beam on the target.

17. An electron gun as in claim 14 wherein the surface of said apertured control electrode defines an angle with a plane perpendicular to the axis of the tube which angle is between 0° and 45°.

18. An electron gun as in claim 15 wherein the diameter of said anode aperture is substantially larger than the diameter of the beam.

19. The method of forming a small uniform electron beam with high current density comprising the steps of generating an electric field near a source of electrons which is substantially perpendicular to the surface of the source to provide substantially parallel flow of electrons from the surface to form a laminar flow beam, providing a divergent electric field spaced from the source for receiving the beam and defocusing the beam after it has travelled a short distance from the surface, providing at least one additional electric field along the path of the beam for further accelerating said beam, said additional field also providing a convergent field for focusing the beam.

20. The method of forming a small, high current density uniform electron beam in a cathode ray tube of the type having a conductive coated envelope, an electron gun at one end of said envelope and a screen at the other end which comprises the steps of providing an electric field which is substantially perpendicular to the surface of a source of electrons to provide substantially parallel flow of electrons from the surface at substantially uniform velocity to form a laminar flow beam, providing an accelerating and focusing field along the path of the beam to further accelerate the beam and focus the beam, and providing an additional final accelerating field between the gun and the coated surface of said envelope to give the beam its final acceleration and focus the beam at the screen.

21. An electron gun for providing an electron beam comprising a cathode having a surface providing a source of electrons, a control electrode adjacent said cathode surface and having a surface providing a continuation of the cathode surface, an anode spaced from said cathode surface and control electrode and cooperating therewith to cause electrons to emit substantially normal from said surface and provide a substantially uniform laminar flow of electrons in a beam from said cathode surface towards said anode, and additional electrode means for receiving and accelerating and focusing the beam.

22. An electron gun for providing an electron beam comprising a cathode having a surface providing a

source of electrons, a control electrode adjacent said cathode surface and having a surface providing a continuation of the cathode surface, said control electrode being at a voltage substantially equal to or more negative than said cathode, an anode spaced from said cathode surface and control electrode, said anode including a surface portion facing said cathode and control electrode, said anode being at a potential which is positive with respect to said cathode and control electrode to cooperate therewith to cause electrons to emit substantially normal and at substantially the same velocity from said cathode surface and provide a substantially uniform laminar flow of electrons in a beam from said cathode surface towards said anode, and additional electrode means at a potential position with respect to said anode for receiving and accelerating and focusing the beam.

23. An electron gun for projecting an electron beam comprising a cathode having a surface providing a source of electrons, a control electrode adjacent said cathode and having a surface providing a continuation of said cathode surface, said control electrode being at a potential equal to or more negative than said cathode, an anode spaced from said cathode surface and said control electrode including a surface portion which faces said cathode surface and control electrode surface, said anode being at a potential which is positive with respect to said cathode and control electrode, said control electrode and anode being shaped whereby to cooperate and provide a substantially uniform accelerating electric field at said cathode surface for initially accelerating electrons at said cathode surface toward said anode to substantially the same velocity in a direction substantially perpendicular to said cathode surface and also providing an electric field in the region between said surfaces which defines an electrostatic lens and at least one additional electrode means along the path of the electron beam at a potential more positive than said anode to provide final acceleration to said beam.

24. A cathode ray tube as in claim **14** including means for applying a control voltage between said cathode and control electrode to control the beam current.

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