March 10, 1959 F. H. NICOLL 2,877,369

ELECTRON BEAM TUBE

Filed June 2, 1955 2 Sheets-Sheet 1

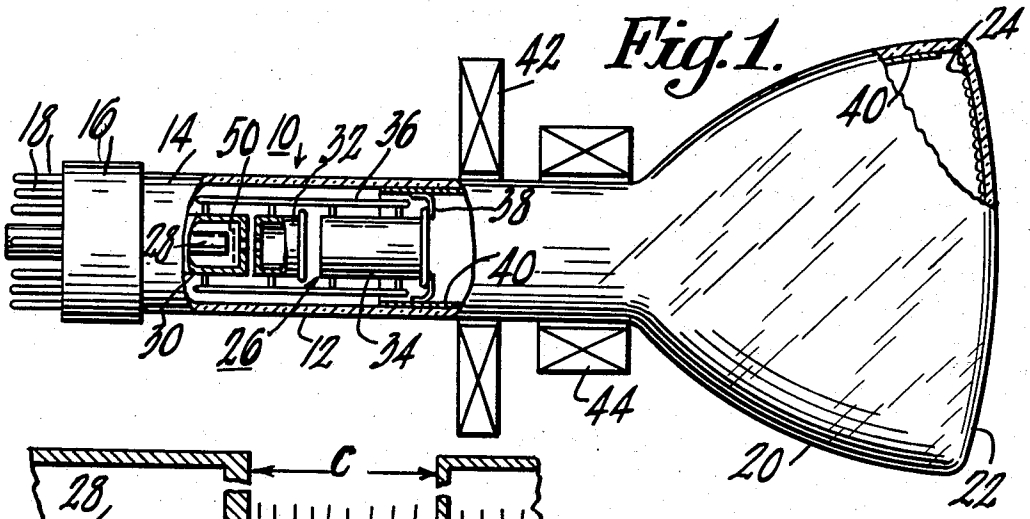

Fig. 1.

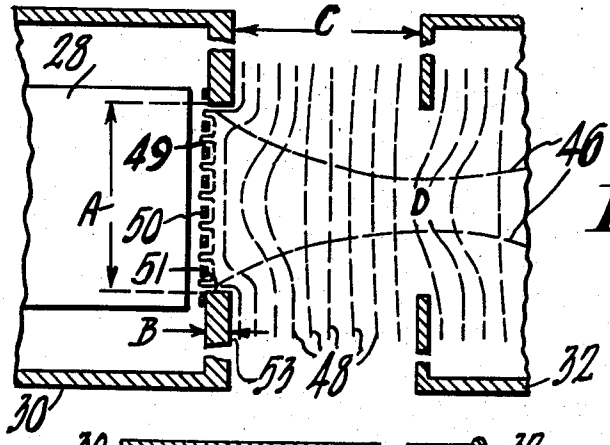

Fig. 2.

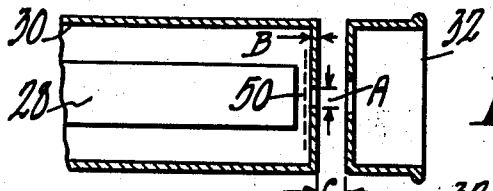

Fig. 9.

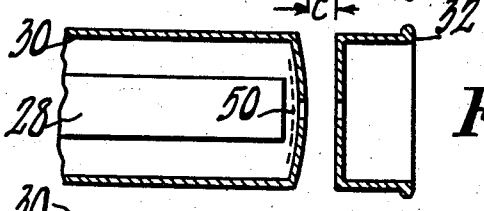

Fig. 10.

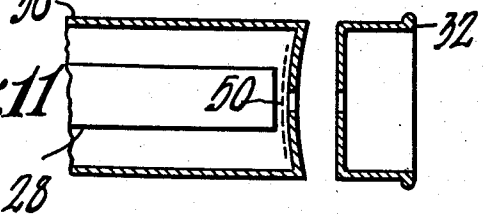

Fig. 11

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March 10, 1959 F. H. NICOLL 2,877,369

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2 Sheets-Sheet 2

Fig. 3.

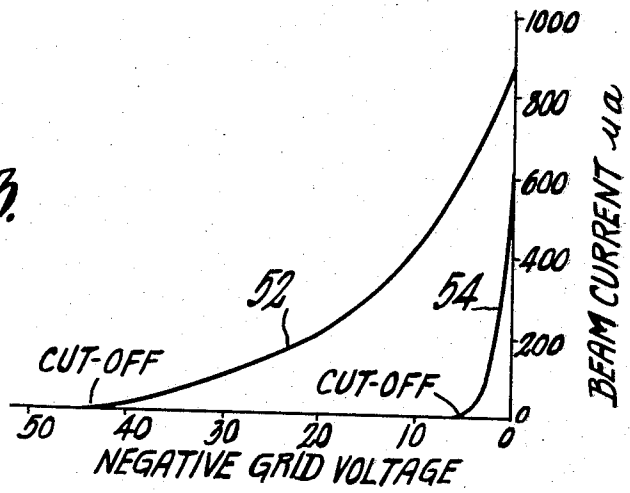


Fig. 4.

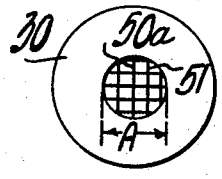


Fig. 5.

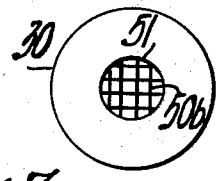


Fig. 6.

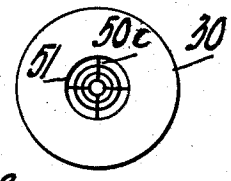


Fig. 7.

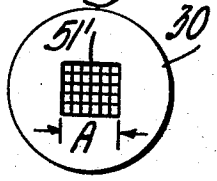


Fig. 8.

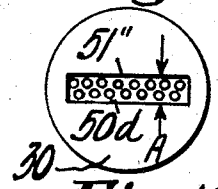


Fig. 12.

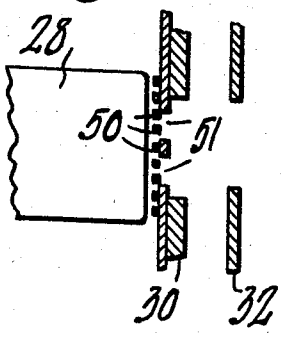
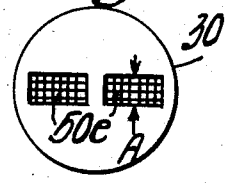


Fig. 13.



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ELECTRON BEAM TUBE

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10 Claims. (Cl. 313—82)

The present invention relates generally to an electron beam tube and, though not limited thereto, is herein described as embodied in a cathode ray tube having a multi-apertured electrode for modulating the intensity of the electron beam therein.

The tube of the invention is characterized by a relatively high transconductance, a relatively low modulation voltage requirement, and a relatively good focus at high beam currents and consequently proves advantageous in television receivers, especially in such receivers using transistors in the video amplifiers thereof.

Previous cathode ray tubes have generally used a control electrode having a single aperture through which the beam passed and which required a relatively large negative signal voltage for the whole range of beam modulation. Thus, where such tubes are used for image viewing purposes, e. g. for television, additional amplifier stages have been required to provide the required relatively large negative control or signal voltages.

It is therefore an object of the invention to provide an electron beam tube having an improved electron-optical system for relatively high beam currents.

It is a more particular aim to provide an improved cathode ray tube having a multi-apertured modulating electrode and which exhibits a relatively high transconductance, low cut-off beam modulating voltage, and good beam definition and which is adapted to operate at relatively high beam currents.

The foregoing and related objects are achieved in accordance with the invention by providing an improved electron beam tube having a cathode and grid spaced along the tube axis. The grid has at least one aperture therethrough and has an axial thickness of between about 5 and about 60 percent of the minimum distance across at least one aperture. A multi-apertured diaphragm or mesh is fixed to the side of the grid adjacent to the cathode. Consequently, each of the apertures of the mesh acts as a separate beam control element for individually focusing a portion of the beam current at a common point within the tube or at a plurality of points having a predetermined spacing therebetween, the focus usually being at a target electrode of the tube.

The invention is described in greater detail in connection with the accompanying two sheets of drawings wherein:

Figure 1 is a side view, partly in section, of a cathode ray tube embodying the invention;

Figure 2 is an enlarged sectional view of a portion of the tube of Figure 1 and illustrating a space potential distribution between some of the electrodes of the tube;

Figure 3 is a chart illustrating the control grid voltage required to bias one conventional cathode ray tube under various conditions in comparison with the control grid voltage required to bias one tube of the invention under similar conditions;

Figures 4 through 8 illustrate different types of control electrodes which may be used in the tube of Figure 1;

Figures 9 through 11 illustrate portions of different types of electron gun structures useful in the tube of Figure 1;

Figure 12 illustrates a portion of an electron gun for producing two electron beams within a cathode ray tube of the invention; and

Figure 13 shows a control electrode of a type useful in the electron gun of Figure 12.

Reference is made to Figure 1 where there is shown a side elevational view, partly in section, of a cathode ray tube **10** according to the invention and comprising an evacuated envelope **12** made of an insulating material such as glass. One part of the envelope includes a neck portion **14** terminated by a base **16** having a plurality of pins **18** for providing electrical access to some of the elements within the tube **10**; the other part of the envelope includes a flared bulb portion **20** closed by a transparent end-wall **22**. The transparent end-wall carries on the inside surface thereof a target element in the form of a fluorescent screen **24**, the screen becoming luminescent on being bombarded by electrons.

An electron gun **26** is disposed within the neck portion **14** to provide a beam of electrons directed toward the screen **24**. The electron gun **26** includes a cathode **28** having a heater therein (not shown), a grid or control electrode **30**, a first accelerating electrode **32**, and a second accelerating electrode **34**. The electrodes, which are spaced along the longitudinal axis of tube, are fixed in spaced relationship by being joined to insulating rods **36** as shown. The second accelerating electrode **34** has spring fingers **38** for contacting a conductive coating **40** on the inner surface of the neck **14** and extending over the inner surface of the envelope bulb portion **20** to a point adjacent to the fluorescent screen **24**. This coating **40** prevents the glass portions of the envelope **20** from becoming indiscriminately charged during tube operation, which would adversely affect beam focusing and deflection.

Means are provided for focusing and scanning the electron beam over the screen **24** to form a raster. These means may include a focusing coil **42** and a deflection yoke **44** disposed around the part of the tube neck portion **14** adjacent to the flared envelope portion **20**. The yoke **44** comprises a plurality of coils forming magnetic deflecting fields in the beam path for providing scansion of the electron beam over the screen **24**.

In Figure 2 there is shown the approximate shape of an electron beam (shown in the drawing bounded by lines **46**) and an electrostatic field, illustrated by equipotential lines **48**, in relation to the cathode **28**, control grid **30**, and first accelerating electrode **32** of Figure 1. The control grid **30** has a single, large aperture **51** therethrough in a direction along the tube axis. A multi-apertured diaphragm or mesh element **50** is disposed across the single aperture **51** and is fixed to the end-wall **53** of the grid **30** adjacent to the cathode **28**. The mesh element may be in any multi-apertured planar shape and is fixed to the control grid by any of the known techniques for welding a mesh element to a support. For example, the welding may be effected by a hydrogen firing operation while the mesh element is maintained in contact with the solid portion of the grid by means of a jig.

The equipotential field lines **48** adjacent to the aperture **51** are given a curvature at the aperture due to the penetration of the field into the end-wall **53** which has a substantial thickness. The portion of the electron-optical field which penetrates the small apertures **49** of the mesh element **50** accelerates electrons at the cathode **28** into a plurality of substantially parallel beams directed from the surface of the cathode through the small apertures **49**. Then, while the electrons are still traveling at

a relatively low velocity, that is, within and just beyond the large aperture **51**, the portion of the electron-optical field between the grid **30** and the first accelerating electrode **32** converges the electrons into a restrained region, D, where the beam exhibits a minimum cross-sectional area. The focusing coil **42** (Figure 1) is then used to image the beam from this region (D) at the screen **24**.

The curvature of the electron-optical field in the large aperture **51**, which produces the minimum cross-sectional area at point D, is determined by the spacing between the cathode **28** and the end-wall **53** and by the axial thickness (dimension B) of the end-wall. It has also been found that the optimum aforedescribed converging action within the large aperture **51**, when a mesh is used across this aperture, is obtained when the thickness of the end-wall portion **53**, dimension B, is from about 5 percent to about 60 percent of the distance, dimension A, across this aperture.

In order to obtain a relatively large penetration of the electron-optical field (Figure 2) through the control grid mesh **50** and adjacent to the active surface of the cathode **28**, a relatively close cathode-to-mesh spacing is used. The cathode-to-mesh spacing is preferably smaller than the distance across an aperture in the multi-apertured mesh **50**. For example, one tube made according to the invention had a distance of about .003 inch across each of the small apertures in the multi-apertured mesh and a cathode-to-mesh spacing of about .0015 inch during normal tube operation.

It has been found that for a given grid thickness B, a good focus at the screen or target of the tube can be obtained only for a certain range of control grid to first accelerating electrode spacings (dimension C in Figure 2). A ratio of the distance represented by the thickness B of the control grid wall to the distance C between the control grid and the first accelerating electrode equal to about 1:3 to about 1:10 has been found to give satisfactory resolution at the target. A ratio of from about 1:3 to about 1:5, i. e. of the order of 1:4, gives an optimum resolution at relatively high beam currents such as, for example, 300 microamperes. It has also been found that the distance between the control grid and the first accelerating electrode should be from about .2 to about one and a half times the distance A across the control grid aperture for the best resolution with the aforementioned ratios.

For example, cathode ray tubes incorporating electron guns having the following electrode dimensions and spacings have yielded the results indicated below. In each case the resolution at the target electrode was measured when the beam current was of the order of 300 microamperes (the beam being cut-off when the grid voltage was lowered to −5 volts with respect to the cathode), the distance across the large aperture in the grid being .035 inch and the cathode-mesh spacing (with the cathode at the temperature of normal tube operation) being about .0015 inch.

Control Grid Thickness, B	Control Grid-First Accelerating Electrode Spacing, C	Resolution at Target
.005	.010	Poor.
.005	.020	Good.
.007	.032	Do.
.009	.032	Do.

Reference is now made to Figure 3 wherein there is compared the performance of a cathode ray tube of conventional electron gun design (namely a gun having only a single control grid aperture), indicated by graph line **52**, and the performance of a cathode ray tube using an electron gun having a multi-apertured control grid and having spacings and dimensions in accordance with the invention, graph line **54**. As indicated in the drawing, while the conventional cathode ray tube had a cut-off voltage of −45 volts, a similar tube using an electron gun according to invention required a cut-off voltage of −5 volts, the useful current at the target in each case being of the order of 900 microamperes with zero volts at the control grid.

Figures 4, 5, 6, 7, 8, and 13 illustrate some of the forms which the mesh element **50** may take. In Figure 4 a wire mesh **50*a*** is shown having 200 wires per inch and a 60% transmissivity and with crossed wires at the center of the control grid aperture **51**. Similarly, Figure 5 shows a wire mesh **50*b*** of the type depicted in Figure 4 but with a mesh opening centered in the large aperture **51** in the control grid. Figure 6 illustrates yet another mesh element **50*c***, this one having a spider-web-like mesh. As shown in Figures 7 and 8 the single large aperture **51** in the control grid **30** may be square or rectangularly shaped, the dimension A in each case referring to the minimum distance across the aperture. As illustrated in Figure 8, the mesh element **50*d*** may take the form of an apertured plate instead of a wire mesh as in the aforedescribed mesh elements. Also, the apertures in the control grid **30** may take the form of a plurality of apertures and with each of the apertures itself having a mesh element **50*e*** therein (Figure 13). In the last named arrangement there is provided, in effect, a control element having a plurality of apertures wherein each of the apertures is itself sub-divided by a mesh element into a plurality of apertures. In each of the aforementioned examples the mesh element is of a multi-apertured, substantially planar shape and is preferably substantially symmetrical about the center of the large aperture **51**.

Figures 9, 10, and 11 illustrate portions of different electron gun assemblies which may be used with a mesh element **50** fixed to a control grid. In these three figures as well as in Figure 1 the mesh element **50** is indicated schematically; it will be appreciated that the mesh element is actually fixed to the grid **30** as shown in Figure 2. While the mesh element **50** may be a flat element (Figure 9) fixed around its periphery to a flat control grid **30**, the control grid surface may instead be bowed either outwardly (Figure 10) or inwardly (Figure 11) in order that the mesh follow the contour of the control grid surface to which the mesh is fixed. The bowing illustrated in Figures 10 and 11 (which is exaggerated in the drawing for purposes of illustrating the bowing) is used to prevent the mesh from buckling when heated, during normal tube operation, and short circuiting to the cathode **28**. The bowing gives a pre-stressed effect to the mesh forcing it to move, if at all, in the same direction as that in which the control grid surface is bowed. Thus the distance of the mesh to the cathode is determined by the control grid surface contour. The aforedescribed bowing is not chosen to be of such a degree that it appreciably affects the electron-optics (focusing in particular) of the tube in which the gun is used.

Reference is made to Figure 12 where there is illustrated a portion of an electron gun of a type capable of producing two separate, focused electron beams, each beam being subject to control by a grid-cut-off bias of about −5 volts. The electron gun of Figure 12 has a control grid **30** having two large apertures **51** and a wire mesh **50** across each of the large apertures. While the use of appropriate second accelerating electrode to first accelerating electrode voltage ratios brings the two beams to focus at a single point on the screen of the tube, when the second accelerating electrode to first acceleration electrode voltage ratio is greater than about 50 to 1; the two beams come to two foci at the screen, and separated by about .075 inch thereat, when the second accelerating electrode to first accelerating electrode voltage ratio is between about 10 to 1 to about 30 to 1. The use of two beams having individual foci at a predetermined distance from each other at the screen is useful in eliminating the appearance of a line structure between adjacent scansions on the screen of a television viewing tube.

What is claimed is:

1. An electron beam tube having a tube axis, a cathode and a control grid spaced along said axis, said grid having a portion lying substantially in a predetermined surface, said portion having at least one aperture therethrough and having an axial thickness of between about 5 and about 60 percent of the minimum distance across said at least one aperture, and a multi-apertured mesh fixed to the side of said grid portion adjacent to said cathode and across said at least one aperture and lying substantially parallel to said surface.

2. The electron beam tube described in claim 1 and wherein said control grid has two apertures.

3. The electron beam tube described in claim 1 and wherein said at least one aperture is of substantially circular cross-sections.

4. An electron beam tube comprising a cathode for providing a source of electrons, a target, an accelerating electrode intermediate said cathode and said target for accelerating electrons from said cathode toward said target, and a control electrode intermediate said cathode and said accelerating electrode for controlling the flow of electrons toward said target, said control electrode having a portion thereof defining an aperture therein and a multi-apertured mesh element across said aperture and fixed to the side of said electrode adjacent to said cathode, the thickness of said control electrode portion being between about 5% and about 60% of the minimum distance across said aperture, the ratio between the distance represented by the thickness of said control electrode portion and the distance between adjacent portions of said electrode portion and said accelerating electrode being from about 1:3 to about 1:10.

5. An electron beam tube comprising a cathode for providing a source of electrons, a target, an accelerating electrode intermediate said cathode and said target for accelerating electrons from said cathode toward said target, and a control electrode intermediate said cathode and said accelerating electrode for controlling the flow of electrons from said cathode toward said target, said control electrode including an apertured element and a multi-apertured diaphragm across the aperture in said element and fixed to the side thereof adjacent to said cathode, the ratio between the distance represented by the thickness of said apertured element and the distance between said element and said accelerating electrode being from about 1:3 to about 1:10.

6. An electron beam tube comprising a cathode for providing a source of electrons, a target, an accelerating electrode intermediate said cathode and said target for accelerating electrons from said cathode toward said target, and a control electrode intermediate said cathode and said accelerating electrode for controlling the flow of electrons from said cathode toward said target, said control electrode including an apertured element and a multi-apertured diaphragm across the aperture in said element and fixed to the side thereof adjacent to said cathode, adjacent sides of said diaphragm and said apertured element having substantially the same contour, the ratio between the distance represented by the thickness of said apertured element and the distance between said element and said accelerating electrode being from about 1:3 to about 1:5.

7. An electron beam tube comprising, spaced along a tube axis, a cathode for providing a source of electrons, a target, an accelerating electrode intermediate said cathode and said target for accelerating electrons from said cathode toward said target, and a control electrode intermediate said cathode and said accelerating electrode for controlling the flow of electrons from said cathode to said target, said control electrode including an element

having a single circular aperture axially therethrough and a multi-apertured diaphragm across said single aperture and fixed to the side thereof adjacent to said cathode, the smallest cross sectional distance across each of the apertures in said diaphragm being greater than the distance between adjacent surfaces of said diaphragm and cathode during normal tube operation, the ratio between the distance represented by the thickness of said apertured element and the distance between said element and said accelerating electrode being of the order of 1:4.

8. A cathode-ray tube comprising a cathode for providing a source of electrons, a target, an accelerating electrode intermediate said cathode and said target for accelerating electrons from said cathode toward said target, and a control electrode intermediate said cathode and said accelerating electrode for controlling the flow of electrons from said cathode toward said target, said control electrode including an apertured portion lying substantially in a predetermined surface and a multi-apertured diaphragm across the aperture in said portion and lying substantially in said surface and fixed to the side thereof adjacent to said cathode, the thickness of said portion being from about .05 to about .6 of the average distance across the aperture in said element.

9. A cathode-ray tube comprising a cathode for providing a source of electrons, a target, an accelerating electrode intermediate said cathode and said target for accelerating electrons from said cathode toward said target, and a control electrode intermediate said cathode and said accelerating electrode for controlling the flow of electrons from said cathode to said target, said control electrode including an element having a circular aperture therein and a multi-apertured diaphragm across the aperture in said element and fixed to the side thereof adjacent to said cathode, the distance between said element and said accelerating electrode being from about .2 to about one and a half times the diameter across the aperture in said element.

10. An electron beam tube comprising a cathode for providing a source of electrons, a target, an apertured accelerating electrode intermediate said cathode and said target for accelerating electrons from said cathode through said accelerating electrode and toward said target, and a control electrode intermediate said cathode and said accelerating electrode for controlling the flow of electrons from said cathode toward said target, said control electrode including an element having a circular aperture therein and a multi-apertured wire mesh across the aperture in said element and fixed to the side thereof adjacent to said cathode, the smallest cross sectional distance across each of the apertures in said mesh being greater than the distance between adjacent surfaces of said mesh and cathode during normal tube operation, the ratio between the distance represented by the thickness of said apertured element and the distance between said element and said accelerating electrode being of the order of 1:4, the thickness of said disc being from about .05 to about .6 of the diameter of the aperture in said element, and the distance between said element and said accelerating electrode being from about .2 to about one and a half times the diameter of said aperture in said element.

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